Energy Supply in a World of High Demand



The Aspen Institute

Energy and Environment Program

John Deutch, Chair
Leonard L. Coburn, Rapporteur

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2008 Forum on Global Energy, Economy and Security

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Published in the United States of America in 2008
By The Aspen Institute

Printed in the United States of America

08-013
ISBN: 0-89843-494-7

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Foreword

Two significant studies released in 2007 highlighted concern about the ability of energy producers to meet growing demand in a secure, lower-carbon way. The *World Energy Outlook 2007* of the International Energy Agency, with a detailed look at the growth of demand in China and India, the emerging giants of the world economy, concluded that trends in demand, imports and greenhouse gas emissions projected out to 2030 were even worse than in the previous year's *Outlook*. A U.S. National Petroleum Council study, *Facing the Hard Truths about Energy*, similarly noted the challenges of meeting a projected 50 percent increase in energy demand by 2030.

The 2008 Aspen Institute Forum on Global Energy, Economy and Security explored the question posed by these reports: "How will supply meet demand?" A select group of U.S. and international leaders and policy experts from energy producing and consuming industries, governments, and research organizations were invited for a dialogue designed to encourage new, collaborative, cross-disciplinary thinking on issues of critical national and global importance. An informal atmosphere and a not-for-attribution rule encouraged candid exchanges and creative thinking.

The dialogue was chaired by John Deutch, Institute Professor at the Massachusetts Institute of Technology and former U.S. Undersecretary of Energy, Deputy Secretary of Defense, and Director of Central Intelligence. His many years at the center of U.S. and global energy and security policy discussions gave him the experience to focus the discussion and the skill to chair the meeting with firmness and good humor. He was also of great assistance in shaping the agenda. A keynote address by Marvin Odum, President of Shell Oil Company, and an introductory, scene-setting conversation with Lee Raymond, former CEO of ExxonMobil and Chairman of the National Petroleum Council study, were highlights of the meeting. The highly qualified group of speakers provided a wealth of information and a variety of perspectives, and the diverse expertise of the participants contributed substantially to the richness of the dialogue.

The Institute acknowledges and thanks the Forum sponsors – ExxonMobil, Invictus Capital, Aramco Services Company, Chevron Corporation, DaimlerChrysler, and Shell Oil Company – for their financial support. Without their generosity and commitment to our work, the Forum could not have taken place.

On behalf of the Institute and the Forum participants, I also thank Leonard Coburn, who served as rapporteur. His extensive knowledge of energy enabled him to capture the highlights from a wide-ranging discussion in this summary report. Timothy Olson's efficient management of the administrative arrangements for the Forum was responsible for a pleasant and smoothly run meeting, and I am grateful for his conscientious support.

This report is issued under the auspices of the Aspen Institute, and neither the Forum speakers, participants, nor sponsors are responsible for its contents. Although it is an attempt to represent views expressed during the Forum, all views expressed were not unanimous and participants were not asked to agree to the wording.

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Energy Supply in a World of High Demand

Leonard L. Coburn
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Energy Supply in a World of High Demand

American and world consumers are raising many questions as they cope with high energy prices, and the answers are not easy to accept. Demand for oil and gas is expected to remain robust until 2030, the limit of most projections. While demand in the developed world will grow modestly, demand is strongest in the emerging and developing economies, with the greatest growth in China and India. World economic growth may be slowing; however, all estimates indicate this is a short-term phenomenon. Even with today's slowdown, energy demand continues to grow, and in the long term, economic growth will resume.

The question facing energy consumers today is whether oil and gas supplies will keep pace. While some experts argue that the world has insufficient oil and gas resources to meet future demand, many think that resources are adequate and it is the political and technical constraints placed on access to, investment in, and production of new resources that will make it difficult to meet growing demand. Add the likely overlay of the imposition of a carbon price to reduce greenhouse gas emissions, and the cost of producing and using oil and gas will increase. If political and technical constraints continue and new environmental costs are significant, the result will be high oil and gas (and other energy) prices into the foreseeable future.

Policy measures to change these "hard truths" confront two inexorable facts: a basic lack of understanding of the size of the energy industry, and the time it takes for change to occur. For example, 62 percent of the oil used in the United States is converted to gasoline and diesel fuel, which amounts to about 200 billion gallons every year, or 12.8 million barrels per day. The magnitude of this number is hard for most people to comprehend. To provide some perspective, 200 billion one-gallon milk containers lined up next to each other, each six inches wide, would circle the Equator 960 times. To reduce consumption significantly, policies have to be substantial. Further, the time necessary to implement change within the industry is measured in years and decades, not weeks or months. In the United States, from the time of acquiring an offshore oil or gas lease to first production is approximately a dozen years or more. A child entering first grade in 2008 would not benefit from such production until he or she has graduated from high school twelve years later in 2020.

The group of energy experts assembled by the Aspen Institute in June 2008 discussed the fundamental issues underpinning the imbalances between oil supply and demand. In a candid assessment of oil supplies, a consensus evolved during the meeting that conventional oil production has reached or will reach a peak or plateau in the near future. Production in 2007 was about 85 million barrels per day and likely will never exceed 100 million barrels per day. It is not that there are insufficient oil resources in the world or that the technical barriers are insurmountable; rather, the three major categories of oil producing countries lack the motivation, political desire, or technical capability to bring new supplies forward. For example, in the former Soviet Union (FSU), resources for the most part are plentiful. Russia, however, has decided for political reasons not to produce much more than 10 million barrels per day even though production of up to 14 million barrels per day is possible. Azerbaijan has not discovered sufficient new reserves to sustain new production, and Kazakhstan has slowed its production growth for a variety of political and economic reasons. In OPEC, production is not likely to increase much in the future due to lack of financial motivations. Of the countries that have additional reserves, most simply do not need more money or value it less now than in the future. The rest of the world (ROW) is struggling to offset a significant decline of existing production and is not likely to produce substantially more oil. Thus a combination of motivational, political and technical constraints, as well as limitations on access to new resources by International Oil Companies (IOCs), will restrict future production.

On the demand side, world energy demand growth is projected to continue to grow over the next 20 years. By some estimates, 40 percent more energy will be needed globally, and 80 percent more in the developing world. Given the constraints on producing more oil, however, there is great skepticism that these robust growth projections are feasible. China, where strong economic growth over the last three decades has led to strong energy growth, continues to target economic growth for the future. But can energy supplies keep pace? The potential shortfall has led China to undertake a variety of aggressive economic and foreign policies to secure future energy resources. It is also assiduously developing its own resources.

Transportation fuels are projected to be the fastest growth sector for the future, with much of world oil used in automobiles and trucks. The mismatch between growing oil transportation needs and the ability of oil suppliers to meet expectations was most apparent in the Forum. Automobile manufacturers are struggling to increase the efficiency of their current fleet while moving towards other types of autos such as hybrids, plug-in hybrids, electric-power, and fuel-cell. Moving to alternative fuels for internal combustion engines can also achieve better supply and demand balance, with the development of advanced biofuels an important part of the solution.

Natural gas markets present a separate set of issues, although the geopolitical issues associated with natural gas are essentially the same as those for oil – IOCs (International Oil Companies) versus NOCs (National Oil Companies), access to reserves, resource nationalism, changing fiscal regimes, and infrastructure development and safety. However, the discussion of the natural gas industry focused on differences – the long-term contractual nature of most natural gas sales, the need for pipelines to connect buyers and sellers, and the evolving market for liquefied natural gas (LNG). Another important difference is price formation in natural gas markets, with most prices currently set in regional rather than global markets. In the various regional markets, some natural gas prices are linked to oil prices, while in others gas-to-gas competition and futures markets govern price formation. A global natural gas price is beginning to evolve as LNG markets become the marginal source of supply, linking prices in the various regional markets.

Energy security was an important and underlying element in all these discussions. While total energy independence is impractical if not impossible for most countries, excessive dependence on foreign sources implies energy insecurity. The U.S. and other nations have grappled with this problem for decades and have developed several mechanisms and policies to help mitigate the worst dangers, including diversification of supplies and energy sources, stockpiling of oil in strategic reserves, and international cooperation. In most situations, these policies have been sufficient to cope with the worst disruptions, but their future adequacy is in question. As global natural gas use expands, greater dependence on foreign sources will mean even more energy insecurity. A host of policy instruments, some similar and some different from oil policies, will be necessary. Nuclear power and renewables are valuable for energy source diversification and the production of clean energy in the electric power industry, where increasing reliance on natural gas is creating new energy security stresses in the U.S. and Europe. Development of commercial nuclear power in some countries will lead to novel solutions such as fuel leasing to deal with proliferation concerns.

Climate change will have a growing influence on energy security as political institutions grapple with the implications. Extended infrastructures – pipelines, electric grids, transit routes – will require international cooperation as well as robust domestic policies to deal with the adequacy, reliability, and safety of these systems. Finally, governmental organizations will need to be strengthened to deal with the full set of crosscutting issues affecting today's energy security. In the U.S., energy security is rarely a major concern of the foreign policy establishment. Within the U.S. government, bureaucratic myopia leads to lack of coordination and conflicting policies.

Some of the most important questions discussed at the Forum relating to supply, demand, and security included:

- Will oil prices approaching $150 per barrel bring forth new supplies?
- Is sufficient investment being made to meet future demand for oil and gas?
- What political, technological, economic, or other factors inhibit the ability of IOCs to continue to increase production?
- Do NOCs, who control oil reserves, have the incentive and motivation to increase production?
- If high prices are likely to cause demand destruction, are demand projections too high?
- What is the likelihood that new legislation will be enacted to regulate carbon and other greenhouse gases, and by how much and when will it increase oil and gas prices?
- What will be the likely impact of high prices on natural gas markets? Will natural gas prices remain linked to oil prices? Will global natural gas prices emerge, or will regional markets and prices continue?
- How will consumers respond to higher gasoline prices, and how will these responses affect the development of alternative transportation fuels and vehicles?
- How will these shifts impact oil demand?
- Lastly, what impact will higher oil prices and the consequent adjustments have on the energy security of the United States and other importing countries?

Although the Aspen Forum did not reach definitive answers to many of these questions, the discussions helped shed more light on the “hard truths” about today’s oil and gas markets and the possibilities of achieving major changes.

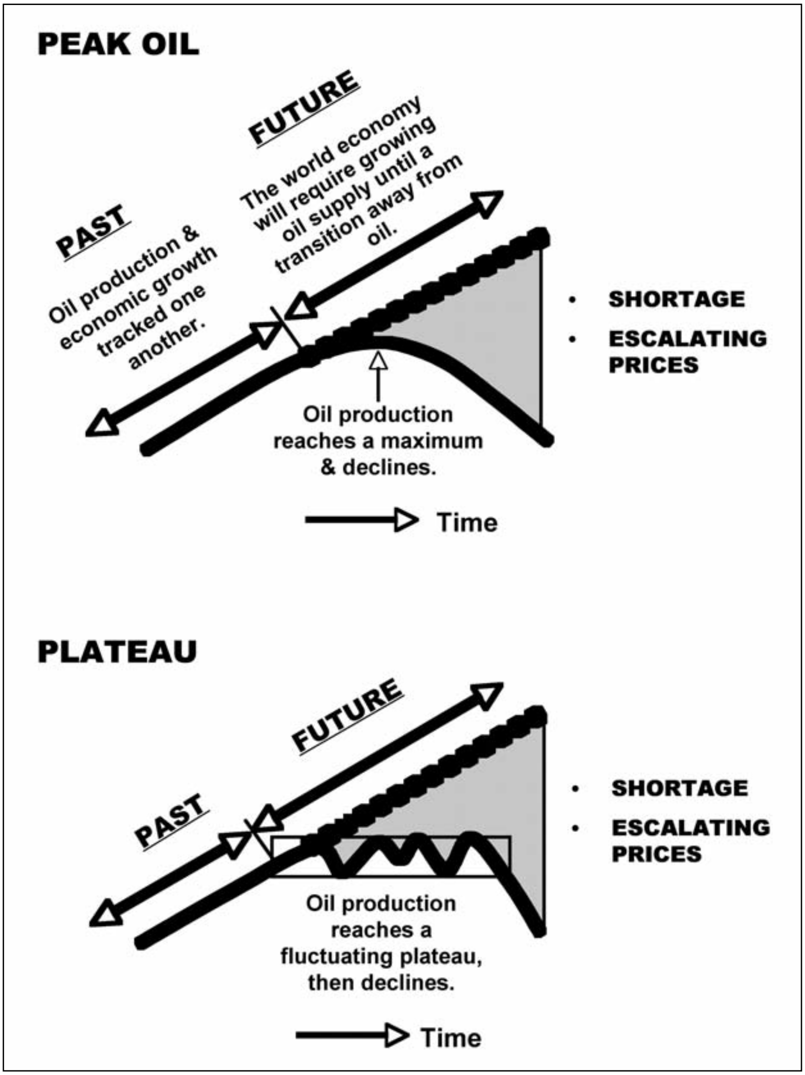
Oil Supply

The group agreed that hydrocarbon fuels – coal, oil and natural gas – will continue to be the fuels most demanded and supplied for the foreseeable future. In addition, there was a general agreement that the world is not running out of energy resources (discovered and undiscovered, economic and potentially economic). The same general conclusion was reached for oil specifically – the world has plentiful resources for the foreseeable future. (Most projections go out to 2030, the limit of the foreseeable future in this discussion). The group did recognize, however, that there are growing limitations to continuing expansion of oil production from conventional sources. These include political, economic, technical, safety, environmental, infrastructure, and human resource constraints.

Facing the Hard Truths about Energy, a July 2007 study by the National Petroleum Council (www.npc.org), provided a comprehensive view of global oil and natural gas to 2030 and made clear that a broad-based approach is essential to addressing global and U.S. energy problems. Many of the themes raised in this report were discussed in the Aspen Forum.

Oil supply depends on current and future production from proved reserves, i.e., discovered oil deposits that are economic to produce at current oil prices. Some argue that the level of proved reserves has peaked and that the world faces a declining supply of oil. Others oppose this peak oil theory, arguing that the oil peak is at least 20 or more years in the future since adequate conventional and unconventional resources exist that can be found and developed. Even among experts who do not believe a peak has been reached, an increasing number argue that oil production may shortly reach a plateau of 100 billion barrels per day or less, compared to today's production of about 85 billion barrels per day. Peak oil proponents contend that oil prices must rise in the face of increasing demand and declining supplies. Others are less pessimistic and contend that supply and demand eventually will balance while oil prices stabilize. Some of the latter argue that supply and demand may balance at lower levels, assuming that public policies will bring demand in line with future supplies.

Two Versions of Peak Oil



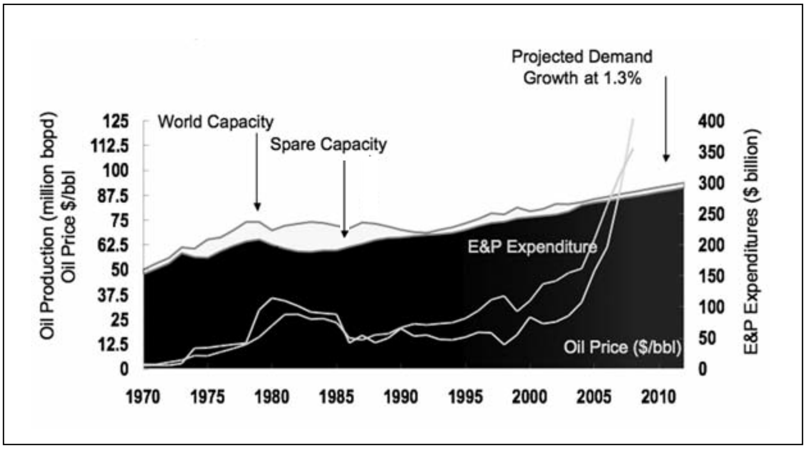
Source: R.L. Hirsch, MISI

World conventional oil production is forecast to go into decline at some future time. In one scenario, production could peak and then decline. In another, production could plateau before it declines. Higher prices, expanded exploration, improved technology, and development of unconventional oil could delay the peak or extend the plateau. Limitations on access to reserves, local or regional conflicts, and other above-ground constraints could accelerate the onset of decline.

One of the basic facts of the petroleum industry is that the technology for new production techniques requires substantial expense and an average of about sixteen years to be conceived and adopted. Part of the cost can be provided by government; however, in the United States, petroleum-related technology spending has decreased in recent years.

The level of industry spending on exploration and production (E&P) also affects future levels of production. Expenditures have grown recently, but not enough for production to keep up with projected demand. One model assumes that from 2005 to 2025 planned OPEC and non-OPEC production increases of 25 million barrels per day will occur. Assuming recent historical decline rates, however, a loss in production from today's fields of almost 24 million barrels per day will offset this increase, leaving a production increase of only 1 million barrels per day. Assuming that world demand will increase by 13.6 million barrels per day during the same period, a potential supply gap of about 12.5 million barrels per day remains.

Oil Supply and Demand



Source: Schlumberger. Data from BP Statistical Review, IEA Oil Annual Summary, Monthly Oil Market Report, Medium-Term Oil Market Report, Citigroup.

Increasing world demand and high oil prices lead to higher exploration and production expenditures, but technical and other constraints make it increasingly difficult to expand production.

Will this gap be filled? Many doubt the ability of producers to meet future growth. For example, a 1-2% growth rate does not seem very large; however, when compounded over many years, the absolute amount of the growth eventually becomes daunting. At world production of 50 mmbd, 1-2% was 500,000 to 1 million barrels per day; at 100 mmbd, 1-2% will be twice as much, or 1-2 million barrels per day by which production must increase every year.

One way to consider the situation confronting the oil market is to think about the world in three segments: OPEC, the former Soviet Union (FSU), and the rest of the world (ROW). OPEC controls about 73% of world oil reserves, FSU about 13%, and ROW about 14%. OPEC produces 43% of current supply, FSU about 16%, and ROW about 41%. Each of these areas has differing incentives and motivations to increase investment and production. In addition, technology has a significant impact on the ability and willingness to invest and produce.

The Arabian Gulf countries of Saudi Arabia, Kuwait, Iran, Iraq and UAE possess about 77% of OPEC's reserves. These countries reached their production peak in the early 1970s. Future production is limited mostly by politics, lack of motivation, investment levels, and the less desirable quality of the oil. While it is possible that an additional 5 million barrels per day will be produced within the next ten years, a rapid increase in production is not physically possible in the very near future. For example in Kuwait, which has a 40% budget surplus even without a personal or corporate income tax, there is little motivation to increase production. Saudi Arabia, UAE, Qatar and Kuwait all have created sovereign wealth funds as a way to invest the large surpluses from the growing wealth that high oil and gas prices have brought them. These countries simply have more money than they currently know what to do with.

Russia, Kazakhstan, and Azerbaijan control over 97% of reserves and production in the FSU. Production in these three countries grew rapidly from 1999 to 2007, from 7.5 million barrels per day in 1999 to 13 million barrels per day in 2007, providing 60% of world production growth. Lack of reserves does not impede production in Russia or Kazakhstan. For example, Russian reserves appear to be about 80 billion barrels, although some estimates place the figure much higher at

117 billion barrels. Russian production easily could continue to grow to 14 million barrels per day by 2010; however, politics and taxation have halted growth at about 9.5 million barrels per day in first half of 2008. Government policies have encouraged the renationalization of oil production so that state-controlled companies today produce about 40 percent of Russia's oil. This resource nationalism, the state control of oil and gas resources and the incorporation of resource control into domestic and foreign policies, is a significant political constraint affecting future production. Taxation policies have left little incentive for companies to expand production into high cost regions, since the marginal tax rate for exported crude oil is about 90%. In the first half of 2008, oil production declined for the first time since 2000.

In Kazakhstan, reserves are sufficient to double production to 3 million barrels per day, but the increase has slowed due to pipeline constraints and a slowdown in the development of new fields. In Azerbaijan, reserves can support today's production of 1.2 million barrels per day, but there have been no new exploration successes, limiting future growth.

The ROW contributes 41% of world oil production from only about 14% of conventional reserves. Most of the fields are in decline, with one expert estimating a decline rate of 7% per year. With the exception of Brazil, most significant producers are at or past their peak production. Overall production from the ROW peaked in 2003. While new production from ultra deep offshore development masks the decline rate, such fields typically reach their peak and decline more quickly, indicating that this phenomenon is likely to be temporary. In parts of the ROW, as in OPEC and the FSU, heightened resource nationalism restricts investment opportunities for private capital by IOCs. In the ROW, the IOCS and others have failed to replace the reserves being used. The difficulty in stemming decline rates and bringing new production on line and on time has increased. There is little doubt that IOCs bring capital, technological expertise and project management to the development of reserves. While they have increased E&P spending, restricted access to proven reserves has limited the impact of their expenditures. IOCs today have access to less than 25% of worldwide reserves and full equity access to as little as 6%.

Moreover, renewed efforts to produce more from fewer reserves have led to cost inflation as higher expenditures chase fewer rigs and fewer skilled personnel. Easy conventional oil projects are largely off-limits to IOCs. Most projects open to IOCs are technically challenging and expensive, usually those located in deepwater or hostile environments, or those in which the oil and gas deposits pose significant challenges, such as toxic associated gas, heavy oil, shale oil, by-product waste or remote locations. These technological challenges increase the risks and costs associated with new production. The plain fact is that even with large profits, IOCs struggle to reinvest them because they have fewer opportunities due to limited access to reserves.

Unconventional oil production offers enormous potential; some estimate that there are 10 trillion barrels of resources in heavy oil (bitumen), oil sands, and oil shale. But the potential comes with equally enormous challenges. Recovery factors are much lower than for conventional oil, while the costs of production are significantly higher. Most of these unconventional resources are located in Canada, United States and Venezuela.

Canadian oil sands are being produced, but due to high costs, water constraints, potential costs for carbon dioxide emissions, and a shortage of trained personnel, estimates for the level of production have diminished to 2.5 million barrels per day by 2015 from recent projections of twice that level. Venezuela's heavy oil (bitumen) growth has slowed considerably due to the current political environment and may not increase much beyond the 800,000 barrels per day now produced. Most oil shale in the world is found in environmentally sensitive areas of the American West, and environmental permits are not likely to be granted on a scale needed to have a significant impact on production. Even where permits are granted, production will be very expensive and will require more water and energy than is readily available. By some estimates, combined production from unconventional sources by 2015 may reach only 4 to 4.5 million barrels per day from the current 2.3 million, with a most optimistic forecast of 6 million. Oil prices will have to stay above $80 per barrel for these resources to be economic, and climate change legislation that puts a significant price on carbon emissions will further diminish their economic viability. Also, with high negative environmental impacts, the decision to produce may not be made on economic grounds.

In the U.S., high gasoline prices have stimulated a political debate on the benefits from opening the restricted areas of the Outer Continental Shelf (OCS). A 2007 Energy Information Administration study, estimated that about 18 billion barrels of oil reserves potentially were available once restrictions were lifted. EIA projected that exploration and development could start in 2012 with first production by 2017. For the OCS, production could increase by 2030 from 2.2 million barrels per day to 2.36 million barrels per day, or 7 percent higher. Overall U.S. production would be 3 percent higher or 5.6 million barrels per day in 2030. EIA's estimates are based on old estimates made before recent improvements in seismic technology and reflect the minimum that could be produced. Others have estimated much higher levels of reserves and production.

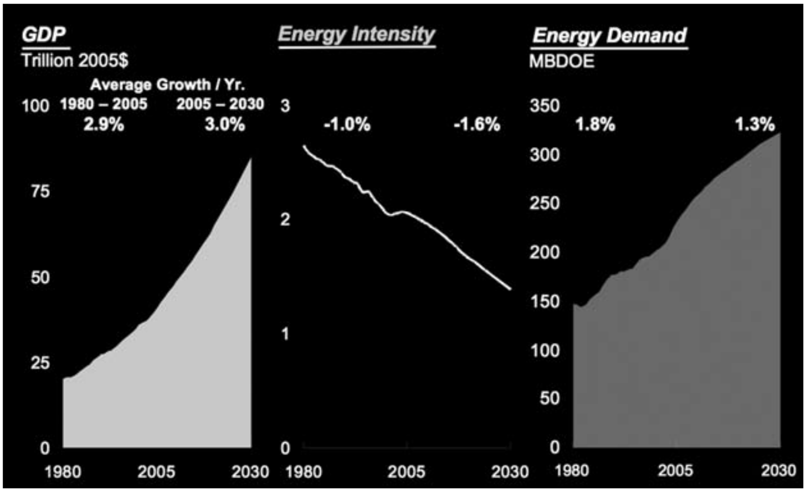
A lingering question is the impact of high prices on all of these limitations – will high prices change government and company views on the decision to produce more? For those governments awash in money, high prices are not likely to change perceptions. State controlled companies often are swayed by political considerations first with economic considerations secondary; in other words, is the country more inclined to preserve its resources for the future than produce them today? Moreover, many want to preserve high prices by limiting production and are content with their current level of revenues. IOCs definitely prefer to invest and produce to take advantage of high prices; however, their options are limited by the factors discussed. Overall, high prices are not likely to change the willingness of most governments and state controlled companies to increase production.

All of these factors and issues led the group to the conclusion that there are significant clouds on the oil supply horizon, with many agreeing that we are nearing a world oil plateau if not an oil peak. However one views the future, peak or plateau, high oil prices with political and economic turbulence are likely.

Demand and Economic Impacts

The concern about oil supply grows out of projections of increased global, United States, and Chinese energy demand. Such forecasts matter because of the possible impact of supply shortfalls on prices and the economy as a whole. Based on estimated global economic growth of 3 percent per year to 2030, global energy demand is expected to increase by 1.3 percent per year. The economy-energy growth relationship is not one-to-one, since increasing the efficiency of energy use will offset some energy demand growth. Energy intensity, a measure of the amount of energy needed to produce a unit of economic output, has decreased historically by 1.6 percent per year. Nonetheless, one estimate presented to the Forum indicated that energy demand growth in the developing world will be double that of global energy demand – 80 percent versus 40 percent. Energy use in transportation will grow the fastest at 1.7 percent per year, followed by power generation at 1.5 percent, industrial use at 1.2 percent, and residential and commercial use at 0.7 percent.

Global Economics and Energy



Source: ExxonMobil

Even with accelerating improvements in energy intensity, the amount of energy required to produce a unit of GDP, strong economic growth to 2030 may lead to an approximate doubling of energy demand.

According to this forecast, Asia will experience the largest growth, and China will account for more than half of this. China's startling energy demand increases are directly linked to its economic growth. China's GDP grew by almost 10 percent annually over the last decade. One of the principal drivers of this rapid economic growth was the growth of its foreign trade (exports and imports), which averaged over 23 percent in the same time period. Overall, China's foreign trade grew from $361 billion in 1999 to $2,578 trillion in 2008.

A projection of demand in the power generation sector shows that the 20 percent of the world's population in the OECD countries, which now use 60 percent of the world's power, will increase their use by 70 percent by 2030. Non-OECD power generation will more than double. In the OECD, power generation will increase by 0.9 percent per year, with the largest growth occurring in the renewable sector at 2.2 percent per year, followed by natural gas at 1.9 percent, nuclear at 1.5 percent, coal at -0.4 percent, and oil at -2.8 percent. OECD projections include a cost associated with carbon. Despite the rapid growth of renewable energy, coal and nuclear power will still dominate power generation in 2030.

In non-OECD countries, due to higher economic growth, power generation will grow much more rapidly, at 2.2 percent per year to 2030. Non-OECD projections do not include the cost of carbon. Nuclear power grows the fastest at 4.2 percent per year, followed by renewable energy at 3.5 percent, natural gas at 2.3 percent, coal at 1.8 percent, and oil virtually flat. For the non-OECD, coal and natural gas will dominate power generation in 2030.

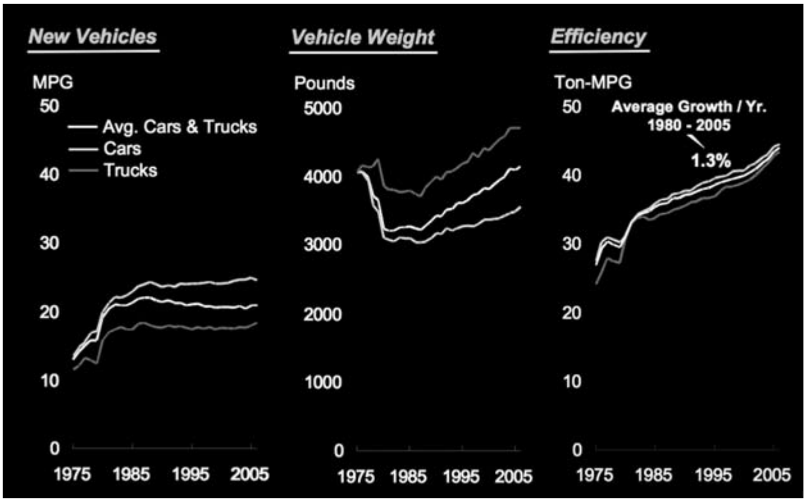
In the transportation sector, a similar split between the OECD and non-OECD plays out in growth patterns to 2030, with the OECD growing by 0.6 percent per year and the non-OECD growing by 3.1 percent per year. Different types of vehicle use have different growth dynamics, as heavy vehicles (trucks) are driven more by GDP growth, while light duty vehicles (automobiles) are affected more by personal income. In the OECD, increasing vehicle efficiency and the growing use of biofuels in light duty vehicles lead to overall negative annual growth of -0.5 percent, while heavy duty vehicle energy use increases by 1.7 percent per year. In the non-OECD, a different pattern emerges as light vehicle energy use increases significantly at 3.4 percent annual growth, followed by other transportation (jet fuel and heavy petroleum products) at 3.6 percent and heavy vehicles at 2.8 percent. Light duty vehicle energy use has already been accelerating in the non-OECD countries, growing by 5.2 percent year from 2000 to 2005.

In the United States, where automobile penetration is nearing the saturation point, the transportation picture differs substantially from that in China or the developing world. With no change in Corporate Average Fuel Economy (CAFE) requirements after 1985, the fuel economy of new cars and light trucks, which had increased substantially in the late 1970s and early 1980s, peaked in 1987 at 26.2 miles per gallon and then declined to 25.4 mpg in 2006. Energy use increased substantially with the weight and power of vehicles as American consumers shifted their purchasing habits to sport utility vehicles and pick-up trucks with lower CAFE standards.

Projections vary for future transportation energy consumption in the U.S. For example, the Energy Information Administration's (EIA) June 2008 Annual Energy Outlook projects that average new vehicle fuel economy will increase to 35 miles per gallon by 2020 based on the 2007 law, but then increase only marginally to 36.6 mpg from 2020 to 2030. Based on this projection, in 2030 the U.S. would use about 9.7 million barrels per day of gasoline while crude oil would be about $70 per barrel in 2030 (in 2006 dollars) or $113 in nominal dollars. The EIA also provided a range of gasoline use based on high and low crude oil prices. With high prices in 2030 ($119 per barrel in 2006 dollars, $186 nominally), the light duty fleet would use about 9 million barrels per day of gasoline; in the low crude oil price situation ($42 per barrel in 2006 dollars, $65 nominal), gasoline consumption would be higher at about 10.4 million barrels per day.

A private sector analysis that incorporates possible future policy changes in its projections, such as climate change legislation and further increases in vehicle miles per gallon due to enhanced technological changes (more hybrids and other alternative fueled vehicles), shows increasing vehicle fuel economy through 2030, with a growth of 2 percent per year for the entire period 2005-2030. As a result of these differences, the private sector projection indicates that gasoline consumption will increase from today's consumption of about 8.6 million barrels per day and peak in 2015 at 9. 2 million barrels per day and then decline to about 7 million barrels per day 2030.

U.S. Light Duty Vehicles – Fuel Economy

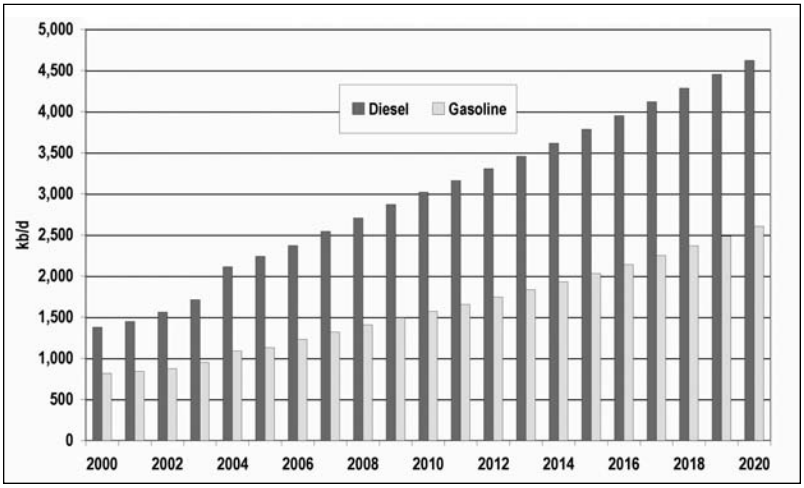


Source: ExxonMobil. Data from EPA.

Improvements in vehicle efficiency in the United States since 1985 have been used primarily to meet consumer demand for increased weight and power, resulting in a slight decline in vehicle fuel economy.

China's situation is dramatically different. The number of automobiles reached 44 million in 2007, up from 16 million in 2000. If all vehicles, including motorcycles, are included, then China's vehicle population was 160 million. In addition, China's automobile production has developed at spectacular rates over the last decade. Total output reached 8.9 million vehicles in 2007, quadruple that of 2000. Annual production is expected to hit 24 million by 2020, with a car population of more than 62 million by 2010 and 160 million by 2020.

China's Automobile Stock: 1995-2020



Source: Kang Wu, East-West Center, Honolulu, Hawaii.

The increase in private ownership will cause the number of autos on the road in China almost to quadruple by 2020, leading to dramatic growth in gasoline demand.

The enormous expansion in China's vehicle population will lead to dramatic growth in its gasoline demand. From 2000 to 2007 this demand grew 7.2 percent per year, while diesel demand grew even faster at 9.1 percent per year. Gasoline and diesel consumption will increase at an annual average of 5.3 percent. Economic and transportation growth will lead China's overall petroleum product demand growth to about 13 million barrels per day by 2020, second only to the U.S. Previous escalation in oil use transformed China from a net oil importer before 1993 to the world's second largest importer today.

China's subsidies for gasoline, diesel and jet fuel factor into the rapid growth in demand for these products. With price caps in place, China's refineries are not profitable, although any deficit is supposed to be made up by the state. These subsidized prices have led to product shortages and underinvestment.

As previously indicated, one analysis estimated that global energy demand will increase by 1.3 percent per year to 2030. Oil, gas and coal are projected to continue to predominate in meeting this demand, even with rapidly growing shares of nuclear and renewable energy. In the oil sector, the world will need 113 million barrels per day. In this scenario, a variety of fuels, including unconventional oil and alternative liquid fuels, and an increasing call on OPEC will be required to meet the demand. But the Forum discussion of supply indicated that it is highly unlikely the world could produce 113 million barrels per day by 2030 and disputed the assumptions underlying this demand projection.

Several conclusions can be drawn from the deeper examination of energy demand. Economic progress, especially in developing countries, will drive global energy demand higher despite substantial efficiency gains. Oil, natural gas and coal are indispensable to meeting this energy demand, even with rapid growth in nuclear and renewable energy. Significantly changing CO_2 emissions requires global participation, major changes in energy efficiency, technology gains, and massive investment.

The Forum discussion took place in a particularly volatile oil price environment, with oil prices having more than doubled from the 2006 average and up over 50 percent since December 2007. With these price increases coming on top of housing and credit market turmoil, participants asked why the U.S. was not already in a crushing recession. There is no doubt that energy price increases affect overall macroeconomic performance. Rising oil prices increase the cost of other commodities, and these costs get passed along. Oil prices are also passed along directly into energy products and services that are purchased directly, such as gasoline and heating oil. Consumers also experience a noticeable erosion of real disposable income and wealth, because they cannot easily reduce or substitute for their use of energy immediately.

There is a distinction between earlier price shocks that were largely caused by supply shortfalls or the way they were handled (higher prices due to embargoes, revolutions, and wars,) and the demand shock occurring today stemming from strong economic growth that is not matched by oil supply growth. Strong foreign economic and energy demand growth and the low value of the dollar contributed to the recent oil price increase, especially in the U.S., but these factors also stimulated strong U.S. export growth, which partly offset the economic impact of the price increase. The significantly lower energy intensity of the U.S. economy compared to earlier years and a more effective monetary policy have also reduced the impact of the recent oil price increases relative to earlier shocks. Thus, the overall impact may be a significant drag on near-term growth, cutting GDP growth by 0.7 to 1.5 percent from 2008 through the end of 2009, but increased oil prices at the level recently experienced are alone not enough to cause a recession.

Transportation and Alternative Fuels

As transportation is a major component of projected energy demand growth, the Forum discussed the perspective of two auto manufacturers and the prospects of alternative transportation fuels and technologies. In a U.S. market with 260 million vehicles on the road today and 16 million vehicles sold each year, the manufacturers' emphasis was to deliver reliability and consistent performance, lower emissions, provide jobs, offer value, and develop vehicles that move the country towards more alternative energy use. Each manufacturer is considering a spectrum of vehicles that rely on technological advances to the internal combustion engine while working on new technologies such as hybrid electric/gasoline motor drives, plug-in hybrids, electric vehicles (motors and batteries) and hydrogen fuel cell propulsion vehicles.

One manufacturer emphasized that the goal of all domestic auto makers is to have 50 percent their vehicles capable of using alternative fuels by 2012. This commitment focuses on the use of E85 (85 percent ethanol) and biodiesel in vehicles. By increasing the use of alternatives, this manufacturer estimated that the U.S. could rely on more than 54 billion gallons of alternative fuels by 2020, or about 25 percent of total liquid fuels used for road transportation. Achieving this goal requires the price of alternatives to be less than gasoline and diesel on an energy basis. (Pure ethanol provides only about 68 percent of the energy of gasoline; E85 has about 73 percent of the energy of gasoline.)

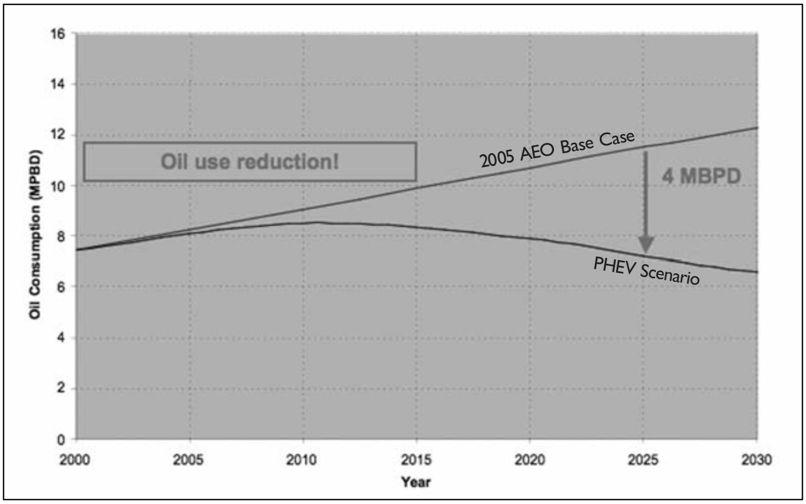
Another manufacturer focused on plug-in hybrids as a possible alternative and estimated that an aggressive program of manufacturing and selling plug-in hybrids could save 4 million barrels of gasoline a day by 2025. Plug-in hybrids come in several varieties. Some rely more on the storage capabilities of the battery to power the vehicle, while others depend less on the battery and more on the combination of electric motors and gasoline motors. In either case, the battery is critical to the development and success of the plug-in hybrid, whether the manufacturer chooses the nickel metal hydride or lithium-ion battery. Substantial battery technology innovation is still required to increase capacity, decrease cost and extend service life. The energy density of the battery poses one problem; each battery provides very little energy. In order to increase the range of a vehicle, many batteries are needed, which add weight to the vehicle and decrease its passenger or cargo capacity. Another problem is discharge swing; the greater the level of discharge each time the battery is used, the sooner the battery will have to be replaced – a costly undertaking for electric powered vehicles. Today it is difficult to make batteries that can last five to ten years. Until manufacturers find solutions, battery costs will remain high.

Despite these problems, using plug-in hybrids can reduce CO_2 emissions and oil consumption. Depending upon the fuels used for power generation, hybrids can offer additional CO_2 emissions reductions. In the U.S., with high hydrocarbon electricity generation, the total reduction in CO_2 emissions, from producing the fuel and driving the car, will be about 4 percent per vehicle. In France, which relies heavily on nuclear power, the reduction would be about 34 percent.

Plug-in hybrids present many consumer benefits including less gasoline consumption and lower costs for the portion of energy costs derived from electricity. Society benefits from lower CO_2 emissions and better air quality. The electric power industry can utilize its capacity more efficiently if consumers recharge batteries at night.

On the other hand, the use of plug-in hybrids creates collateral issues. Water consumption is a growing concern in the U.S. Today about 39 percent of water consumption is used to run and cool electric power plants, and a large portion of future electric power growth will occur in water stressed regions. The societal benefits from lower automotive CO_2 emissions may not be so clear cut if the U.S. continues to rely heavily on coal for electric power generation. Unless carbon capture and storage becomes commercially available, using more electricity for plug-ins may not produce the CO_2 reductions that many expect.

Potential Oil Use Reduction with Plug-in Hybrid Vehicles



Source: Toyota USA

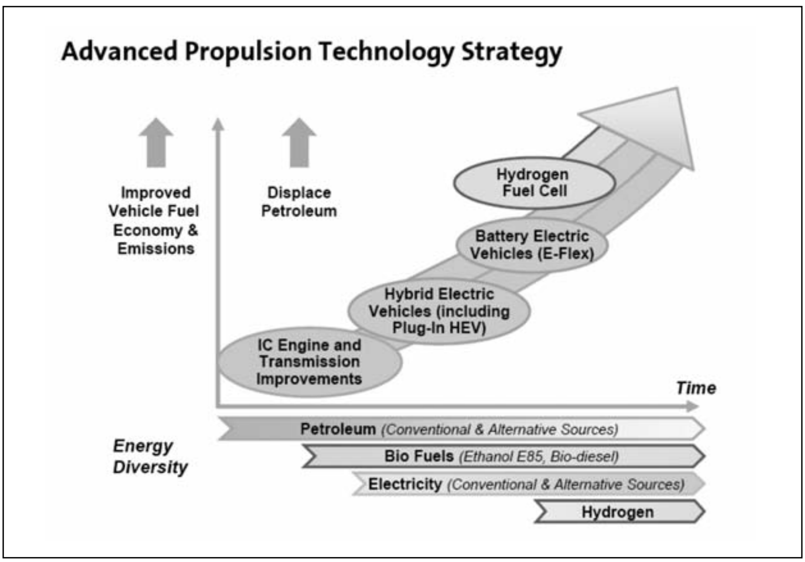
Assuming 100% hybrid vehicle sales in the United States after 2010 and 50% sales of plug-in hybrids after 2020, a highly optimistic scenario, oil consumption in autos could be reduced by 4 million barrels per day by 2025.

Hydrogen fuel cells may have great long term potential, but participants considered the challenges to be substantial. These include finding ways to reduce the cost and improve the durability of the fuel cell and reducing the costs associated with producing hydrogen and storing it in a vehicle. One auto manufacturer indicated that economic fuel cell vehicles are a long way off.

Another manufacturer, recognizing the likelihood of some form of CO_2 emission control in the near future, discussed the flexibility associated with a cap-and-trade system compared to a carbon tax. The industry is familiar with the CAFE standards, which allow substantial flexibility in how the auto company meets them. A carbon cap permits the fuel industry to determine the best mix of fuels, markets and prices to achieve the carbon limits. In the view of one manufacturer, a cap-and-trade system would make alternative fuels cheapest for consumers.

The experts agreed that finding an optimal solution among the various options is not easy or straightforward., and that each solution has its benefits and detriments. The figure below shows one manufacturer's concept of the time horizon for the widespread adoption of various alternative technologies and fuels and the relative contribution each can make to improved emissions and the displacement of petroleum.

Market Penetration of Advanced Automotive Technologies



Source: Chrysler

The vehicle fuels and technologies that could have the greatest impact on emissions and petroleum use are likely to penetrate the market most slowly.

After considering the various U.S. options available for future automobiles, the discussion turned to a more thorough examination of fuels that could be used in internal combustion engines, specifically diesel and cellulosic ethanol. The discussion outlined the goals that an alternative fuel should meet: stabilize and reduce greenhouse gas (GHG) emissions, reduce consumption of petroleum and enhance energy security, and provide the greatest good at the lowest societal cost.

The experts focused on whether enhanced use of diesel, an option used in more than half of European autos but rarely discussed in the U.S., could meet these goals. European fleet GHG emissions already are lower than those in the U.S. by about 12 percent, and future targets are 26 percent lower than current levels. The characteristics of the U.S. fleet differ from those of Europe, however, and these differences will affect whether diesel is a good option for the U.S. Taxes in the U.S., at $0.38 per gallon average for all motor fuels, compare to $4.00 per gallon average for the EU. Most European cars have manual transmissions (80 percent), while the U.S. relies on automatic transmissions (93 percent). Most European cars have 4 cylinders (84 percent), while U.S. cars split among 4 cylinders (28 percent), 6 cylinders (47 percent) and 8 cylinders (23 percent). In addition, European cars on average are lighter (only 32 percent weigh 1400 kilograms or more) while the majority of American cars are heavier (63 percent weigh 1400 kg or more).

All these characteristics have made diesels increasingly the car of choice in Europe as they increased their efficiency, became quieter, and lowered their emissions in a cost-effective manner. In addition, compared to current hybrids, diesel powered cars are less costly on an emission and variable cost comparison. Diesels currently outsell hybrids by a factor of 30 to 1 due to the lower life-cycle cost of a diesel compared to a hybrid. Rising oil prices have not reduced this cost advantage because the price of the nickel and lithium used in batteries has increased as well. As a result, European consumers this year are buying more diesel cars than gasoline and hybrid powered cars combined.

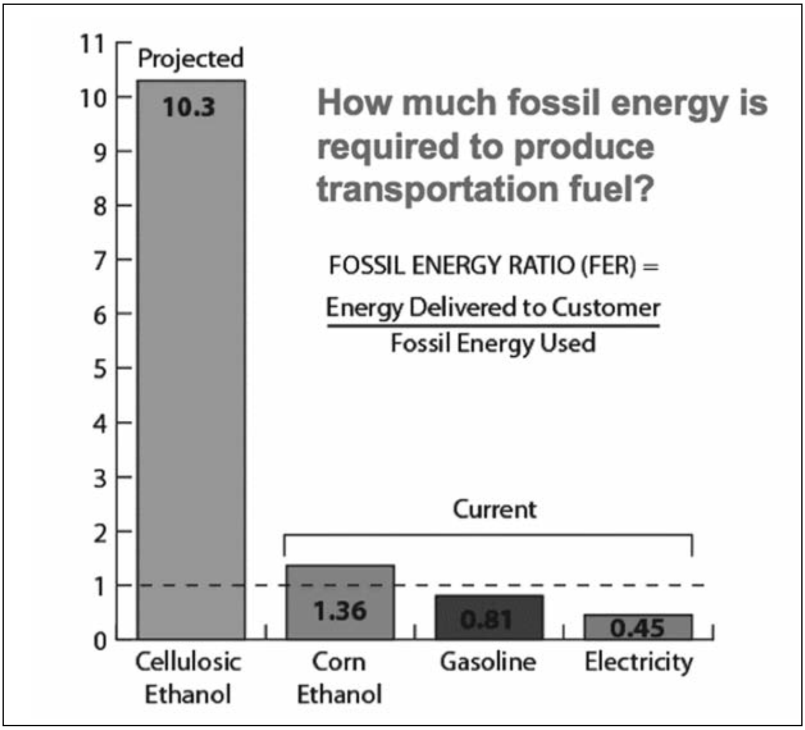
A study done in California showed that Environmental Protection Agency (EPA) fuel efficiency testing does not reflect American driving habits. EPA test results placed more emphasis on city driving, while the California analysis assumed more highway driving. The researcher's objective was to prove hybrids with larger batteries best match the way American's actually drive. Hybrid technology works best in stop-and-go traffic, while diesel-powered autos do better on the highway. The study concluded that for the average driver, diesel technology and fuel is preferable to electric/gasoline hybrids.

Assuming the accuracy of this study, diesel could be one way to meet proposed new federal and state emission standards while at the same time lowering consumption of petroleum products. U.S. auto manufacturers are aware of the benefits of diesel powered cars, but are moving in different directions to meet emission and fuel consumption issues. One of the directions is more emphasis on biofuels.

Biofuels have received the greatest public support in the U.S., and in their variety offer the potential to be produced in most areas of the world. One expert predicted that with plausible technology developments, biofuels could supply 30 percent of global transportation fuel demand. To realize that goal, advanced biofuels must be developed from dedicated energy crops, separately and distinctly from food. Not all advanced biofuels are the same; some take more energy to produce than others. For example, cellulosic ethanol currently requires significantly more energy to produce in comparison to the energy it provides than does corn ethanol or gasoline. Different chemical processes are needed to break down the initial source – sugar, starch or cellulose – and some processes are more energy intensive than others. Moreover, ethanol or diesel may not always be the desired fuel, since other fuel molecules could be produced as long as they are compatible with the current fuel infrastructure: production, transportation, engine characteristics, and power derived from the fuel. These other fuels include butanol and biogasoline, which can be produced using bio-chemical or thermochemical processes.

Since there are a range of biofuels and different refining processes, there also are a range of biomass feedstocks including algae, trees, and grasses. The yield of the biomass is a significant factor in the production of these fuels, since higher yields will lower the costs of land and transportation to the refinery and reduce the environmental impact of the crops. One way to increase the biomass yield is through genetic modification of the plant. Gene modification of the feedstock can also reduce the difficulty and cost of refining. One expert suggested that among the crops with the greatest potential as feedstocks for biofuels are switchgrass, high-biomass sorghum, and miscanthus.

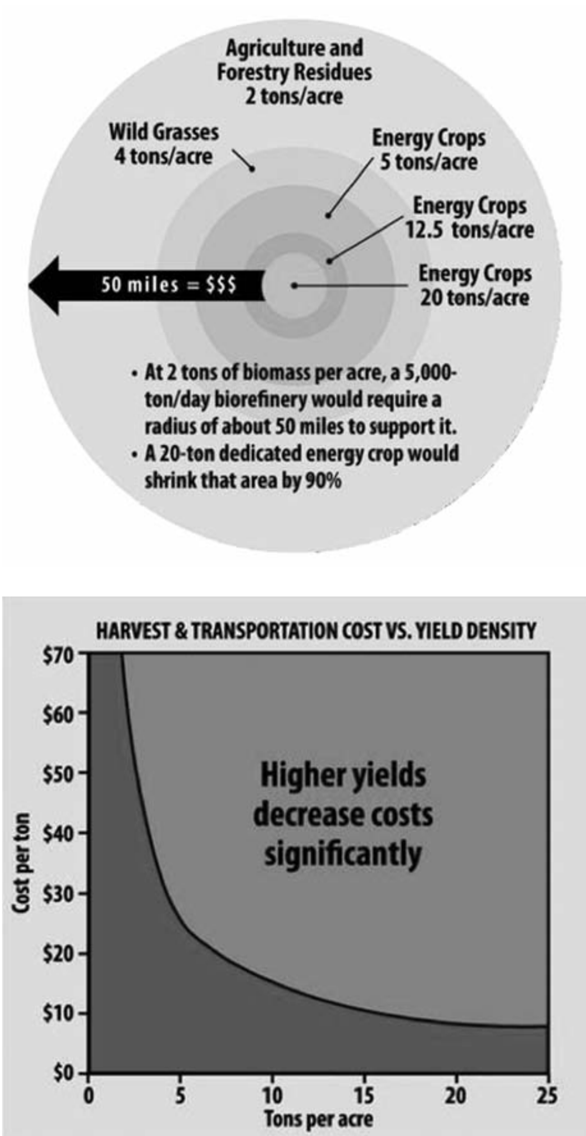
Fossil Energy Used to Produce Transportation Fuels



Source: Ceres, Inc., from Biofuels Joint Roadmap, June 2006, DOE. Data derived from Brinkman et al. 2005.

The amount of fossil energy required to grow, transport, and refine cellulosic ethanol is currently much greater than that required to produce corn ethanol, gasoline, or electricity. One goal of genetic modification of crops is to reduce this disparity.

Biomass Yield Matters



Source: Ceres, Inc.

Increasing the yield of energy crops through genetic modification can dramatically reduce the amount of land needed and the costs of transporting the feedstock to refineries.

There are several commonly stated objections to biofuel production. The most important are whether biofuel crops compete with food production, whether there is sufficient land for both energy and food crops, and whether the use of biofuels actually reduces carbon emissions. In fact, the Forum was told, the best way to ensure the adequacy of energy and food crops is to increase the yield of both. Using genetically modified grains and energy crops would produce enough of both without competition with each other. U.S. land use patterns show that there will be sufficient land for both energy and food crops as long as marginal, idle and convertible (e.g., changing from rangeland to feedstock production) acreage is used. On this basis as much as 60 million additional acres could be available, which could produce up to 120 billion gallons of fuel or 85 percent of current U.S. gasoline demand. An interesting way to think about using land for large scale biofuels production is to consider the land as biomass reserves. If one acre could produce the equivalent of 209 barrels of oil, then 100 million acres would be equivalent to 20.9 billion barrels of oil, or about 70 percent of today's U.S. oil reserves.

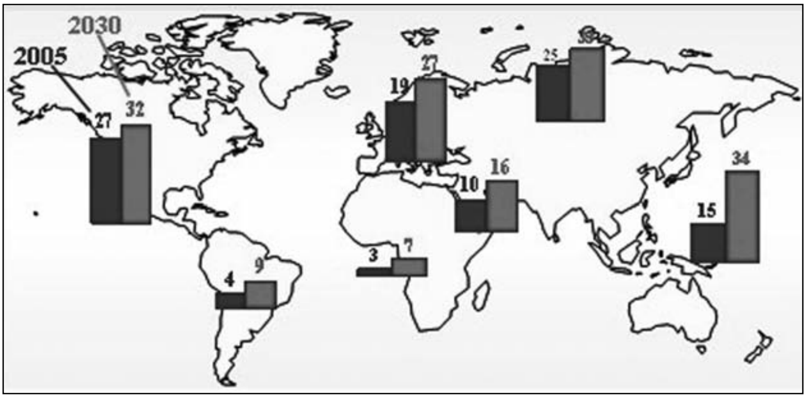
Natural Gas

Based on world GDP growth of 4 percent per year through 2030, world natural gas consumption is expected to grow by 1.7 percent per year (compared to oil at 1.2 percent per year, coal at 2.0 per cent per year, and renewable energy at 2.1 percent per year). This means that total world natural gas consumption will increase by 52 percent, from 104 trillion cubic feet (Tcf) to 158 Tcf, accounting for 24 percent of world energy consumption in 2030, virtually the same share as in 2005. The industrial sector will remain the largest user of natural gas at 44 percent, followed by power generation at 41 percent and all other users at 15 percent.

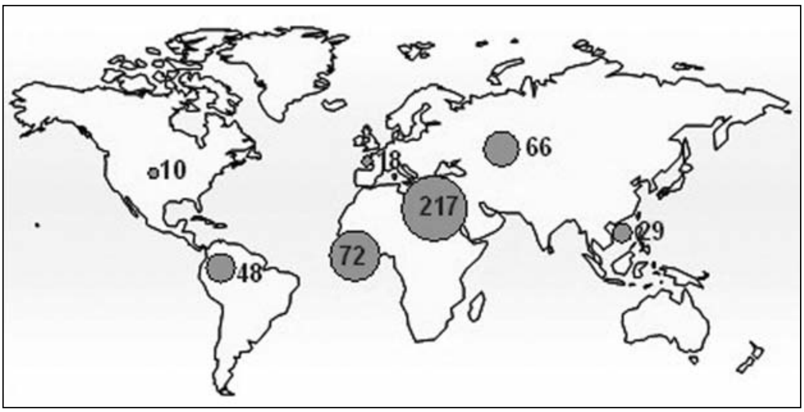
Natural gas consumption patterns will change between 2005 and 2030. While the OECD accounted for half of natural gas consumption in 2005, by 2030 non-OECD will account for close to 60 percent of all consumption. This change is due to the 74 percent growth in the non-OECD, most of it from Asia, where consumption more than doubles. Chinese growth will be over 275 percent!

Analysts consider natural gas reserves, about 6,186 Tcf (173 trillion cubic meters – Tcm), adequate for the future. However, the reserves are not distributed evenly; Russia, Iran and Qatar hold 57 percent of world reserves. Beyond these economically recoverable reserves, the U.S. Geological Survey estimates that there are another 4,133 Tcf (115 Tcm) of undiscovered natural gas resources.

Gas Consumption by Region 2005 and 2030



Reserves to Production Ratio 2006



Source: Energy Administration Information

Natural gas consumption patterns will change by 2030, with Chinese growth driving a 125 percent increase in Asian demand. Reserves are concentrated in regions with lower projected demand growth.

An important question is whether the reserve base can meet future demand in various regions. World-wide, the reserve base can support 59 years of demand. But North American reserves can support only 10 years, Europe 18 years, Russia 66 years and the Middle East 217 years. This mismatch implies that large portions of the world – North America, Europe and Asia – increasingly will depend upon imports of natural gas from Russia, Central Asia, the Middle East and Africa. The ability or willingness of these regions to maintain and increase their gas exports was discussed in depth in the 2007 Aspen Forum. The conclusion reached then still applies today: the three largest reserve holders, Russia, Iran and Qatar, all have domestic, political and technical reasons for limiting future exports, leading to significant uncertainty in the ability of future supplies meeting growing demand. While extensive pipeline systems link Europe with Russia and Africa and will reach the Middle East in the future, and while North America has an integrated pipeline system, many areas must rely on liquefied natural gas (LNG) to meet future requirements. Increasingly, a global natural gas market is evolving based on LNG trade linking producing and consuming regions where pipelines cannot be used.

The table below shows the evolution of the LNG trade from unevenly distributed and dominated by OECD Asia buyers (Japan and South Korea) to a more even distribution by 2030:

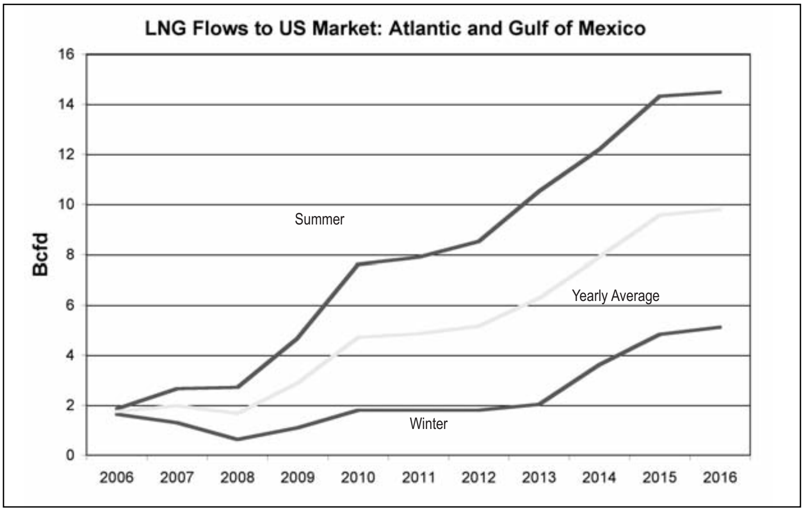
World LNG Trade

Buyers	2006	2030
OECD Asia (Japan & S. Korea)	57%	26%
Non-OECD Asia (China, India, Taiwan)	9	21
OECD Europe	25	29
OECD North America	9	26

LNG trade will become more diversified in the future. The largest absolute demand growth will be from Asian economies, although Asia's much larger initial share means that its percentage of global LNG trade will decrease to less than half of a much larger market. To meet this growth, supplies from the Middle East increasingly will shift to Asia. Japan and South Korea have been the traditional consumers of LNG, while China, India and Taiwan will be the new destinations. Almost half of all LNG trade will be heading to Asia. Asian demand will continue to be tied to long-term contracts, while markets in the U.S., U.K. and Belgium will rely more on spot market trades to balance the LNG markets.

U.S. LNG trade is expected to quadruple in future years primarily because traditional sources of natural gas supply, domestic production and Canadian imports, will shrink. LNG will fill the supply-demand gap. This trade is very uneven, with summer deliveries exceeding winter deliveries by a factor 3 or 4 to 1. One reason for this imbalance is that winter U.S. natural gas prices set on the NYMEX do not account for the premium that Europeans are willing to pay during the winter heating season. This premium disappears in the summer and U.S. NYMEX prices make it attractive to sell LNG into the U.S. market. The U.S. can accommodate this trade, since presently it has sufficient LNG receiving capacity and is building more than enough for the future. The U.S. also normally adds natural gas to underground storage in the summer for use during the winter heating season and has sufficient storage capacity to accommodate the swing in supplies. Storage is distributed around the country near all the large consuming markets.

U.S. LNG Deliveries by Season



Source: Sempra

Higher prices in Europe attract a larger percentage of spot LNG cargos in the winter, but ample storage allows U.S. buyers to increase imports in the summer and hold supplies for the winter heating season. This differential is expected to increase.

In the future the Middle East will be the swing supplier of LNG and the U.S. will be the swing consumer, each with the ability to balance the Atlantic and Pacific markets. Moreover, natural gas futures trading has grown dramatically and often exceeds oil futures trading. A highly liquid, flexible market indicates that the U.S. market is well suited to play this balancing role.

Geopolitical factors affecting oil markets are having a similar impact in natural gas markets. Gas supplies are concentrated in Russia and the Middle East. Resource nationalism, taxation, and investment policies of Gazprom, the sole exporter of Russian gas, limit Russia's ability to produce and export natural gas. In the Middle East, Iran and Qatar are the largest producers. Domestic politics, rising domestic natural gas consumption, nuclear issues, and sanctions limit Iran's export potential. Qatar, where IOCs can invest in partnership with state-owned companies, placed a limit on future exports since technical experts questioned whether Qatar's natural gas reserves can support additional long term commitments and whether the market can absorb additional LNG exports. Qatar's current LNG exports of 30 million tons per year will increase to 77 million tons per year by 2012 and then stop growing. Until these questions can be resolved, Qatar's future natural gas production will be directed to domestic needs for power generation, desalination and industrial growth and not to the export market. A wide range of issues affect the remaining producers, including government stability, investor attitudes, and government policies toward IOCs – for example, access, profit sharing, and enhanced regulation. The Forum discussed several theoretical scenarios involving interruption of Russian or Middle Eastern gas supplies. In each situation, price spikes occurred during the disruption but prices returned to normal after supplies resumed.

A political debate was taking place in the U.S during the time of the Forum regarding access to restricted areas for new drilling, both offshore and onshore. The group discussed what would happen to supply if these restricted areas were opened. The total natural gas resource that would become available was estimated to be about 138 Tcf. Although reserves are not proved, the impact on U.S. production would be positive, growing slowly from 2010 and by 2018 making about 2 Tcf per year more gas available through 2030, even with offsetting declines. Current U.S. production is almost 23 Tcf and projected 2030 production is about the same. Adding 2 Tcf would increase U.S. natural gas production by almost 9 percent. LNG imports would decline as a result, since LNG is considered to be the marginal future supply. Interestingly, the price impact from these additional domestic supplies was not large, up to a maximum of $0.42 in 2017 at Henry Hub (the most important domestic pricing market).

A broader question on pricing is whether natural gas prices are regional or global. From one point of view, natural gas prices still are set in regional markets despite the growing LNG trade. In some markets there is a strong linkage to oil prices, while in others this linkage has been broken. Some experts believe regional markets are still largely separate. Others are convinced that the NYMEX price is approaching a global price for spot LNG cargoes, which constitute 40% to 50% of the LNG available in the spot market. Still others think the spot prices are still quite far apart based on where cargoes are going (Middle East to Asia or Middle East to Atlantic), although a convergence is likely sometime in the future.

There are four strong regional markets: North America, United Kingdom, Continental Europe and Northeast Asia. While China and India are increasingly important, they are using pricing structures developed in other Asian markets and cannot be considered new, separate markets. Each of the four regions differs in its source of gas supplies, contract reliance and extent of market liberalization – all factors that influence natural gas pricing.

In addition, two factors in natural gas markets differentiate them from oil markets. First, gas markets have been characterized by long-term contracts which guarantee debt service and share project risk between buyers and sellers. Pipelines and LNG facilities are expensive, with large front-end capital investments usually financed through debt. Second, natural gas has been transported through pipelines that have natural monopoly characteristics and require economic regulation. Where natural gas prices were not artificially tied to oil prices, these factors led them in different directions.

Importing countries developed pricing mechanisms – "take-or-pay" and "price escalation" – in their long-term contracts to help control prices once the natural gas arrived. These contracts often referenced local energy markets for comparison. In Japan, for example, gas competed primarily with heavy oil in electric power markets. Consequently, price escalation clauses relied on the Japanese Custom Clearing Price for Crude Oil (JCC or Japanese Crude Cocktail). Other Asian countries, such as South Korea, Taiwan, and now China adopted this pricing formula in their contracts. In these nations the link to crude oil is firmly entrenched and hard to break.

In Continental European markets, natural gas contracts developed in the Netherlands, which developed prices in reference to competitive fuels such as heavy and light fuel oil. While other factors such as coal and electricity pool prices have been introduced recently, the original linkage to oil remains.

In the U.S., Canada, and the U.K., where domestic production initially supplied the markets, pricing evolved in a different way. Markets in each country were liberalized during the late 1970s and early 1980s, allowing for gas-to-gas competition. In each country competitive sources of gas were available, customers were free to choose among suppliers, the transmission systems were open to third parties, and pipeline access was nondiscriminatory. As a result, short-term commodity trading replaced long-term contracting. By and large these three markets broke their link to oil; however, in times of gas shortages, the gas-oil pricing link was re-established for limited periods of time.

In sum, Northeast Asia and Continental Europe still are dominated by long-term contracts with natural gas pricing linked to oil prices, although many of these linkages are weakening as other commodity linkages are introduced or as natural gas prices are capped to reduce the impact of oil price shocks. In North America and the U.K., short-term commodity trading is the norm. Gas-to-gas competition sets natural gas prices with some weak linkages to oil in times of natural gas shortages. In North America, this commodity pricing is based on Henry Hub prices on the NYMEX. This market, which many in the industry consider the most liquid natural market in the world, helps establish a transparent price for natural gas. Although regional pricing factors still control most natural gas transactions, recent LNG transactions in the spot market appear to have the characteristics of a global market making it appear that a loose world pricing mechanism is emerging since regional prices have been very close to each other. For a robust spot market to work effectively, sufficient LNG capacity has to be available. More capacity is being built, and tankers could be used as a fast way to enhance storage capabilities. However, present day capacity limits the effectiveness of LNG spot markets.

Moreover, there are significant uncertainties surrounding the future of LNG markets, at least after 2012. Many agreed that in the near term supply and demand factors are relatively well understood. But beyond 2012, the uncertainty grows due to dramatic cost escalation in the industry. In recent years more capacity was added due to declining costs, but this will not be true for the future. Previous capacity additions were based on cost estimates of $200/ton. New cost estimates based on the large run-up in the price of steel and other commodities show that new capacity will cost $500/ton or more. This increase means that new investment in additional capacity may not be made until costs stop rising or prices increase sufficiently to cover future cost estimates.

The experts also questioned where new LNG supplies are likely to come from. As noted above, Qatar now has a moratorium on all production beyond 77 million tons, its present level of commitments. Some made the point that Qatar does not need additional money since it is among the wealthiest countries on a per capita basis. Iran, the other Middle East supplier with large reserves, has its own domestic constraints and cannot expand its LNG capacity any time soon. Russia, the largest natural gas producer and reserve holder, has long been a pipeline-dominated country. With very few LNG projects ready, it has barely entered the LNG market. Indonesian production has entered a decline. Nigerian LNG capacity is fully committed for the foreseeable future and the country's internal problems are inhibiting new investments. There are some bright spots such as Australia and Angola, but the addition of new production linked to additional LNG capacity appears quite limited for the long-term.

The pricing discussion led to the conclusion that there is still no global price for natural gas, only regional pricing with locally determining factors. The long run expectation that liberalized markets would undermine the oil-based pricing in Northeast Asia and Continental Europe has not occurred. Today, the question remains whether oil pricing will set natural gas prices directly through contract linkages or indirectly through interfuel competition. But if oil becomes less important in stationary uses, the rational for linking natural gas prices to oil lessens. Should natural gas continue to be linked to oil if oil is predominantly a transportation fuel where natural gas does not compete? Further, how will carbon pricing affect the relationships among fuels? Both are questions with no immediate answers. In the short term, natural gas and oil prices will continue to be linked in some fashion in some markets in some time periods. But for the long term, the factors that will set natural gas prices are unclear.

Energy Security

Energy security concerns have been a cornerstone of energy policy in the U.S. and many other countries. In its narrowest form, energy security often is equated with dependence on foreign oil. More broadly, energy security can encompass a range of energy issues across all energy sectors. In the Forum's analysis of energy security, the experts focused on six areas primarily from the perspective of the U.S.: the geological and geopolitical realities of oil and inelasticity of the transportation fuels market; rapid increases in global or interregional trade in natural gas; global nuclear power fuel cycle development and countries with or on the threshold of nuclear weapons capability; increasingly extended and vulnerable energy delivery systems; climate change and long term security implications; and organization of the U.S. government to address these issues more effectively.

The experts considered a range of policies and technologies instituted over the past 30 or more years to reduce oil dependence. The policies include addressing sudden disruptions of the oil market through international coordination in the International Energy Agency, domestic stockpiling in strategic petroleum reserves, and the development of orderly functioning markets. Increasing and diversifying oil supplies have been consistent policy goals, albeit not fully realized. Finally, government has promoted the development of technologies for greater vehicle fuel economy, alternative fuels, electric and hybrid-electric vehicles, and flex-fuel vehicles. While these and other policies will not lead to "energy independence," the discourse made clear that broadening the technology and policy options can lower the threat and impact of disruptions in oil supplies. The experts also cited the old adage that oil and water do not mix and noted that in the U.S. energy and water policies are considered separately without taking into account the huge amount of water required for energy production and use.

The U.S. and the world increasingly are becoming more focused on natural gas markets as a source of energy insecurity and are developing technologies and policies to cope with the concerns. As gas markets evolve from regional to global, the security threats change. By 2030 Europe is likely to become as much as 70 percent dependent on natural gas imports, primarily from or through Russia. U.S. foreign policy options may be limited by the security concerns of its allies. As Europe reaches out to the Middle East and Central Asia by developing pipelines or LNG markets, the U.S. must take these actions into account in its foreign policy. The U.S. has had a "multiple oil pipeline" policy for Central Asia and may have to consider a similar policy for natural gas as European dependency grows. Moreover, technology will play an increasingly important role alleviating security concerns as unconventional natural gas becomes a larger portion of overall production and becomes more "conventional."

The proliferation of nuclear power raises security concerns of a different type. Leasing presents one approach to providing fuel for light water reactors while avoiding more proliferation risks. The spent fuel would be returned and the lessee would agree that it will not engage in enrichment or reprocessing. Leasing offers countries the ability to obtain new fuel and avoid major enrichment and waste management efforts. This approach is being pursued by Abu Dhabi and contrasts with Iran's approach. For the distant future, technology, e.g., burning transuranic waste, could be developed as an alternative way of dealing with the waste issue.

The group discussed whether the use of more nuclear power was a step forward or backward. Those more concerned about clean energy saw it as a step forward, while those whose greater concern was nuclear proliferation disagreed. All agreed, however, that if nuclear power is to progress, governments should be facilitators in the process and not pick winners and losers.

Extended energy delivery systems provide a prime opportunity for international cooperation, especially between producers and consumers. For example, new gas pipelines provide new markets for gas producers while gas consumers can diversify their sources of supply, resulting in a "win-win" arrangement. Important transit routes require international cooperation to maintain safety. For example, maintaining open transit through the Straits of Malacca requires the cooperation of all producers and consumers that rely on the vital waterway. Energy systems also can be upgraded to provide more resiliencies in the event of natural or hostile disruptions. A good example is the development of smart electricity grids using advanced power electronics, sensors, controls, communication, modeling, and decentralized decision-making. Ensuring the adequacy and sufficiency of these infrastructure systems poses separate challenges than protecting them. Both are important. The U.S. for example, requires additional infrastructure to meet its growing economic needs. How to provide this infrastructure in a timely way is an increasingly urgent problem. Some experts criticized the current process for siting new projects, which leads to long delays and often cancellations, and recommended a more streamlined procedure.

The energy security implications of climate change are a relatively new concern. Projected climate changes pose a serious threat to world security through drought, melting glaciers, disease, population displacement, refugees and more. Participants questioned the ability of weak or failing governments to deal with these issues. Climate change, security, and energy dependence are interrelated challenges that require robust energy policies and actions, and the solutions to energy challenges will be more difficult to achieve in this broader context.

The American participants in the Forum questioned whether the organization of the U.S. government allowed it to deal effectively with these energy security concerns. Most thought that the lack of sustained attention to energy issues undermined U.S. foreign policy and national security. The U.S., by and large, has treated energy policy as something separate from foreign or security policy, both substantively and organizationally. It is a myth that the Secretary of Energy has the authority to develop and implement energy policy broadly. In reality the Secretary's statutory authority is quite limited and is unlikely to be enhanced. A new structure is needed that can bring together the relevant agencies to develop broad-based domestic and international energy policies and deal with climate change issues and technology challenges. One participant suggested the creation of an assistant to the president or a special assistant in the Security Council with the authority to convene the appropriate agencies to develop policy and budget initiatives.

Some of the experts urged a complete, thoughtful re-organization of the energy policymaking apparatus. Others argued that to develop effective new governmental organizations takes too much time. They urged that the special assistant approach would work faster and perhaps more effectively than a reorganization of the Cabinet departments.. Many liked the idea of an Energy Security Fund with long-term funding, not an annual appropriation, to handle the long lead times necessary for effective government research programs. Participants also urged the development of greater trust between politically appointed policymakers and career staff who are necessary for the successful implementation of new policies.

Conclusion

The constraints of politically off-limits oil are more likely than geological constraints to prevent oil production from meeting projected demand growth by 2030. The constraints fall into several categories, including lack of motivation to produce more oil by countries with large reserves and little need for more current revenue; changing political incentives such as resource nationalism, political unrest, and political antagonism to the developed world; and lack of technical ability to develop the resources.

In the transportation sector, the largest user of oil, there are short- and long-term ways to mitigate the potential supply-demand mismatch. Automobile manufacturers are increasing the efficiency of internal combustion engines and developing alternative fuels and technologies. Hybrids and plug-in hybrids are near-term possibilities, genetic modification of crops to make possible cheap and abundant biofuels holds promise for the mid-term, and a complete transition to all electric or fuel cell vehicles is on the drawing boards. All would reduce oil demand by substituting alternative forms of energy.

The natural gas sector raises a similar problem of supply-demand imbalance. Upstream, politically off-limits gas reserves limit supply options. Downstream, the focus is on pricing mechanisms in regional markets and the global natural gas market that is evolving slowly with the expansion of LNG trade.

With both oil and gas, energy security questions are growing due to continuing reliance on hostile or unstable countries for supply as global demand increases. Diversification of supply sources, increased efficiency of use, and fuel substitution remain the most promising solutions.

APPENDICES

Agenda

Energy Supply in a World of High Demand

Chair:

John Deutch, Institute Professor, MIT

Friday, June 27

SESSION I: Oil Supply

"Hard Truths About Energy" A U.S. National Petroleum Council Report	**Lee Raymond,** former Chairman and CEO, ExxonMobil, Interviewed by **John Deutch**
Technical Constraints	**Rodney Nelson**, VP Innovation & Collaboration, Schlumberger
Russia and Central Asia	**Ray Leonard**, VP (Eurasia) Kuwait Energy Company
Energy and Environment	**Lynn Coleman**, retired partner, Skadden, Arps; Lecturer in Energy and Environmental Law, University of Virginia

SESSION II: Demand and Economic Impacts

Global Oil Demand	**Roberta Luxbacher**, General Manager, Corporate Planning, ExxonMobil
Chinese Oil Demand	**Kang WU**, Senior Fellow East-West Center
Economic Effects of High Prices	**Chris Varvares**, President, Macroeconomic Advisers

Saturday, June 28

SESSION III: Transportation and Alternative Fuels

Manufacturer's Outlook	**Reginald R. Modlin**, Director – Environmental Affairs, Chrysler
Manufacturer's Outlook	**Jaycie Chitwood**, Senior Strategic Partner, Advanced Technology Group, Toyota USA
Penetration of Alternatives	**Kevin McMahon**, Partner, The Martec Group
Biotechnology for Biofuels	**Richard Hamilton**, President and CEO, Ceres, Inc.

SESSION IV: Natural Gas

Global Gas Outlook	**James M. Kendell**, Director, Natural Gas Division US Energy Information Administration
LNG Trade	**Octávio Simões**, VP Commercial/ Development, Sempra LNG
Gas Pricing	**Jim Jensen**, President Jensen Associates
Politics and Gas Supply	**Amy Myers Jaffe**, Fellow for Energy Studies, Baker Institute for Public Policy, Rice University

Sunday, June 29

SESSION V: Energy Security

Major Risks	**Ernie Moniz**, Director MIT Energy Initiative

SESSION VI: Conclusions

Key points of discussion	**Herman Franssen**, President, International Energy Associates

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