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King Abdullah Petroleum Studies and Research Center

Substitutes for Liquid Fuels: Outlook in a Low Oil Price Environment

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About KAPSARC

The King Abdullah Petroleum Studies and Research Center (KAPSARC) is a non-profit global institution dedicated to independent research into energy economics, policy, technology, and the environment across all types of energy. KAPSARC's mandate is to advance the understanding of energy challenges and opportunities facing the world today and tomorrow, through unbiased, independent, and high-caliber research for the benefit of society. KAPSARC is located in Riyadh, Saudi Arabia.

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Key Points

The case for alternatives to gasoline and diesel was historically built on economic concerns; that the world might be running out of oil, which would then become prohibitively expensive. More recently, the argument has been refocused around carbon abatement and avoiding the social costs of climate change.

In the past, initiatives to pursue alternatives to oil would have come to a halt if confronted with the precipitous fall in oil prices seen over the past 18 months.

Today, the impetus to continue investing in technologies that can be cost competitive with refined oil products is provided by global climate governance discussions. The outlook is therefore unlikely to be affected by short term oil price weakness.

Innovators attempting to find viable alternatives to oil are now more likely to be venture capital backed entrepreneurs than major oil companies.

The target ‘cost’ for low carbon alternatives is not based on the current or expected future price of oil but the underlying cost of oil development and production (excluding fiscal rents) plus the social cost of carbon.

Background to the Workshop

Following the global financial crisis, three-and-a-half years of abnormally stable crude oil prices at around $100/bbl had created expectations that this represented a 'new normal.' But, when the extent of oversupply in the market became obvious to participants, oil prices started declining in the summer of 2014. The drop turned into a rout when it became clear that market assumptions of a Saudi production cut to maintain prices proved wide of the mark. The resulting oil prices, in whatever new range they eventually settle, will inevitably curtail investments in expanding the pool of future conventional, unconventional and, importantly, alternative fuels. The Saudi (and OPEC) strategy appears to have a long-term horizon directed toward conserving oil's position in the global energy mix and in the transport sector in particular.

In December 2015, KAPSARC's workshop Substitutes for Liquid Fuels: Outlook in a Low Oil Price Environment was held in Riyadh. Expectations of high oil prices have now come to a rather abrupt end, but will the growth of alternative fuels taper off as it did during the 1980s price slump? Back then, investments in substitutes were almost completely shut down as a similarly oversupplied market alleviated shortage fears resulting from the oil crises that so markedly characterized the decade before. There are arguments that can be made that "this time is different," as the advancement of alternative liquid fuels could be driven by a combination of continuous technology gains, emission reduction policy goals and political considerations in specific sectors such as the corn-based ethanol mandate in the U.S.

What Path for Growth in Future Demand for Mobility?

Personal transportation is a function of income, price and urbanization. Income is still the determining factor in spurring demand for car ownership, especially within a range of $5-20k gross domestic product (GDP) per capita. Beyond those income levels, further demand growth for vehicle ownership will lessen, resulting in an S-shaped curve. Geography also plays a role, perhaps related to urbanization, in that the saturation level, measured in the number of vehicles per capita, differs depending on location. The key question is whether the typical S-curves of car ownership historically exhibited in OECD countries will be replicated or whether policy directives restricting car ownership (such as those currently applied in China) will lead to outcomes that result in far lower rates of expected transportation fuel consumption growth. Historical income and price elasticities of automotive ownership demand and oil demand in the transport sector in the OECD are fairly well understood. However, it is still unclear whether large non-OECD countries with vast and growing middle class populations, such as India and China, will approach similar saturation points in demand for private transport vehicles or settle at a lower level.

Many long term projections suggest that the bulk of global oil demand will be accounted for by the transport sector, especially in the non-OECD countries. Although accounting for a smaller proportion of overall growth, demand for petrochemicals feedstock is expected to grow faster than that for transport. However, there are important limitations to the reliability of forecasting transport fuel demand. Even well-studied countries such as the U.S. present confusing demand patterns. 'Peak gasoline demand' in the U.S. had become widely accepted, but low oil prices appear to be driving the current uptick in gasoline consumption this year – a cause of surprise to many demand modelers. With respect to China, there is an apparent divergence between car ownership and gasoline demand, further pointing to methodological weaknesses in projecting future demand trajectories for transport fuels in various countries. There are also questions as to whether policies in the non-OECD countries focus on curtailing automobile ownership as such, or rather try to discourage the frequency of use of private transport. The status symbol aspects of car ownership can thus result in low utilization rates and low vehicle miles traveled (VMT). A large segment of the population in developing countries who are finding their way into the middle class, furthermore, have never experienced personal mobility before. Perhaps they will not pursue the option of owning a car and instead opt straight away for high convenience, low cost car sharing solutions and/or services – including ZipCar, Uber and their competitors.

The ramifications of China's transition from an export-focused industrial economy toward a consumer and services oriented one is having profound implications, not only for the relative demands for diesel and gasoline (contrary to earlier expectations of continued emphasis on diesel as the most rapidly growing part of the demand barrel) but it is also leading to a mismatch between demand and supply as a result of a refining industry focused on middle distillates (diesel and jet-kerosene). Indeed, as a result, China is emerging as an important exporter of surplus diesel.

Drivers of Demand for Transportation Fuels

Future demand growth for oil will also be impacted by efficiency gains in internal combustion engines. Although substantial progress has been made, total fuel economy gains in new vehicles have moderated in the U.S., reflecting increasing sales of light-duty trucks compared to passenger cars and, in China, these have in some years even reversed. Joint improvements in fuels and engine technologies can lead to significant improvements in transport efficiency, such as joint R&D work between automotive and oil companies in gasoline compression-ignition technology (involving changes in fuel injection timing, combustion temperatures and fuel specifications).

Such efforts show the potential to substantially improve miles per gallon (mpg) ratios for gasoline-fueled internal combustion engines (ICE). Larger gains have been noted in the light vehicles sector than in the heavy transport sector. But even modest gains would have a far larger impact on oil demand. For instance, an improvement from 7 mpg to 10 mpg in the heavy trucks sector can far outweigh fuel savings in the light vehicles by moving from 35 mpg to 50 mpg, reflecting much greater vehicle utilization and the diminishing returns to fuel economy improvement. It has to be noted that, although fuel economy gains in heavy duty vehicles are much more limited, this also means that their substitution potential is higher.

Autonomous Vehicles – Driving Demand Growth or a Nail in the Coffin for Oil?

With respect to autonomous driving technologies, most publicly spearheaded by companies such as Google, it is not at all clear whether this would lead to more intensive or less intensive demand for mobility and hence fossil fuel demand and GHG emissions. Improved efficiencies derived by more automated driving patterns might save on fuel.

> *...but the greater comforts of "not driving" and attending to other tasks while being transported without the need for active driving attention might dramatically increase the demand for mobility, leading to an increase in energy use and emissions.*

A major research initiative is underway in MIT to answer some of these questions as R&D work on autonomous driving gains momentum and becomes increasingly accepted as an achievable technology. Certainly many of the visions of this future foresee electrification as a key component of success.

Liquid Fuel Alternatives: More than just Economics?

In discussions on climate change and reducing emissions, participants and stakeholders often place more importance on decarbonizing the power sector than the transport sector. This is mainly because transport 'only' accounts for about 14 percent of global greenhouse gas (GHG) emissions, third after power generation and industrial processes. However, conventional fossil fuels in transport remain as one of the largest contributors in industrialized economies – in the U.S., transport accounts for one-third of total carbon emissions. Moreover, transport's GHG emissions have increased at a faster rate than any other energy using sector.

Alternatives to conventional burning oil based fuels in transport range from electric power to biofuels to liquid conversion of natural gas (e.g., GTL, CNG and LNG). Candidates to replace oil-based fuel in ICEs ideally possess a number of characteristics including:

- Certainty of availability.
- Reasonable pump prices.
- Compatibility with existing engines without much modification.
- Compatibility with the existing fuel distribution chain, etc.

When it comes to electrifying transport, three main issues continue to prevent its widespread adoption: cost, range anxiety and the source of power. While battery costs (particularly for lithium-ion) have shrunk significantly, substantive improvements in battery technology with respect to both costs and especially energy density still need to occur before electric vehicles (EVs) can be seen as efficient alternatives to gasoline- or diesel-powered automobiles. Lithium-ion batteries' energy density, expressed in MJ/kg, is still 60 times lower than gasoline. Issues of range anxiety and the high costs of dismantling old infrastructure and constructing entirely new ones remain key challenges to electrifying the vehicle fleet. The emission reduction benefits of EVs depend on the source of grid electricity – a very basic reminder that often escapes much popular discussions on the role of EVs in the "decarbonization" of national economies. Having EVs in a state or region, which employs primarily coal-fired power plants as a source for grid electricity does not make much sense if the goal is to reduce greenhouse gas emissions in the short term. But, electrification of transport may be an interim enabling step to longer term decarbonization.

Corn Ethanol - When Politics becomes the Driver

The long established U.S. corn-based ethanol program has been subject to much critical discussion. This program, like other government policy initiatives, can be analyzed on least three levels: its description along self-proclaimed objectives; its actual objectives seen from a public choice/rent – seeking perspective; and finally from its actual outcomes after about two decades.

The ostensible objectives of the policy are national security, energy independence and rural development. It should be noted that the U.S. 'shale revolution' and the consequent surge of U.S. light tight oil production, achieved without continuing government subsidies and interventions, achieved far more in in terms of energy security objectives than the more expensive ethanol program.

The rent-seeking aspects of the program are the dominant feature for some U.S. – based analysts: it is seen as a function of the political influence of the agricultural lobby and members of the Senate who represent agricultural states.

In terms of actual outcomes, the program is an inefficient means of reducing fossil fuel use in the automotive fleet. The cost of this inefficiency is more glaring in the context of the resurgence of the U.S. as a crude oil producer and resulting low prices. Even if considered without reference to economic costs, recent literature has questioned whether the program actually led to appreciable (if any) reductions in GHG emissions once land-use change was taken into account. Although blending ethanol increases the level of octane in gasoline and thereby improves air quality, this does not necessarily mean that it can help in mitigating the wider issue of global warming, an important distinction when considering the often quoted climate benefits of biofuels.

Achieving pricing parity is not likely to be sufficient to induce consumers to increase the use of E85 (the highest mandate concentration of ethanol in the U.S.) as a transportation fuel. Its low energy content, one-third less than gasoline, requires more fueling stops – something consumers are typically loathe to do. U.S. refiners, furthermore, will be unable to meet the biofuel blending requirements without increasing the cost of transportation fuels (the so-called "blend wall"). This is a consequence of the mandate, which strictly limits other low cost compliance options. In some cases, the optimum refinery strategy could be to cut runs, the worst of possible solutions but nonetheless representing the least cost given the U.S. Environmental Protection Agency (EPA) ethanol mandate. By some analyses, technical constraints and cost risks could increase the price of gasoline by over 25 c/gal at an annual cost to the U.S. economy in excess of $40 billion. However, renewable fuels in the U.S. are here to stay, even in a low oil price environment, given the vested interests and system already in place since the establishment of the ethanol mandate.

GTL and LNG – Niche Players

GTL as an alternative fuel to replace oil may be cost competitive in some locations depending on the price arbitrage. However, while natural gas is less carbon intensive than oil, the conversion efficiency of gas to liquid via the Fisher-Tropsch process leads to losses, resulting in no benefits in terms of GHG emission reductions. In some cases, GTL can lower local pollution as well as promote the use of stranded gas assets.

LNG, as an option to use natural gas in transport, will probably only be a substitute in niche markets such as heavy duty vehicles and shipping in the medium term. The use of LNG is not likely to become ubiquitous because of the difficulty achieving high volumetric energy density in transport and because of other constraints in terms of availability and infrastructure.

Venture Capital and Private Equity

One of the secular changes since previous price cycles is that the main drivers of innovation have become the hundreds of entrepreneurs engaged in the pursuit of low carbon alternatives to oil products. In past cycles, major oil companies and consuming nations' governments funded research. They cut back as soon as prices fell, but the drivers and incentives are not the same for companies that have been capitalized by investors with a longer-term view.

When it comes to financing alternative technologies in the transport sector, but applicable to the wider energy sector as well, an important role is played by venture capital (VC) and private equity (PE). These investment vehicles typically target hurdle rates of return at the 25–30 percent range for both development and deployment types of investment – significantly higher than hurdle rates required by large corporations financing off their own balance sheets or by banks on project finance terms.

This may seem expensive, but these investors look at the proposition differently.

From the point of view of VC/PE entering into new "breakthrough" energy technology areas, the emphasis of financing decision is on estimates of future perpetual cash flow. It can be hard to judge the timing of an exit decision (to cash out). It is also clear that, in the highly uncertain context of the VC business area, VC owners need to assume that they will have to invest in the project and not depend on collateral investments by other non-VC investors.

In the context of developing countries, their high cost of capital might not favor newer energy technologies that exhibit higher initial capital investments that are offset by lower operating costs. Factor endowment differences between high and low income countries might mean that newer capital intensive energy technologies are more likely to be commercialized initially in richer rather than poorer countries.

Can/should the Fossil Industry Play a Role alongside Governments?

Given the difficult trade-offs between the various policy objectives of economic growth, energy security and environmental sustainability, it is often the case that governments end up proposing technological solutions that alleviate the risks of zero-sum games among powerful political and economic constituencies. Of course it is clear that technology alone, without the appropriate policy context, seldom provides viable solutions to the challenges posed by climate change and local environmental pollution. There is considerable debate over just what the appropriate role of government should be with respect to new technology ventures (in energy as in other sectors), especially during the critical commercialization phase also known as "the valley of death."

Should government support new technology ventures with a view to incubating new industries for future success or allow the market to determine success or failure in passing through these "valleys of death." The appropriate role of government is obviously a debate in itself, although it can be argued that governments achieve the best results when they focus on supporting industrial development via lowering transaction costs and promoting the "ease of doing business" without being subject to the obvious dangers of subsidizing favored constituencies on noneconomic grounds.

Private companies are increasingly venturing into traditional government territory. In the lead up to the COP21 climate change talks in Paris last year, it is remarkable that a group of the world's largest integrated oil and gas companies signed a document that commits them to play a substantive role in reducing emissions. There are cynics who remain unconvinced of this move, seeing it as a PR stunt. Right or wrong, it appears that the companies have finally realized that they should "be part of the solution rather than part of the problem." It is likely that neither extreme position fairly explains the move by this group of 10 companies.

Ultimately, a stable policy environment with clear directions on emission reduction in the fossil fuels sector is better for the collective interests of both business and society. The lack of trust in large oil companies by the general public is often referred to as part of the background that led to the joint declaration by the oil and gas companies. It is far from clear whether this lack of trust is more specific to OECD countries, which have strong environmental constituencies. For example, the current government of India outlawed foreign financing of NGOs in India so that the environmental sensibilities of the West are not inappropriately imposed on the electorates of developing countries with legitimate aspirations for cheap energy, industrial development and economic growth.

The outlook for alternative liquid fuels seems to be driven by policy and climate change rather than serious prospects of being cost competitive with fossil fuels in the short term. Therefore, we might reasonably conclude that the low on price environment will not slow their development in the short or medium term.

About the Workshop

KAPSARC convened a workshop in December 2015 with some 40 international experts in the areas of global oil markets, alternative fuels, electric vehicles and venture capital, to discuss the impact of lower oil prices on the future of alternative liquid fuels. The workshop was held under Chatham House rules. List of Participants:

Mohammed Alajaji – Research Analyst, KAPSARC

Samer AlAshgar – President, KAPSARC

Amer Ahmad Amer – Fuels Chief Technologist, Saudi Aramco

Shahad Al Arenan – Research Analyst, KAPSARC

Robert Armstrong – Director MIT Energy Initiative, MIT

Hassan Babiker – Transport Analysis Team, Saudi Aramco

Ibrahim Binmayouf – Director Economic Research Department, SAMA

Nicholas Chase – Visiting Fellow, KAPSARC

Adam Christensen – Postdoctoral Researcher, Wisconsin Institute for Discovery

Anne-Sophie Corbeau – Research Fellow, KAPSARC

Tilak K. Doshi – Senior Research Fellow, KAPSARC

Bassam Fattouh – Director, Oxford Institute for Energy Studies

Antoine Halff – Head, Oil Industry & Markets, IEA

David Hobbs – Head of Research, KAPSARC

Abdulrahman Al Ibrahim – Governor, SWCC

Masaatsu Koyama – Senior Demand Analyst, Saudi Aramco

Coby van der Linde – Director, CIEP

Michael Lynch – President, Strategic Energy and Economic Research, Inc.

Meena Marafi – Manager, Kuwait Institute for Scientific Research

Raffi Mardirosian – Principal, Flagship Ventures

Mohammed Muaafa – Research Associate, KAPSARC

Fernando Oliveira – Visiting Fellow, KAPSARC

Rajendra Pachauri – Director General, TERI

Lucian Pugliaresi – President, EPRINC

Jitendra Roychoudhury – Research Fellow, KAPSARC

Ahmed Al Sayari – Balance Payment Specialist, SAMA

Hamed Al Sayari – Former Governor, SAMA

Khalid Sayouhi – Oil Demand Analyst, Saudi Aramco

Rami Shabaneh – Research Associate, KAPSARC

Matthew Shouler – First Secretary, British Embassy

Simon Stoddart – Chief of Staff, IEF

Sammy Six – Research Associate, KAPSARC

Matteo Terrevazzi – Lead Gas Analyst, Saudi Aramco

Meeyoung Toh – Vice President of Oil Markets and Downstream, IHS Energy

Abdullah Al Tuwaijri – Collaboration, KAPSARC

Karsten Wilbrand – Innovation Manager Alternatives, Shell Global Solutions

Nourah Al Yousef – Associate Professor of Economics, King Saud University

Notes

About the Team

Tilak K. Doshi

Tilak is a senior research fellow focusing on oil and gas markets. He holds a PhD from the University of Hawaii/East-West Center, Honolulu, Hawaii, U.S. Prior to joining KAPSARC, he worked as chief economist for the Energy Studies Centre at the National University of Singapore.

Sammy Six

Sammy is a research associate focusing on global oil and gas market dynamics. He holds a master's degree in international relations from Ghent University, Belgium. Before joining KAPSARC, Sammy worked as a researcher for the Clingendael International Energy Programme (CIEP) in The Hague, the Netherlands.

Shahad AlArenan

Shahad is a research analyst focusing on oil markets. She holds a BSc in Electrical and Computer Engineering from Effat University.

Ziyad AlFawzan

Ziyad is a research analyst focusing on oil markets. He holds a BSc in Industrial Engineering from King Saud University.

Nader AlKathiri

Nader is a research associate at KAPSARC specializing in modeling energy markets. He holds a MS degree from KAUST.

About the Oil Team

The KAPSARC Oil team is engaged in research that covers oil markets and industry norms. Focused research areas of the team include security of demand from the perspective of the large Middle East oil exporters, economic determinants of vertical integration in the oil industry, the role of joint crude oil stockpiling in seller-buyer interactions, and pricing norms in long term crude supply contracts. The workshop on alternatives to liquid fuels in a low oil price environment is part of KAPSARC's ongoing research interest in identifying factors influencing long term oil demand.

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