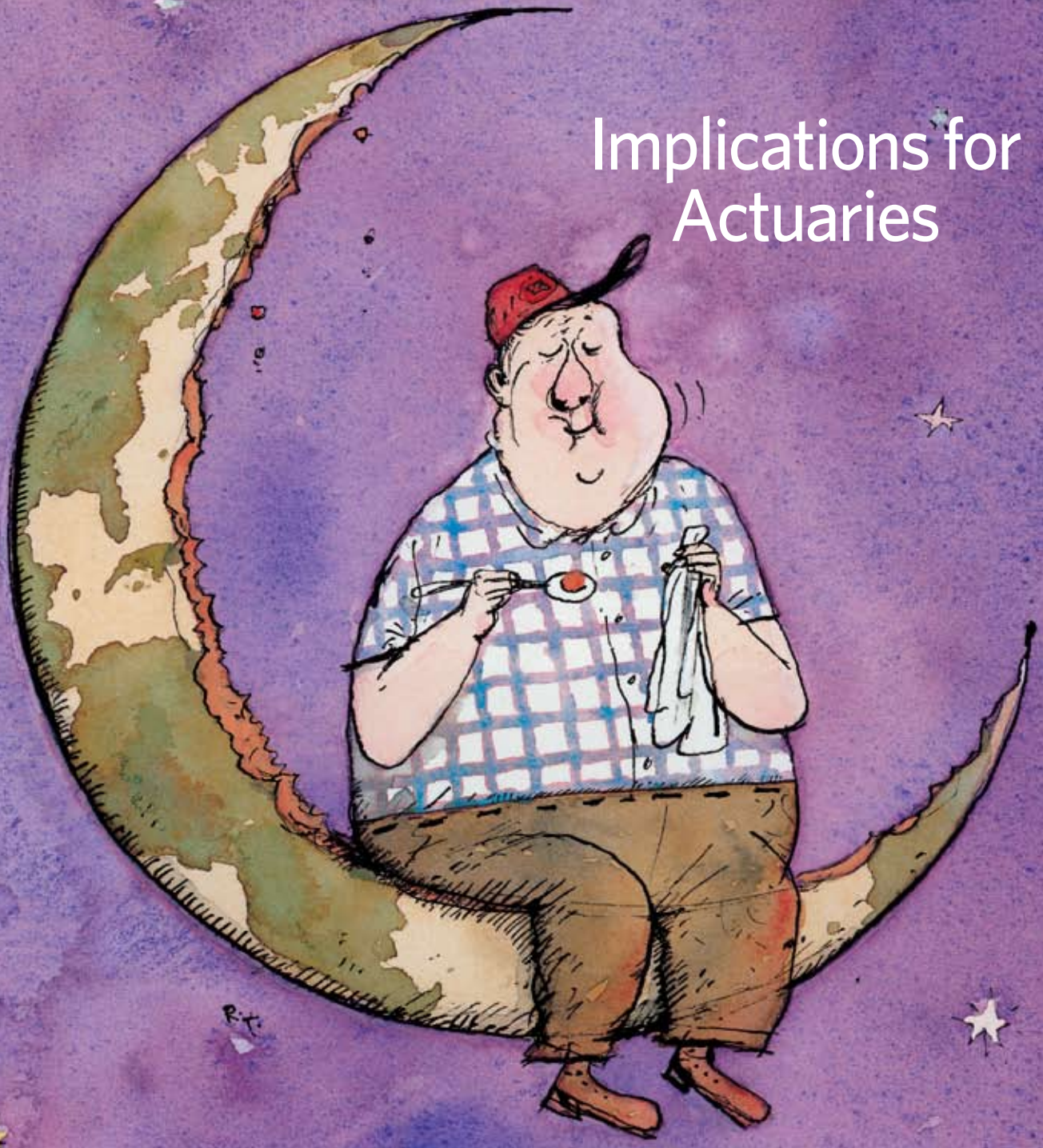
Our Finite

Implications for Actuaries



World

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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 what might work. Some things being tried—such 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.

The world is running out of the natural resources we depend on. So why are we still behaving as if they'll last forever?

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. Fig. 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.

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.

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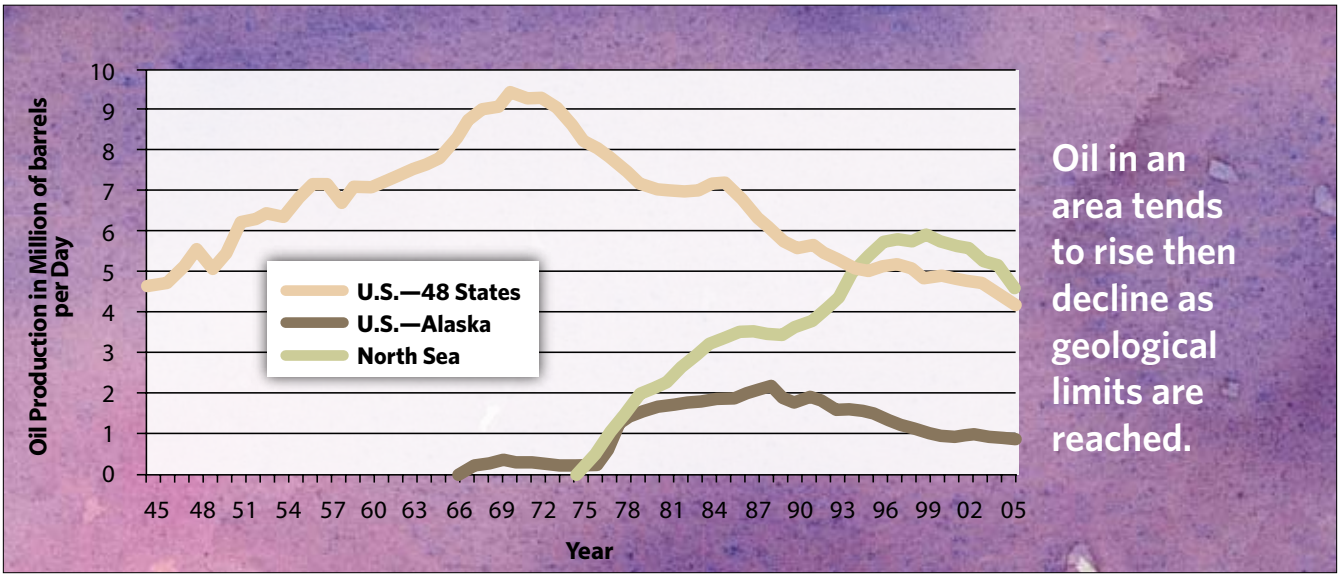

There is a significant possibility that other major producers are at or near the point of declining production as well. Six of the eight largest oil producers, including Saudi Arabia and Iran, are now showing production declines. Saudi Arabia indicates that its decline in production is voluntary. We can't know if this statement is true, or if it's simply cover for declining production due to geological constraints.

How can Saudi oil production reach geological limits? Haven't we heard time and again about its limitless reserves? The "proven reserves" of many countries in the Middle East are being questioned because they seem to be at odds with information from other sources. Matt Simmons (an adviser to the Bush administration), in his book *Twilight in the Desert*, concludes that not only are Saudi Arabia's reserves significantly overstated, but production from its largest field is close to geological decline.

Because oil is a finite resource, we know that even with technological improvements, all countries will start to show declining oil production. Mathematical models generally suggest that worldwide production will peak between 2005 and 2012, but some analysts believe the decline won't occur until 2020 or later. If the recent decline in Saudi production is due to geological constraints, there is a significant possibility that the decline in worldwide oil production may begin in the next year or two.

Natural Gas

Natural gas is difficult to transport, so it tends to stay in its own local markets. Major users of natural gas, including Europe and the United States, are now discovering that their own supplies are declining, and new plans will need to be made.

To make up for its shortfall, Europe plans to import natural gas from Russia via pipeline. Some are concerned about this plan, because it's not clear how reliable a supplier Russia will be.

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's not clear that this plan will work, because a huge amount of LNG will be needed. Countries that might theoretically produce LNG in the required quantities, such as Russia and Iran, are talking about forming a cartel.

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 global warming and diversion for agriculture. 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.

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.

Some of the recent global warming seems to be resulting in positive feedback loops. For example, melting permafrost releases methane gas, which in turn increases global warming. The current situation is of sufficient concern that we're being warned to take steps to reduce carbon emissions, so as to try to mitigate further warming.

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, 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 inputs to produce a combustible liquid for autos. 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 be depleted 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 it 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. Further research is needed regarding precisely what changes can be expected. The following are some hypotheses about 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 know that an economy that's growing at 5 percent per year can coexist with interest rates in the 5 percent range. But can all of today's debt be serviced if there is a long-term decline in economic growth? There is also the issue of massive write-offs when huge chunks of the economy no longer make economic sense. Furthermore, once lenders realize the downturn is long term, how many will be willing to make 10-year or 20-year loans?
- **Failure of economic assumptions to hold**. We've been raised in a world where supply and demand are generally in balance. An increase in demand results in a greater price, which in turn leads to a greater supply. If the particular item isn't available, substitution is generally possible.

Once we reach geological limits, these basic principals seem much less likely to hold. An increase in energy demand won't translate into greater supply. Distribution of the limited available supply seems likely to reflect considerations other than price, such as rationing and long-term alliances. There may also be military conflict over available supplies.

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- **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.

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 levels.

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 very 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. Increases in hurricane strength and the number of forest fires as the result of global warming may adversely affect both homeowners' coverage and auto coverages.

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 to go around 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.

How Did We Get Into This?

Fifty years ago, in 1957, Rear Adm. Hyman Rickover made a speech (see resource list) in which he pointed out the close association between the rise in the standard of living and the increased use of fossil fuels. He also pointed out that fossil fuels were a finite resource and could be expected to become less available because of depletion between 2000 and 2050—oil and natural gas at the beginning of that period, coal at the end of it. He said his generation should "think soberly" about its responsibility to future generations. Students should be taught about the expected decline in fossil fuels, so they can start making plans to handle the difficult transition.

Why wasn't the educational effort Rickover advocated undertaken? This may be related to another issue he talks about in the same speech: the close association between energy consumption and political power. The country with the most energy resources will dominate and those with little energy will be at the bottom of the pecking order. People in political power know this and try to spin their energy-related announcements accordingly.

Given this background, it's not too surprising that American textbooks omit the story of America's decline in oil and natural gas production since the early 1970s. Omitting this story also conveniently omits other related topics, such as the role this decline played in the U.S. transition to a more service-based economy and the bigger issue: the expected worldwide decline in oil and gas production.

As the result of these omissions, most of today's population grew up believing that the world's energy resources are infinite. This has had multiple ramifications:

- Little effort has gone into quantifying the world's fossil fuel resources. Instead, each country's pronouncements have been accepted at face value and even inflated because of anticipated "reserve appreciation." Knowledge of true oil reserves is poor; knowledge of true natural gas reserves is even worse.
- Economic theory has grown up in a period of expanding (worldwide) fossil fuel resources, without realizing that this is likely to be a temporary situation. We hear much about the role of labor and capital but little about the role of adequate energy supplies. Long-term economic growth is practically accepted as an axiom, with no thought as to whether this makes sense in a finite world.
- Researchers trying to solve the oil-shortage problem, through substitutes such as ethanol from corn and oil from oil sand or shale, haven't understood that natural gas shortages are likely to be just as severe a problem as oil shortages, in virtually the same time frame. Because of this, the substitutes seem to trade an oil shortage for an even quicker gas shortage.

What Can Actuaries Do?

The first step is to educate ourselves on the topic. A list of suggested reading is provided with this article. There is also much information on the Internet, and panel discussions on this topic can be added to actuarial meetings.

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 economic models. Actuaries are known for their long-term view of issues. Even though we're not economists, we should be questioning current economic thinking, which tends to be short term and doesn't account for likely shortages in the long run. In many people's thinking, supply is determined by weekly oil and natural gas inventories, even though these are tiny compared with the rapidly depleting worldwide supplies. People expect that price signals will occur enough in advance of shortages 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. We should be pointing this out to decision-makers.

Economists seem to view the past 60 years as typical of what can be expected in the future. Yet, looking at the broader picture, we can see that the past 60 years reflected rapidly growing fossil fuel use, and the future is likely to reflect the opposite. Economic models need to be reviewed in this light. What's the expected relationship between stock prices and inflation when fossil fuel use is declining? 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?

The United States does not at this time have any long-term plan for dealing with depletion issues and climate change. We don't know, for example, whether we should be moving toward nuclear energy and electric cars or toward more trains and bicycles. There are two issues: making our political leaders aware of the need for a plan and determining what this plan should be, considering all the questions involved. Developing a plan will require individuals from many disciplines. Actuaries would seem to be able to play a key role in this, given their modeling skills and long-term view of situations.

Clearly, there is much to be done. We can hope that many of us will choose to be involved. ●

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Resources

"Crude Oil: Uncertainty about Future Oil Supply Makes It Important to Develop a Strategy for Addressing a Peak and Decline in Oil Production." Government Accountability Office. http://222.goa.gov/new.items/d07283.pdf

"Energy Resources and Our Future," speech by Rear Admiral Hyman Rickover on May 14, 1957. http://www.energybulletin.net/23151.html.

The Empty Tank: Oil, Hot Air, and the Coming Global Financial Catastrophe, Jeremy Leggett, Random House, 2005.

The Long Emergency: Surviving the Converging Catastrophes of the Twenty-First Century, James Howard Kunstler, Atlantic Monthly Press, 2005.

Twilight in the Desert: The Coming Saudi Oil Shock and the World Economy, Matthew R. Simmons, John Wiley and Sons Inc., 2005.

"The Oil Drum"—http://www.theoildrum.com/ Blog with many reports and discussions relating to expected oil and gas shortages and climate change.

Speeches by Matthew R. Simmons of Simmons and Co. International—http://www.simmonsco-intl.com/research.aspx?Type=researchspeeches