Peak energy: promise or peril?

The notion that we're running out of fossil fuel is gaining support in some unexpected quarters. But is peak energy good or bad news for the climate? **Kurt Kleiner** reports.

Will we continue to use fossil fuels to the detriment of our planet and the human population? Or can we clean up our act in time to avoid calamitous change? That's the dilemma the world currently faces, yet in spite of efforts to transition to alterative energy sources, projections show that annual fossil fuel demand is likely to increase 45 per cent by 2030.

But those projections make an important assumption — that there will be enough oil, coal and natural gas to meet the demand. That's a view that is increasingly being challenged by researchers, who are now looking at what declining fossil fuel supplies might mean for the Earth's climate. Although some say that a peak in energy production could allow us to avoid the most serious consequences of climate change, others fear that we will still suffer disastrous impacts and run out of energy to boot.

"It's not enough to sit back and say, 'Oh, because we're going to run out of fossil fuels we don't have to worry about the climate.' But [this] does seem to indicate that the more fossil fuel rich scenarios used by the Intergovernmental Panel on Climate Change have little likelihood of being realized," says Robert Brecha, a physicist at the University of Dayton, Ohio.

The concept of fossil fuels peaking first came about in 1956, when an American oil-company geophysicist named M. King Hubbert correctly predicted that US oil production would climax in the early 1970s[1]. Hubbert had noted that production of any particular oil field followed a roughly bell-shaped curve: production increased until about half of all oil had been recovered from the field, at which point it went into abrupt decline. Hubbert simply extrapolated the curve to production numbers for the United States as a whole. Since then, others have suggested that global production of oil — and of fossil fuels in general — will follow a similar curve, peaking either now or in the near future.

RICH RESERVES

"This is not saying that climate change will not happen. We're saying we need to have good idea what the fossil fuel reserves are," says Catherine Gautier, a physicist at the University of California, Santa Barbara, who helped organize a session on how peak oil could affect the climate at the American Geophysical Union's Fall Meeting in December. Given the economic importance of fossil fuel reserves, you'd expect we would know what's out there. In fact, it's a contentious area. Opinions run all the way from the cornucopian, which holds that supplies are limitless for all practical purposes, to the pessimistic, which sees supplies markedly declining early in this century.

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In the hope of accurately forecasting peak production, some analysts are calling for a rigorous evaluation of global fossil fuel reserves.

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Of the authoritative estimates of the world's existing energy reserves, two of the most quoted come from the Paris-based International Energy Agency (IEA), set up by the Organisation for Economic Co-operation and Development, and from the London-based World Energy Council (WEC), a consultative body to the United Nations. According to the IEA, the world is practically swimming in oil of one kind of another. The agency estimates proven oil reserves — oil that is known to exist and to be recoverable at a reasonable cost — to be 1.3 trillion barrels. That's enough to satisfy current global consumption for 40 years. Ultimately recoverable reserves, which include oil not found yet but believed to exist, are estimated at 3.5 trillion barrels. Adding in 'unconventional' sources, such as extra-heavy oil and oil from tar sands, the total resource base rings in at 6.5 trillion barrels. That compares with only 1.1 trillion barrels produced so far.

Estimates for natural gas look similarly large. The IEA says that proven reserves of natural gas are 180 trillion cubic metres, or about 60 years of supply at current rates of consumption. Coal is also plentiful, according to the WEC, which estimates 847 billion tonnes of proven recoverable reserves. At current consumption, that's about 150 years' worth of supply.

And there's even more than that if you consider the entire potential hydrocarbon energy reserves found anywhere on Earth. In 1997, Hans-Holger Rogner, at the time a systems analyst at the University of Victoria, Canada, attempted to quantify[2] all of the hydrocarbon resources in the world, including unconventional oil and gas as well as methane hydrates, an exotic form of the gas that exists in frozen deposits beneath the ocean. Methane hydrates alone contain the energy equivalent of 137.5 trillion barrels of oil. All told, the Earth's crust holds hydrocarbons containing the energy of 212.6 trillion barrels of oil.

That might be good news for the economy, but it's potentially terrible news for the climate. According to one calculation[3], if all of those fuels were consumed, emissions would peak at 30 gigatonnes of carbon per year early in the twenty-second century, atmospheric CO_2 concentrations would exceed 1,400 parts per million (p.p.m.), and global average temperatures would shoot up by 8 °C by the twenty-third century. By comparison, current atmospheric CO_2 concentrations are about 385 p.p.m. Most estimates for acceptable atmospheric greenhouse gas concentrations — those that would result in a warming of less than 2 °C above

pre-industrial values — currently hover around 450 p.p.m.

UNCERTAIN ESTIMATES

But the extent of climate change could be limited if the supply of fossil fuel starts to decline soon. Some argue that global oil production has already reached its peak. For instance, Colin Campbell, a retired oil-company geologist and leading peak-oil theorist, thinks that conventional supplies peaked in 2005 and that overall production — including unconventional sources such as oil from deep-water drilling or from tar sands — will hit its high point sometime in the next few years, with every subsequent year bringing a decline. The idea is steadily gaining support. In January, consultant BDO Seidman LLP released a survey of chief financial officers of US oil and gas exploration companies that showed 48 per cent think the world either has already reached its peak production of petroleum, or will in the next few years.

David Rutledge, an electrical engineer at the California Institute of Technology in Pasadena, has recently applied a similar idea to coal. His results suggest that, far from being plentiful, coal reserves might be about to hit a peak followed by a gradual decline in supply. "Historically, estimates have been too high," Rutledge says, taking historical reserve estimates for British coal as an example. From the first comprehensive survey in 1871 until about 1962, British coal reserves were calculated at about 150 to 200 billion tonnes. But production peaked in 1913, and eventually estimates started to come down. Today's reserves are thought to stand at around 150 million tonnes, one-tenth of historical values. By looking at global coal production trends and applying a version of Hubbert's method, Rutledge now reckons that total global coal production in the future will amount to about 435 gigatonnes — around half of the 847 gigatonnes of recoverable reserves estimated by the WEC. But with so much at stake, how could official estimates be this far off? Critics put it down to a combination of misreporting by interested parties, systematic problems in methodology and institutional over-optimism. "The whole question we're discussing would be obvious and easy to understand if there was valid information in the public domain. That is no longer the case," says Campbell. Oil data that used to be publicly available are now closely guarded by some governments and businesses, he says.

The IEA, the WEC and other groups that tabulate reserves have to compile the estimates from a variety of different sources, many of which are considered questionable by peak-fuel theorists. For instance, in the 1980s and 1990s nations in the Organization of the Petroleum Exporting Countries greatly increased their estimates, collectively adding 300 billion barrels to their reserves. Campbell and others are sceptical about these huge additional reserves because reserve size forms the basis of production quotas for each country, giving them an incentive to inflate the numbers. Saudi Arabia alone reports 260 billion barrels of reserves, or about one-fifth of global oil reserves. But that number is reported by the government and is not open to outside verification.

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Matthew Simmons, a long-time energy investment banker, concluded in his 2005 book *Twilight in the Desert* that Saudi reserves were much smaller and that Saudi Arabia would soon be unable to increase production. Rutledge is equally sceptical about the sources for coal estimates. "If someone does the appraisal for a mine, and they sell it to investors, there's a huge penalty for being wrong. If a government overestimates coal reserves, no one loses a job over it. And no politician wants to hear there are 50 years of coal instead of 100," Rutledge says. In a 2007 report on coal, the US National Research Council said that current reserve estimates are unreliable, with many of them using numbers and methodologies that have not been updated since the 1970s[4]. The same year, the German think tank Energy Watch Group undertook a country-by-country analysis[5] of coal reserves and production. It concluded that, under optimistic assumptions, coal will probably peak in 2025 at about 30 per cent over present-day production, after which it will begin a relatively steep decline (Fig. 1).

Not everyone agrees that the energy outlook is so dire, though. Peter Jackson, an oil analyst who works for Cambridge Energy Research Associates (CERA) in the UK, argues that improvements in technology and incentives from rising prices are likely to keep oil production at a plateau for decades after the peak is achieved. He also thinks that unconventional supplies such as tar sands will become more attractive as technology improves. In addition, he has reason to believe that reserves are larger than peak-fuel theorists suggest. In 2006, a CERA study estimated that the global oil resource base is actually 3.74 trillion barrels — three times as large as some assessments. Jackson says that the estimate comes in part from detailed, field-by-field numbers that CERA keeps. "Obviously we have a finite resource. The problem is that we don't know how big the resource is yet," says Jackson. "Anyone

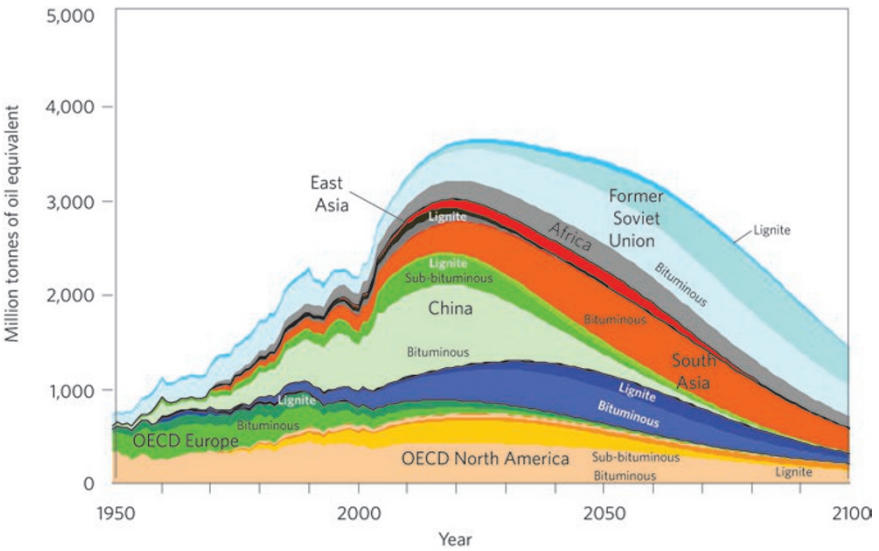

Figure 1 Running out of coal. Chart, adapted from an Energy Watch Group report[5], shows projected regional production of three types of coal: lignite, bituminous and sub-bituminous. The group expects coal production worldwide to peak around 2025.

who argues that we know that accurately, I would argue, doesn't understand the issue."

One solution to clearing up the uncertainty around current estimates is to have an international effort, similar in scale to the Intergovernmental Panel on Climate Change (IPCC), to compile a trustworthy estimate of the fossil fuels that are left, says Andrew Dessler, an atmospheric scientist at Texas A&M University in College Station. Part of the organization's job would be to pressure companies and governments to make detailed reserve information public. "This is something we must know. You wouldn't drive your car if you didn't know how much gas was in it," he says.

Conceivably, such an assessment could also inform the IPCC on the likelihood of its most fossil fuel-rich climate scenarios. But Nadejda Victor, an economist at the US National Energy Technology Laboratory in Pittsburgh who has worked on emissions scenarios for the IPCC, says that modellers are right to assume a plentiful supply of fossil fuels. According to Victor, most scenarios assume that the factor driving energy use is demand and that supply is unlimited to some degree. "It's not unlimited, of course. The point is there are enough fossil fuel reserves, proved reserves, for decades," she says.

FUELLING A CRISIS

But if Rutledge's coal estimates are correct, burning all remaining conventional oil, gas and coal reserves would produce an atmospheric CO_2 concentration of 470 p.p.m. in 2100 and a temperature increase of 1.8 °C in 2150. That's well under the highest IPCC projections, which suggest CO_2 levels as high as 970 p.p.m. by 2100, even without carbon-cycle feedbacks. "If you say that the amount of coal that's going to be mined is a third of what people assumed, that has to be good news for climate change," Rutledge says.

A recent analysis[6] by climatologists Pushker Kharecha and James Hansen, however, suggests that Rutledge's estimates may be conservative. They concluded that emissions from fossil fuel will climax in 2077 at 14 gigatonnes of carbon per year and atmospheric CO_2 will rise to 575 p.p.m. by 2100. Brecha reached similar conclusions in a recent *Energy Policy* paper[7]. If the peak-oil theory is correct, he projects that CO_2 concentrations will level out at about 550 p.p.m. around the middle of the century. "It's better than the huge amounts that the IPCC sometimes postulates. But it's still not good enough," Brecha says.

What may be most important for the global climate, however, is what replaces conventional energy sources as they run out. Running out of oil, for example, could be climatically disastrous if it becomes cost-effective to replace it with a coal-based liquid fuel for transportation while coal reserves are still plentiful. Speaking at the American Geophysical Union's December meeting, atmospheric scientist Ken Caldeira reported that in the mid-term, replacing oil with coal-based liquid fuel would raise global temperatures by 2 °C above pre-industrial levels by 2042 instead of 2045. If that oil was replaced by renewable energy, the 2 °C rise would be pushed back by 11 years to 2056, says Caldeira, who is based at the Carnegie Institution in Washington DC. And in the long run, replacing oil with coal could raise temperatures by 20 per cent. "Coal's abundance, and its carbon intensity, is far more than enough to keep carbon dioxide levels above what we consider dangerous well into the next century," says Kharecha.

Without strict limits on emissions from fossil fuels, most experts agree that emissions will still cause a rise in atmospheric CO_2 concentrations beyond the 450 p.p.m. that most analyses suggest will limit the chances of unacceptable warming. In addition, some researchers, including Hansen and Kharecha, now think that we need to reduce atmospheric CO_2 concentrations to 350 p.p.m. to avoid a dangerous level of warming. But while limiting fossil fuel use would certainly mitigate climate change, a transition to renewable energy might be affordable only while we still have the advantage of fossil fuels. "Without cheap fossil fuel energy it becomes much more difficult to make a painless transition to a whole new energy system," Brecha says. He adds that the answer to both climate change and peak fossil fuels is the same — conserve energy and replace fossil fuels with renewables. "We know we'd better start switching, both for the climate, and because of economic issues," he says.

Published online: 19 February 2009

doi:10.1038/climate.2009.19

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