World oil production: focus on non-OPEC supplies

A summary the recent National Academy of Science workshop on supply and demand.

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The ability of petroleum production to meet demand is being questioned more insistently in recent years. Given the profound importance of this issue, the US National Academy held a *Workshop on trends in oil supply and demand and potential for peaking of conventional oil production* in the fall of 2005 in Washington, DC. Both the question of peak oil production and possible means to provide new supplies and reduce demand were examined.

Based on the best science available to industry, government and academic researchers, Workshop participants reached a consensus that non-OPEC oil production would peak by about 2010. This may be welcomed by some and cause great concern among others. Whatever the case, it should not be ignored.

PAST FALSE PREDICTIONS

Unfortunately, the topic is much more controversial than it should be. From the beginning of the oil industry in 1859, skeptics have loudly voiced concern that the world was squandering its fossil fuel resources, and that oil production would soon begin to decrease. Time and again these pessimists have been proven wrong, eventually discrediting even the idea that oil production would ever decline. To make matters worse, many oil peak forecasters often expressed a deep dislike for modern society, and seemed to believe that the end of oil would automatically lead to a collapse of population, civilization and purge the earth of much of the unpleasantness associated with modern industrial society.

Doom and gloom stories have long held a fascination for people everywhere. Whether it is a survivalist in a remote camp, waiting for the black helicopters to land, or a science fiction fan watching the latest version of the *War of the Worlds,* or believers waiting for the Second Coming of the Messiah, disaster scenarios have always appealed widely to our imagination. This is perhaps rooted in humankind's bitter struggle for existence; for most of its history life hung by a thread, always imperiled by a failed harvest, changing climate, plague or pestilence.

In today's world, such stories continue to be widely popular but are generally taken much more as entertainment. Advances in science and technology appear to have enabled humanity to overcome any obstacle, from AIDS to the threat of avian flu. Any failures are viewed as exceptions to the rule and the payment for an incompetent government's failure to organize properly, rather than an indication of a fundamentally flawed approach. Indeed, the lesson should be that, provided warnings are heeded (e.g., levees maintained, tsunami warning system in place), society should be able to cope with any threats to its existence and even to its prosperity. It is in this spirit that one should approach the problem of understanding energy demand and supplies.

Crude oil production in the continental US peaked in 1970 and has declined continuously since that time. Production in the North Sea reached a plateau in the late 1990s and has recently dropped sharply; a majority of non-OPEC producers are facing diminishing prospects and reduced production. In contrast, oil production in the Former Soviet Union fell by about one-third in the early 1990s, not due to a lack of resources, but to mismanagement and the collapse of the economy and the central government. Production has since recovered substantially.

PRESENT PREDICTIONS

It is perfectly reasonable to ask how petroleum production might evolve over time, and to understand all of the geological, political and economic factors that influence production. Since petroleum provides almost 40% of the world's primary energy, knowing over what time scale petroleum production might be sufficient to meet demand is essential to avoid a significant supply disruption.

Most surprisingly, some of the major international oil companies have begun to warn that the industry faces an uncertain future regarding its resource base. ExxonMobil, in its 2004 report, *The future of energy: A view to 2030,* indicated that it expected non-OPEC production to reach a plateau by about 2020, after which OPEC would have to supply all demand increases, Fig. 1. Chevron has adopted the most aggressive stance, placing full centerfold advertisements in major newspapers and large ads in trade magazines and journals. Chevron's web site (Fig. 2) maintains copies of the ads and a bulletin board for discussion.

There are several difficulties associated with predicting peak oil production. The first is that political and economic factors are generally ignored; as has been seen in the past, these factors may be the most important and overwhelm any other consideration. Producers may decide to withhold production for many reasons, none of which are amenable to quantitative analysis. Such decisions become more likely as it becomes increasingly evident that the resource base is finite. The most reasonable approach is to ignore these factors; this allows one to make predictions based on resource availability alone, and gives an optimistic estimate of the time frame for peak production.

Taking this important (and usually unstated) assumption, two approaches have been used to make forecasts. The first is to look at what the oil industry itself is doing, what projects are planned over the next decade or so, what decline rates and production rates are expected in existing fields; this requires a detailed knowledge of petroleum company operations and thus excludes those outside the industry. The second is to use estimates of petroleum resources in various production provinces to model future production trends. The most popular model originated with M. K. Hubbert; he used logistic growth curves to predict the peak in US oil production in 1970. Other models have been used; they give roughly the same answer when used properly.

The problem can be further broken down into examining peak production in two, overlapping categories: non-OPEC and World. Non-OPEC oil provinces have been explored extensively by the major oil companies (outside the FSU). This resource base is reasonably well understood, and, since these producers do not restrict output in an attempt to support prices, production forecasts can be made with some confidence. Further, major oil companies should pay close attention to this category, since OPEC resources are, for the most part, inaccessible, and once non-OPEC production peaks, these companies will face a diminished future.

The understanding of OPEC reserves is entirely different. There has been some dispute over the proven reserves of Persian Gulf countries that were increased substantially around 1988. Since an independent assessment is not possible, there is much uncertainty regarding proven-plus-undiscovered reserves of OPEC states. Examining non-OPEC production separately avoids this controversy, allowing prediction of the timeframe in which OPEC countries will need to meet most or all of the incremental demand increase. Evidently, as fewer and fewer regions or countries can increase production and compensate for declining production elsewhere, the entire system becomes more and more prone to instability; the threshold to much greater instability will come when only Persian Gulf producers are expected to increase production.

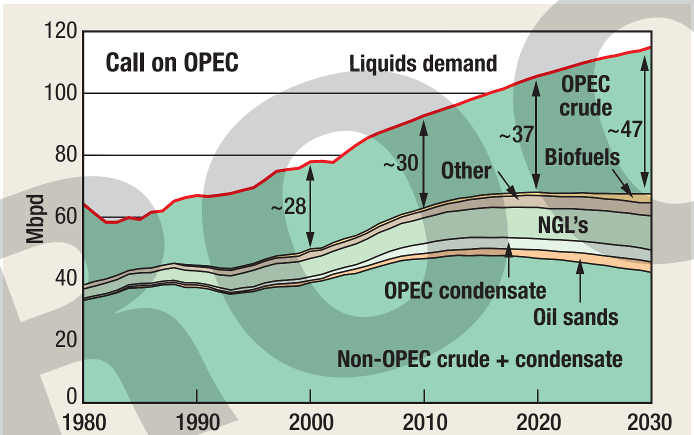

Fig. 1. ExxonMobil's forecast to 2030.

Resource assessment and production. Early in the Workshop, the US Geological Survey (USGS) gave the results of its World Petroleum Assessment (2000). It is the first detailed science-based study, and the first to include the effect of reserve growth in estimates of the resource base. It is by far the most thorough and credible study of world petroleum resources ever made; results are publicly available on the USGS web site. The USGS allocates petroleum resources to three categories. The first, proven reserves, are those that can be produced with certainty from known deposits. The second category, undiscovered reserves, are those that are likely to be discovered in a given geological system based on a fairly detailed knowledge and understanding of petroleum generation in source rock, migration and trapping. The third category is reserve growth, and is the additional petroleum from such processes as field extension, infill drilling and improved enhanced oil recovery.

Unlike the first two categories, reserve growth only prolongs a plateau or slows a decline in production from a given field. This is a crucial point; some analysts simply treat all three categories as equivalent and add them together to obtain a "total in-place resource." This is incorrect and cannot be used to determine when peak production might be expected.

The USGS resource assessment, done on a country-by-country basis, can be used to forecast future production trends for both OPEC and non-OPEC producers. While the USGS itself has not done such an analysis, it has examined current production trends and found them to be consistent with its assessment. Other analysts have used the assessment to forecast a timeframe for peak production; results for non-OPEC producers are comparable to those obtained by petroleum industry analysts discussed below.

Both ExxonMobil and PFC Energy Consultants looked at non-OPEC production using oil industry field-by-field and project plans; both came to similar conclusions. Exxon stated (as noted above) that non-OPEC production would peak within the next 10 years, or soon after 2010, after which OPEC producers would be expected to add about 1.2 million bpd of new capacity. The detailed basis for this forecast was not discussed, but the fact that such projections are presented by a major oil company is a radical departure from past practices. The PFC presentation was much more detailed, emphasizing that the real supply problem is expected after 2010, in agreement with ExxonMobil.

Even if large amounts of oil remain to be found, discovery rates are far below replacement rates so that, unless exploration becomes much more successful, a near-term production decline must be expected. Finally, PFC compared its forecasts for several regions with results from what it called the "demand driven model" of the US DOE Energy Information Administration (EIA). The EIA model predicts North Sea crude oil and NGL production of 6.5 million bpd in 2010; current production is about 5 million bpd and declining (9% in the past year); for Australia, the EIA 2010 production is 1.0 million bpd, while current production is 0.6 million bpd and declining; for the non-OPEC Middle East, EIA 2010 production is 2.2 million bpd compared to current production of 1.6 million bpd and declining. Unless the production declines for all of these regions are reversed very quickly, it would appear that the EIA projections cannot be correct.

The results of these industry-sponsored, project-based forecasts are compelling. It is difficult to believe that they can be very far wrong, given their very short time horizon (five years). Even if they were off by as much as five years (non-OPEC peak in 2015), there would still be cause for considerable trepidation. As it is, the 2010 non-OPEC peak production date should be a wake-up call and stimulate immediate action on the part of consumers, industry and government.

The International Energy Agency (IEA) examined demand and supply scenarios and also concluded that projected market trends raised serious concerns. Much larger CO_2 emissions and large inputs of capital were cited. Another worry, in common with ExxonMobil and PFC, was increased vulnerability to disruptions, as a few Middle Eastern countries assumed an increasingly dominant role for petroleum supplies. While no critical transition point was cited by the IEA, it seems that it would be unwise to assume that the reference (business as usual) scenario will actually unfold.

Other forecasters emphasized the possibility of a global (rather than just non-OPEC) peak in production in the near future, or by about 2010. The resource estimates on which this conclusion is founded are much below those in the USGS study. This approach makes the crucial assumption (always unstated) that all producers will continue to supply the market even as it becomes obvious to everyone that peak production is imminent. While this is reasonable for the unorganized non-OPEC producers, it is not at all the case for OPEC members. It also neglects to look at the sensitivity of the results of their modified Hubbert model to their resource estimates.

The credibility of this approach is paramount. Ultimately, world oil production will peak. The key is to convince everyone of their veracity this time after being wrong so often in the past. Asking the question somewhat differently is one way to rebuild confidence. By looking at non-OPEC instead of global oil production, and using project-based as well as reserve-based models (which give about the same answers), it should be much easier to convince politicians, policy makers and perhaps even consumers that immediate action is required.

Mitigating factors. Economists would assert that the usual market response to a product shortage is the development of substitutes. The Workshop looked at alternatives to conventional oil. Liquid fuels have been derived from heavy oil, tar (oil) sands, (oil) shale, natural gas (gas to liquids), coal (coal to liquids) and biomass. While supply-side solutions are more glamorous and receive much more attention, mandating much higher efficiency automobiles might reduce demand significantly; improvements to be expected given normal technological advances and market penetration were also examined.

There is now considerable understanding of other liquid fuel production technologies within the petroleum industry. Many large-scale projects, such as shale processing and synfuels (e.g., coal to liquids), were begun in the early 1980s, but these were abandoned when the price of oil fell drastically in 1986. However, research has continued at a steady pace since that time. Producing oil from tar sands is now a major industry in Canada. Plants to produce liquids from natural gas are operational, and much larger plants are under construction. Ethanol production from sugar cane and corn is now done on an industrial scale. Thus, projections and evaluations of alternative fuel technologies can be made with much more confidence than was possible during the 1970s.

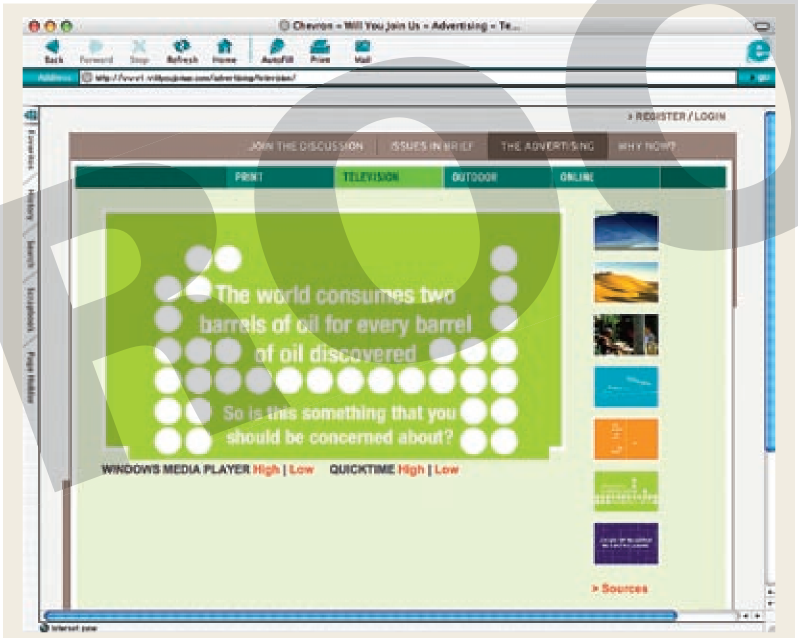

Fig. 2. Chevron advertising from its website: www.willyoujoinus.com

ExxonMobil, as part of its project to understand where liquid fuels might be produced and when peak non-OPEC production might be expected, evaluated the possible contribution of these alternatives: In its judgment, these can contribute less than 10 million bpd to supply by 2030. Thus, it is not realistic to expect a one-for-one replacement of cheap conventional oil even by all of these other alternatives combined.

Other speakers reviewed these supply-side alternatives individually. Production of bitumen (tar) from Canadian "oil sands" has been expanded significantly over the past decade, and now stands at over one million bpd. The engineering accomplishments have been impressive. Some of the resource is accessible with surface mining techniques (on a massive scale), but the majority of the deposits are recovered using steam-assisted gravity drainage (SAG-D); this requires precision drilling of long horizontal wells deep in the earth. Steam is injected into the upper wellbore and tar flows to, and is recovered from, the lower wellbore.

This process is energy intensive compared to conventional oil extraction, and requires large amounts of natural gas (about 1,000 cf/bbl) both to extract the tar and for refinery upgrading. Natural gas production has reached a plateau in North America, with prices far above all forecasts. While it is possible to minimize or eliminate natural gas consumption, for example, by building coal or petroleum coke plants or nuclear reactors to generate electricity and steam, this adds significantly to the cost and complexity of the projects. Production is predicted to reach 4 million bpd by about 2025, provided the required energy inputs are available. This is well below several years of incremental demand growth over the next two decades.

ExxonMobil has begun construction of a large GTL plant in Qatar, at an estimated cost of $7 billion. NGLs are separated from the incoming gas, and the remaining methane is combined with steam and oxygen and converted to syngas, a mixture of hydrogen and carbon monoxide. Using Fischer-Tropsch synthesis, this is converted to 150,000 bpd of liquids, of which 80,000 bpd is diesel, 30,000 bpd lubricants and the remainder is other hydrocarbons; the ultraclean diesel would command a premium price, but cover a small fraction of world demand. Several plants of this size would need to be placed in service every year to have any impact. It was estimated that reserves of at least 100 Tcf are needed to supply this facility, and that the only other possible locations for such a large-scale operation are Iran and Russia.

This technology competes directly with LNG and other petrochemical projects that are much simpler and perhaps more profitable. The negotiated price of the natural gas was not mentioned, but it is probably well below that obtained by other producers for available alternatives. In addition, the estimated energy efficiency (energy content out/energy content in) is generally quoted at about 60%, considerably below that of LNG plants. Although the Qatar plant is certainly a major scientific, engineering and financial triumph for ExxonMobil, widespread utilization of this technology to make even a million bpd contribution to liquid fuel supplies does not appear reasonable within 5 to 10 years.

Producing liquid fuels from coal would appear to be quite attractive, since world coal reserves are enormous and are found in countries that are or are planning to use large amounts of liquid fuels, such as the US, India and China. However, the proposed advanced coal-to-liquids plants would also produce large amounts of electricity (most likely requiring significant investment in transmission lines and grid integration) and are quite complex. Such plants have never been built and operated on any scale. Unless the CO_2 were sequestered, there would be a large increase in carbon emissions from such plants.

The liquefaction process is similar to that for natural gas, with the qualification that the starting material has much less hydrogen than methane. The coal is first cleaned, combined with steam and oxygen and converted to syngas, which is then converted to a liquid using the Fischer-Tropsch (FT) process. Useful liquids and hydrogen are recovered, and remaining gases are burned to generate electricity. The hydrogen is used to convert wax produced in the FT reaction to additional liquids. Overall efficiency (including power generation) was estimated at 50%. It was proposed that if all went well, one advanced plant producing 120,000 bpd might be operational by 2010 in the US, and about 4 million bpd of liquid fuels might be produced by 2030 from 35 plants. This would only replace 20% of current consumption, would mean an increase in coal mining in the US by a factor of about 1.7.

Liquid fuel is currently produced from heavy oil on a significant scale. However, super-giant deposits of heavy oil are found in only a few countries, notably Russia and Venezuela. The possibility of an immense expansion of production from these countries is remote. And while deposits of shale with high organic content (imaginatively known as oil shale) in the US West are extensive, turning such material into liquid fuel is extremely challenging. It is unlikely that they will ever make more than a token contribution to supply.

The final supply-side possibility considered was liquid fuel from biomass. The gist was that large-scale fuel production from biomass cannot be expected in the near term. It should be noted that the scientific and technical optimization of these processes, including starch-derived and the emerging cellulose-derived ethanol, as well as biodiesel and other biomass processes, might see improved efficiency using genetic engineering. This has only recently begun. One might hope for major advances in this area over the long term, in contrast to other supply side technologies.

Finally, the possibility of reducing demand by moving to much-higher-efficiency internal combustion engines was discussed. While significant improvements are possible, as is evident from hybrid and diesel technology presently available, any significant reduction in US demand would take decades at normal replacement cycles. This assumes that gasoline remains inexpensive and that Congress mandates efficiency improvements by increasing CAFE standards for automobiles and light trucks. The possibility that gasoline might increase considerably in price due to increased demand from Asia, or to the US being forced to deal with its balance of trade problem, was not considered.

OPEC's public position was clearly stated at the Workshop and followed what some (but not all) OPEC producers have expressed publicly. That is, OPEC had adequate reserves and would meet market demand far into the future. Unmentioned was that OPEC is well aware of possible resource constraints, and has done its own projection of non-OPEC production. Based on highly optimistic forecasts of North Sea and Mexican output, they predict a non-OPEC peak by about 2015.

While the Workshop reviewed many important issues regarding liquid fuel supplies, other crucial economic factors were never mentioned, and a systems approach to the problem—reviewing lifting cost, exploration and development cost, market power, demand elasticity, and refining cost and profits—was not attempted. In particular, the role that market prices play in reducing consumption was neglected.

In many European countries with excellent standards of living, *per capita petroleum consumption is one-half of that in the US.* Most of this differential is due to much higher taxes on gasoline and the much greater investment in public transportation. That is, once gasoline prices increase substantially due to resource constraints or some other factor, efficiency will become mandatory rather than merely a perceived virtuous option. If it could be done instantly, using today's numbers, US demand at European levels would mean taking 10 million bpd out of world demand. It can be obtained without abandoning personal transportation and central heating, as demonstrated in Europe.

The critical role of the vast US imbalance-of-payments was not discussed by any speaker. The US trade deficit is about 6% of its gross domestic product, or $720 billion per year (2005); about 30% of this, $250 billion, is due to crude oil and petroleum product imports. It is widely understood that this is not sustainable and will need to be addressed in the near future.

SUMMARY

By the end of the Workshop, there was a consensus among the participants that non-OPEC production of conventional oil would peak in the near future, probably by about 2010. Such a conclusion from a Workshop does not have any formal endorsement from the National Academy. The hope was to assemble a special study group to produce a report that could be supported publicly by the Academy, and that such a report would begin a much larger debate on how the US should prepare for imminent strains on conventional petroleum supplies and begin the transition to a system that acknowledges limited resources and a finite planet. **WO**

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