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Our World Is Finite: Implications for Actuaries

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We all know the earth is finite. The number of atoms in the earth is finite; the number of molecules of a given type can change over time, but is always finite. Our actuarial models, however, seem to assume an infinite world, one where investments compound indefinitely into the future, and other factors—mortality, morbidity, accident frequency, trend rates—follow patterns that are similar to the past, without reaching any limits.

Evidence is building from the physical sciences that we are starting to reach some of earth's limits. Unless we can find some technological solutions, once these limits are reached, we can expect to see a very changed world. Instead of having constantly increasing resources available to us, we can expect ever-decreasing resources to be available. Instead of seeing year after year of growth, increasing longevity and improving morbidity, we can expect the opposite.

Some of the places where we may be reaching barriers to growth include oil, natural gas, fresh water and climate change. The first three present depletion issues; climate change represents something very different. Since the world is finite, climate is affected by our activities, particularly the burning of oil, natural gas and coal.

What's the chance of a technological solution? It's not clear. If we need to make a very major change—such as producing electricity primarily from nuclear energy, for example, or transporting people and goods in battery-powered or solar-powered cars and trucks—the change would take massive investment and at least 20 or 30 years to implement. At this point, we don't even have a clear idea of what might work. Some things being tried—such of as ethanol from corn—look to be very partial solutions at best. And the shortages of oil, natural gas and fresh water may be only a few years away.

Oil Depletion

In any single location, oil production typically rises for a number of years. Then, without warning (except through mathematical models), it begins to decline. Figure 1 illustrates oil production for the original 48 of the United States, for Alaska and for the North Sea. All show the pattern of rising production, followed by decline. The highest year for oil production in the United States was 1970. Eventually, we can expect that world oil production will begin to decline as well.

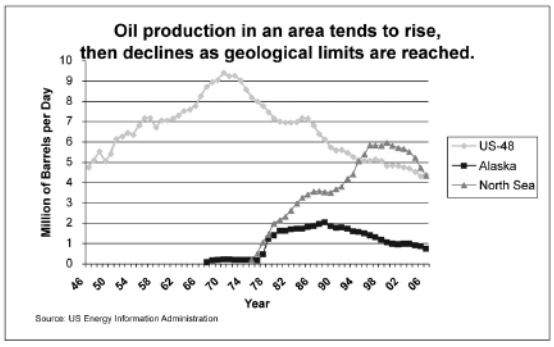

Figure 1

The reason production first rises, then declines, is that the available oil in a given location is being removed. To date, technology doesn't seem to

improve this situation. Instead, new technology seems to allow oil companies to remove oil faster, so that newly drilled sites empty more quickly.

The United States, Europe and Australia have now all reached irreversible decline in oil production, barring some major technical innovation. Mexico recently announced that Cantarell, its largest field, is exhausted, so its production can be expected to decline. Exports to the United States are expected to decline even faster, since Mexico, like other oil exporters, satisfies its own oil needs first.

Because oil is a finite resource, we know that even with technological improvements, eventually world production will begin to decline. How soon this will occur is subject to debate. Some believe the worldwide decline in oil production has already has already begun. According to data of the U.S. Energy Information Administration, the highest month of world crude oil production was May 2005. Production since then seems to be trending slightly lower, even though oil prices are high by historical standards.

Others are not convinced geological constraints have yet been reached, but are concerned about the fact that oil production is not rising, despite high prices. The U.S. Government Accountability Office in March 2007 issued a report called, "Crude Oil: Uncertainty about Future Oil Supply Makes it Important to Develop a Strategy for Addressing a Peak and Decline in Oil Production". The U.S. Energy Department asked the National Petroleum Council to look into the situation. Its report is called "Facing the Hard Truths about Energy" and includes forecasts by peak oil groups. The Association for the Study of Peak and Gas-USA forecasts a peak in world oil production between now and 2015.

Natural Gas

Natural gas is similar to oil, in that production in an area begins to decline once geological limits are reached. It is different from oil in that it is difficult to transport. For this reason, the North American natural gas market tends to be separate from that of the rest of the world.

For the United States, the highest year of natural gas production was 1973. Since then, a variety of measures have helped keep supply and demand in reasonable balance. Once supply started declining, the price of natural gas rose, and many industrial users moved their operations to other countries, where supplies were less expensive. Alternative sources (including coal bed methane) were found, and imports from Canada were increased.

Now, even these measures are beginning to fail; Canadian production is declining, and some of the alternative sources are reaching their limits. At the same time, demand is increasing. New gas-fired electrical plants have been built, and most of the new ethanol plants use natural gas. In Canada, the facilities that process oil sands are large users of natural gas.

To make up for the projected North American shortfall, the current plan is to import more liquefied natural gas (LNG) from overseas. It is doubtful that this plan will work because not enough LNG plants are being developed overseas to cover the gap. Countries are showing increased interest in keeping natural gas for themselves since gasoline is in short supply, and compressed natural gas can be used to power automobiles.

Fresh Water

Fresh water is needed for drinking and irrigation, but here too we are reaching limits. Water from melting ice caps is declining in quantity because of global warming. Water is being pumped from aquifers much faster than it's being replaced, and water tables are dropping by one to three meters a year in many areas. Even some rivers, especially in China and Australia, are close to dry because of diversion for agriculture and global warming. While one could theoretically increase the fresh water supply through desalination, this is an energy-intensive process, so oil and natural gas limitations become important.

Climate Change

For many years, researchers thought that climate change was likely to be a very slow process, with minimal change expected for the next 100 years. Recent research has shown that climate change isn't linear. Instead, there can be long periods with little change, followed by "tipping points," with changes of as much as 5 degrees Celsius (9 degrees Fahrenheit) possible in as few as 10 years.

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Such a change may make much of the world uninhabitable. Some predictions indicate that with a 5 degree Celsius increase, sea levels can be expected to rise and deserts can be expected to spread across much of the central latitudes. The remaining habitable land would be primarily in Russia and Canada.

We don't know enough about climate change prediction to know how close we are to a tipping point. We do know, however, that the pace of climate change seems to have increased in the past few years, with larger increases in temperature and stronger hurricanes and typhoons.

Can Technology Help?

While we've been trying to come up with solutions, success to date has been limited. There have been some successes in oil; deep water drilling, for example, has added some new production in recent years. But the new techniques haven't stopped, or even significantly slowed, the decline in older fields, and have had at most marginal impact on the percentage of oil in place that can be produced.

When we have tried to find substitutes, we've mostly managed to trade one problem for another:

- *Ethanol from corn.* As currently produced, uses large amounts of natural gas and fresh water to produce a surprisingly small amount of ethanol (20 percent of U.S. corn production to replace 2.4 percent of gasoline energy). Because of limitations on natural gas, fresh water and suitable land, production cannot be expanded significantly, and may need to be scaled back.
- *Oil from oil sands or oil shale.* Requires large amount of energy inputs, currently from natural gas, as well as large amount of fresh water inputs.
- *Coal to liquid and coal substitution for natural gas.* Likely to exacerbate global warming and raise pollution levels. If used to replace both oil and natural gas, coal is likely to deplete in less than 50 years.
- *Deeper wells for fresh water.* Requires more energy to pump the water farther. In locations that use aquifers that replenish over thousands of years, the available water will eventually be depleted.

There are a number of promising technologies—including solar, wind, wave power and geothermal—but the amount of energy from these sources is tiny at this time. Nuclear power also seems to have promise, but has toxic waste issues and is difficult to scale up quickly.

What's Ahead?

If we're not able to find technological solutions, the world may change very radically, very quickly. The following are some hypotheses regarding the kinds of changes we may see:

- *Lower economic growth rates and possibly long-term negative economic growth rates.* With fewer resources, economic activity is likely to decline. There will be a need to find replacements for many products simultaneously—heating fuel, transportation fuel, plastics, synthetic fabrics, fertilizer (currently made from natural gas), and asphalt, among other things. Living standards are likely to drop, because we don't have infinite resources for replacing all the things that are declining in availability.
- *Collapse of debt-based economies.* We are already experiencing a decline in credit availability. What happens if there is a long-term decline in economic growth as well? Once lenders realize the downturn is long-term, how many will be willing to make 10-year or 20-year loans? Our monetary system is based on debt—the continued contraction may overwhelm the system.
- *Failure of economic assumptions to hold.* In a world of constant shortages, an increase in demand will no longer result in an increase in supply. Substitutes may not be available. Oil producers may not willingly sell oil at any price—some may chose to keep oil in the ground to get a better price later, or may sell only to allies. Rationing may be necessary.
- *Increasing mortality and morbidity.* In the natural sciences, researchers often talk about "overshoot." Overshoot occurs when the population of a given type (deer, yeast, ants) grows rapidly in the presence of a limited resource, but then uses up this resource. One example is ants with a pile of sugar; another is yeast in a bottle of grape juice, which eventually becomes wine. Once the limited resource is used up, the population can't be maintained at its high level, and rapid population decline occurs.

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World population has grown rapidly in the presence of fertilizers made from natural gas, irrigation from non-renewable aquifers, and inexpensive transportation to bring food to market. Once these become less available, it's not clear that the world can maintain its current population level. Some forecast a decline to about 2 billion.

- *Climate change.* This is the wild card. If water levels rise significantly, coastal cities may be inundated, forcing large populations to abandon their homes and move inland. If deserts expand and aquifers deplete, large areas of the world may become uninhabitable. Fighting may occur over the limited resources that are available, further reducing population level.

Implications for Actuarial Assumptions

If the above hypotheses hold, there are clearly serious ramifications for the insurance industry. A collapse of debt-based economies could mean the end of insurance companies, at least until alternative non debt-based currencies can be established.

A somewhat more favorable scenario might occur if governments intervene and guarantee historical debt. But even this scenario wouldn't be very favorable for insurers, because massive inflation would likely take place as the result of more and more dollars being available to purchase fewer and fewer resources. Consumers would soon learn that a dollar today could be expected to purchase significantly less tomorrow. As a result, they would tend not to purchase long-term coverages such as whole life or long-term care. Furthermore, rampant inflation would make pricing and reserving a huge challenge for actuaries.

The pooling of risk on short-term contracts, such as health insurance, term life insurance, homeowners insurance and auto insurance may continue in a highly inflationary economy. Even for these coverages, though, significant changes are likely. For example, multiple families may move into a single house, to save on heating costs. This could leave other homes vacant, and more prone to vandalism. As noted previously, mortality and morbidity may increase, making past benchmarks less useful. Auto insurance may have better-than-expected results, because of declining auto usage.

Social Security and other government-sponsored retirement programs will need to be reconsidered in light of the declining resource base. With a declining base, there may be barely enough resources for those who are working, leaving little to spare for retirees and the disabled. Also, people will tend to have fewer children, once they realize how little promise the future holds. All these issues will make programs such as Social Security more difficult to maintain. If these programs remain at all, we might expect them to provide very limited benefits, applicable only to people at advanced ages.

What Can Actuaries Do?

The first step is to educate ourselves on the topic. Panel discussions on this topic can be added to actuarial meetings. There is much information on the Internet. I am on the staff of a Web site called TheOilDrum.com, which discusses "Energy and Our Future."

Another thing actuaries can do is look at our own actuarial models in light of some of the issues discussed in this article. If nothing else, this analysis may help us realize that predicting the future based on the past is much less certain than it was a few years ago.

We can also question current economic thinking. People expect that price signals will occur enough in advance of shortages so that adequate substitutions can be made. In fact, lead times of 20, 30, or even more years are needed, and the market doesn't come close to signaling needs that far in advance. Some other issues: Can economic growth be expected to continue in an era of reduced resource availability? Does the widespread use of debt continue to make sense? Does globalization make sense when transportation costs are very high?

Finally, actuaries can work to get governments (federal, state and local) to start addressing these issues. Even though the likely future decline in oil and gas production has been known since the days of Jimmy Carter, little has been done to address this issue since he left office. Actuaries can work to see that this changes.