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America is poised for a major transformation of its vehicle transportation system, based on a progressive shift from petroleum gasoline to other alternative fuels, including ethanol and methanol.

Not only are the technologies to lead such a shift already commercially available, but 17 million flex fuel vehicles are ready to take full advantage of the shift away from petroleum gasoline—while minor technical adjustments will allow millions of conventional automobiles to burn cleaner, increasingly cheaper alternatives such as ethanol and methanol, as well as E85 and other fuel blends.

Americans already use alternative fuels thanks to the ubiquitous presence of E10 (10% ethanol, 90% gasoline) at gas pumps around the country. Fears that increasing the percent of ethanol in higher fuel blends will damage automobile engines, are not borne out by the facts—while increasing that percent will lead to higher octane performance and cleaner tailpipe emissions.

In addition, through greater reliance on alternative fuels like ethanol and methanol, auto makers will be better poised to meet the future Corporate Average Fuel Economy standard, or CAFE, which is set to rise to 54.5 miles per gallon by 2025. The higher octane rates of methanol and ethanol will allow carmakers to build smaller, more efficient engines, which will also lead to lower carbon emission rates—something that will please environmental regulators.

Today, most of the ethanol used in E10 and other blends comes from corn. Many of the worries concerning corn ethanol are exaggerated (of the U.S.’s 280 million acres of cultivated farmland, for example, only 88 million produce corn—and of that barely one-fifth is used to produce corn ethanol). However, a far more promising feedback for ethanol and methanol fuel production exists with America’s new abundant supplies of natural gas (NG).

The shale natural gas revolution is bringing real energy security to America, making the U.S. the world’s biggest NG producer, with total reserves exceeding 350 trillion cubic feet, making it the fifth largest in the world. It can also serve as the springboard for a transportation revolution, supplying gas for compressed natural gas vehicles (more than 12 million are on the road worldwide) and for inexpensive conversion to methanol and ethanol.

Natural gas-derived ethanol and methanol will be fuels that are American-made, creating American jobs and American transportation independence, in ways no boycott or production cuts by the Organization of Petroleum Exporting Countries (OPEC) can ever threaten again. Brazil, China, and Europe are already making the change-over to ethanol and methanol as principal transportation fuels. Thanks to abundant natural gas, the outlook for the United States looks even more promising—as well as technically and commercially feasible.
The papers published here are selected from the talks given during a conference held at the Hudson Institute on May 7, 2015, entitled “Fueling American Growth: How Energy Independence Will Power Our Transportation Future.”

Participants included:

John Hofmeister, Former President, Shell Oil Company, Keynote Speaker

Reuben Sarkar, Deputy Assistant Secretary for Transportation, Department of Energy

Coleman Jones, Biofuels Implementation Manager, General Motors

Brian West, Deputy Director, Fuels, Engines, and Emissions Research Center, Oak Ridge National Labs

Scott Segal, Head of Policy Resolution Group, Bracewell and Giuliani, LLP

John Eichberger, Vice President, Government Relations, National Association of Convenience Store Owners

Greg Dolan, CEO, Methanol Institute

Michael Jackson, Director of Research, Fuel Freedom Foundation

If there was one general consensus that emerged from the speakers and questions at this day-long conference, it was that America is poised for a major transformation of its vehicle transportation system, based on a shift from petroleum gasoline to other alternative fuels, including ethanol and methanol.

Not only are the technologies to lead such a shift already commercially available, but a national light duty vehicle fleet already exists to take full advantage of the shift away from petroleum gasoline thanks to the Renewable Fuel Standard. These are cars built by automakers as flex fuel vehicles, a fleet some 17 million cars strong. These cars are able to run on more than one fuel, usually a gasoline-ethanol or gasoline-methanol blend. Other automobiles can be modified to perform in the same way, at a minimal cost. In either case, the flex fuel fleet represents an important starter kit for developing ways to move America away from reliance on petroleum gasoline as consumers’ only real choice in auto fuels and toward cleaner, cheaper alternatives.

Unfortunately, certain issues have come to fog discussion of so-called “alternative” fuels such as methanol and ethanol and need to be cleared away.

One issue is the confusing information—and sometimes misinformation—on the characteristics of alternative fuels and how they are made.
Ethanol, for example, is nothing more than ethyl or grain alcohol, which can be distilled from a variety of feedstocks, including plants—most notably in this country, corn (a separate issue I address below). As a fuel, it burns much cleaner than gasoline, meaning fewer toxic emissions such as ozone and tailpipe carcinogens. The higher the blend with gasoline, the fewer greenhouse emissions, as well.

Right now the 10% ethanol/90% gasoline fuel blend, or E10, is pretty standard across the country. Claims that an E15 or even higher ethanol blend like E85 will do damage to car engines are not borne out by the facts. It is true that pure ethanol gets fewer miles to the gallon than gasoline, but those miles come with a bigger octane punch, as high as 100 or more. That’s one reason why it’s so popular as a fuel for Indy 500-style race cars, as well as its lesser known cousin, methanol.

Methanol is likewise made from a variety of feedstocks, even from carbon dioxide emissions. It’s the simplest of all the hydrocarbons, consisting of one oxygen atom and a methane molecule, but it’s the one with the highest octane potential. Its downside is that it gets two-thirds of the energy value of gasoline, and is not as clean for the engine. However, a simple $100–$200 investment can turn an internal combustion light duty vehicle into a clean-running methanol-driven vehicle.

Although it is cheap and easy to produce, methanol is not as widely used as an alternative fuel, since ethanol was the primary focus of the Renewable Fuel Standard created in 2005.

Despite its best intentions, the Renewable Fuel Standard (RFS) has also become a drag on the adoption of alternative fuels. It’s unpopular with oil companies and gasoline makers who had to refit to mix ethanol with their gasoline; it’s particularly unpopular with auto companies, who had to build a certain percentage of their fleets to meet the RFS requirements—only to see consumers continue to stick to conventional gasoline. The consensus among RFS opponents has been that the legislation was both unnecessary and raised unrealistic goals about “alternative fuels” which neither the consuming public, nor auto makers, were prepared to meet.

Unfortunately, there is another standard that’s been imposed on the auto industry, namely the Corporate Average Fuel Economy (CAFE) standard, first instituted in 1975 and now set to rise to 54.5 miles per gallon by 2025. In fact, there is no realistic way any carmaker will be able to meet that expectation without smaller, high compression, and more efficient engines—which in turn means these engines will require higher octane in order to deliver the same number of drivable miles. That can only happen if ethanol and methanol get higher into the mix, which will also have the advantage that their higher octane rate will come with a lower carbon emission rate than gasoline—something that will please environmental regulators as well.

In other words, by growing out their flex fuel fleet; building cars with smaller, more efficient engines; and encouraging investment in a retail fuel distribution network that will supply the alternative fuels to keep those engines running; today’s automakers can realize CAFE’s future goals, as well as the goals of RFS, without going bankrupt or abandoning America’s roads to the electric car.

Mention of electric cars raises another point. Isn’t going electric the ultimate solution to America’s reliance on petroleum gasoline, and indeed all hydrocarbon fuels—with the added benefit of no carbon emissions? The answer is yes—eventually. But even the most optimistic forecasts saw an electric car/gasoline-electric hybrid light vehicle fleet growing to only two out of every 10 cars in
the U.S. by 2030, and now lower gas prices makes that target seem unreachable. An exhaustive study by MIT concluded that the electric car’s limited market appeal “means that their impact on fuel use and emissions is unlikely to be significant over the next few decades”—while a conventional combustion engine car can’t be switched over to electric power the way it can to ethanol and methanol.

**AMERICA’S CURRENT SHALE GAS REVOLUTION HAS TO BE PART OF ANY SERIOUS DISCUSSION OF MOVING THE COUNTRY TOWARD FUELS OF THE FUTURE.**

The RFS was originally built around promoting the use of biofuels, particularly corn ethanol, which has become another contentious, even incendiary, issue in the discussion of alternative fuels.

It’s a debate that arises every election year when presidential candidates travel to Iowa and other Midwest states whose farmers have come to rely on tax credits for converting corn into ethanol fuel as required by RFS. This has triggered a growing distrust of the entire biofuel industry as a government-subsidized “racket” with subsidies and credits that are tantamount to handouts, but which has also devoured America’s supply of corn and driven up its price to perilous proportions—some even claim to the point that it adds to worldwide hunger.

The truth is, many of these fears are exaggerated. Of the U.S.’s 280 million acres of cultivated farmland, only about 88 million produces corn—and of that barely one-fifth is used to produce corn ethanol. If anything, the corn ethanol industry has probably increased the amount of corn produced in this country over the past decade, including for food use. And if the subsidy to America’s farmers really is a handout, it’s not one that’s going to go away anytime soon—not while there is a Congress and a Department of Agriculture.

Instead, it’s important to realize that the original purpose of RFS (i.e. to trigger a growing shift away from a reliance on foreign imported oil to homegrown biofuels) hasn’t been realized. Instead, the ratio of ethanol-to-gasoline seems permanently stuck at 10%. The hope that consumers would graduate to E15 or even E85 has faded, at least as far as corn ethanol is concerned.

The purpose of this conference was to consider the role of alternative fuels above and beyond corn ethanol. Indeed, except in one or two presentations and some questions, corn ethanol hardly came up. Instead, the focus was on ethanol and methanol derived from a far more abundant feedstock, namely natural gas.

As this conference has shown, America’s current shale gas revolution has to be part of any serious discussion of moving the country toward fuels of the future.

The shale revolution is a real revolution, bringing real energy security to America. In 2000, hydraulic fracking produced one percent of U.S. gas supplies; today it’s approaching 40%, making the U.S. the world’s biggest NG producer. America’s natural gas reserves mean the shale revolution is here to stay. Today total reserves exceed 350 trillion cubic feet, making it the fifth largest in the world. With new extraction technologies, that’s expected to grow to 2.7 quadrillion cubic feet over time—or equal to the two countries with the biggest reserves, Russia and Iran, combined.

America’s growing abundance of natural gas led it to become already one of the fastest-growing alternative fuels, as compressed natural gas (CNG). Presently more than 12 million CNG vehicles travel the road worldwide,
while CNG is becoming popular in the United States for trucks, buses, and other heavy duty vehicles.

Conference participants demonstrated, however, the most promising use of natural gas in transportation is as a feedstock for producing methanol and ethanol. The use of natural gas to make methanol is already well-established; converting to ethanol is no mere laboratory experiment either. Companies like Coskata in Illinois (whose Director of Project Development, Loula Merkel, was invited to the conference but was unable to attend) have developed natural gas-to-ethanol processes that are up and running, and increasingly cost-effective. Cost-effectiveness is the key.

This brings up the other big change in America’s energy picture that has seemed to undercut interest in alternative fuels, namely the precipitous plunge in oil, as well as gasoline, prices since 2015. In fact, today American motorists pay less for a gallon of gas in constant dollars than they did in the heyday of cheap gas, in the pre-Arab boycott 1960s. With prices like this, why would consumers—let alone lawmakers and energy policy strategists—take an interest in methanol and ethanol at all?

In fact, there are several good reasons. One is that experience has shown that commodity prices that go down also tend to go up over time, especially oil prices. Anyone who thinks that $30 or $40 a barrel oil will be the norm in 2018 or 2020 needs to think again—certainly the experts don’t imagine prices will remain much below $60 in three years, even with the most optimistic production scenario. By introducing the shift to alternative fuels now, policymakers can prepare America for the day when prices get back to the $70 to $100 range, rather than face an angry public that wants to know why we didn’t do something to move away from petroleum gasoline back when we had the chance.

The other reason is that if oil is cheap, natural gas is even cheaper. As the participants in this conference showed, oil and natural gas prices became decoupled in the mid 2000s, with the first rising and falling with the global market, and the other trending ever-downward (see Figure 1, page 47). Whether it’s natural gas used for CNG vehicles or as feedstock for ethanol and methanol, natural gas will remain significantly more cost-effective than oil as a source for transportation fuel for a very long time to come.

Above all, it will be a source that’s American-made, producing American jobs and American transportation independence, in ways that no boycott or production cuts by the Organization of Petroleum Exporting Countries (OPEC) can ever threaten again.

Brazil, China, and also Europe are already looking to the change-over to ethanol and methanol as principal transportation fuels. Thanks to abundant natural gas, the outlook for the United States looks even more promising and plausible—as well as more profitable for those who become part of this, the next American transportation revolution.
When I travel to places where gas averages a dollar-per-gallon lower than prices last year, people ask me, “Why is your foundation, Citizens for Affordable Energy, still operating? You won. You achieved affordability.”

We haven’t achieved affordability. In fact, the recent reduction in prices is a pretty significant step backward in where we need to go. It creates comfort and a sense of security without any basis for either. The primary reason that I care so much about alternatives and future fuels as a person from the oil patch is because I know the
limitations on oil availability. I know what’s possible and
what’s not. The appetite for oil worldwide will never, ever
be satisfied from the oil patch. It can’t be. There will never
be enough oil.

The risks, the costs, the geopolitics really cannot begin to
address the two billion people on this earth who don’t
have access to oil-based petroleum fuels. There just
isn’t enough. Nature has not been kind or generous
even to create a sufficient amount of recoverable oil for
all to afford. We are headed for an era in which, without
substitutes for oil, many will not have access to oil at any
price. Moreover, what oil remains available poses a
challenge to risk and affordability.

There are benefits that we’ve received from today’s
energy system, and I am speaking broadly from a
power generation and delivery standpoint to a fuels
development, fuels delivery, and fuels consumption
standpoint. However, the pressing reality is
much different. We have the largest, second dirtiest, and
oldest energy system in the world. I don’t know how many
people get out of bed in the morning and jump up and
down for joy to have the largest, second dirtiest, and
oldest energy system in the world. I know I don’t. Not
when we are surrounded with technological advantages
that address the rest of our normal lives, such as our
nutrition, our health care, information needs, analytical
needs, our global travel and personal mobility needs, our
defense needs, etc.

**WE HAVE THE LARGEST, SECOND
DIRTIEST, AND OLDEST ENERGY
SYSTEM IN THE WORLD.**

While we are out in front leading the world across so
many sectors of our economy, when it comes to energy
we rely on electrons and molecules from the world’s
oldest energy system. But when we consider future
opportunities for energy development, that is, to me,
when the pulse begins pounding. That's when you can get
excited, jump out of bed in the morning. If molecules and
electrons for the future get you going, there’s no end to
the possibilities as we look ahead.

What’s possible is not just the steady state capital
infusion of six hundred, seven hundred billion dollars a
year, which the industry makes on our behalf to keep the
existing system running, even if with “band aids and
paper clips.” What’s possible can actually be expanded
upon at a solid rate of return to spend upwards of a trillion
dollars a year to move beyond where we are, to where we
could be. To spend a trillion dollars a year instead of six or
seven hundred billion dollars a year would soon make a material difference in the future prospects of the energy system and our economy. Were we to put that three, four hundred billion dollars additional into what’s new, what’s technologically different, what’s cleaner, what’s more efficient, what’s more effective, what’s safer, what secures the nation even more than it is secured today, then we could become truly excited.

The economic multiplier of such investment creates jobs right here at home, creates value for investors, creates security for citizens, and reduces the drag of waste on the environment. Why can’t we seem to get unplugged from the oldest and second dirtiest energy system and move towards a new system? It is a mystery that most of us in this room have been grappling with not just for a few months and probably not just for a few years, but frankly for a decade or more, as we realize that the aging system simply isn’t what it used to be.

That three to four hundred billion extra per year, with an economic multiplier of a traditional three times or better, puts a whole lot of economic impetus into an economy that struggles to grow. If you read this week’s analysis of the .02% GDP growth for the first quarter of 2015, which is likely to be revised downward at the end of the second quarter, we’ll realize that we may have actually experienced negative growth in the first quarter of the year. I don’t know about you, but the people I talk to certainly said it felt like negative growth to them, as they experienced the first quarter after all these years since 2008 of truly anemic recovery compared to what we have experienced heretofore.

Energy is at the heart of making this nation more secure. Enough energy is absolutely critical. We’re fortunate to have considerable energy natural resources. Many nations have limited or few such resources, and not enough to deliver basic security and economic well-being. Energy is clearly the lubricant for what makes everything else possible. If you don’t have enough, then you’re paying too much. Our job is to make sure we have more than enough. Those of us from the energy producing industry always look at availability in the market to make sure it is amply supplied and affordable.

Contrary to popular belief, oil companies don’t actually like high oil prices. They like predictable, rational prices that deliver a return on investment over time. Companies do not like spiking, ever-higher prices because of what happens as a consequence. The cure to high oil prices is high oil prices. People stop buying. Surplus is developed and prices collapse.

Then what’s the cure to low prices? Low prices, because people stop producing and sure enough, we run into shortages and prices rise. This ever-continuing volatility is not good for the industry, it’s not good for national security, and it is horrific for the economy. Oil companies have been around a long time. They see beyond the advantages of volatility, either way, and look for those predictable price spots. They call them sweet spots when you can achieve an attractive investor return; maintain a stable workforce; invest in R&D; and produce enough energy to keep the nation well-supplied.

The security aspect starts with the power generation system, which is the oldest part of our energy system. There is quite a bit of attention being paid to EMP, or electromagnetic pulse attack—which you saw in the movie, Oceans 11, when Las Vegas’s power distribution was shut down so people could rob a hotel casino—by agencies of the federal government, including Department
An EMP attack would shut down most, if not all, of the U.S. energy grid. It would be devastating to our national security and would result in millions of deaths due to a lack of secure electricity.

People are concerned about the lack of energy security because of the unplanned consequences of changing environmental regulations on new or existing coal-fired generation. The facts of the matter are that the power generation system has been mostly taken for granted. From that kind of a high risk, as well as the security-driven importance of alternative transportation fuels when there isn’t enough affordable oil, we can’t be too prepared for an uncertain future. Mere rhetoric about the future of energy is more harmful than most people realize, because it creates a false sense of security.

The worst rhetoric that I’ve heard in recent years is the so-called “all in, all of the above” energy plan of the current Administration. The reality is it is nothing but rhetoric. I am not one for confusing American citizens on what is or what isn’t. And “all in, all of the above” may be fine as an aspiration, and I’ll accept it as such, but as a description of a strategy or a policy, it’s deceitful. It does not exist. What does exist, however, is the high risk of the simple reality of what we face in the marketplace today. Power generation is headed for serious risk of supply deficiency in my judgment. Our energy future is based on aspiration when, in fact, it should be based on perspiration and doing the work needed to build it out.

I am in favor of EPA higher standards on emissions, but the manner in which we are going about it, by rushing to conclusions without recognition of risks, is wrong. I have talked with multiple CEOs of utilities who are simply tired of the fight and of not being listened to. They are set to shut down coal plants at the number necessary to achieve what they need to meet new regulations; this would result in a serious loss of coal plants over a relatively short period of time. Without a plan for alternatives to replace those coal plants, our nation will be at great risk. Such risk is magnified in the worst weather, such as polar vortexes in winter or hot, steamy summers.

People die when energy is not available. I work in an industry where we know and understand that. We need to have a plan, which takes time to develop and implement. We put ourselves at great risk by rushing to achieve what we are trying to achieve without a plan to substitute alternatives for what we are currently doing. It puts ourselves at great risk, given the age of the system; the inability to put pipelines in place to move...
gas to where coal currently is used; the time it takes to substitute coal-fired for gas-fired generation; the inability to adjust the grid rapidly to the variances of increased use of renewable energy. Seriously bad things can happen without a plan, which takes time to develop and implement.

While bureaucracies may say that they can handle the risk, they aren’t the ones that deliver on risk. It’s the utilities that operate and that deliver on the risk, so when I hear the utilities saying to me, “We are not going to be able to meet the risk,” I pay more attention to them than to those who assure the risk from their bureaucratic safety zone.

Power generation for the 21st century could be so much different if we went about creating it by using time and planning to our advantage. For example, people who work in nuclear energy know that the current approach to nuclear energy can be displaced by a much different approach, such as small, customized nuclear reactors and the use of thorium over uranium. We must finally come to grips with nuclear waste and make waste management a higher priority than it has been recently, so that we actually store that waste, as we thought we had committed to three decades ago. With proper re-thinking and regulatory support, I still believe that the future of nuclear could be quite bright.

Clean energy natural gas refueling station. Natural gas is an excellent alternative fuel. It is relatively inexpensive (depending on location, half the price of gasoline) and contains less carbon than any other fossil fuel, thus significantly reducing exhaust emissions. (Photo by Car Culture, Getty Images)

Then there is the opportunity for carbon capture and sequestration (CCS). People are giving up on carbon capture and sequestration because of the costs, but we’ve never really explored it. We have never really tested it. We have never really committed ourselves, because we keep on revisiting and revising our commitments. FutureGen is a thing of the past. The previous administration killed it. The next administration restarted it and has since killed it. There will not be a FutureGen.
project, through the entirety of the Bush administration and the entirety of the Obama administration. It’s done for. That’s not a good test.

Those who have experienced CCS, as I have in other parts of the world, still believe that this is a technology that we can develop, pay for, and utilize. Overall, what you achieve is the more efficient use of coal, if you’re gasifying it, and an economically feasible price of coal relative to other commodities in the long term.

**NATURAL GAS HAS A BRILLIANT FUTURE AS A SOURCE FOR GENERATING POWER.**

Natural gas has a brilliant future as a source for generating power. There is also solar, wind, and storage, which would need to be developed at scale and with sufficient materiality to make a difference to our energy security. With storage, whether it’s hydrogen or other storage mechanisms such as industrial batteries, the opportunity for a 21st century of renewable and rejuvenated power generation presents itself to us, provided we build more distributed generation and accompanying intelligence into the grid. We should get on with it as a matter of national priority and build out with appropriate enabling regulation.

Then, we get to transportation and fuels, and of course, this is why we’re here. This happens to be my favorite subject and where I’m focusing more and more attention and efforts. The creativity of American capitalism, the ingenuity of innovators, and the need for alternative energy sources means that the opportunities in the upstream, midstream, and downstream businesses of future fuels couldn’t be better.

Obviously, I am a fan of and participant in the movie *PUMP*, which focuses on a future of alternative fuel choice. I’m also delighted and grateful to the Fuel Freedom Foundation for having produced it. It’s a great job done by so many people. If you visit fuelfreedom.org and click on the “Our Work” tab, you can scroll down and click on *PUMP* which will give you information about how to watch it. The effects, the music, the scenes, a little bit Hollywood, but also incredible truth, absolute reality in the possibilities, confidence in the solutions, because they are being contributed by people who know, people who do this for a living, people who work it every day, people who have committed their life, their professionalism and their livelihood to the possibilities of alternative fuels.

**THE CREATIVITY OF AMERICAN CAPITALISM, THE INGENUITY OF INNOVATORS, AND THE NEED FOR ALTERNATIVE ENERGY SOURCES MEANS THAT THE OPPORTUNITIES IN THE UPSTREAM, MIDSTREAM, AND DOWNSTREAM BUSINESSES OF FUTURE FUELS COULDN’T BE BETTER.**

In the last five years, there has been increased focus on domestic oil and natural gas production. This has made a dramatic difference not just to our nation, but to the world. The opportunity to utilize natural gas for transportation fuels, ranging from compressed natural gas, liquefied natural gas, ethanol, methanol, and gas-to-liquids has never been better. The transportation electrification prospects using battery vehicles, hydrogen fuel cell vehicles (which today are actually taking their place on the highways of California because the leadership of California is assuring the development of some 100 refueling stations for hydrogen vehicles) likewise has never been closer. Two fuel cell vehicles—
one from Hyundai, one from Toyota—are actually hitting the market this year. We see increased evidence of battery vehicles across much of the nation.

The opportunity for investors to build new infrastructure for the midstream and downstream for these alternative fuels is growing apace. This enables, for example, a current distributor of traditional gasoline in a city like Little Rock, Arkansas, where the distributor might have 150 multi-branded gas stations to tap into a natural gas pipeline and create a leadership position in methanol manufacturing by putting capital to work to make, distribute, and sell methanol from natural gas and to be the first in his region to produce M85 for sale to vehicles across that region. Such entrepreneurial initiative might perhaps trigger interest by Wal-Mart in Northwest Arkansas; think about the national possibilities of methanol across the Wal-Mart network of the nation.

We need to think about moving step-by-step to a more affordable, cleaner alcohol fuel that works in flex fuel vehicles (FFVs) adjusted to accept such fuel, as we witnessed in the movie PUMP. There will be software adjustments, with the cooperation of automotive

IN THE LAST FIVE YEARS, THERE HAS BEEN INCREASED FOCUS ON DOMESTIC OIL AND NATURAL GAS PRODUCTION. THIS HAS MADE A DRAMATIC DIFFERENCE NOT JUST TO OUR NATION, BUT TO THE WORLD.
manufacturers, as they have cooperated in Brazil and in China, to make flex fuel vehicles a major step forward in the substitution of such fuels for oil products. The opportunity for FFVs in this country to be powered by alcohol fuel is every bit as powerful as in those China and Brazil. We have no rational reason why not to move forward. The economy grows as the midstream gets developed along with the manufacturing and the distribution to support retailers who take the risk and assume the opportunity to get into the alternative fuels business.

WE NEED LEADERS TO MAKE A DIFFERENCE, EVEN WHEN IT IS UNPOPULAR, BY HELPING CHANGE FEDERAL AND STATE REGULATIONS CURRENTLY IN THE WAY OF ALTERNATIVE FUELS.

What does it take to make all this happen? It takes just a few enablers to create the new power generation system of the 21st century, with its innovations, its security aspects, and the opportunity to supplant oil imports coming from an ever more dangerous and unreliable world by other domestic alternatives. Forgive the boldness of my statement, but it first of all takes leaders who actually lead. Leaders who are willing to make a difference, to stand up to those who disagree and say, “This is where we’re going.” We need leaders to make a difference, even when it is unpopular, by helping change federal and state regulations currently in the way of alternative fuels.

The easiest job in the world is simply to say “No.” It takes limited intelligence, little sophistication, and rejection of complexities in modern society. What’s hard work is how you get to yes on alternative pathways in the face of resistance from opponents. If we can’t get to yes in the regulatory world, my advice is to die trying, because the nation needs it. We can’t take no as the answer. Remember my first point on energy is that there is not enough oil for future generations to enjoy the benefits going forward, that much we know from our past. There will never be enough oil for a variety of reasons, and we will never get past the damaging effects of the volatility of oil if we don’t have competition from alternatives to oil.

We’ve got to get to the regulatory “yes” that’s required to adopt the full range of alternatives to oil products. That’s not easy. That’s hard work. It takes a lot of intellect, creativity, and a lot of personal energy. It also requires considerable influence, particularly when you are trying to make changes facing up against those who would rather not see changes occur. We need frank and factual information, not political agenda. The politics of energy has always been energy’s greatest obstacle. If we continue to allow the politics to dominate us, there will be a crisis of energy unavailability. We will be overcome by stiflingly high prices and energy shortages.

We need to inform the regulatory leaders, through frank and factual conversations, about the prospect for economic value creation and the environmental upsides of fuel competition. If we stay on the path we are on, our economy will suffer due to a lack of fuel competition, availability, and affordability. If we stay on the path we are on, we will not have a cleaner environment.

What is in the way today, apart from the lack of leaders who lead, and regulations that enable, is obvious and massive public unawareness. Extraordinary lack of knowledge, which I believe every one of us by our presence here today is willing to acknowledge, must be addressed. Lack of awareness feeds the politics of
perversity. By perversity, I am speaking about those who use the tools of politics to not just refute the other side but to essentially punish it, by not seeking mutually agreeable solutions.

We could each have a view about which side utilizes more perversity than the other, but for me who lives well beyond the Washington beltway, I see both sides outdoing the other and performing all too well. No wonder we are where we are, facing multiple frustrations along the pathways to alternative fuels. The politics of perversity and the politics of energy are a combustible combination, where the outcomes are too often simply nil.

In addition, the fragmentation of governance continues to afflict us. Executive agency finger-pointing, congressional finger-pointing, adjudication recalcitrance—all at the federal level. Then you get to the states where it happens all over again. Then you get to the communities, the municipalities, and the counties, where we face it again. It’s at every level of our federal system. I’ve written at length about the fragmentation of governance in my book (Why We Hate the Oil Companies: Straight Talk from an Energy Insider—Palgrave MacMillan, 2010). While all may not agree with my ultimate solution of an independent regulatory agency for energy and the environment, similar to the Fed for the monetary system, we could still do a lot to decrease fragmentation.

Because of my time in the corporate world within multiple industries where leaders can act with authority to make change, I now realize I did not truly understand what stands in the way of public policy change. Set aside political perversity. Set aside leaders who don’t lead well. Set aside public unawareness.

There is something else that I’ve come to understand more fully as I’ve tried to work on public change, not just in my own respect and through Citizens for Affordable Energy, but in cooperating with the U.S. Energy Security Council, with the Fuel Freedom Foundation, and with any number of additional NGO’s and environmental groups and individuals with high impact. It’s the power of the status quo, as I’ve come to learn, to throw out enormous and debilitating roadblocks in front of the advocates of change. The power of the status quo is perhaps the greatest obstacle in the way of energy change.

This power involves almost everyone who contributes to, who manages, and who maintains what we have today. It’s a very large and powerful group from all sectors—

IF WE STAY ON THE PATH WE ARE ON, OUR ECONOMY WILL SUFFER DUE TO A LACK OF FUEL COMPETITION, AVAILABILITY, AND AFFORDABILITY. IF WE STAY ON THE PATH WE ARE ON, WE WILL NOT HAVE A CLEANER ENVIRONMENT.
industry, companies, government, NGO’s, and individuals. They don’t always agree with each other but what they do agree upon is the reality that the status quo works. Yes, the lights are on, and yes, you can go out from this meeting and fill your tank with gasoline, maybe blended with a little corn ethanol, that will carry you from here to Pittsburgh. But don’t waste my time imagining a system that threatens today’s reality. Don’t worry me over what isn’t; let me stay focused on what is. The current system works. It has its risks, it has its insecurities, but it works today and it will probably work tomorrow as well. The question people like us are asking is, will it also work in 2020, 2025? Maybe, but probably not by 2035. What do we do about that? What we do is embrace the daunting reality of the challenges we face. In the first instance, education comes to the top of the list. We have to educate ourselves, our fellow citizens, everyone who needs to know what our options are. Second, this means also we have to engage in order to educate.

I took some 250 Shell managers, in my final years in the company, to 50 cities across the country to engage our customers and local leaders. Many of them were frightened by the thought of going into town hall meetings full of complete strangers. Five managers per city who had never had town halls, other than with their own staffs, now faced the general public in cities across the nation with no defense but their own knowledge and personality. Frightening yes, but did they learn quickly? Most of them wanted to do more and more as they got into the process. Engagement can be hard but it has its own dynamic and is absolutely critical to the process of education.

Thirdly, we have to be persistent. We wouldn’t be here today if it weren’t for persistence, would we? Persistence matters, because we believe what we believe, we know what we know, and we are going to do what we can do. Persistence matters. We all face the inevitability of crisis otherwise. When crisis takes over it looks like five dollar or more gasoline—or worse, not enough gasoline. Crisis also looks like power brown-outs and black-outs at the worst times of year, at the peak hours of the day. That’s crisis, when the lights go out at a peak hour and you can’t find gas at any price.

Ultimately, the success of what we are going to do, ladies and gentlemen, and I never thought I would say this, but in fact in recent speeches I’ve been saying it regularly. What we really have to do here—given all the realities of the regulatory disablers, the public’s lack of awareness, politics in energy and political perversity, and ultimately the powers of the status quo—what we have to do is to embrace incrementalism as our way forward.

As an advocate of transformational change, it is difficult for me to even mouth the word. But as a realist and pragmatist, gaining ever more experience in the world of public policy and democratic policy making, it is ever clearer that incremental change is the only change that’s viable under the circumstances.

There is a concept called “successive approximation,” which many of you will have learned about when it was in vogue in the 1960s and 70s. I understand it’s hardly mentioned today. Successive approximation is the technique of learning how to do something in increments, such as a child learning to walk by first crawling and then THE POWER OF THE STATUS QUO IS PERHAPS THE GREATEST OBSTACLE IN THE WAY OF ENERGY CHANGE.
taking assisted steps followed by unstable independent steps followed by mastery of balance over time. As we consider embracing incrementalism, we need to figure out how to “successively approximate” the steps forward in remaking our energy system for power generation and fuel choice for transportation. As we consider such steps, our goal should include foregoing crisis, which means we need to identify steps that get us on our way and carry out the implementation as rapidly as we possibly can.

WHAT WE HAVE TO DO IS TO EMBRACE INCREMENTALISM AS OUR WAY FORWARD.

We could argue that we would be aided and assisted by crisis, but in the near term, it’s not here today and likely not tomorrow. We shouldn’t wait for it. And frankly, the powers of the status quo will try to make sure that we don’t experience such crisis that would rapidly change minds. They obviously, and more practically, best defend their positions by protecting the status quo by avoiding crisis.

Successive approximation and incrementalism are what get me out of bed for now. A little bit of change today, that conversation with a particular person tomorrow, that speech the day after tomorrow, that opportunity to attend another event next week, that
opportunity to engage a committee chair, a ranking member, a member of an appointed group of executives in the executive branch, those opportunities to make the point, those opportunities to use frank and factual information, those opportunities to strip the facts of politics and to simply look at the reality of our alternatives. Those opportunities continue to come along and keep motivation growing. We’ll have to take advantage of them.

I don’t see a revolution coming our way. So let’s get on with the important, necessary, and for the sake of progress, incremental steps that make a difference.

I don’t see a sudden awakening on these topics in a nation that should have had multiple awakenings. I see more hard work. I see more science. I see more research. I see more persuasion down the pathway of trying to achieve what we’re trying to achieve, and a meeting like this is an excellent way to come together on what it is we have to say and to agree on what to do.
Over the last year, Oak Ridge National Labs (ORNL) has been investigating the potential benefits of high-octane fuels. Particularly ethanol, which is the largest volume biofuel in the U.S. (Figure 1). The nation has been at an E10 “blend wall” for a few years. We use about 130 billion gallons of gasoline per year, so the blend wall is at about 13 to 14 billion gallons. Currently over 99% of ethanol is used in E10, with very little being used in higher level blends. If the Renewable Fuel Standard continued to mandate the use of more ethanol, how might the nation comply?

E15 is legal now since the EPA’s approval of the waiver in 2010. Several manufacturers permit the use of E15 in their newer vehicles. The EPA waiver says E15 is legal to use in 2001 and newer vehicles (although many of the vehicle manufacturers don’t necessarily agree). For those unfamiliar with flex fuel vehicles (FFVs), these FFVs can use any blend of ethanol and gasoline. They are historically underutilized, consuming less than 1% of the nation’s ethanol.

**FIGURE 1**

**Ethanol is Currently Our Largest Volume Biofuel**
This analysis will describe the prospects for a high-octane, mid-level ethanol blend. A great way to create high-octane fuels with excellent engine performance is to have a 25%, 30%, even 40% ethanol blend with conventional gasoline.

Flex fuel vehicles have not been terribly successful for a number of reasons, even though they can use any blend of ethanol and gasoline (Figure 2). There are over 17 million of these vehicles on the road today. The intent of the Alternative Motor Fuels Act of 1988 was to enhance energy security by giving consumers and the nation options for vehicles that could use any blend. But consumers have historically avoided flex fuel (also known as E85) because it is frequently not priced on a cost competitive basis, such as on dollar-per-BTU or dollar-per-mile basis. The consumer can be further confused because the amount of ethanol that is actually in the E85 or the flex fuel can vary widely (from 51 to 83% ethanol). One thing that is encouraging is that some of the E85 pumps are blender pumps; so the consumer can actually choose E30, E40, or E50. The bottom line is that flex fuels have not been successful at displacing petroleum because the consumers have not accepted them.

Ethanol is an excellent octane booster (Figure 3), with a very nonlinear blending effect; two thirds of the octane benefit is realized from the first one third of the ethanol blend volume. The EPA also opened the door for a high-octane E30 in the Tier 3 rule, which was finalized last year. The option is still there, but at present a high-octane certification fuel does not exist. It is a challenge to get something like E30 in the marketplace, but it is certainly more straightforward than trying to deploy millions of electric, natural gas, or hydrogen fuel cell vehicles. The infrastructure (e.g., dispensers) does need some attention to realize this high-octane mid-level ethanol blend vision, but it is less daunting than some of the alternatives.
THE BOTTOM LINE IS THAT FLEX FUELS HAVE NOT BEEN SUCCESSFUL AT DISPLACING PETROLEUM BECAUSE THE CONSUMERS HAVE NOT ACCEPTED THEM.

The United States already has a gasoline infrastructure and an ethanol infrastructure, so changing the relative volumes of the two should not be that difficult. It would not be as daunting or difficult as the alternatives cited above. One of the dispenser manufacturers at the National Ethanol Conference a couple of years ago mentioned that they typically sell 20,000–40,000 dispensers per year. If the fuel of the future is, for example, E25 or E85, then it would be unfortunate to look back in five years and have installed 100,000 E10 dispensers that are not compatible with future fuels. From an energy security perspective, I would rather have the infrastructure and not need it, than need the infrastructure and not have it. The time to install the infrastructure for the fuel of the future is now.

Figure 4 covers data from a single cylinder research engine and is based on research from Jim Szybist and Derek Splitter at Oak Ridge National Labs. It is a figure of an engine map with 9:2:1 compression ratio. Think of the y-axis as torque (in single cylinder research, engines use Indicated Mean Effective Pressure) and the x-axis is engine speed (rpm). This research engine is actually based on a turbocharged, direct-injection Pontiac Solstice.

THE UNITED STATES ALREADY HAS A GASOLINE INFRASTRUCTURE AND AN ETHANOL INFRASTRUCTURE, SO CHANGING THE RELATIVE VOLUMES OF THE TWO SHOULD NOT BE THAT DIFFICULT.
engine. With the factory 9:2:1 compression ratio and 87 octane gasoline, the red area shows the available torque and power. If the compression ratio is raised to 12:1, as the blue area shows, the engine becomes more efficient, but the available torque is severely limited because of the knock. The map for this condition is shown by the blue area. Thus with 87 octane gasoline and a high compression ratio, the knock is just too severe and significantly limits the available power. In this configuration, this is not an engine that a consumer would want to drive in a car with a conventional powertrain.

However, with the 12:1 pistons and a high-octane E30 fuel, as shown in orange, the available torque is doubled compared to that with the 87 octane gasoline. This doubling of torque is important because lines of constant power look like this curved white line in the middle of the figure. Imagine driving today’s car with 87 octane E10 or E0, at 2800 RPM cruising down the road; but with this future engine, the engine can slide up that white curve to the left, lowering speed, increasing torque, and maintaining the same power.

Having a new high-octane fuel in the marketplace would move the nation toward multiple goals, one of which is improving engine efficiency.

A new high-octane fuel could make better use of ethanol properties, moving the nation toward multiple goals:

- Engine efficiency can improve with increasing ethanol and octane
- Data suggest that E25-E40 blend in future vehicles can return equivalent “tank mileage” as E10 in conventional vehicles
- Energy density penalty is linear with increasing ethanol concentration
- Power and efficiency gains are non-linear
- Volumetric Fuel Economy Parity means every gallon of ethanol displaces a gallon of gasoline
  - CAFE (fuel economy) benefit to OEM is significant
  - GHG Benefit is significant
- Can help nation achieve RFS compliance
- Legal to use in >17M legacy FFVs

There is an optimum ethanol blend in the range of 25 to 40% ethanol where one can achieve “volumetric fuel economy parity,” which means the vehicle gets the same miles-per-gallon fuel economy with this high-octane, mid-level ethanol blend that you would get with E10 in today’s vehicles, despite the lower energy density from the higher ethanol blend. This means the consumer wins (or is at least not penalized). For this idea to be successful, all stakeholders (the consumer, the ethanol producers, the vehicle manufacturers, and the energy companies) need to derive some benefit.
The benefit to the manufacturers would be a significant Corporate Average Fuel Economy (CAFE) benefit and lower greenhouse gases (GHGs). Energy companies would achieve enhanced RFS compliance if ethanol is the source of high-octane. That is a potential bridge to this high-octane mid-level ethanol blend. There are over 17 million legacy flex fuel vehicles on the road today, most of which use E10. These vehicles could use this high-octane mid-level ethanol blend legally. Once the fuel is widely available, manufacturers could begin to offer vehicles dedicated for this fuel. For this to be a resounding success, the fuel needs to be widely available.

We are currently doing some engine and vehicle work on high-octane fuels for the Vehicle Technologies Office (VTO) and the Bioenergy Technologies Office (BETO) of the Department of Energy. Several of the projects also have industry involvement including Ford, GM, and the Coordinating Research Council (CRC). The BETO high-octane fuel effort includes a vehicle level demonstration as well as work with National Renewable Energy Laboratory (NREL) and Argonne National Laboratory (ANL) on market analysis, greenhouse gas analysis, and infrastructure compatibility.

The benefits of downsizing engines, for example, were demonstrated recently in a vehicle that is available today (Figure 5). The Ford Fiesta EcoBoost is equipped with a 1 liter, 3 cylinder turbocharged gasoline direct-injection (GDI) engine. The turbo GDI engine is the kind of engine that can take advantage of high-octane fuel.

![FIGURE 5](image_url)

**Benefits of Engine Downsizing with High-Octane E-Blend Demonstrated on Late-Model Turbo GDI Vehicle**

<table>
<thead>
<tr>
<th>FUEL</th>
<th>E0</th>
<th>E15</th>
</tr>
</thead>
<tbody>
<tr>
<td>RON</td>
<td>90.7</td>
<td>97.8</td>
</tr>
<tr>
<td>AKI</td>
<td>87.7</td>
<td>92.6</td>
</tr>
<tr>
<td>Btu/gal</td>
<td>113,100</td>
<td>106,700</td>
</tr>
<tr>
<td>Relative Btu/gal</td>
<td>1.00</td>
<td>.943</td>
</tr>
</tbody>
</table>

Addition of 15% ethanol boosts octane, improves engine performance and efficiency.

For this car, the manufacturer does note in the owner’s manual and at the fuel filler label that the vehicle is E15 compatible. The owner’s manual further notes that regular gasoline is recommended, but that premium fuel will provide improved performance and is recommended for "severe duty usage."
Figure 5 also shows the relative fuel economy on three different test cycles, including the “US06” test, a high-load certification cycle that involves full-throttle acceleration and high speed operation. This would definitely be considered severe duty service, particularly for a car with a small engine. The car was evaluated with 87 octane E0 and the same gasoline blended with 15% ethanol, producing a “premium E15” with 92.6 AKI or 98 RON as shown in the table. For the US06 test, the efficiency improvement with the high-octane fuel was 4.6%. There were no changes to compression ratio, or shift schedule, only the fuel was changed. When the vehicle is subjected to severe loads with high-octane fuel, there is a significant efficiency improvement because the car is knock-limited with regular gasoline; switching to a high-octane fuel allows the engine to operate at more efficient conditions thus improving efficiency.

Among the possible approaches to getting such a high-octane blend into the marketplace, one approach could be to use “market pull.” One scenario would have FFVs be the bridge to having this fuel widely available in the marketplace. Imagine retailers advertising to FFV owners that their vehicle will run better with this fuel. In the experiment, four legacy FFVs were evaluated in a wide open throttle (WOT) acceleration test with 87 octane E10 and 100 RON E30. Three of the four vehicles were significantly faster with the high-octane E30. These are off-the-shelf vehicles; there were no changes to the vehicles except the test fuel. It is worthwhile to note that the GMC Sierra FFV showed a similar performance improvement in the E30 experiment as a similar Chevrolet Silverado FFV tested with E85 in Car and Driver. This result highlights the non-linear octane blending effect of ethanol mentioned previously; while 85% ethanol provides a significant ethanol boost, 30% does as well, such that the acceleration performance is improved by a similar amount. There are over 17 million consumers driving FFVs; is it possible to get them to actually clamor for this fuel because their trucks and SUVs perform better when towing?

IF 50% OF THE FLEX FUEL VEHICLES ON THE ROAD TODAY WERE TO USE E30 50% TIME, THE U.S. WOULD CONSUME AN ADDITIONAL 500 MILLION GALLONS OF ETHANOL PER YEAR. THIS INCREASED ETHANOL CONSUMPTION WOULD BE A WIN FOR ENERGY SECURITY SINCE ETHANOL IS A DOMESTIC ENERGY SOURCE.
If 50% of the flex fuel vehicles on the road today were to use E30 50% time, the U.S. would consume an additional 500 million gallons of ethanol per year. This increased ethanol consumption would be a win for energy security since ethanol is a domestic energy source.

Another scenario for increasing use of high-octane certification fuel is the regulatory approach. Unleaded gasoline was mandated in the 1970s; a similar requirement for octane could be one way to get a new fuel into the marketplace. The U.S. is one of the few developed nations in the world that does not have octane specifications. The ASTM D4814 and D5798 fuel specifications do not have an octane requirement; octane is regulated by the states. Regular 87 octane gasoline is available everywhere, but in the high altitude states, there is still some 85 octane gasoline offered and sold, although no current manufacturers permit the use of this fuel in their vehicles. When building an engine, the manufacturer is going to be concerned about the consumer who is going to damage the engine by putting the wrong fuel in the vehicle, and then seek warranty claims.

Regulating octane in the U.S. would not be a new precedent. In fact, in Europe they have 95 RON regular everywhere, which is roughly equivalent to the current premium fuel offered in the U.S. Still another scenario involves corn ethanol. Corn ethanol is 47% renewable, while 42% of the energy comes from natural gas. Therefore, one path to put more natural gas into the transportation sector is to produce more corn ethanol. The U.S. consumed over 13 billion gallons of ethanol in 2013, largely as E10 blended into gasoline. The energy that this amount of ethanol represents in our gasoline pool is equivalent to almost 7 million light duty CNG vehicles. The U.S. has about 150,000 natural gas vehicles. Natural gas is a significant domestic source of energy transportation, even though few people recognize it as such.

In light of these figures, it seems clear that an E30 infrastructure is a more tenable goal than directly fueling millions of vehicles with natural gas along with the requisite infrastructure.

The Renewable Fuel Standard has been and can continue to be a driver. The fuel economy credit for manufacturers to build flex fuel vehicles will end in 2019. In 1988, Congress passed the Alternative Motor Fuels Act, a law that made the FFV possible and gave the OEMs incentive to build these vehicles for energy security reasons. While not yet a significant contributor to non-petroleum fuel use, if OEMs stop building them, the nation will clearly never achieve that energy security objective. If OEMs can continue to build flex fuel vehicles and the nation invests in more flex fuel dispensers or more E25/E30 pumps, then the OEMs could transition to vehicles dedicated to a high-octane blend such as 100 RON E30. It would be interesting to conduct a market study to see if current FFV owners will buy high-octane E30, or “Renewable Super Premium for your FFV.” We’ve shown that FFVs experience a performance improvement with high-octane E30; it is conceivable that these vehicles could realize a
fuel economy improvement in a towing situation. In such a market study, it would be helpful for the high-octane E30 to be priced attractively.

Long range (Figure 6), how do we define a new high-octane fuel? Some suggest that the focus should be on fuel performance; the (as yet undetermined) specification might be met in a variety of ways. One retailer might offer E25 that meets the specification, another might offer E40, perhaps blended with natural gasoline. The U.S. has an abundance of natural gasoline, and it is considerably cheaper than finished gasoline, so that could help lower the cost of a mid-level ethanol blend, and the higher ethanol content could be used to help offset natural gasoline’s low octane number. Other high-octane fuels that meet the specification could contain additional refinery streams or other biofuels.

FIGURE 6

Some Potential Routes

Maintain RFS, let RINs work

Maintain OEM incentive to build FFVs

Continue to build out Flex Fuel and/or E25 Infrastructure

Offer High-Octane E25 as “High-Octane Fuel for your FFV”

- Conduct a Market Study
- Price HOF below regular, or at least between 87 octane regular and “normal premium”
  - Oil will not be $50/bbl forever
- Avoid blending E15 with even lower octane blendstocks
  - E15 in a “good” blendstock can make midgrade or premium
- Remember that domestic corn ethanol is a GHG win, even when gallon of ethanol displaces two thirds of a gallon of gasoline
  - Cellulosic is even better
  - Both are better still when a gallon of ethanol displaces a full gallon of gasoline!
  - Don’t overlook other potential fuels (e.g., butanol)


- Performance specification can likely be met with array of components (ethanol, butanol, bio-derived HCs, refinery streams)
Creating a Common Market in Future Fuels

John Eichberger, Vice President, Government Relations, National Association of Convenience Store Owners

Retail market development (Figure 1) is critical to the development of market opportunities for future fuels. When we talk about future fuels, we too often ignore the retail market and what it takes to deliver these products to the customer. Instead, we talk about the technology that can run on it and the fuel specifications that need to be used and optimized for the engines. Yet, if the customer cannot access it, it does not make any difference. What goes into the retailers considerations when they are thinking about alternative fuels? The Fuels Institute, which is a think tank the National Association of Convenience Store Owners (NACS) launched a couple years ago that I’m running, did a study last year, and I am going to use it to point to elements that retailers will look at when thinking about whether to go on a new fuel.

The critical element is to first understand that there are about 150–155,000 fuel retailers. Convenience stores run about 128,000 fuel outlets and they sell 80% to 85% of gas in the country. Even though about 50% of convenience stores are branded with signage from major oil companies, 98% to 99% are independently owned and operated.

Even though about 50% of convenience stores are branded with signage from major oil companies, 98% to 99% are independently owned and operated.

The refining industry is divesting from retail. They still have a brand presence on the street, but they do not own those stores. They have some contractual obligations and the retailers do too, but they are owned and operated by independent retailers. 58% of convenience stores sell fuel at one-store companies. These are true mom and pops. When we start thinking about cost of investment, these companies do not have a lot of capital to invest in new technology, new fuels, or new systems unless they know they will get a return on investment.

The 500 plus stores comprise a 17% market share. The growth opportunity is in the 51 to 200 store model. This is typically a more nimble company which can take chances on making investments in new technology and equipment but is not limited by the bureaucratic situation on its ability to take a risk.
In 2014, 69% of convenience stores sales were from the fuel island. 69% of gross sales is fuel related, yet only 39% of pre-tax profit is fuel. 39% is actually a bigger number considering it used to be in the 25% range. Fuel is a driver to get customers to the store, but about 30% of sales come from consumers going inside the store to buy something.

Getting customers into stores is critical, so we thought about what fuels retailers might want to offer. Retailers have to consider how many customers would be interested in a product and how to get the customers to come into the store if it’s offered. The retailer has to figure out how to convert them to a customer when the retailer is making 60%, used to be 70%, profit. Last year was a great year for margins, gross margins being net profit, (i.e. this is what I sold it for minus what I bought it for).

Not including cost of operation, credit cards, business stuff, the average margin was $0.22 per gallon in 2014. All in all, 2014 was without a doubt the best year since 2000 because there was a dramatic drop in price. Contrary to what people think, retailers make money when prices go down and lose money when prices go up. My members make money every time the price goes down because competition does not require them to match the declining price at a quick rate. Therefore, they can hold onto margin while prices are going down. When prices are going up, competition dictates that retailers do not pass through increases faster than their competitors do. They wind up playing a game of chicken: how fast can they increase their prices to cover their costs? They lose margin on the way up.

2015 was a great year for retailers, but profits are still $0.22 per gallon. After removing cost, net profits are $0.06 per gallon. That is not a huge profit margin market. It used
to be $0.02 to $0.03. If a retailer can make a nickel profit on a gallon to gas, they are doing well.

How can retailers bring new products to market and how fast can they realistically bring them to market? The Model T was invented 107 years ago. Since then, how much progress have we made? The Model T ran on gasoline 107 years ago. Today, 98% of the vehicles on the road run on gasoline, diesel fuel, or blends. The primary fuel is still petroleum-based. The turnover of the fleet takes time, as does getting consumers to adopt the new technology or new fuel for their vehicles (Figure 2). Cars are the second largest investment any consumer makes, second only to their house. For some people, their car even costs more than their house. Retailers have to keep in mind that change takes time. How long will it take to change to a new fuel? The Fuels Institute wanted to do contracted Navigant research to do a forecast of the vehicle park.

Figure 2 highlights vehicle registrations from 2012 (bottom) to 2023 (top). The red symbolizes gasoline internal combustion engines and the tan represents flex fuel vehicles. They are depicted next to each other because the majority of flex fuel drivers do not use E85, they use gasoline. Gas and flex fuels made up 98% of the market share in 2012. By 2023, we are expecting a drop down to 92%. That is not a huge drop, looking only at a gasoline decrease from 93% to 83%. There is an erosion in market share for the gasoline dominant market, but it is a slow erosion.

The greatest growth being seen is in diesel. It is a fuel people are comfortable with and does not require a new mindset or any new change of behavior. For example, if retailers start pitching electric vehicles, they are asking the customer to completely change the way they power their vehicle. When we started thinking about this and looking at the opportunities, we had to ask: what is the market there? Looking at high-octane fuel, the market is really going to be right in the sweet spot, but the question is how much?

There are about 17 million flexible fuel vehicles on the road, or about 6%–7% of the market. The rosiest forecasts claim maybe 10% of the market. If CAFE credits

GAS AND FLEX FUELS MADE UP 98% OF THE MARKET SHARE IN 2012. BY 2023, WE ARE EXPECTING A DROP DOWN TO 92%.
change, are we going to lose the production of flexible vehicles going forward? If that is the case, the market share goes down, so now we start thinking instead about E10 or E15 for certain vehicles and who can buy it.

A retailer thinks, “What is my potential market for selling a new product? Who are my customers? What they are like? Are they going to buy the new fuel?” Let’s look at E85. The Fuels Institute went out to retailers that we knew sold E85 and we asked them, “Would you be willing to share with us your daily sales data? We want to look at volume price and margins for E85 and unleaded fuel so we can run a comparison.” Two hundred stores gave us data for 18 months. The study focused on how much money retailers could make if they invest to sell E85. How much money can they make? How much fuel can they sell? Let’s take a look at some of the numbers.

Taking all the numbers together for AFDC, growth energy, and RFA: out of 150,000 gasoline retail locations, 2,700–3,300 stations sell E85 (Figure 3). The uptake has been 14% annually, but that is not a big number. If retailers are going to be producing flex fuel vehicles and trying to bring a flex fuel to market and the stations are not going to sell that fuel, retailers are not going to get any market penetration.

Why are retailers not selling E85? I mentioned before, the number of flexible vehicles in the market was 6%–7% in 2014. A retailer is going to think hard about whether or not they can generate enough sales from that 6%–7% potential customer pool to justify the investment (Figure 4). A retailer has to consider how many tanks to have. As a retailer, if I am offering a two-tank configuration at a premium and taking a regular tank and I’m blending mid-grade E85, I have to replace something. I replace my premium tank for my regular tank. If I’m a little more dangerous-minded in terms of my long term sustainability. But if I’m going to replace a tank, I’m going to give up two grades of fuel. When I give up mid-grade and premium, if I have three tanks, maybe I can make an adjustment more carefully, effectively, and efficiently without replacing any of my gasoline grades.

I can put E85 in a tank and that also gives me the ability to blend down some mid-level blends we’ve been talking about today. But if I have to put in the new tank, we’re looking at six figures, $100,000 to $150,000, to put in a new tank. In California, it could be up to $200,000 to $250,000 because of the tank tightness testing requirements. That is a big investment, especially if you’re only making $40 per station per year—and that’s a pre-tax profit we’ve seen in the last couple years. Another question retailers need to ask themselves is: are my

---

**FIGURE 3**

How Many Stores Sell E85?

*E85 stations have increased an average of 14.3% annually.*

- AFDC: 2675
- GROWTH ENERGY: 2804
- RFA: 3349

<table>
<thead>
<tr>
<th>Year</th>
<th>AFDC</th>
<th>GROWTH ENERGY</th>
<th>RFA</th>
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dispensers compatible? E85 has been in the market for a long time. No one was certified as an E85 dispenser until 2010. That means that every dispenser in the market prior to 2010 that was selling E85 was doing so in violation of federal law.

Federal law requires testing by natural testing laboratory certification, so if retailers’ dispensers are not compatible, they have to understand if there is an upgrade kit or replacement options. I have heard it costs $6,000 to $8,000 or more for an easy five-compatible dispenser, compared to an E10 regulated dispenser.

Retailers also have to consider if their tanks on lines underground are compatible. Most likely they are, but they have to be listed. They need to know what they have underground. That may not be always possible. Who is going to supply them? I know a guy down in north Texas who has an E85 station and he said, “John, I don’t sell anything. It sits there. I dust it, that’s all I do.” We were near the Fuels Institute and a guy came up to me on the street and asked, “What’s your price? I can get you a supplier from Nebraska to north Texas and save you $0.50 a gallon.”

If you can supply a product in a cost-effective way, it makes sense to go into this market. Yet 50% of the stations in the country are branded by the refinery supplier. There are restrictions on what can be sold. In 2007, the Energy Act allowed E85 to be sold under certain conditions. However only 3,000 out of the 75,000 eligible stations in the country sell E85. E85 can be sold under the canopy or brand of suppliers as long as it is clear it is not the product of that brand or supplier, but that it is only for future contracts and does not abrogate existing contracts. So there are restrictions, yet 50% of the unbranded retailers still have not run to the E85 market.

There are other business questions preventing the sale of E85, such as: what marketing support might retailers receive from the other industries and their suppliers, and what kind of return on investment might they expect for critical element?

Two hundred stations said they sold 2,500 gallons of E85. We sold 5,000 and I asked, “Is that a lot?” It depends on how many gallons of product are sold and the percentage of volume. I compared it to E85 sales compared to another sales, which is the proxy for converting. All those stores averaged 2.8%. E85 sales equaled 2.8% of their own lead sales. That may not be enough to encourage somebody to move to E85, but the question is: do those stores represent the best operators or are they doing something different? Of the 200 stores, who are the 10 on average that sold the most E85 per month, and what did they do?

Based upon zero discounts for E85 to unleaded, all went to $1.20 and then the percent on the sales represent E85 sales. The top 10 stores averaged $0.50 below unleaded.

IN 2007, THE ENERGY ACT ALLOWED E85 TO BE SOLD UNDER CERTAIN CONDITIONS. HOWEVER ONLY 3,000 OUT OF THE 75,000 ELIGIBLE STATIONS IN THE COUNTRY SELL E85.
Unleaded totaled to $3.50 a gallon which equaled about 6.2% of unleaded sales. E85 delivers fewer miles per gallon on a BTU adjusted basis. It is somewhere around 25%, so the economist in the room will say we need to be 25% below unleaded, which doesn’t pan out.

If retailers are selling gas over $3.50 and are selling E85 for three bucks, flexible customers may shift (Figure 5). If retailers are getting a 6% to 7% bump percentage share of E85 to unleaded, maybe they will try to convince those customers to switch; that might be an incentive for retailers to move forward into E85 because that would show some market potential. Retailers have an idea of what they might sell gallon-wise, and what profit they might make.

Now, E85 is delivering from those stores about $800 a month in pre-tax profit. Medium grade and premium are delivering $1,200 a month, and diesel is delivering $4,200 a month. Diesel showed $0.75 per gallon margins last year, which makes it a wonderful product for retailers to sell, they love it. When it was able to be offset by RIN values in July of 2013, E85 delivered $2,000 in pre-tax margin. That is a nice return—so the question is, can retailers generate enough sales within that margin to make investment in E85 worth their effort?

When talking about other products, such as E15, the same considerations come into play (Figure 6). How many of my customers can run on E15? According to Renewable Fuels Association, two thirds of the cars on the road are on renewals, so the EPA says you can use them. The auto industry does not agree.
More vehicles are approved for E15, but not all 2015 models are approved for E15. The limitations mean that retailers have to think about who can they sell it to, who can use it, and if their equipment is compatible. Retailers have to think about what it might take for configuration. To go to 30% ethanol, for example, an E85 compatible infrastructure is necessary, which is much more expensive.

In order to optimize engines, there needs to be production of a fuel that has a high octane value. Keeping it below 25% ethanol concentrations can be very critical because a lot of the equipment being put in place now is 25% compatible. There are also some regulatory hurdles to overcome in terms of the appropriate listing of those dispensers. The warranty from the manufacturer gives a lot of flexibility and a lot of power to influence regulators. Natural gas as a regular fuel is one.

Natural gas gives a gasoline-gallon equivalency, for half the price of gasoline at retail. When gas was $3.50, retailers could sell natural gas for $1.50, $1.75, $1.25, and the retailer margin on it was about three or four times higher than that on gasoline. If retailers can get a fleet to agree to bring their natural gas vehicles to their station, they can actually generate a return on investment calculation fairly easily. One of the chairmen of NACS went on a quick trip to Wisconsin; they have themselves converted 50% of their distribution fleet to natural gas. They are installing infrastructure that is supported by their fleet and while they do that, they are recruiting other fleets

IN ORDER TO OPTIMIZE ENGINES, THERE NEEDS TO BE PRODUCTION OF A FUEL THAT HAS A HIGH OCTANE VALUE.

NATURAL GAS GIVES A GASOLINE-GALLON EQUIVALENCY, FOR HALF THE PRICE OF GASOLINE AT RETAIL.

to convert to natural gas, and are making a pretty good business investment on that.

Hydrogen has a long way to go before it is a widespread fuel. From a retail perspective, though, it makes a lot of sense, because the consumer cannot recharge hydrogen at home. They can recharge electricity at home. They cannot put hydrogen reformers in their home. Hydrogen refueling infrastructure experience is three to five minutes for a 300 or 400 mile range. From a retail perspective, it’s about $2 million per site right now for all government support. But, there is a model to make a return on investment for hydrogen, and it addresses a lot of the environmental issues and performance requirements in the auto industry.

Electric recharging, I’ve told my guys in NACS, I don’t think is a threat or an opportunity at this point. 90% of consumers drive 40 miles or less a day. The typical electric vehicle has a 40 or 50 mile range, so the target customer can recharge at home and maybe get a top off at the office. How often does a 20 mile, one way commuter have to stop at a convenience store for any reason other than to buy gas? If they are recharging at home or at work, they do not need to stop at a retail station (Figure 7). There are a lot of PR, benefits for putting in a charging station. For example, I have a chairman of fuel who just put in a couple fast charges in Indiana. Why? Because he’s getting a lot of positive PR, and every single electric vehicle and plug-in vehicle has a computer that lists where all the electric charging stations are located. He’s received positive marketing for that good faith effort.
Retailers are looking to liquid fuel. Liquid fuel is going to be 97% to 98% dominant in the market for the next 20 years. The forecasts from the Energy Information Administration (EIA) and from other organizations is maybe 4% market share for non-liquid alternatives. Even hybrids are only projected to get 5% market share by 2040. Hybrids have been around a long time, so there is no change in behavior required by the customer. Again the question is: do retailers have customers who want to fuel? How much will the equipment cost? Can they get a reliable supply?

Now, if a customer buys the wrong fuel by mistake, then what happens? Who’s responsible for the Clean Air Act violation? Who’s responsible when there is damage to an engine? If one of the 2013 cars that is not warranted for E15 uses the fuel, then there is confusion regarding who would be responsible for damage. Retailers have to think about that because it is not necessarily a legal liability, it’s a brand value. If you go to your mechanic and they sold you bad fuel, who is responsible for that? Are consumers going to say that they bought the wrong stuff? No, they will blame it on the retailer, and then they will tell everyone that the retailer is selling bad fuel and ruining their car. That is a concern retailers have to take into account as well as how much can they sell and what is their ROI? How long is it going to take to make a profit?

No matter what fuel we are talking about, if we aren’t able to answer important questions in a way that’s cost-effective, retailers are likely going to say no thank you, I am going to continue selling the fuel that 98% of my customers want me to sell. On the other hand, if we can answer those questions, and give them a positive return on investment and get an opportunity to expand market share, they will be more inclined to jump at it. So we need to identify these hurdles and knock them down, if we really want to open the retail market to alternate fuels.
The Resurgence of Methanol as a Global Energy Resource

Greg Dolan, CEO, Methanol Institute

I am here to talk about the other alcohol: methanol. There has been a global re-emergence of methanol as an energy resource and a resurgence of methanol production in the U.S. The Methanol Institute is a trade association that represents methanol producers, distributors, technology companies supporting traditional chemical derivative markets, and emerging energy markets. We provide a lot of work on delivering safe handling tools across a global methanol distribution chain. We have offices in Washington, Singapore, Brussels, and Beijing.

When talking about the drivers for alternative fuels, the focus is on three primary issues (Figure 1). One is scale: there needs to be a feedstock base that is large enough to support a global transportation market. The second driver is sustainability. It has to be shown that emerging alternative fuels are cleaner than conventional fuels, with low-end or no-end carbon pathways to these fuels. The last driver is government subsidies and policy, which I will touch upon later.

**Feedstock**

Methanol can be made from many resources because it has a large feedstock base. Most methanol is made conventionally from the steam affirmation of natural gas.

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**FIGURE 1**

**Alternative Fuel Drivers**

**SCALE**
The feedstock base needs to be large enough to support global transportation market.

**SUSTAINABILITY**
There needs to be a viable pathway to low or no carbon transport, while reducing smog.

**SUBSIDY**
Can’t rely on government support forever, so someone needs to make money.

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There are technologies that are commercially available to gasify and use paralysis to turn biomass into methanol fuel, which is why methanol is also known as wood alcohol.

Let’s look more closely at feedstock (Figure 2). The Methanol Institute just joined a German network, the Regenerative Methanol Network who is looking at the development of CO₂ based methanol in Germany. One of their problems is that they have too much electricity production. To address this, they can take those extra electrons and use water electrolysis to separate out the hydrogen and CO₂, which are feedstocks for methanol.

There is also work being done by Professor George Olah, a Nobel Prize laureate at the University of Southern California (USC), who has studied methanol economy. He is working on catalytically stripping CO₂ from the atmosphere to use as a feedstock for methanol.
production. If we can create large feedstock bases, then we can increase sustainability. There are a wide range of markets that could be met with methanol, such as chemicals, plastics, paints, glues, and resins.

The shale gas revolution is creating a lot more interest in domestic methanol production. Last year, the U.S. produced three million metric tons, or over a billion gallons, of methanol. By 2017 or 2018, the U.S. will again become a net exporter of methanol. New methanol production means billions of dollars of investment, thousands of permanent jobs, and tens of thousands of construction jobs. Each of these plants needs an investment of billions of dollars, while each plant will create about 250 permanent high paying jobs and about 2,500 construction jobs.

Over the past ten years, methanol has shown a significant value to gasoline on an energy equivalent basis (Figure 3). Retailers can make money selling methanol as a transportation fuel. However, eventually somebody needs all that money. There cannot be reliance on government support for the future.

**FIGURE 2**
Methanol Made from Many Sources

**FIGURE 3**
Methanol Value
Methanol-Crude-Gasoline Comparison $/MMBtu

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Growth in Transportation

Over the last decade, the transportation industry has transitioned from a chemical commodity to a global energy resource (Figure 4). The light blue area at the bottom show the chemical demand which typically grows at GDP rate. Everything above that is emerging energies markets, where there has been a lot of growth.

Those energy markets now represent 45% of total methanol demand. On a global basis, about $21 billion gallons of methanol are used for these emerging energy markets. That is a direct methanol fuel, and diesel substitution MTBE is still an important market for methanol. Another emerging fuel is Dimethyl Ether (DME), which can be produced from methanol. Methanol is a great hydrogen carrier for fuel cell technologies, but the fastest growing segment of this new energy resources market is direct transportation fuel, which is growing at about 23% a year. Transportation fuels are segmented

FIGURE 4
Chemical Commodity to Energy Resource

2003–2013 CAGR:
Energy: 10.8%
Total: 6.0%

2013–2017 CAGR:
Energy: 12.7%
Total: 8.1%

Source: IHS Chemical 2014 Update, April, 2014.
Excludes integrated methanol demand for methanol to olefins and propylene.
into three markets: passenger cars, shipping trucks, and buses.

Australian companies, for example, are marketing a blend of gasoline, ethanol, and methanol together. Ethanol is a great core solid for methanol because the two alcohols play well together. There are three segments in the methanol-gasoline blend market (Figure 5). There are low level blends, including M3 (3% methanol and 97% gasoline); the current EU fuel standard, EN 228, allows retailers to blend up to 3% methanol and gasoline. There has been an uptick of M3 in the UK, Netherlands, and other niche markets in Europe. There are also higher level blends, up to M15 (15% and 85% gasoline). The third tier is M20 to M30, which are sometimes called A20 and A30, because it is using alcohol to provide an octane boost to the fuel pool. Methanol can help with that. Our methanol is about half the cost of ethanol, so it can provide all the octane needed at a much more affordable rate.

**China**

China currently uses $7 million metric tons of M15 a year. Passenger cars are the existing fleet currently using M15 fuel. No changes are being made to the vehicles to run on M15 fuel, looking at the Chinese market. The domestic automobile makers in China produce less than 25% of the cars sold in China while the remaining 75% of the cars are sold or built by the international original equipment manufacturers (OEMs). These vehicles are running on M15 fuels today, and there are trials now with these fuels in Australia and Israel. Chinese entities are looking to take advantage of the low cost shale gas here in the U.S.

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### Figure 5

**Methanol-Gasoline Blend Options**

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<tr>
<th>M3 – M15</th>
<th>M20 – M30</th>
<th>M51 – 100</th>
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<tr>
<td>- EU allows M3 (EN228); Blended a.o. in UK and NL</td>
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<td>- China uses M15; Estimated 7 million metric tons ~75% of cars build by international automakers</td>
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<td>- Trials in Australia, Israel, a.o.</td>
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<td>- Automakers in U.S. call for higher octane to facilitate greater engine efficiency; (higher compression, turbocharging, downsizing)</td>
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<td>- Fit with ePure drive toward E20 in Europe</td>
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<td>- ASTM D5797 standard revision</td>
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<td>- M100 dedicated vehicles; (e.g. Geely)</td>
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<td>- Use of SI technologies in Light and Heavy Duty vehicles</td>
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<td>- Few changes needed to existing vehicle technologies at low cost</td>
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produce methanol, and then export some of that back to China to use it in their cars or to use it in plastics industries.

There are dual fuel configurations being done in China today, where they run a truck on diesel fuel and also have a second tank. Once you get the mileage up on heavy-duty truck highway loads, convert it over to methanol. Those retailers can displace as much as 40% to 50% of the diesel fuel consumption with this sort of dual fuel capability.

**Europe**

I was meeting in Sweden a couple weeks ago with Volvo and they think DME works across their entire fleet of vehicles, which they are excited about. In Europe, Scania is one of the big engine manufacturers. Scania is running buses today on what they call ED95, which is 95% ethanol and 5% diesel. The same blend can be done with methanol because those are spark ignition engines rather than compression ignition engines. There are ways of using methanol as a substitute for diesel in the heavy duty market.

EPure, which is the ethanol trade group in Europe, has been pushing for E20 in Europe (A20 to A30 alcohol blends together). There are also high proportion fuels, such as methanol flex fuels or dedicated vehicles that are running on anything from M51 to M100. Coleman Jones is here, and he’s chairing a task force that’s updating the ASTM standard for methanol. The Methanol Institute has been doing that for approximately three to four years. We
WE CAN TAKE ADVANTAGE OF METHANOL’S HIGHER OCTANE AND DEVELOP AN ENGINE THAT RUNS ON HIGH OCTANE FUELS.

can take advantage of methanol’s higher octane and develop an engine that runs on high octane fuels.

On the heavy duty side (Figure 6), methanol is not an ideal diesel blending fuel. Methanol is high octane, which is great for mixing it with gasoline but as a low cetane.

Cetane is a key performance measure for a diesel fuel that is being used in a combustion engine. But there are ways around that, such as emulsifiers, some of which are being developed commercially because methanol and diesel can be blended together. A great diesel fuel can be produced by taking the methanol dehydrated and turning it into DME, a diesel fuel replacement.

*Methanol and the U.S. 114th Congress*

Turning to the political side, Congress has seen the introduction of the Fuel Choices and Deregulation Act (Figure 7). A similar bill was introduced in the last Congress. This one was introduced by Senator Rand Paul, and the legislation would provide a CAFE credit to automakers who introduce fuel choice enabling vehicles that can run on anything other than gasoline. Natural gas (ethanol and methanol), propane, hydrogen fuel cells, and plug in electric vehicles would all qualify as fuel choice enabling vehicles. The legislation would provide a credit to automakers who introduce these vehicles of eight miles per gallon or 54 mile per gallon obligation, under the CAFE credit.

This is a really significant carrier for the automakers because the other legislation that was introduced in past Congresses, which we think will be introduced in the

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**FIGURE 6**

Different Technology Options in HDV Segment

- **DIESEL BLENDS**
  - DME
  - DUAL FUEL
  - MD95
  - SPARK IGNITION

**BENEFITS**
- High break thermal efficiency
- Low emissions
- Low soot
- Easy handling
- Compatible with existing engine technologies
- Opportunities for optimization
- Affordable

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Future Fuels: The Coming Revolution in American Vehicle Transportation

house in the next couple of weeks, is the Open Fuel Standard Act. That bill would be more of a requirement to the automakers to introduce increasing volumes of these fuel choice enabling vehicles. 69% of voters support the federal government requiring automakers to make cars that run on fuels other than oil. There is a real interest by the public for fuel choices at the pump, and there has been quite a bit of discussion about the Renewable Fuel Standard (RFS) today.

There is a mandate right now to get to 36 billion gallons of renewable fuels by 2022, but finding a pathway to get to that is difficult for two reasons. On the fuel side, it is hard to get the volumes of cellulosic fuel that could meet those requirements by 2022. The running joke is that it is easier to buy a unicorn than a gallon of cellulosic ethanol. The other problem is that in the vehicle tanks it is difficult to get beyond E10, and the industry has hit that blend wall right now. There has been little commercial interest in E15—maybe only 100 stations selling E15. And for E85, the CAFE credits are going to be expiring.

The Energy Information Administration (EIA) estimates that the volume of E85 sold in U.S. today is 40 million gallons a year. That 40 million gallons a year has been flat over the past five years. To put that in perspective: there are 3,000 E85 pumps in the U.S. and about 36 gallons of E85 are sold in each of those pumps daily. In comparison, a typical gasoline pump sells more than 500 gallons per day. With 18 million ethanol flexible vehicles per year, that’s just 2.2 gallons of E85 per ethanol flexible vehicle. Typical gasoline consumption is probably more like 475 gallons per vehicle.

Clearly EPA has mismanaged the program and mismanaged it pretty grossly. There is legislation being introduced in both the House and Senate to modify or repeal the RFS (Figure 8). I would argue that if we are going to repeal and replace the RFS, then it should be replaced with the Domestic Fuel Standard. One of the purposes of the RFS was to stimulate a market for domestic feedstocks for alternative fuels. Currently the biggest feedstock is natural gas. When Ernest Moniz was at MIT, he chaired a study on the future of natural gas. The study identified methanol as the most efficient and economical liquid transportation fuel that can be made from natural gas. In regards to the Domestic Fuel Standard, Congress is debating what to do about the

**FIGURE 7**

**Methanol and Congress**

- *Fuel Choices and Deregulation Act* was introduced by Sen. Rand Paul (S. 889) and Rep. Rod Blum (H.R. 1944) to provide a CAFE credit for automakers that introduce fuel choice enabling vehicles.

- *Open Fuel Standard Act* to be reintroduced requires automakers to introduce Fuel Choice Enabling Vehicles.

- According to April 2015 poll by RFA and Morning Consult, 69% of voters support the federal government requiring automakers to build cars that run on fuel sources other than oil.
future of the RFS because clearly the 36 billion gallon target cannot be met. Congress is going to do something, not this year and probably not the next, but in the near future.

In conclusion, even though there is inconsistent public policy in the U.S., Europe, and other markets around the world, the Methanol Institute thinks methanol fuels will succeed because: there are a long list of feedstocks, methanol can be made from long-term sustainable fuels, there are no real technical barriers to using methanol as a transportation fuel, methanol will make money, and there will be significant economic benefits to using methanol as a fuel.

**FIGURE 8**

Renewable Fuel Standard vs. Domestic Fuel Standard

- The RFS calls for 36 billion gallons of renewable fuels by 2022, but there is no viable pathway to get there.

- Hit blend wall for E10, little commercial interest in E15, and E85 FFV CAFE credit expires 2017 model year.

- Legislation has already been introduced in both the House and Senate to modify or repeal the Renewable Fuel Standard.

- MI argues that Congress needs to repeal and replace the RFS with a Domestic Fuel Standard opening door to the use of domestic natural gas for methanol fuel production.
Natural Gas: The Key to Revolutionizing the Transportation Market

Michael Jackson, Director of Research, Fuel Freedom Foundation

A substantial change has occurred in the last five years in regards to U.S. energy supply, and that change opens the opportunity to rethink how to bring natural gas derived fuels into the transportation market.

When I was doing this analysis in California in 2004, the supply of natural gas was limited. There was not enough natural gas to consider widespread use in the transportation market. Natural gas could be used in some niche markets but was not widely used in the light duty market. Today that has completely changed. Now, it is possible to start thinking about natural gas derived fuels like ethanol and methanol in the light duty transportation market.

Ethanol is in the market today, but mostly as E10. There is a price differential between natural gas and petroleum today and that provides an opportunity for low cost natural gas derived fuels, but only low volumes of E85 are sold. My talk today will cover: the possible pathways which will put some of these fuel technologies in perspective; the vehicle technologies needed in order to bring these technologies to the marketplace; and the success factors that are needed for fuel and vehicle combinations to enter the marketplace.

Figure 1 shows how natural gas has been decoupled from petroleum on an energy basis. On the left hand side of the chart are historical prices and the right hand side of the chart are projected prices in dollars per million BTU. Projected prices are the reference case from the Annual Energy Outlook (AEO) for 2015. There was a peak in 2012 where the delta between oil and natural gas pricing was a

FIGURE 1
Decoupling of Natural Gas and Oil Prices

Source: EIA AEO 2015 Reference Energy Prices
factor of six. There is a huge opportunity to take natural gas and convert it to liquid fuel, which would compete with gasoline. The conversion costs need to work out in terms of production, distribution and marketing. The upward arrow illustrates upward price pressure from the demand from developing countries, an increase offset by improving fuel economy in developed countries. The downward arrow shows price pressure because of increased natural gas supply and in some cases the difficulty of getting gas to market. That difficulty can be overcome by converting natural gas to liquefied natural gas (LNG). LNG is priced on the world market and LNG can be shipped throughout the world. There are also other opportunities such as natural gas derived liquid fuels for the U.S. transportation market.

**THERE IS A HUGE OPPORTUNITY TO TAKE NATURAL GAS AND CONVERT IT TO LIQUID FUEL, WHICH WOULD COMPETE WITH GASOLINE.**

In any case, Figure 2 starts off with natural gas as a feedstock. For example, it is possible to take natural gas to generate electricity, then distribute that electricity to use in electric vehicles. Natural gas can also be converted to hydrogen for use in fuel cell vehicles. Natural gas can also be compressed and distributed at natural gas vehicle stations. Earlier, John Eichberger of the Fuels Institute mentioned the high cost of compressed or LNG stations. LNG makes some sense in the heavy duty sector. Some fleets are adopting LNG in their operation. However, fleets that consume high volumes of energy (typically high mileage vehicles) can take advantage of low natural gas prices to offset the high station costs.

On the other hand, it is difficult to make the case for compressed natural gas use in the light duty sector. Incremental vehicle costs are in the $2,000 to $5,000 range and even with natural gas prices, 50% of gasoline payback takes 10 years or more. It is hard for a customer to want to accept these economics. There is another pathway that has been investigated a number of times by California in the 1980s and more recently in a study by the National Research Council. This pathway is to take natural gas and convert it to a liquid fuel like methanol, ethanol, or synthetic gasoline and use this fuel in internal combustion engines. Coupling an alternative fueled internal combustion engine with vehicle electrification would create a vehicle that meets all upcoming environmental challenges at the lowest costs.

In the 1980s, California embarked on a program after a comprehensive study to investigate various feedstocks, conversion pathways, and vehicle technologies to displace petroleum. Methanol was chosen in that study and was demonstrated first in dedicated vehicles designed with high compression ratios to optimize on the higher octane of methanol. Methanol as M85 was also demonstrated in flexible fuel vehicles (FFVs) which were designed to use M85 or gasoline or any combination of these fuels. FFV technology came out of the California methanol program. California worked, along with others, to pass the FFV credits in the Alternative Motor Fuels Act (AMFA) in 1988. California’s idea was to provide automakers with incentives to build and sell FFVs and to
require fuel providers to sell alternative fuels, particularly methanol, when enough FFVs were operating in California. California Air Resources Board (CARB) developed a regulation that would require petroleum companies and fuel retailers to supply methanol once the number of FFVs exceeded 20,000. This regulation was never implemented since the environmental benefits of methanol could be achieved with reformulated gasoline. The driver in California was focused at this time at reducing the tailpipe criteria pollutants and not necessarily greenhouse gases. Methanol provided lower NOx and particulate matter (PM) emissions in heavy duty vehicles. GM went on to commercialized methanol buses and these were used in LA for a number of years. Eventually these buses were converted to ethanol. There were other heavy duty manufacturers that participated in the California program. Caterpillar, Cummins, Navistar and Ford all provided methanol demonstration vehicles. The idea was to displace gasoline and diesel in as many end-use sectors as possible so that a barrel of oil would be displaced, not just gasoline or diesel.

In the 1990s California also demonstrated natural gas in medium and heavy duty applications. For example, the UPS van truck is a medium duty CNG application. The Walmart tractor trailer and the Unocal gasoline delivery trucks were LNG applications. All these alternative fuel applications were built by automakers or engine manufacturers, and commercial fueling facilities were constructed to support the demonstration.

Today there are about 17 million FFVs in the U.S., but compared to the total light duty fleet this is still fairly small. We at the Fuel Freedom Foundation are investigating increasing the flexible fuel vehicle (FFV) population with vehicle conversions. The technology is fairly straightforward especially with the advent of computer engine controls. Flex fuel vehicle cost is especially low in comparison to compressed natural gas vehicles, where energy storage costs dominate (Figure 3). High energy storage costs are also an issue with battery

**Flex Fuel Vehicle Cost is Especially Low in Comparison to Compressed Natural Gas Vehicles, Where Energy Storage Costs Dominate.**
electric vehicles and high energy conversion costs for fuel cell vehicles.

FFV technology on the vehicle side is fairly cost effective to implement. This works for ethanol. It can also work for methanol. In fact current ethanol FFVs have been shown to operate on M56 meeting performance and tailpipe emissions expectations, though there is some concern about material compatibility and evaporative emissions. For E85 and M56, an existing FFV can’t distinguish between the two fuels, since these fuels have roughly the same combustion characteristics.

When I first started in the alternative fuel business, we were pitching the positive environmental benefits of alternative fuels. This was the selling point and was mostly aimed at regulators.

However, the consumer has a number of concerns that must be satisfied. The consumer wants adequate infrastructure. That is one reason why the FFV was developed because the California demonstration program early on lacked sufficient methanol station density and state employees were actually leaving their vehicles on the freeway when they got to half a tank of methanol.

There were state employees who would go, “Half a tank, I can’t make it to the airport. Send a replacement vehicle.”

Consumers are not going to buy alternative fueled vehicles without acceptable vehicle attributes. What was missing in past attempts to get wide spread adoption of alternative fuels? In my view, the top one is having an acceptable value proposition. Clean air, reduce petroleum consumption, and lower greenhouse gases did not motivate the purchase of alternative fuel vehicles and the alternative fuel costs did not offset the higher cost of the alternative fuel vehicle. If there is not a value proposition for the consumer, if the fuel is not cheaper and if the cost per mile integrated over the vehicle is not cheaper, it is not going to be accepted in the transportation market.

There needs to be an alternative that works for everybody. In the past, we were always chasing the lower costs of gasoline and diesel (on a lifecycle cost per mile basis). We had to monetize the societal and environmental benefits to show that alternative fuels were more cost effective than petroleum fuels. Really, the goal is for alternative fuels to be cheaper than petroleum fuels. The question is how do we get there? This can be accomplished with alternative fuels that are cheaper than petroleum fuels, and by minimizing the on-vehicle costs needed for alternative fuels.

An FFV produced by automakers has little or no incremental cost. It is possible that existing gasoline vehicles could be converted to ethanol FFVs at low costs. Maybe all that is necessary is to change the engine software. Of course, the conversion would have to meet all environmental regulations. There might be some cost associated with this type of conversion, but it would seem to be a lot less expensive than other conversions like compressed natural gas. If we can increase conversions and add to the existing FFV fleet, then maybe there would
be enough vehicles to interest John Eichberger’s retailers into supplying the fuel.

Alternative fuels need to be priced competitively at the pump. Fuels should be priced on an energy basis. Vehicle efficiency also needs to be considered. E85 pricing data from recent studies shows that a 50 cent discount to gasoline looks like a sweet spot balancing sales and retail margins. Eventually, the consumer will probably want a higher discount depending on their fuel mileage and the convenience or lack of convenience in fueling and station locations.

Vehicle attributes drive the purchasing decision. Cost is obviously the most important attribute, but others also contribute to the purchase decision. Coleman Jones, at GM, pointed out that a Honda consumer preference study performed several years ago rated fuel economy 26th. There are times where fuel economy is rated in the top five buying decisions, but I have been at conferences where people say paint color was the most important preference. Performance, vehicle range, storage, interior space, and safety is a given. Why would a consumer buy something that is less than what the automakers give them with the baseline fuel?

There are sellable attributes like green image (HOV lane access in California for example). That gets you some market share, but it is not going to capture the mass market. The consumer needs to save money in the long run for mass market adoption.

Consumers also have to be comfortable using the fueling infrastructure. The density of the stations and pricing are important. When consumers pull up to a gas station, they understand how the current fueling system works. If a retailer introduces a new fuel, it needs to be comparable in terms of ease of use for the consumer. Liquid alternative fuels play a premium here.

There also needs to be reasonable business case throughout the supply chain (Figure 4). Everybody needs to recover costs and realize some profit for the alternative fuel to be successful.
Turning to the positive environmental impacts. My alternative fuel has to have equal or better tailpipe emissions. Today’s cars are very clean, emissions are at hundreds of a gram per mile, and Tier 3 emission standards are going to make them even cleaner. There needs to be equal or better fuel cycle emissions for the vehicle, all the way from fuel production, distribution, and retailing to end use for both greenhouse gas emissions and criteria emissions. If the retailers’ gasoline or their gasoline with an additive leaks into the ground, and it contains an ether like MTBE, there could be a big issue with groundwater contamination. So, all potential emission issues need to be considered when introducing a new fuel.

Let me discuss the greenhouse gas (GHG) impact of fuels and vehicle technologies. Figure 5 shows GHG emissions for gasoline, ethanol, methanol, hydrogen, and electricity on a per vehicle basis. This analysis assumes that gasoline, ethanol, and methanol produced from natural gas have the same upstream emissions (or carbon intensity). If ethanol was produced with bio renewable fuels, ethanol would have lower emissions than shown here. The first bar on the left hand side of Figure 5 represents the fleet average GHG emissions in 2005 (536 g of CO₂ equivalent per mile), 80% reduction of the vehicle average is shown as the red line (107 gm of CO₂ equivalent per mile).

The next technology illustrated is representative of a port fuel injected (PFI) 2005 passenger car which shows 18% lower GHG emissions than the 2005 fleet average. The next set of results is based on combining various...
advanced technologies. The first combination includes direct injection, downsized, variable valve timing, turbocharging—Adv ICE DI. This technology lowers GHG emissions to 29% less than the 2005 fleet average. The next advanced technology combination includes the Adv ICE DI with hybridization. This reduces GHG emissions by 49% compared to fleet average gasoline. The last technology combination incorporates all the previous technologies and adds high compression (for gasoline this requires a high octane fuel to be available) and a plug-in electric architecture—PHEV, Adv ICE 50-50. The utility factor for this PHEV was assumed to be 50% electric, 50% liquid fuel. This technology lowers GHG emissions by 72% compared to the fleet average. In sum, the ethanol and methanol technologies have lower GHG emissions than the gasoline fueled combinations. High compression is assumed for all the advanced combinations and both alcohols have more favorable fuel properties like higher heat of vaporization and faster flame speeds.

THE NATURAL GAS SUPPLY IN THE U.S. CREATES AN OPPORTUNITY TO PRODUCE AND SUPPLY NATURAL GAS DERIVED LIQUID FUELS. ALCOHOL FUELS WILL ENABLE MORE EFFICIENT, NEWER VEHICLES TO LOWER THE GREENHOUSE GAS IMPACT AT A COST TRAJECTORY THAT IS BETTER THAN ANY OTHER TECHNOLOGY COMBINATIONS TODAY.

The most advanced technology package (PHEV) for ethanol and methanol reduces GHG emissions by 75% and 77%, respectively. For comparison, hydrogen fuel cell and battery electric vehicle technologies are also shown on this chart. Hydrogen depends on whether it is produced onsite with natural gas or if it is produced, centralized, and distributed to retail stations. For BEVs, I used two electricity production assumptions: the California marginal which is natural gas based electricity production and the average U.S. electricity production. Hydrogen fuel cells and BEVs are the gold standard relative to GHG and criteria emissions and this is reflected in the low GHG emissions. Both technologies have emissions lower than the 80% reduction. If lowest GHG emissions were the only consideration it would be obvious that BEVs or hydrogen fuel cell technology should be widespread. Ultimately, these technologies will be needed in the future, but costs today and near term projected costs for these technologies are too high for mass market adoption. Instead, incrementally improving current ICE technology coupling with high octane fuels
like ethanol and methanol could very well compete as lower costs options to advanced gasoline technologies.

What can we conclude from this GHG analysis? First, that higher octane fuels enable higher ICE efficiency. Ethanol, methanol and any of the combinations with gasoline will give higher octane. Is it E30? Is it M30? Is it M56? Is it E85? Gasoline could also be refined to provide high octane gasoline, but at a cost higher than ethanol or methanol gasoline blends. It is hard to project what will be successful in the market place. The second conclusion is that high efficiency ICE coupled with electrification provides a cost-effective pathway to getting to the needed GHG reductions. Turbocharged, direct injection, engine downsizing, down speeding, and high compression with high octane fuels can achieve GHG emission reductions near 80%. These technologies can be implemented with incremental changes and that is the path that automakers are taking. Vehicle and fuel retailers need to minimize the future fuel and vehicle cost if this pathway is going to be successful in the marketplace. Higher octane gasoline is an option, but potentially more expensive, especially if octane is increased by reforming in the refinery.

Ethanol and methanol may be the best fueling options in low-level, mid-level, or high-level blends. For PHEV platforms, battery cost will need to be minimized. Automakers might not need to go to a PHEV; perhaps start-stop hybrid technology will get them far enough to meet the current CAFE standards. Ultimately, however, automakers will have to have technologies that are near or better than 80% reduction from the 2005 fleet average GHG emissions.

The natural gas supply in the U.S. creates an opportunity to produce and supply natural gas derived liquid fuels. Alcohol fuels will enable more efficient, newer vehicles to lower the greenhouse gas impact at a cost trajectory that is better than any other technology combinations today. There is a possibility that these fuels can lower cost fuels on an energy basis at the pump, but the industry still needs to execute to make this happen. The current fleet of FFVs, coupled with conversions can create a demand in areas like Salt Lake City, Denver, and Western Pennsylvania, where building a production facility could be justified and profitable to take natural gas to a liquid fuel (Figure 6). There is a lot needed for alternative fuel success.

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FIGURE 6

What is Needed for Alternative Fuel Success

- Consumer Value Proposition
- Acceptable Vehicle Attributes
- Adequate Fueling Infrastructure
- Acceptable Business Case for Producers and Retailers
- Positive Societal and Environmental Impacts
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