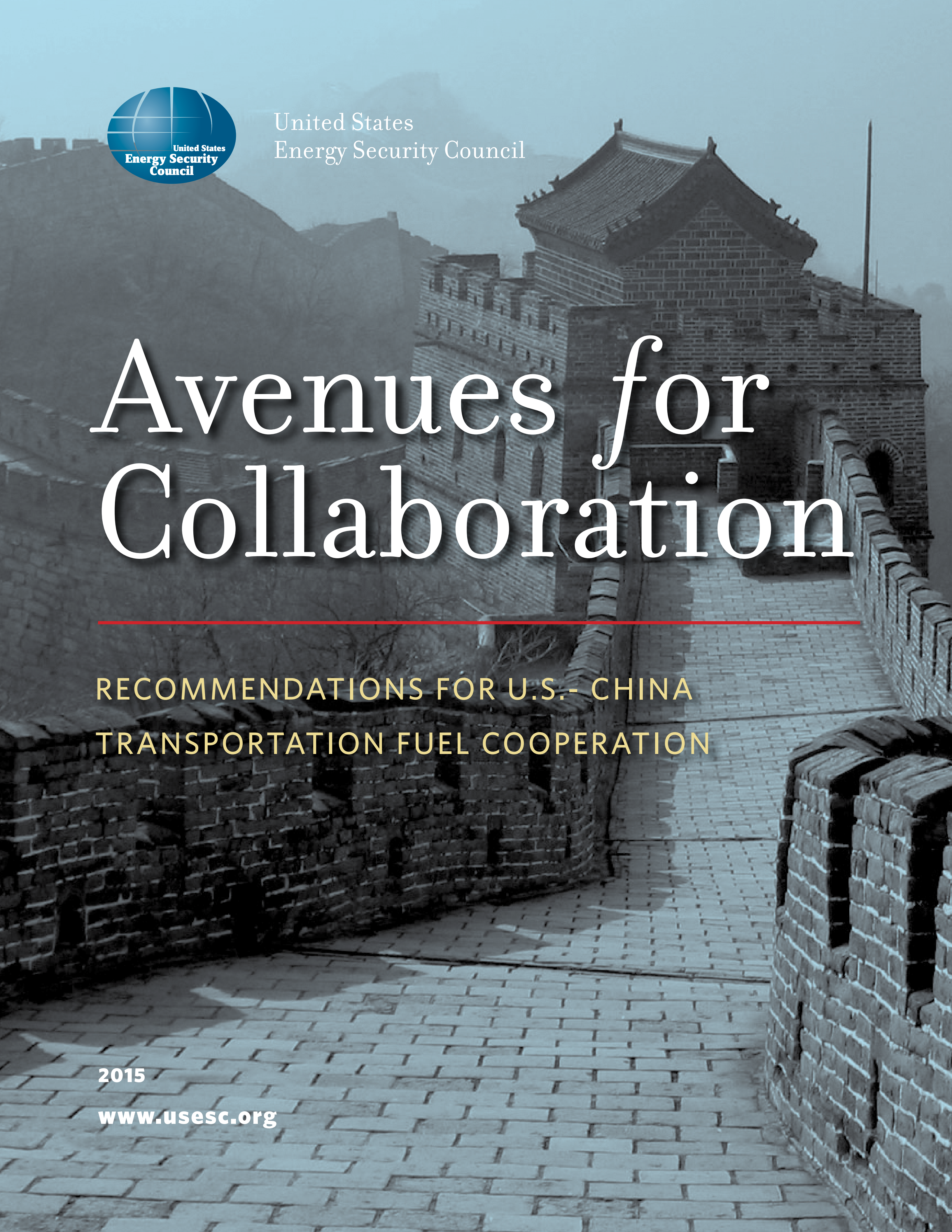

United States
Energy Security Council

Avenues *for* Collaboration

RECOMMENDATIONS FOR U.S.- CHINA TRANSPORTATION FUEL COOPERATION

2015

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List of Acronyms

ARPA-E	Advanced Research Projects Agency – Energy
BCM	Billion cubic meters
BEV	Battery electric vehicle
BTEX	Benzene, toluene, ethylbenzene and xylenes
CAAEFA	China Association of Alcohol & Ether Clean Fuels and Automobiles
CAAM	Chinese Association of Automobile Manufacturers
CAFE	Corporate Average Fuel Economy
CBM	Coal bed methane
CCWG	U.S.-China Climate Change Working Group
CERC	U.S.-China Clean Energy Research Center
CMM	Coal mine methane
CNG	Compressed Natural Gas
CO	Carbon monoxide
CPCIA	China Petroleum and Chemical Industry Association
DMDF	Diesel methanol dual fuel
DME	Dimethyl Ether
DR	Demand response
DRMS	Demand Response Management Systems
EISA	Energy Independence and Security Act
ELR	European Load Response
EPA	United States Environmental Protection Agency
ESC	European Stationary Cycle
ETC	European Transient Cycle
EV	Electric Vehicle
FFV	Flexible Fuel Vehicle
FT	Fischer Tropsch
FYP	Five Year Plan
GTL	Gas to liquids
HC	Hydrocarbon
JAFAA	Joint Alcohol Fuel Automobile Alliance
LNG	Liquefied natural gas
Mcf	million cubic feet
MIIT	Ministry of Industry and Information Technology
MIT	Massachusetts Institute of Technology
Mmbtu	million British thermal units
MOT	Ministry of Transport
NDRC	National Development and Reform Commission
NEA	National Energy Administration
NEV	New Energy Vehicle
NGV	Natural Gas Vehicles
NHTSA	National Highway Traffic Safety Administration
NOx	Nitrogen Oxides
OFS	Open Fuel Standard
OPEC	Organization of Petroleum Exporting Countries
PHEV	Plug in hybrid electric vehicle
PM	Particulate matter
RFS	Renewable Fuel Standard
RNG	Renewable natural gas
ULEV	Ultra Low Emission Vehicle
USESC	United States Energy Security Council
VAM	Ventilation air methane

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"China and the U.S. will not necessarily transcend the ordinary operation of great-power rivalry. But they owe it to themselves, and the world, to make an effort to do so."

– HENRY KISSINGER

Executive Summary

This report will identify areas in which the United States and China can develop a common agenda in the field of fuel choice by opening vehicles to fuel competition and allowing fuels made from energy commodities with which the two countries are well endowed to compete against petroleum fuels over market share in the transportation fuel sector. The two countries jointly manufacture roughly forty percent of the vehicles that roll onto the world's roads. As such, they are in a unique position to shape the global automotive market and open large numbers of vehicles to fuel competition. If fuel choice becomes a standard feature in vehicles sold in these two markets, due to economies of scale and other factors there is likely to be a spillover effect to the rest of the world. The recommendations below aim to achieve that.

- **INSTITUTE A FUEL CHOICE PATHWAY FOR FUEL ECONOMY STANDARD COMPLIANCE**
  In order to focus fuel consumption standards on the goals of reducing the importance of oil to the economy and of improving air quality, rather than on reducing the consumption of energy writ large, ease the fuel consumption obligation of auto manufacturers that open up the majority of the vehicles they produce in a given model year to fuel competition.

- **FOCUS ON HEAVY DUTY VEHICLES**
  ease the heavy duty vehicle fuel consumption requirement for manufacturers that open at least half of their production in a given model year to non-petroleum fuels of some sort, whether alcohol fuels, dimethyl ether, compressed natural gas, liquefied natural gas, or any other option.

- **EMBRACE COAL BASED TRANSPORTATION FUELS AS A WAY TO IMPROVE URBAN AIR QUALITY IN CHINA**
  Expand the scope of clean fuels and vehicle emissions control technologies collaboration under the Emission Reductions from Heavy-Duty and Other Vehicles action item of the U.S.-China Climate Change Working Group to include fuel options such as methanol and dimethyl ether. Explore multiple technological paths, and conduct joint production of demonstration engines and vehicles for testing in collaboration with private sector companies, to speed the commercial introduction of the technology in both countries.

- **STRENGTHEN THE SINO-AMERICAN JOINT ALCOHOL FUEL ALLIANCE**
  Build on the existing platform of the Joint Alcohol Fuel and Automobile Alliance to make it into an official, inter-governmental channel for information exchange and collaboration on all matter related to alcohol fuels and include such cooperation in the framework of the U.S.-China Clean Energy Research Center (CERC).

- **COLLABORATE ON JOINT STANDARDS FOR AFTERMARKET VEHICLE CONVERSIONS TO COMPETING FUELS**
  Collaborate to determine joint standards for conversion kit certification and installation procedures. The conversion kit market needs to be further deregulated to offer safe, but low-cost conversions for broader consumer adoption of substitute fuels – particularly for older vehicles. Such a program would help guarantee safe installation of tanks, fittings, and any cabin detection ability if needed, while ensuring that post-conversion tailpipe emissions remain as stringent or actually improve.

- **INCREASE UTILIZATION OF UNCONVENTIONAL GAS**
  Intensify coal mine methane collaboration with a special focus on the safe and economic utilization of low concentration coal mine methane and ventilation air methane, specifically with an eye to upgrading the methane for conversion to transportation fuel.

  Jointly demonstrate, test, and share best practices regarding small scale gas-to-transportation fuel options in conjunction with methane production from landfills, sewage treatment facilities, rural gas production from agricultural byproducts, coal bed methane and coal mine methane including methane from abandoned coal mines, and stranded shale gas.

- **BUILD THE FOUNDATION ON WHICH ELECTRIFICATION CAN OCCUR**
  In order to create the foundation on which future mass adoption of battery electric vehicles can occur once they become competitive China must create the conditions for its electricity system to accommodate large scale charging. The U.S. and China should enhance their cooperation on Demand Response and Demand Response Management Systems as it relates to electrified transportation and initiate additional pilots in the pilot cities of the New Energy Vehicle plan to study the challenges and solutions of load management associated with BEV adoption.

- **TREAT WASTEWATER AS A RESOURCE**
  The United States and China should include waste water to energy and specifically to transportation fuel as a topic for analysis, technology cooperation, information exchange and sharing of best practices, and consider joint demonstration projects.

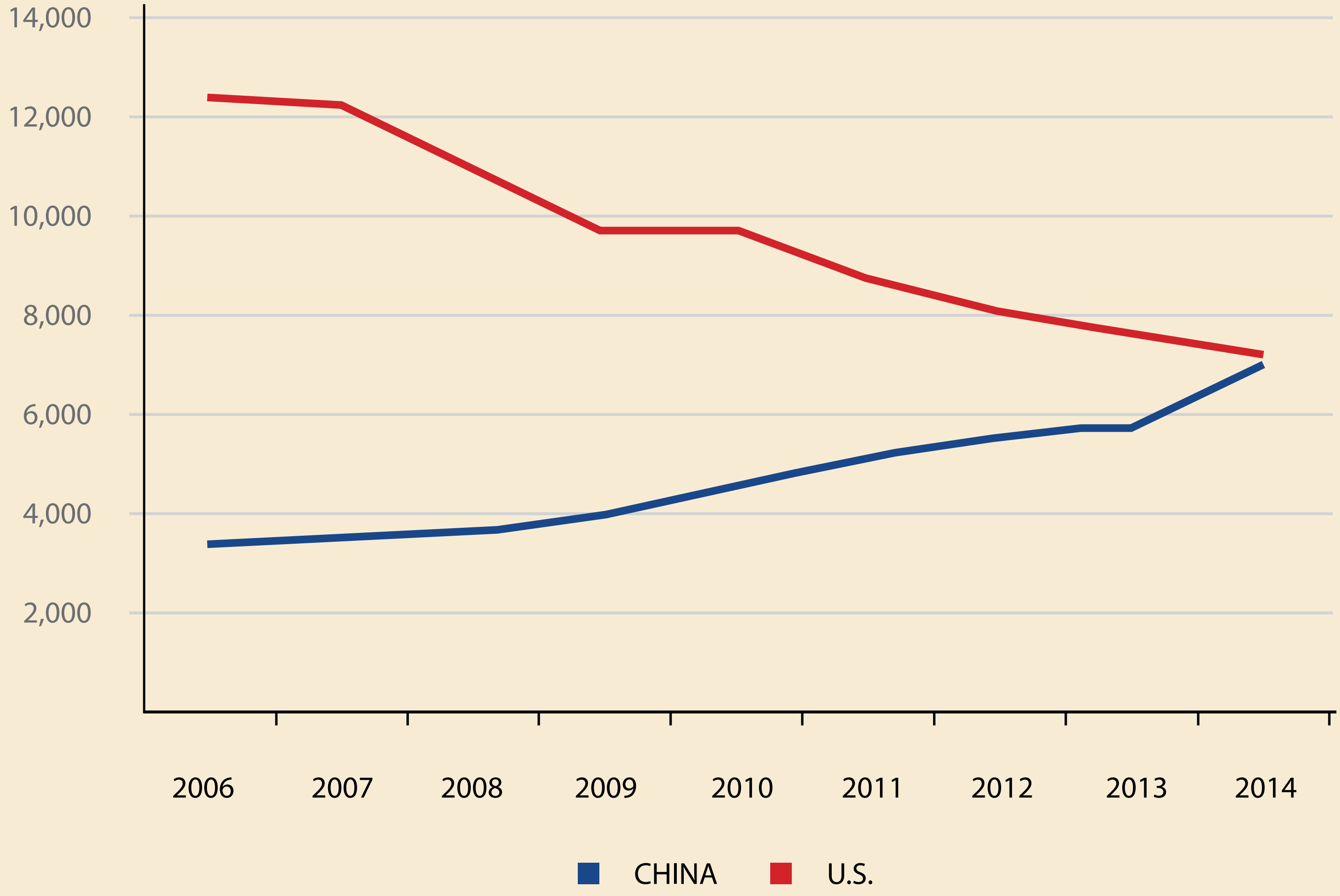
Introduction

The recent decline in oil prices has been a shot in the arm for the global economy while posing an economic and strategic challenge to some oil exporting regimes. The relief at the pump is fragile and not likely to be long-lasting. Just like a combination of circumstances – a strong dollar, increased supply from the shale operations in the North America, tapering demand in the developed world and the prospects of lifting the sanctions on Iranian oil, not to mention a decision by Organization of the Petroleum Exporting Countries (OPEC) not to reduce production in response to all of the above - brought to the price drop of 2014-2015, a different set of drivers could lead to the opposite outcome. A cut in OPEC production, trouble in one or more major oil exporting countries, a slowdown in North American production due to lower prices or the convergence of a few of these factors could before long drive oil prices to the three-digit level where they may once again help trigger an economic recession as was the case in 1974, 1979, 1991, 2000 and 2008 – an average of once a decade.

There are early signs that the pendulum may already be moving in the direction of higher prices. Persistent low prices are tightening operations in the North American oil industry. In the first half of 2015 many projects have been shelved or streamlined; U.S. rig count, a key barometer of drilling activity, has been consistently on the decline; oil services companies have announced massive layoffs; and independent oil and gas companies, particularly those with high production costs, are facing defaults and bankruptcies. It would therefore be a mistake to sink into complacency and view low oil prices as the new normal.

The current slump in oil prices should not mask the fact that oil still holds immense strategic importance due to the fact that it brooks virtually no competition in the global transportation fuel market. While electricity in contrast is generated from a wide variety of commodities, almost all of the energy that moves people and goods throughout the world is petroleum-based. This gives the commodity and its major reserve holders, mainly Russia and the members of the OPEC, inordinate power on the world stage. And while it may appear to some that this power is eroding, we should be clear: as long as oil remains the sole commodity which makes the world go around, consumers will be exposed to periodic oil shocks and vulnerable to one degree or another to the decisions made by the oil cartel and its fellow travelers.

CRUDE OIL IMPORTS (IN THOUSAND BARRELS)

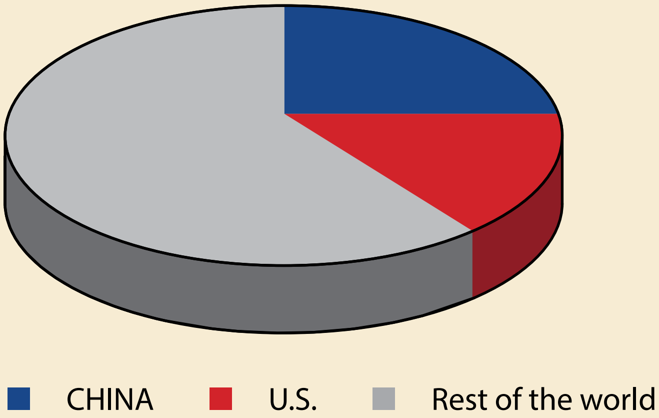


To shield the global economy from the ruinous impact of future oil shocks it is necessary for the transportation fuel market - and more specifically, light, medium, and heavy duty vehicles - to be open to fuels derived from other energy commodities in addition to, or instead of, petroleum. Depending on the application and the location, this can include fuels derived from coal, natural gas, biomass, recycled CO2, as well as electricity generated from non-renewable and renewable sources. This way, if oil returns to unfriendly territory, consumers will be able to shift on-the-fly to cheaper fuels and hence drag the price back to equilibrium.

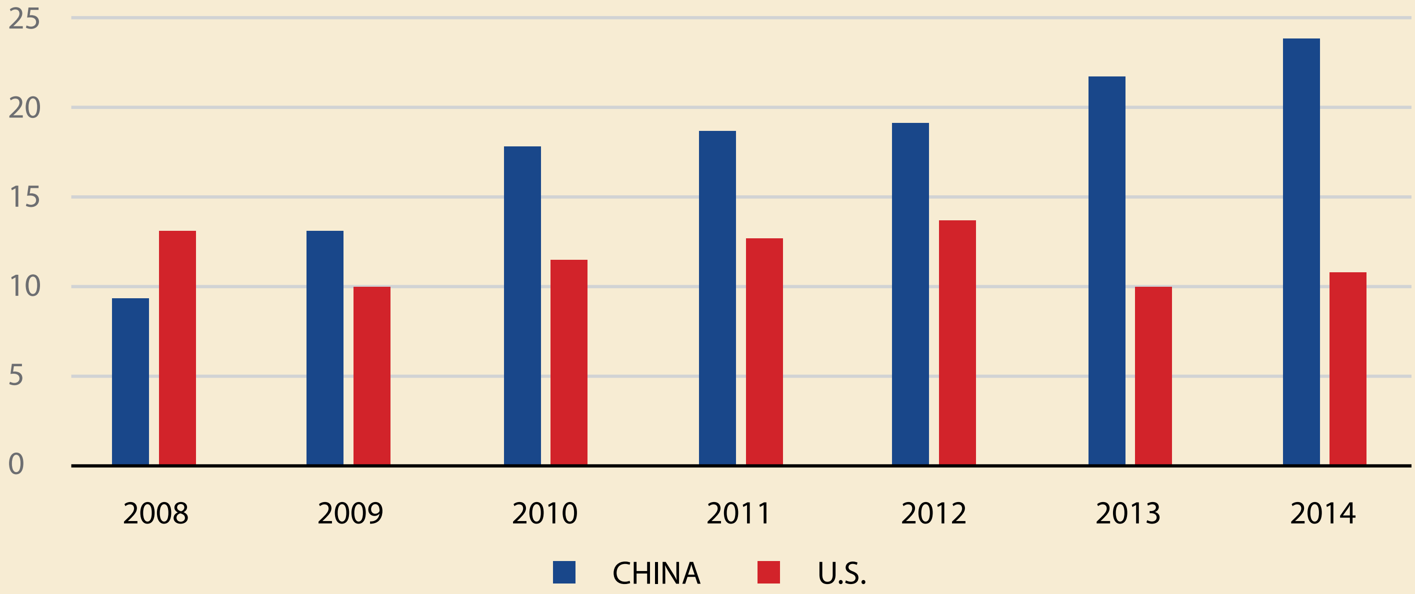
To shield the global economy from the ruinous impact of future oil shocks it is necessary for the transportation sector to be open to fuels derived from other energy commodities in addition to petroleum. This way, if oil returns to unfriendly territory, consumers will be able to shift on-the-fly to cheaper fuels and hence drag the price back to equilibrium.

Breaking oil's virtual monopoly over the transportation fuel sector should be a common goal for the world's two largest economies: China and the United States. China's car fleet is currently 90 million strong, but it is growing by leaps and bounds. By 2020 China will have 200 million vehicles, according to the China Association of Automobile Manufacturers, a fleet nearly the size of the United States.' China and the United States already comprise one third of the global demand for oil and its products. Both are also dependent on energy imports. While in recent years U.S. oil import dependency has dropped from 60 percent of its consumption to under 30 percent, nearly 60 percent of China's oil and over 30 percent of its natural gas currently is imported. China's strategic petroleum reserves account for barely 20 days of oil imports which means that if for some reason its lead supplier – Saudi Arabia – went off the market, China's reserves would suffice for only four months. This growing dependency, primarily on the Middle East, is shaping China's international behavior, and, adding new geopolitical stress to the international system, could be detrimental to U.S.-China relations.

WORLD VEHICLE MANUFACTURING



VEHICLE SALES IN CHINA AND THE U.S. (IN MILLIONS)



The two countries also share similar vulnerabilities related to spikes in crude prices. America's purchasing power is the fuel that keeps the Chinese economy going. When the U.S. economy slows down millions of Chinese lose their manufacturing jobs and China, the world's largest economy, slows down. China, for its part, is the second biggest foreign owner of America's debt, holding some $1.2 trillion in U.S. bonds, and its borrowing capacity is essential for the United States to meet its budgetary needs. It is therefore in both countries' interest to cooperate in keeping oil prices stable and affordable by accelerating the shift to a competitive market in transportation fuels. The two countries' wealth in other energy commodities which can be transformed into transportation fuels – coal, shale gas and biomass – enables them to diversify their fuel supply in ways that can insulate their economies from oil price fluctuations. Such cooperation also stands to reduce the vulnerability of the global economy to Middle East instability, insulate it from oil shocks and reduce the risk of tensions over access to oil which could undermine global security and embroil the United States and China in unwanted military interventions.

The two countries are well suited to jointly address the problem by virtue of the fact that collectively they manufacture roughly forty percent of the vehicles that roll onto the world's roads. As such, they are in a unique position to shape the global automotive market and open large numbers of vehicles to fuel competition. If fuel choice becomes a standard feature in vehicles sold in these two markets, due to economies of scale and other factors there is likely to be a spillover effect to the rest of the world.

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Another major driver for opening the transportation sector to competition is the all-engulfing environmental crisis in China's major cities caused in no small part by vehicle air pollution, particularly from diesel powered heavy duty vehicles. Studies suggest that vehicle emissions contribute more than 70 percent of nitrogen oxides (NOx) in major cities and are the dominant source of PM2.5 (pollutant particles smaller than 2.5 microns in diameter which are detrimental to human health as they can get lodged within the lungs and increase the risk of cancer, asthma, heart attacks, respiratory diseases, and premature deaths). Beijing's PM2.5 score for example averages 100 micrograms per cubic meter, and in winter months it can hit 300. The World Health Organization recommends a PM2.5 cap of 25. This pollution crisis involves occasional city-wide shut downs and serious health problems, creating a sense of urgency to seek effective ways to reduce vehicle pollution while continuing to satisfy the Chinese people's desire for cars.

The United States is sensitive to China's energy needs and wishes to collaborate with China to the best of its ability to jointly expand the global energy pie, opening the door to a wider variety of energy resources, clearing pathways for cleaner and cheaper energy to compete in the market, encouraging energy investment and increasing the efficiency of energy usage. To this end, in 2008 it established with China the Ten Year Framework for Cooperation on Energy and Environment with the goal of facilitating exchange of information and best practices and involving the lead agencies in both countries. This framework includes topics like clean and efficient vehicle technologies; design and modality of transportation systems; and transportation infrastructure. Additionally, the two countries formed in November 2009 the U.S.-China Clean Energy Research Center (CERC) which accelerates development and rapid deployment of critical technologies for clean energy in the United States and China. One of the flagship projects of CERC is the Clean Vehicles Consortium which promotes research on advanced batteries and energy conversion; advanced biofuels and clean combustion; vehicle electrification; advanced lightweight materials and structures; vehicle-grid integration; and energy systems analysis, technology roadmaps and policy.

While efforts to improve vehicle efficiency are helpful elements in addressing the two nations' energy security concerns, this report will focus on another pillar of the solution: fuel choice. It will identify areas in which the United States and China can develop a common agenda in the field of fuel choice by opening vehicles to fuel competition, allowing fuels made from energy commodities with which the two countries are well endowed, like natural gas, coal and biomass, as well as electricity generated from the above commodities plus from nuclear and renewables, to compete against petroleum fuels over market share in the transportation fuel sector. This report aims to augment existing efforts, providing recommendations specific to the effort of achieving fuel choice and diversification which can speed the transition of the global transportation sector from a single fuel system to a multi-fuel one.

The timing of this report is important. In September 2016, the 13th Five Year Plan (FYP) will be submitted and presented before the National People's Congress. This plan will detail China's development blueprint for the years 2016-2020 spanning a range of social, economic and environmental issues. As a prelude to the publication of the FYP, in November 2014 China has already unveiled the Energy Development Strategy Action Plan (2014-2020), detailing its energy policies for the second half of this decade. It included a cap set on annual primary energy consumption set at 4.8 billion tons of the standard coal equivalent until 2020 and a goal to increase the share of non-fossil fuels in the total primary energy mix to 15 percent by 2020 from 9.8 percent in 2013 with the goal of reaching 20 percent by 2030. Implied from the plan is an increase in the share of natural gas in the nation's energy mix as well as nuclear power and renewables. The plan also calls for considerable investment in clean coal technologies; this stems from the understanding that coal will continue to dominate the energy mix for many years to come. Many aspects of the plan will be essential to the effort of diversifying China's transportation fuel market, and the methods to achieve this goal will be included in the new FYP. The year 2016 will also be the year in which U.S. presidential candidates will have to present their vision for U.S. energy policy and for the future of the Sino-American relations. The policies suggested here do not require subsidies, new tax-incentives or other handouts. They simply lay the foundation for a free and competitive fuel market from which all Americans and Chinese – and indeed much of the world - could benefit.

Main Fuel Choices in China and the United States

1. NATURAL GAS

There are various possible pathways for natural gas to play a bigger role in transportation: it can be used directly as compressed natural gas (CNG) by compressing natural gas to less than one percent of its normal volume and storing and distributing it in hard containers; it can be liquefied at extremely cold temperatures and stored in cryogenic tanks in the form of liquefied natural gas (LNG); or it can be used to generate electricity which in turn can power plug-in hybrids (PHEV) or pure electric vehicles (EV). It can also be used to make liquid fuels like methanol, ethanol, diesel or gasoline.

The shale gas boom has inundated the United States with cheap natural gas and underscored the potential of using natural gas-based transportation fuels as substitutes to those made from petroleum. A large amount of gas is used in the power sector, with important economic and environmental benefits, but only one percent of U.S. natural gas is used as automotive fuel. Comparing the cost-per-energy-source on an energy content basis reveals the degree of the folly in America's current utilization of its natural gas bonanza. The current price of one million British thermal units (mmbtu) derived from natural gas is under $3. The price of U.S. coal is more or less the same. At roughly $50 per barrel the price of 1 mmbtu derived from oil is about $15. This means that from a pure economic standpoint, the arbitrage opportunity of replacing coal with natural gas is zero while that of replacing oil with natural gas is $12 per mmbtu. Despite the cheap price of the North American natural gas, and the various benefits its use offers, the United States is home to only about 150,000 of the world's roughly 18 million natural gas vehicles.

In China, on the other hand, with higher natural gas prices ($10-$12 mmbtu), the arbitrage opportunity is less pronounced, but there is an equally important attribute to the use of natural gas. Natural gas is a cleaner burning fuel than gasoline or diesel, with smog-producing pollutants reduced by 60 to 90 percent. This makes natural gas an attractive competing fuel in the effort to curb air pollution. Gas is also 30 percent cheaper than China's diesel and gasoline. With half the size of America's vehicle fleet, China has ten times more registered natural gas vehicles, most of them in cities close to natural gas fields like Chongqing, Urumchi, Xi'an, and Lanzhou. This number is expected to double by 2020. China also has more natural gas refueling infrastructure.

There are about 3,000 CNG stations and 1,800 LNG stations in China, compared to 1,378 CNG and 93 LNG stations in the United States. (There are only 90,000 retail fuel stations in China compared to about 120,000 in the United States). NGV stations are opening in China at more than twice the rate they are opening in the United States and their number is expected to double by 2020.

China's natural gas prices are three times higher than America's, yet it has ten times more NGVs and twice as many natural gas refueling stations than the U.S.

Despite all the benefits of natural gas its market penetration is facing challenges. As a report by the Hamilton Project of the Brookings Institute stated: "Natural gas can replace oil in transportation through a number of channels. However, the field between natural gas as a transportation fuel and petroleum-based fuels is not level. Given this uneven playing field, left to its own devices, the market is unlikely to lead to an efficient mix of petroleum-and natural gas-based fuels."[1]

As a transportation fuel, gas is available in very limited locations at this time, in some cases ruling out long-distance travel in a dedicated NGV. Suited primarily for heavy-duty vehicles, it is typically used for garbage trucks and transit buses. Moreover, the up-front cost of a passenger vehicle could be cost prohibitive for the average consumer, depending on the country and the regulatory and safety standards. The cost to convert and certify existing vehicles to CNG in the United States is roughly $10,000. In China, on the other hand, it is between a tenth and a third of the price. CNG also requires a much larger tank, which takes up valuable trunk space.

These problems are less relevant for the heavy duty sector. One major opportunity for petroleum displacement with natural gas lies with fleets – especially trucks, city buses, garbage trucks and other heavier vehicles. Given their fuel use, CNG and LNG are better suited for those vehicles than for passenger cars. The substantial cost savings at the pump allows for quicker recovery of the price differential between the natural gas vehicle and its diesel or gasoline counterpart. Because many fleet vehicles return to a centrally-located filling station at the end of a work day, the necessary investment in natural gas infrastructure is not prohibitive. Assuming a significant price spread between natural gas and diesel, the market share of LNG and CNG in the heavy duty fleet has an opportunity for substantial growth, particularly because of the regional nature of much of the freight industry.

1 Christopher R. Knittel, *Leveling the Playing Field for Natural Gas in Transportation*, The Hamilton Project, Brookings Institute, June 2012.

China is now the largest and fastest-growing market for LNG used in trucking. By the end of 2015, 220,000 heavy trucks and 40,000 buses in China are expected to run on LNG. Major cities like Beijing and Guangzhou are in the process of introducing NGVs to their bus and taxi fleets. In fact, China is also producing those vehicles domestically. Shaanxi Automobile Group, western China's largest truck maker, and Dongfeng Yangste Motor Co., a big bus manufacturer, are among the first companies to manufacture those vehicles.

But perhaps the main barrier to mass adoption of natural gas in China is the availability of the resource. Relatively to its size China is poor in natural gas. This could change if China learned to commercialize its shale gas reserve, the world's largest, and its large domestic deposits of coal-bed methane. Additionally China is planning to become increasingly reliant for its gas supply on Russia - the world's largest reserve of conventional gas. Two major pipeline deals signed in 2014 could ultimately enable China to import 60-100 billion cubic meters of Russian gas at prices competitive with crude oil. Overall China plans to double the share of natural gas in its energy portfolio by 2020, and while much of this gas is likely to be dedicated to the power sector, displacing more polluting fuels, utilizing the gas as an oil substitute in the transportation sector would be a more economic use of the resource. But for this to happen some regulatory reforms are called for. China's National Development and Reform Commission (NDRC) sets the price for every province and for every application. Such volume and pricing allocations distort the market and prevent natural gas from competing in those sectors where its economic value may be the highest. In other words, increasing natural gas' participation in the transportation sector in a meaningful way requires China to embark on both technological and regulatory efforts.

2. METHANOL

Also known as wood alcohol, methanol is a colorless, odorless, clean burning liquid fuel that can be produced from natural gas, coal, biomass, and even recycled carbon dioxide. It is presently the most scalable and easily deployable competitor to petroleum based fuels. The use of methanol requires negligible changes to vehicles and minimal adjustment to the fueling infrastructure. A report by MIT concluded that using natural gas to produce methanol fuel is superior to the use of compressed or liquefied natural gas for vehicles, and recommended that the U.S. government should implement an open fuel standard that requires automakers to certify light-duty vehicles to run on it.[2] When dehydrated, methanol can be turned into Dimethyl Ether (DME) which can be used as a diesel substitute in heavy duty trucks and ships.

Methanol cuts emissions of NOx and volatile organic compounds that form ground-level ozone or "smog." And since methanol contains no sulfur, there are no SO_2 emissions. Methanol is much

2 MIT Study on the Future of Natural Gas, MIT Energy Initiative, 2011.

less reactive than gasoline in the atmosphere and does not contain the toxic BTEX additives found in gasoline – benzene, toluene, ethylbenzene, and xylenes. These compounds are highly carcinogenic, do not readily biodegrade in the environment, and are capable of contaminating groundwater supplies. It has been demonstrated that methanol-fueled auto emissions meet and exceed California's stringent Ultra Low Emission Vehicle (ULEV) emission targets. Methanol is also safer than gasoline, igniting at much higher temperatures and resulting in fewer car fires and explosions in impact accidents. Like gasoline, methanol is toxic when swallowed. And like ethanol, it is corrosive to vehicle parts, but requires relatively low-cost vehicle modifications to accommodate higher blends. Like ethanol, methanol has less energy per gallon than gasoline, which requires more trips to the pump. Therefore, the price per gallon must remain significantly lower than gasoline in order to attract consumers.

Methanol can be blended into gasoline and used at low levels (up to 15 percent) in existing vehicles or at higher levels in flexible fuel vehicles (FFV), which cost an extra $100 or so to manufacture as compared to gasoline only vehicles. There is also a large market for aftermarket conversions of standard gasoline-only vehicles to run on alcohol fuels with conversion prices ranging between $100 and $1,000 per vehicle.

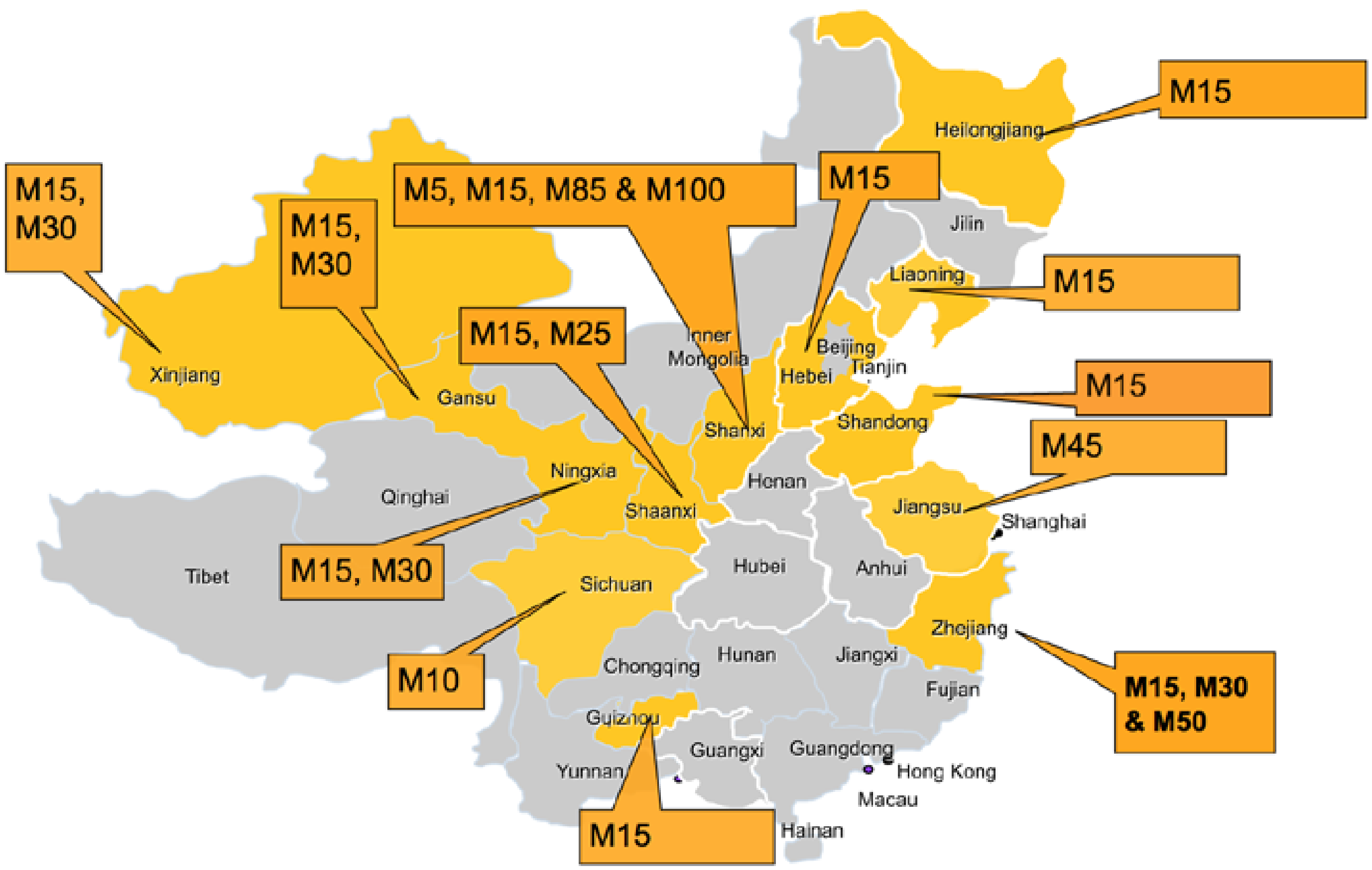
China began its methanol fuel research in the 1980's. In 1995, supported by multiple governmental offices including the Ministry of Science, the Ministry of Transportation, the Chinese Academy of Sciences, as well as the top Chinese universities and Ford, China introduced the first methanol passenger vehicle. At the same time, Shanxi Province began supporting methanol bus demonstrations by public transportation companies.

Today, China is the world's biggest producer and user of methanol, primarily from coal, and due to its low cost as compared to gasoline – methanol is so cheap in China that illegal blending is rampant – fifteen of its provinces already use this fuel widely in millions of cars. Within less than a decade China's methanol use in the transportation sector grew from virtually zero to a point it replaced nearly ten percent of the country's gasoline demand. In 2014, methanol fuel blending surpassed 3 billion gallons with most of the demand being in the form of M15 (15 percent methanol). Throughout China there are 43 blending facilities each with a blending capacity of 30 million gallons. Chinese automakers like Cherry, Geely, Shanghai Automotive, and Maple have rolled out cars that can run on methanol. In 2014, Geely commissioned the assembly line of its newly built methanol-fueled automobile plant in the Chinese city of Jinzhong in Shanxi Province. The plant is designed to produce 200,000 cars and 200,000 engines annually. These vehicles will be configured to run on M100 (100 percent methanol) fuel.

China is the world's biggest producer and user of methanol, primarily from coal. Fifteen of its provinces already use this fuel widely in millions of cars.

The Chinese government is in the process of taking methanol from the provincial arena to the national one. Pilots involving 11 cities in five provinces are currently being finalized and the results will be assessed throughout 2016 with the goal of approving the use methanol on a national scale.

CHINA PROVINCIAL FUEL BLENDING STANDARDS



Source: Methanex, China PDRC's, Shanxi Methanol office

In the United States methanol was used in the 1990s in just over 21,000 cars with approximately 15,000 of these in California. These cars were supported by over 100 methanol refueling stations. Hundreds of transit and school buses were operated during this time period using M100.
By the late-1990s after more than 200,000,000 miles of experience, the use of methanol as a transportation fuel in the United States quickly faded away for a number of reasons. In the 1980s and 1990s, when gasoline was priced below $1.00 per gallon, methanol fuel was not competitive with premium gasoline and methanol FFVs were fueled with gasoline most of the time, making it difficult to build volume sales to encourage the operation of retail pumps. Only four vehicle models were ever offered for commercial sale by the automakers. However, with cheap natural gas prices and a growing domestic methanol industry – no fewer than eight methanol manufacturing facilities are currently being built in Texas and Louisiana – pressure is growing to reopen the door for methanol to enter into America's fuel market.

3. BIOFUELS

The United States biofuels industry has established itself over the years as an important part of the nation's energy landscape and the beating heart of the rural community. More than 14 billion gallons of ethanol, mostly made from corn, and 2.7 billion gallons of biodiesel, mostly made from soybeans, are blended annually into the fuel market. Ethanol is blended with gasoline as a fuel additive because its high level of octane reduces engine knock and increases engine performance. E10, containing 10 percent ethanol and 90 percent gasoline, is the most common blend found at pumps. Other blends like E15 and E85 are available in limited locations. While the former is approved for use in conventional vehicles the latter, which contains a maximum of 85 percent ethanol, can only be used in FFVs.

Ethanol also reduces significantly reduces tailpipe emissions of pollutants such as NOx and BTEX. Despite its economic and environmental benefits, ethanol does have its shortfalls. The fuel is less energy dense than gasoline, meaning fewer miles per gallon as the ethanol content rises. For E10, the mileage penalty is negligible, but for E85, there is a reduction of about 25 to 30 percent. Transportation costs are also higher. The fuel is generally transported by truck, train, or barge to areas close to where it is produced, primarily in the Midwest. As a result, E85 has limited distribution on the East and West Coasts.

While fuel subsidies have been more or less eliminated in recent years a controversial Renewable Fuel Standard (RFS) is still in place, requiring refiners to blend a specific amount of biofuel into the fuel supply in any given year. The widespread availability of biofuels in America's Midwest has given rise to 3,250 retail stations offering E85 today and numerous models of flexible fuel vehicles capable of running on blends of up to 85 percent ethanol. There are nearly 16 million FFVs on U.S. roads today, representing nearly ten percent of the overall fleet.

In fact, roughly 25 percent of new vehicles sold in the United States in 2014 were FFVs capable of operating on up to E85. This includes approximately half of new models produced by Ford, Chrysler and General Motors, as well as select models made by Volkswagen, Land Rover, Jaguar, Toyota, Mercedes-Benz, Bentley and Audi.

China's approach to biofuels is more ambivalent. On one hand, China's National Energy Administration (NEA) has called for state oil companies to include biodiesel in their diesel mix as "a solution to improve air quality and a potential substitute of petroleum." Biodiesel - which is typically comprised of up to 15 percent methanol content – can reduce vehicle pollutant emissions by as much as 70 percent compared with petroleum based diesel. On the other hand, biodiesel as a transportation fuel is not supported by a legal framework. If fact, it is illegal for transportation fuel except in several B5 pilot cities. Furthermore, China has forbidden the use of grain for biofuels production. Nongrain feedstock like sugar, cassava or sweet sorghum are permitted for use in ethanol production but they are limited domestically and by and large must be imported from Southeast Asia.

China is much more interested in approaches that do not conflict with food consumption at all like biodiesel made from cooking oil or non-edible oil-based plants or cellulosic biofuels made from agricultural waste, forest residue and dedicated plants. Apart from the challenges of feedstock availability China faces challenges in the fields of water conservation and technologies for application of second generation biofuels. Bio-aviation fuel, on the other hand, is gradually attracting policy-makers and market attention. In March 2015 Hainan Airlines (in collaboration with Boeing and Sinopec) conducted China's first passenger flight with aviation fuel made from waste cooking oil collected from restaurants in China.

4. VEHICLE ELECTRIFICATION

Vehicle electrification provides a unique energy security benefit as it tremendously increases the number of energy sources able to participate in the transportation sector, adding nuclear, coal, natural gas, hydro-power, wind, and solar to the fuels market. Because they open the door for less polluting fuels to enter the transportation sector Battery Electric Vehicles (BEVs) have become the focus of China's New Energy Vehicle (NEV) Plan. This plan is carried out under the auspices of what is called the "863 Program," which is China's strategic high-tech development program. The goal of the NEV plan is to narrow the technology gap between Chinese automakers and their foreign competitors. The plan focuses on two types of vehicle technologies: energy saving vehicles which are able to reach high fuel efficiency and New Energy Vehicles, primarily EVs, PHEVs and Fuel Cell Vehicles.

In 2009, thirteen Chinese cities were selected as pilot cities for energy saving vehicles and NEVs. The number climbed to 25 by 2011. In 2010 subsidies of RMB60,000 per EV and RMB50,000 per regular hybrid vehicle were announced. In 2012 the Energy Saving and New Energy Vehicle Industry Development Plan (2012-2020) set two main goals to be reached by 2020: bringing average fuel economy for passenger cars below 4.5 L/100km and achieving national production capacity of BEVs of 2 million units a year with cumulative sales and production totaling over 5 million units. Ambitious goals were also set for battery technology and other related electronic components, with the goal of nurturing "two to three enterprises with over 10 million kWh in battery sales; two to three enterprises with core anode/cathode, membrane, electrolyte and other key materials, and two to three enterprises with leading technologies in electric motors and other EV technologies." With regards to charging infrastructure, China is considering providing as much as RMB100 billion ($16 billion) in government funding to build electric-vehicle charging facilities. According to the plan, by 2015, 1,549 charging stations as well as 238,000 charging points will be built in the pilot cities. To spur demand for EVs some cities like Beijing exempt electric cars from restrictions that prohibit drivers from taking their cars on the road on certain days. China also announced last year that all New Energy Vehicles would be exempt from the state's ten per cent sales tax, as long as they can drive at least 30 miles on electricity alone. It also announced that by next year, 30 percent of all government vehicle purchases must be New Energy Vehicles.

But despite strong political support and infusion of large sums of government money in the form of subsidies for both automakers and customers the NEV project is falling short of expectations. For the most part, Chinese consumers lack access to public charging (and unlike many American consumers do not enjoy access to attached-to-the-house garages with easily accessible electric sockets) and affluent Chinese prefer traditional luxury cars rather than environmentally friendly ones often with limited range as with the case of EVs. As a result, sales of EVs in China stood under 40,000 in 2014, less than one percent of new vehicle sales. While this figure quadrupled the sales in 2012, it is still a relatively insignificant portion of the total automobile market and with such weak sales Chinese automakers have insufficient incentive to dedicate their production lines to EV manufacturing.

In the United States the situation is not much better. In 2009, the National Highway Traffic Safety Administration (NHTSA) published the final rule raising Corporate Average Fuel Economy (CAFE) standards for both cars and light trucks. These new standards aimed to encourage the expanded market entry of electric drive technologies. In his 2011 State of the Union address, President Obama called for putting one million electric vehicles on the road by 2015. On the consumer side electric car buyers in the United States receive a tax credit of up to $7,500. Sales of plug-in cars in 2014 stood at 120,000 out of 16 million vehicles sold – like in China, a market share of less than one percent. Altogether the number of plug-in cars on

America's roads was under 300,000 by 2015. Even if EV sales of reach a compounded growth of 30 percent a year their total share of the fleet will be under five percent by 2025. Twenty four models are available today in the United States and 20 additional ones are expected to be introduced by the end of 2016. Yet, so far 80 percent of the vehicles sold are from four models. The fall in oil prices which translates into low gasoline prices has already reduced the motivation of many car buyers to purchase EVs.

Furthermore, in both China and the United States the early adopter subsidies are not going to last much longer. Under current U.S. law, the tax credit is scheduled to phase out once a qualified automaker sells 200,000 vehicles. The Chinese government announced that the amount of the subsidy will be reduced once 50,000 units are sold. In all likelihood, by 2020 almost every automaker will have exhausted its tax incentives quota. Unless Washington and Beijing extend those tax incentives, something that seems unlikely under current political and fiscal conditions, or the cost of electrification drops substantially, EVs will have a hard time remaining competitive with other equivalent vehicles in the market. Another issue in China is the grid's ability to manage the load of charging numerous EVs. Electricity demand varies strongly by time of day. Charging EVs during off peak hours can help balance the grid and to achieve this the recharging must be properly managed. This requires electricity providers to improve the grid and adopt sophisticated demand response and load management systems. For all these reasons and others electrification will probably take off first in the United States and only then develop in China as its electricity system matures.

Choice Enabling Vehicle Platforms

COMPRESSED NATURAL GAS VEHICLES (CNG) use natural gas compressed into a gas canister. They can be refueled from existing natural gas lines or by home refueling stations that tap into such lines.

BI-FUEL VEHICLES have two separate fueling systems, allowing them to run on either CNG or gasoline. Any existing gasoline vehicle can be converted to a bi-fuel vehicle. Authorized shops can do the retrofitting; this involves installing a CNG injection system and CNG cylinder in the trunk, and minor changes in the vehicle's plumbing and electronics.

DUAL-FUEL VEHICLES use diesel for ignition and run on natural gas.

PROPANE VEHICLES also known as liquefied petroleum gas (LPG) or autogas vehicles, come in two forms: dedicated and bi-fuel. Dedicated propane vehicles are designed to run only on propane, while bi-fuel propane vehicles have two separate fueling systems that enable the vehicle to use either propane or gasoline. There are also two types of fuel-injection systems available: vapor injection and liquid propane injection. In both types, propane is stored as a liquid in a relatively low-pressure tank.

FLEXIBLE FUEL VEHICLES (FFV) can run on any blend of gasoline, ethanol, and methanol – regardless of the ratio. Because of its low incremental cost of roughly $100, in the near and mid-term the FFV is the most cost effective platform for enabling fuel competition.

BATTERY OPERATED VEHICLES store electricity in an on board automotive battery and use the electricity to power an electric motor; they may also have a fuel tank and engine that serve as a range extender.

FUEL CELL VEHICLES run on hydrogen to power an on-board electric motor. The fuel cell converts the chemical energy from the hydrogen into electricity through a chemical reaction with oxygen or another oxidizing agent.

Recommendations

1. INSTITUTE A FUEL CHOICE PATHWAY FOR FUEL ECONOMY STANDARD COMPLIANCE

The simplest policy pathway to opening vehicles to fuel competition is the Open Fuel Standard (OFS). This technology neutral policy requires that most light duty vehicles sold in any given market be capable of running on another fuel in addition to or instead of gasoline or diesel, whether liquid fuel, gaseous fuel, electricity, or some combination thereof, stipulating that flex fuel vehicles must be at the least gasoline-ethanol-methanol compatible to count as fuel competitive. However, a strong aversion to mandates among some constituencies in the United States presents a tough challenge for this policy's acceptance. We therefore present an alternative pathway to achieving a similar outcome - one that avoids the need for a politically challenging mandate.

The U.S. Congress responded to the 1973 Arab Oil Embargo by enacting in 1975 Corporate Average Fuel Economy (CAFE) standards intended to reduce America's vulnerability to oil supply disruptions and price spikes by improving the fuel efficiency of cars and light trucks. The 2007 Energy Independence and Security Act (EISA), required that the U.S. Department of Transportation (DOT) establish standards separately for passenger cars and light trucks at the maximum feasible levels in each model year, and that DOT enforce compliance with the standards. Most recently, EPA and the National Highway Traffic Safety Administration (NHTSA) updated CAFE standards for motor vehicles, raising the requirement to 54.5 miles per gallon (mpg) by 2025. China's *Energy Saving and New Energy Vehicle Industry Development Plan (2012-2020)* proposed a fuel consumption target for cars below 4.5 liters per 100 km (about 50 miles per gallon) by 2020. Many analysts are concerned that achieving such standards is not feasible in the current timeline and that even if it were it would significantly increase the cost of new vehicles. The increased cost would in turn serve to depress demand for new vehicles, with negative economic implications.

CAFE's initial objective was energy security – not the control of greenhouse gas emissions. While the law provides EPA with significant leeway in assigning automakers extra credit for making vehicles that run on non-petroleum fuels, the de facto repurposing of CAFE in recent years has resulted in a regulatory diminution of the attractiveness to automakers of certain non-petroleum fuels and the vehicle technologies that enable their use.

Recognizing this problem, we propose an alternative fuel economy compliance pathway to auto manufacturers in both countries, one that in the United States would serve to return CAFE to

A methanol powered car by Geely

its original goal of improving energy security while offering automakers a fiscally conservative pathway to meeting their legal obligations.

CAFE's initial energy security centric vision has been blurred by the desire to use the law to promote greenhouse gas emission reduction goals.

This approach would ease the fuel efficiency requirement for auto makers that choose to open a majority of the vehicles they manufacture in a given model year to fuel competition of some sort, including gasoline-ethanol-methanol FFVs, PHEVs or pure EVs, CNG vehicles, and so forth. This technology and fuel neutral policy, which reflects a recommendation offered by the United States Energy Security Council (USESC) in its report *Fuel Choice for American Prosperity*, would serve to overcome the "who should move first" hurdle faced by non-petroleum fuels and vehicle technologies. The prevalence of petroleum-only vehicles has left little market incentive for filling stations and other fuel infrastructure to offer other fuel choices. The resulting lack of options at the pump in turn reduces the appeal for automobile manufacturers to open cars to fuels that are not commonly sold. This conundrum poses a multi-party coordination problem that in a mature economy such as that of the U.S. is difficult to overcome without public policy of some sort.

The policy differs from previous CAFE centered approaches which offered a fuel consumption credit for each such manufactured car up to a certain limited amount of total credits. Given the limited credits as well as vehicle fleet turnover times in the larger market that policy did not drive sufficient penetration of fuel-choice enabling cars to provide a realistic business case for fuel stations to offer for sale non-petroleum fuels. By conditioning an easing in an automaker's fuel economy obligation on the opening of the *majority* of the new vehicles it produces in a given model year to fuel competition, the new policy would cause the proportion of fuel competition enabling vehicles in the overall market's vehicle fleet to hit 15 to 20 percent - the required tipping point for there to be a business case for the average fuel station to install a non-petroleum pump - within a relatively few number of years. Such an option would benefit the economy by enabling automakers to choose the lowest cost methods (whether efficiency, fuel competition, or some combination thereof) to meeting the government's energy security and air quality goals, and would allow more optimal utilization of both countries energy resource endowment.

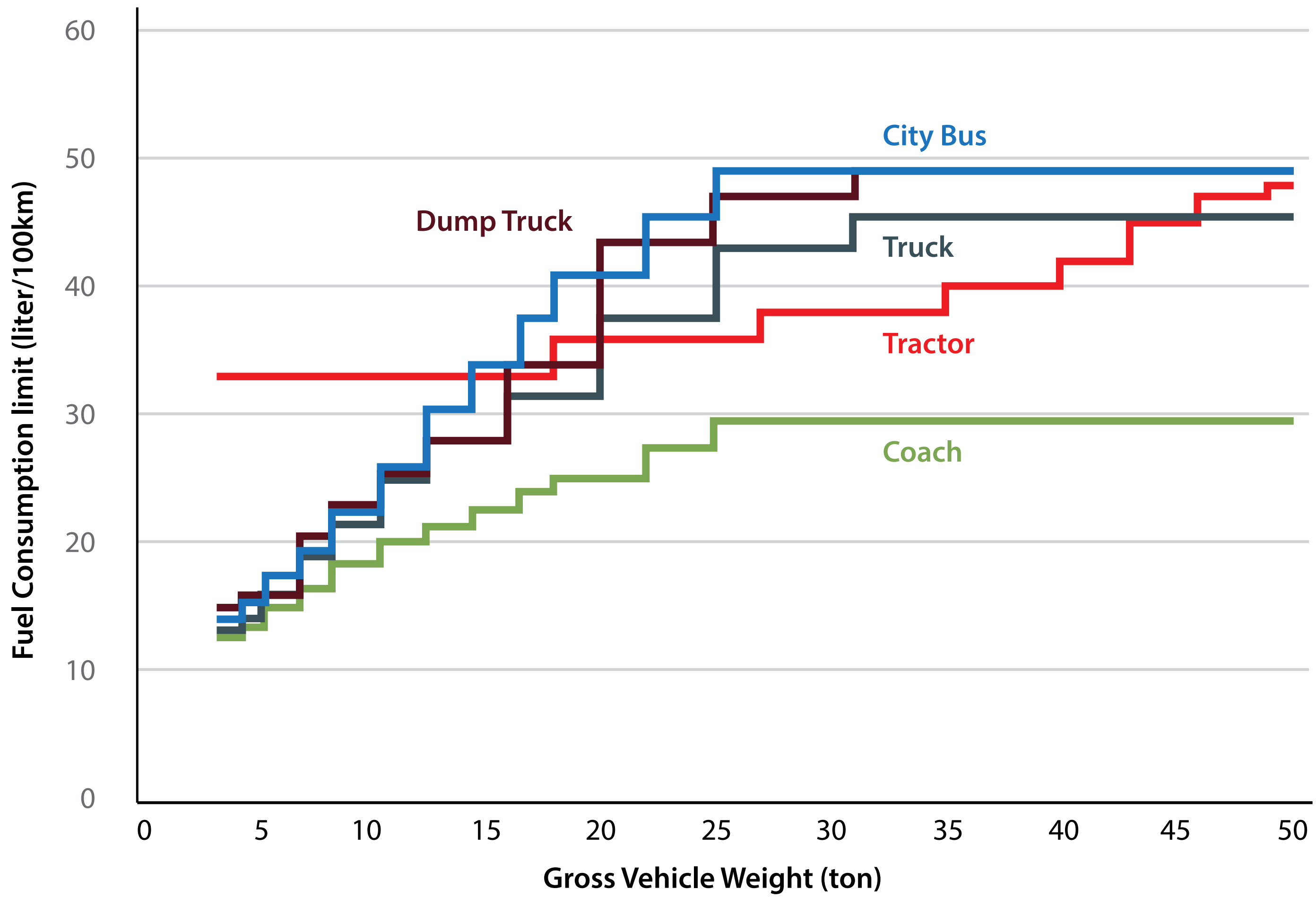
RECOMMENDATION

In order to focus fuel consumption standards on the goals of reducing the importance of oil to the economy and of improving air quality, rather than on reducing the consumption of energy writ large, ease the fuel consumption obligation of auto manufacturers that open up the majority of the vehicles they produce in a given model year to fuel competition.

2. FOCUS ON HEAVY DUTY VEHICLES

In its *Outlook for Energy: A View to 2040*, ExxonMobil anticipates that as compared to 2010 by 2040 the total fuel consumption of the global heavy duty vehicle sector will have increased by 65 percent and will also by then account for some 40 percent of global transportation fuel demand. Reducing the importance of oil-based transportation fuels to this sector will thus have tremendously positive energy security, air quality, and economic benefits. Both the United States and China have introduced fuel consumption standards for their heavy duty vehicle sectors. In China, separate sets of standards have been promulgated by the Ministry of Industry and Information Technology (MIIT) and by the Ministry of Transport

(MOT.) The MOT requires heavy duty vehicles to meet its standard as a condition for the receipt of a commercial license. New heavy duty commercial vehicles manufactured in China, with the exception of certain specialty vehicles, must meet the MIIT's most recent standard, promulgated in February 2014, by July 2015.



Fuel consumption limits stipulated in China's National Standard
(Known as Phase II for new commercial heavy-duty vehicles) Source: Transportpolicy.net

In the United States, medium and heavy duty vehicle efficiency standards coupled with greenhouse gas emissions standards were first issued by the EPA and NHTSA in August 2011. Those standards applied to model years 2014-2018. The EPA and NHTSA are to issue the next set of standards, which will apply to post- 2018 model years, in March 2016.

While both countries' policies focus on the reduction of energy consumption in this sector, adjusting the standards to focus on reduction in the importance of oil based fuels rather than the use of energy writ large would reduce the cost of meeting both governments' air quality goals. For example, as will be discussed in the next section, China's air quality goals would economically be achieved by embracing coal-based methanol fuel for heavy duty vehicles, either as proposed by the MIT Sloan Automotive Laboratory for use in high compression flexible fuel engines, or else in diesel-methanol dual-fuel operation as proposed by Tianjin University's State Key Laboratory of Engines.

RECOMMENDATION

Ease the heavy duty vehicle fuel consumption requirement for manufacturers that open at least half of their production in a given model year to non-petroleum fuels of some sort, whether alcohol fuels, DME, CNG, LNG, or any other option.

3. EMBRACE COAL BASED TRANSPORTATION FUELS AS A WAY TO IMPROVE URBAN AIR QUALITY IN CHINA

In China today diesel accounts for 40 percent of transportation fuel demand and is thus a significant demand driver for oil, not to mention a big source of air pollution. The United States and China are currently collaborating on fuels for heavy duty vehicles under the umbrella of the U.S.-China Climate Change Working Group (CCWG.) This initiative, launched in 2013, has an action item titled "Emission Reductions from Heavy-Duty and Other Vehicles." Efforts under this initiative include advancing policies to reduce CO2 and black carbon emissions like enhanced heavy-duty fuel efficiency standards, cleaner fuels and vehicle emissions control technologies, and more efficient, clean freight. Expanding the scope of "clean fuels and vehicle emissions control technologies" collaboration to include coal-derived fuel options such as methanol and DME would benefit both countries.

China and the United States are the world's largest coal consumers. China is also the world's biggest coal producer, and coal accounts for over 65 percent of its total energy consumption. Despite its natural gas abundance coal still plays an important role in the U.S. energy market accounting for over one third of its electricity generation. While for environmental reasons both countries are trying to reduce the use of coal, the commodity will continue to hold a major part of both countries' energy portfolios for decades to come. The question then is not whether coal will be used but rather how it will be used and for what purpose.

To date coal has been primarily used in the power sector and barely as a transportation fuel. But counter-intuitive though it may seem coal derived fuels like methanol and DME offer significant air quality benefits as compared to diesel. Methanol improves combustion efficiency and reduces vehicle exhaust emissions, including those of particulates, carbon monoxide, and other pollutants which damage human health. Methanol made from coal offers a tremendous improvement in air quality compared to status quo diesel engines, and even as compared to engines compliant with China's most recent (IV) diesel standards.

Substantial work has been done on methanol as a substitute fuel for heavy duty vehicles both in Tianjin University in China and at the MIT Energy Initiative in the United States. The former has focused on dual-fuel methanol-diesel applications for heavy duty vehicles, while the latter has focused on replacing heavy duty diesel engines with high compression gasoline-methanol flexible fuel engines. While the efforts differ in their approach, both find the fuel would significantly improve air quality as compared to diesel. Specifically, researchers at MIT report that a spark ignition methanol truck engine would reduce emissions of NOx and particulates by over 90 percent as compared to a diesel engine without NOx and particulate after treatment and low sulfur fuel – this while boosting power by over 30 percent, at no cost increase for the engine, and with an attractive cost for the fuel itself.

Counter-intuitive though it may seem, coal-derived fuels like methanol and DME offer significant air quality benefits as compared to petroleum based diesel

Tianjin University researchers compared emissions from dual-fuel methanol-diesel operation with China's Phase IV diesel emissions standards using various European tests for emission measurement from heavy-duty diesel engines (specifically, the European Stationary Cycle (ESC), European Transient Cycle (ETC) and the European Load Response (ELR) tests) as carried out by China's State Key Laboratory of Engines at Tianjin University. The air quality improvement gained by dual-fuel methanol-diesel operation is substantial as shown in the chart.

	HC	CO	NOx	Soot
ESC-China IV	0.46	1.5	3.5	
ESC-DMDF	0.026	0.01	3.108	
ETC-China IV	0.55	4	3.5	
ETC-DMDF	0.006	0.006	3.347	
ELR-China IV				0.5
ELR-DMDF				0.201

Emissions from Diesel-Methanol Dual-Fuel Operation vs China's IV Diesel Standard (In g/kWh)

Source: State Key Laboratory of Engines, Tianjin University

RECOMMENDATION

Expand the scope of clean fuels and vehicle emissions control technologies collaboration under the Emission Reductions from Heavy-Duty and Other Vehicles action item of the U.S.-China Climate Change Working Group to include fuel options such as methanol and DME. Explore multiple technological paths, and conduct joint production of demonstration engines and vehicles for testing in collaboration with private sector companies, to speed the commercial introduction of the technology in both countries.

4. CREATE A SINO-AMERICAN JOINT ALCOHOL FUEL ALLIANCE

Alcohol fuels like ethanol and methanol offer a variety of environmental benefits to China. Today, refiners use BTEX aromatics as octane boosters. Such aromatics are toxic, carcinogenic and polluting. Alcohol fuels are high octane yet they would obviate the need for aromatics. They contain no sulfur and are therefore conducive to both U.S. and China's efforts to reduce sulfur emissions. Geely's methanol-fueled cars for example have passed Euro IV standards and also showed good Euro V compliance results, with carbon monoxide emissions meeting the Euro V requirement of 23.8 percent. Geely's vehicles also met the Euro V emissions standards for hydrocarbons (21 percent) and NOx at 8.33 percent. Finally, the technology innovation curve for alcohol fuels is more environmentally appealing than that of oil products. As oil prices rise more crude extracted from unconventional sources like tar sands and shale will flow into the market. This means that the environmental profile of petroleum based fuels will get worse and worse over time. The gradual shift to second generation ethanol, as well as the production of methanol from natural gas, biomass and, as we showed above, even from coal, means that contrary to oil, alcohol fuels will become more environmentally friendly over time.

As the USESC argued in its 2013 recommendations report *Fuel Choice for American Prosperity* the expansion of the methanol fuel usage in China could provide invaluable insight on opening the U.S. market to fuel competition in an era of low cost natural gas.[3] China, for its part, could gain insights from America's long experience with ethanol blending and its deployment of millions of flexible fuel vehicles. China and the United States can also share useful information on the air quality benefits of alcohol fuels. Hence, the Council recommended the creation of an alcohol fuel alliance focused on opening transportation fuel markets around the world to alcohol fuels and opening vehicles to their use. Such an alliance would facilitate Sino-American cooperation on alcohol fuels and work with Chinese and U.S. automobile manufacturers to advance the adoption of fuel choice enabling vehicle platforms. Joint actions will include standard development, pilot projects and demonstrations, technical roadmaps, fueling infrastructure development, environmental studies, as well as public awareness and engagement. The Council also suggested that Brazil, another major player in the alcohol fuel market be part of this initiative. In November 2013, the Joint Alcohol Fuel and Automobile Alliance (JAFAA) was created and it enjoys the support of the China Association of Alcohol & Ether Clean Fuels and Automobiles (CAAEFA) which is managed by the China Petroleum and Chemical Industry Association (CPCIA).[4]

3 *Fuel Choice for American Prosperity: Recommendations to the Nation on Opening the Transportation Fuel Market to Competition*, United States Energy Security Council, October 2013, http://www.iags.org/fuelchoices.pdf

4 See www.iags.org/jafa.html

Preparatory Meeting of JAFAA, Beijing, June 2014

RECOMMENDATION

Build on the existing platform of the Joint Alcohol Fuel and Automobile Alliance to make it into an official, inter-governmental channel for information exchange and collaboration on all matters related to alcohol fuels and include such cooperation in the framework of the U.S.-China Clean Energy Research Center (CERC).

5. COLLABORATE ON JOINT STANDARDS FOR AFTERMARKET VEHICLE CONVERSIONS TO COMPETING FUELS

Policies that allow for the conversion of existing dedicated gasoline/diesel vehicles to run on competing fuels can help accelerate the penetration of fuel competitive vehicles in the overall fleet, thus increasing incentives for private sector investment in fueling infrastructure. Allowing consumers greater opportunities to convert their gasoline cars and trucks empowers them to help make a difference – by reducing the importance of oil, improving local air quality, cutting emissions, or saving money at the pump. It also opens the door to mass vehicle conversions by owners of used car lots and vehicle service chains. Consumers with easy access to filling stations that offer competing fuels can thus take full advantage of those fuels' price advantage over gasoline or diesel. In general, there are three types of conversions – switching a gasoline or diesel car to run solely on another fuel (dedicated), changing a vehicle to run on higher alcohol blends (flex fuel), or installing an additional fuel tank so the vehicle can burn the competing fuel as well (bi-fuel). In the United States onerous regulations and staggering cost of conversion has deterred consumers. Although only one E85 conversion kit has been approved by EPA so far, there appears to be considerable potential to expand the number of approved kits to cover a wide range of vehicles and drive down kit prices substantially. EPA responded in 2012 by streamlining some of the rules for conversion of gasoline and diesel engines and vehicles, expanding compliance options to include less burdensome demonstration requirements for older vehicles and greater flexibility concerning testing requirements. However, conversion costs remain prohibitively high.

The cost of converting a light duty gasoline car to CNG is roughly $10,000 per vehicle in the United States. In China on the other hand it is between a tenth and a third of the price. Stricter environmental and safety standards for U.S. vehicles account for some of the cost difference. Over 1/3 of the $10,000 conversion cost in America is a result of the cost of the approximate 10 gallon, Type IV, carbon-fiber CNG tank. According to industry cost estimates, installation labor and other parts for the conversion system account for another 20 percent plus of the price tag for conversion. The remaining cost of conversion is probably a combination of the price tag of EPA compliance and certification and excess profit in the system - some industry specialists believe that the regulatory burden imposed by the EPA most likely constrains competition in conversion kit manufacturing, thus creating a market that results in abnormal profits.

Conversion of vehicles to run on alcohol blends is much cheaper. In order for a standard gasoline car to be able to accommodate alcohol fuels four modifications need to be made:

- Engine control system must be reprogrammed
- Fuel line and fuel tank must be made from materials compatible with alcohols
- Active oxygen sensor must be connected to engine control
- Fuel pump and injectors must be designed for more fuel throughput

Many of the car models on the road today in the United States and China already have one or more of the above modifications. Aftermarket conversion could cost anywhere from $100 to $1,000 depending on the model. According to a study by Resources for the Future the payback for conversion could be as short as six months, depending on location, timing, and various assumptions about vehicle fuel economy and miles driven.[5]

RECOMMENDATION

The conversion kit market needs to be further deregulated to offer safe, but low-cost conversions for broader consumer adoption of substitute fuels – particularly for older vehicles. The U.S. and China should work together to determine joint standards for conversion kit certification and installation procedures. Such a program would help guarantee safe installation of tanks, fittings, and any cabin detection ability if needed, while ensuring that post-conversion tailpipe emissions remain as stringent or actually improve.

6. INCREASE UTILIZATION OF UNCONVENTIONAL GAS

China has significant reserves of unconventional gas, including coal bed methane and shale gas. China's technically recoverable shale reserves are estimated at 33 trillion cubic meters (tcm), the largest in the world, while China's Ministry of Land and Resources estimates technically recoverable coal bed methane reserves, including both coal mine methane (CMM) and coal bed methane surface well extraction (CBM), at 10 tcm. The difficulty is economically extracting these resources and – no less important - bringing them to market. In the case of coal bed methane, the latter is a big challenge due to the remote rural location of many coal mines as well as the low concentration of much of the gas. While the overall volume is large, the volume in any one location is often too small to justify building a pipeline to move the gas to market.

China's shale gas production hit 1.3 billion cubic meters (bcm) in 2014, a fivefold increase over 2013, but also significantly lower than the 6.5 bcm production target for 2015 formulated by the Chinese government in 2011 in its 12th Five Year Plan. Shale production in China is quite a bit more expensive than in the U.S. China's 2014 coal bed methane production from surface wells totaled 3.6 bcm in 2013, but very far from the 2015 target production of 16 bcm. And while coal mine methane production was quite high in 2013, totaling 12.6 bcm (the 2015 goal is 14 bcm) most of the produced gas was utterly lost to the economy by being simply released into the air. In 2013, while total CBM and CMM production was 15.6 bcm, only 6.6 bcm of that gas made it into the market, most of the rest being

5 Arthur Fraas, Winston Harrington and Richard Morgenstern, *Cheaper Fuels for Light Duty Fleet: Opportunities and Barriers*, Resources for the Future, September 2013, http://www.rff.org/RFF/Documents/RFF-DP-13-28.pdf

vented by producers lacking a profitable means of capturing and transporting the resource. China's National Energy Administration (NEA) has already set the 2020 total coal bed methane production target at about 40 bcm.

One of the big obstacles to utilization is a low concentration of gas. China requires utilization of coal mine methane at medium (30-80 percent) and high (above 80 percent) concentrations, however low concentration (below 30 percent) and ventilation air methane (less than 1 percent concentration, henceforth VAM) may be vented. In areas without a ready means of economically utilizing CMM, this creates an unintended incentive for operators to dilute CMM concentration to below 30 percent. Since methane is most explosive in a 5-15 percent concentration (and considered dangerous below 30 percent concentration) this has serious safety implications.

The U.S. EPA has conducted various cooperative feasibility studies on coal mine methane drainage and utilization in China, with examined utilization avenues including onsite uses for the resource as well as options for piping it elsewhere, generating electricity from it, using it as boiler fuel, converting it to vehicle fuel, and so forth. Collaboration and information sharing has also occurred through the Global Methane Initiative led by EPA. China currently leads the world in the number of projects utilizing CMM, however utilization technologies are slow to proliferate across the industry. Also, while China has explored – and in some cases deployed - technologies to utilize low concentration CMM and VAM, much remains to be done on this front.

One high value manner of utilizing the gas is converting it to easily transportable liquid transportation fuels, such as diesel, methanol or other options. Due to the relatively small gas production at many mines, small scale modules to convert the gas into high value liquids are likely to be more feasible and economic than world scale conventionally sized plants. These include both the utilization of Fischer Tropsch (FT) technology to convert the gas to synthetic petroleum products (gas-to-liquids or GTL for short) as well as options to convert the gas into the liquid fuel methanol, DME, and so forth. Conventionally sized GTL plants cost many billions of dollars and require a large flow of gas to be economic. For example, the smallest GTL facility in Qatar has a 34,000 barrel per day production capacity, taking in on the order of 350,000 mcf of gas per day, and cost about $1 billion to build, while the largest GTL project in Qatar with a capacity of 140,000 barrels per day cost on the order of $18-19 billion. Conventionally sized gas to methanol plants, while much less costly, still require large inputs – over 50,000 mcf of natural gas per day to be economic. Various companies have developed small scale, mobile GTL modules, including gas to methanol and gas to DME.[6] The Department of Energy's Advanced Research Projects Agency – Energy (ARPA-E) has funded several efforts in this direction as well. Some of these modules

6 See *Associated Gas Monetization via miniGTL Conversion of flared gas into liquid fuels & chemicals*, Global Gas Flaring Reduction Partnership, January 2014, http://siteresources.worldbank.org/EXTGGFR/Resources/Associated_gas_utilization_via_MiniGTL_Jan_2014_update.pdf

can economically operate with under 1,000 mcf of natural gas input a day and in certain cases well under, depending on the technology. While these technologies hold enormous potential for the monetization of small scale gas resources currently effectively stranded around the world and particularly in China, proving and improving the economics of these small scale technologies and their feasibility in various applications, including a low concentration gas feed, will require the experience of demonstration and deployment – R&D does not only occur at lab scale.

RECOMMENDATIONS

I. Intensify coal mine methane collaboration with a special focus on the safe and economic utilization of low concentration CMM and VAM, specifically with an eye to converting the methane to transportation fuel.

II. Jointly demonstrate, test, and share best practices regarding small scale gas-to-transportation fuel options in conjunction with methane production from landfills, sewage treatment facilities, rural gas production from agricultural byproducts, CBM and CMM including methane from abandoned coal mines, and stranded shale gas.

7. BUILD THE FOUNDATION ON WHICH ELECTRIFICATION CAN OCCUR

Despite the challenges of mass adoption of BEV both the United States and China are aware of the tremendous benefits the technology offers for long term energy security and the environment. This is why much emphasis has been placed in official government-to-government relations on the electrification of transportation. In November 2009, Presidents Barack Obama and the President Hu Jintao launched a U.S.-China Electric Vehicles Initiative with the objective of developing joint standards, demonstrations and a technical roadmap as well as enhancing public awareness and engagement. Several technical workshops sponsored by the U.S. Department of Energy and China's Ministry of Science and Technology took place in 2010-2014 focusing mainly on battery cost reduction and performance enhancement. In addition the CERC-Clean Vehicles Consortium seeks to advance breakthroughs in electric vehicle technologies. Joint research is conducted in advanced batteries and energy conversion, vehicle-grid integration, and energy systems analysis. The November 2014 joint announcement of Presidents Barack Obama and Xi Jinping to extend and expand CERC provides opportunities to continue to address some of the most daunting challenges in BEV adoption.

The electrification of transportation will not be achieved through perpetual subsidization and government handouts but rather through a sustained effort to increase public acceptance and address infrastructure and technology challenges making Plug in Hybrids and EVs not only competitive in price but also products that redefine consumers' expectations. While issues like battery cost, recharging infrastructure and safety are being increasingly addressed we believe that mass adoption of BEV in China will not be able take place without significant modernization of the electricity grid system. Simultaneous charging of multiple EVs places a heavy burden on the electricity system. This load must be properly managed through smart grid applications and energy management systems including vehicle-to-grid protocols and battery management systems that can easily communicate with the power grid to enable demand response (incentivizing consumers to shift from on-peak to off-peak demand) via dynamic pricing and other market based instruments.

Mass adoption of BEV in China cannot take place without significant modernization of electricity grid systems.

North America is by far the largest market for DR programs and Demand Response Management Systems (DRMS). Globally, 95 percent of the DR programs are in North America.[7] China lags behind North America and Europe in implementing demand response. The country's grid system suffers from growing disparity between supply and demand and inefficient market mechanisms and price signals. In fact, power providers have no control over pricing. That is done by the NDRC and the provincial development and reform commissions. Furthermore, China's utilities have strongly resisted market reforms that might diminish their monopoly control over electricity sales.

U.S. companies like Honeywell and IBM have been working with China's major utility State Grid on a handful of demand response pilots, but this effort must be augmented by additional innovative partnerships and business models as well as a joint U.S.-China platform of cooperation aimed at imparting some of North America's experience to China.

RECOMMENDATION

In order to create the foundation on which future mass adoption of BEV can occur once they become competitive China must create the conditions for its electricity system to accommodate large scale charging. The U.S. and China should enhance their cooperation on DR and DRMS as it relates to electrified transportation and initiate additional pilots in the pilot cities of the New Energy Vehicle plan to study the challenges and solutions of load management associated with BEV adoption.

7 Demand Response in China, Azure, http://www.azure-international.com/images/stories/azure/publications/pdf/DEMAND-RESPONSE-IN-CHINA_The-Market-Strategic-Positioning-of-Active-Players_2015_Azure-International_FS.pdf

8. TREAT WASTEWATER AS A RESOURCE

China is facing a serious challenge in dealing with a growing stream of wastewater, which by 2012 amounted to some 68.5 billion tons. The source of the majority of the flow and the vast majority of the 58 percent increase in quantity as compared to 2001 is urban domestic sewage. While China has thousands of waste water treatment plants (3340 as of 2012,) more than 80 percent of the sewage sludge is improperly treated – by some estimates half a million tons a year in Beijing alone - contributing to widespread water contamination, and depending on where the sludge ends up, a potential hazard to the safety of the food supply. According to Li Ganjie, Vice-Minister in China's Ministry of Environmental Protection, "As much as 10 percent of China's surface water system has been severely contaminated, and in some places the pollution level is as high as 39.1 percent."

Sewage sludge consists of water, organic carbon-, nitrogen-, and phosphorous-containing compounds, and a cocktail of pathogens, heavy metals and other toxic organic and inorganic components. Currently a source of contamination, it can if treated properly become among other useful products a source of energy known as biogas. Biogas consists of about 50-80 percent methane and 20-50 percent CO2, as well as traces of other gases. China has an extensive and impressive history of utilizing anaerobic digesters to produce biogas (as well as a safe and stable fertilizer) in rural areas. This is a solution that can be applied on a much larger and more sophisticated commercial scale to maximize the amount of biogas that can be produced in urban wastewater treatment centers. While biogas can be used to generate heat and power that can be used by a wastewater treatment facility itself to reduce the cost of operation, it can also be upgraded to produce transportation fuel, the economics of which can be quite a bit more attractive.

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The first way to utilize biogas as transportation fuel is to refine it to increase the ratio of methane to about 97 percent and to remove contaminants and moisture. It can then be used as CNG. CNG made from biogas is known as renewable natural gas (RNG.) It can be used directly in a CNG vehicle or used mixed with CNG. Indeed, some 60 percent of the fuel used by CNG vehicles in Sweden is RNG.

It is more cost effective to use biogas to replace expensive oil based transportation fuel than to generate power from it to replace inexpensive electricity. For example, an analysis done regarding options for a Brazilian waste water treatment plant concluded: "The financial and economic analyses show that the RNG project will have a net present value that is approximately five times larger than the green electricity project [...] When the worse-case scenario, which is when CNG base case prices are reduced by 20 percent, for the RNG project is compared to the best-case scenario for the green electricity project, which is when green electricity auction prices are increased by 20 percent, the RNG project still has a much higher net present value than the green electricity project."[8]

Biogas can also be converted to liquid transportation fuels like methanol, diesel and so forth utilizing small footprint biogas-to-methanol or biogas-to-liquids modules as discussed in an earlier section.

RECOMMENDATION

The United States and China should include waste water to energy and specifically to transportation fuel as a topic for analysis, technology cooperation, information exchange and sharing of best practices, and consider joint demonstration projects.

8 Karina Johnson Lassner, "Financial and Economic Analyses of Biogas-to-Energy Projects in Brazil," Nicholas School of the Environment, Duke University, http://hdl.handle.net/10161/3688

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