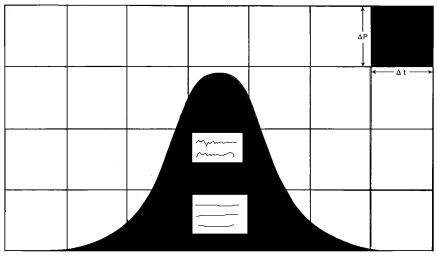


M. KING HUBBERT CENTER FOR PETROLEUM SUPPLY STUDIES

M. KING HUBBERT CENTER
Petroleum Engineering Department
COLORADO SCHOOL OF MINES
GOLDEN CO 80401-1887

When Will The Joy Ride End?
A Petroleum Primer

Randy Udall & Steve Andrews

BLACK MAGIC During the last century oil has transformed the world. British coal launched the Industrial Revolution, but American oil put the pedal to the metal. No other material has so profoundly changed the face of the world in such a short time. Petroleum is black magic, the lifeblood of our civilization. The petroleum industry provides 40% of the globe's energy and is humanity's largest commercial enterprise. Oil is our most concentrated, flexible, and convenient fuel. Without petroleum there would be no automobile industry, no tourism. Without petroleum 2% of Americans could not feed the remaining 98%. But oil is more than energy. It's the key feedstock for plastics, medicines, clothing, pesticides, paint, and thousands of other products. Fueling Toyota or fabricated into Tupperware, petroleum is the world's premier commodity. Soon, experts say, world oil production will reach an all-time high, an apex, a *peak.* Then, after a short plateau, it will decline forever. What historians will someday call the Oil Era will last only about 250 years. In 1999 we are closer to the Era's end than to its beginning.

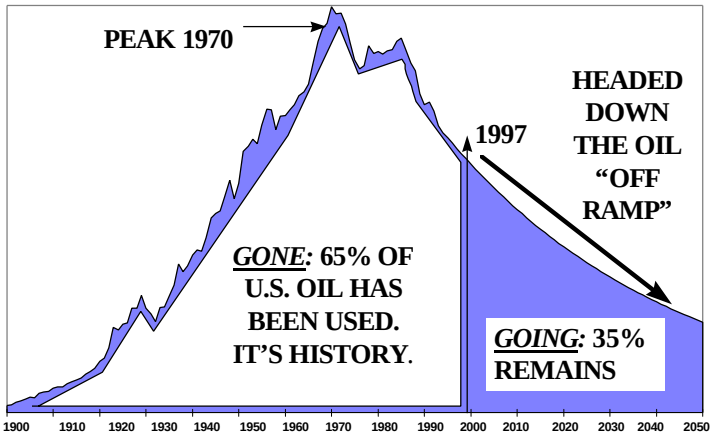
THE OIL TRIBE In 1859 oil was struck in Pennsylvania. The magic fluid unleashed Yankee ingenuity, put America on wheels, and helped to create the world's richest superpower. The transformation was unimaginably swift: In 1859 Americans traveled on horseback; in 1969 they drove Mustangs and flew to the Moon. Today it is difficult to overstate oil's importance to our economy. The U.S. has four percent of the world's people, but uses 25% of the world's oil. We are an Oil Tribe, the Petroleum Clan, imbibing about 3 gallons per person per day. The automobile is our most cherished icon, a new car our symbol of success. The local gasoline station is our secular temple where each week 150 million Americans "fill 'er up." An average American drives 1,000 miles a month, 12,000 miles a year, the distance to the Moon every 20 years. The Oil Tribe numbers 270 million. Hungry for speed, addicted to motion, we consume our weight in petroleum every 7 days.

HC#99/1-1-1
JANUARY, 1999

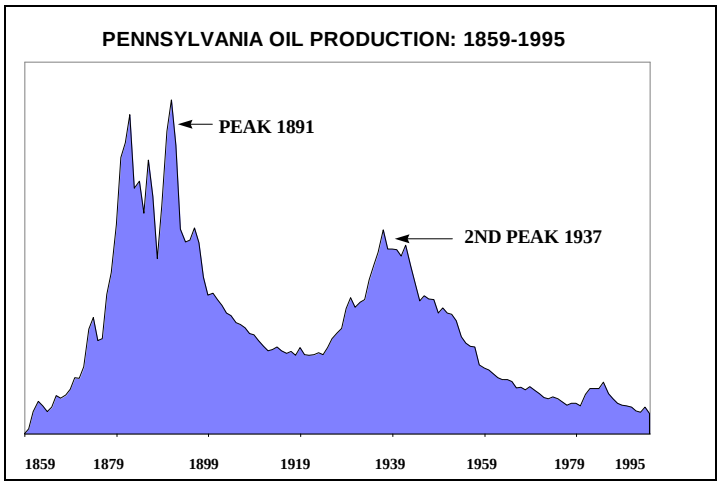
BLESSED BY GEOLOGY Cheap oil has always been an American birthright. Through fate and geology, the United States was extravagantly blessed. Our original cargo was about 260 billion barrels; only one country, Saudi Arabia, had more. Oklahoma alone possessed more oil than Germany or Japan. California had more than Germany, Japan, France, Spain, Denmark, Sweden, Finland, and Italy combined. The U.S. has—or rather *had*—20 times as much oil as India, 10 times as much as Brazil, 3 times more than China. From 1859 to 1939 the U.S. produced two-thirds of the world's oil. After Japan attacked Pearl Harbor in oil-starved desperation and Hitler failed to capture Russia's Baku oil field, American petroleum, and the industrial output it nourished, triumphed in World World War II.

STRENGTH THROUGH EXHAUSTION
As recently as 1950 the U.S. was producing half the world's oil. Forty-eight years later, we don't produce half our *own* oil. Domestic production peaked in 1970, 29 years ago, and today we produce just 45% of the crude we consume. To fuel our economy we've drilled more and pumped longer than any nation on Earth, pursuing an oil policy that's been called "Strength Through Exhaustion." Although the U.S. remains the world's third largest producer, about 65% of our known oil has been burned. It's downhill from here.

U.S. OIL PRODUCTION 1900 TO 2050

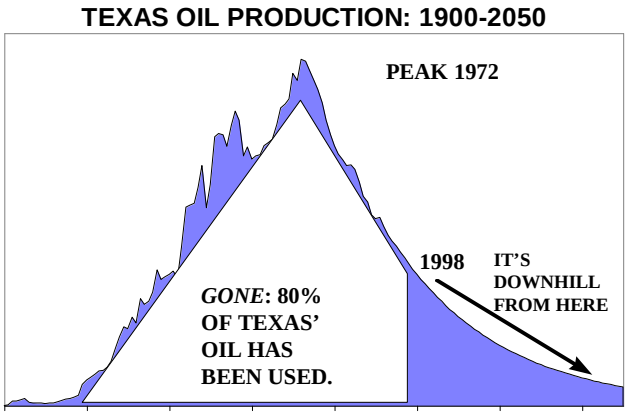


LIKE DEATH AND TAXES Perhaps for the same reason that State Farm sells life insurance rather than death insurance, oil companies shun words like *extraction* and *depletion*. Instead they prefer *production*, as in "Chevron produces oil." This implies that we can manufacture oil at will, the way we do jeans or computers. In truth, petroleum reserves are finite and depletion is a reality like death and taxes. To grasp this concept, consider Pennzoil. Our most famous motor oil honors the state where the Oil Age began. Prior to the automobile, most oil was burned in kerosene lamps. For the first 25 years of the Oil Era Pennsylvania was the world's leading producer. In 1891 the Quaker State produced enough oil to light the U.S. for 7 *months*. Today the state's oil could power the U.S. for only 3 *hours*. The 19,000 wells that remain in Pennsylvania collectively produce 6,900 barrels each day. In contrast, Saudi Arabia produces 8 million barrels per day—1,100 times as much—from just 1,400 wells.
HC#99/1-1-2



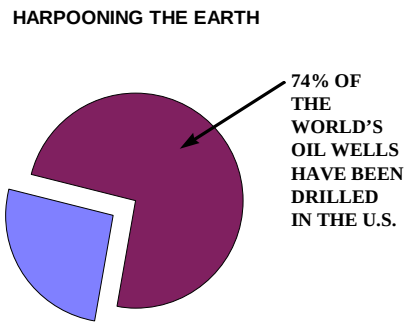
A typical Pennsylvania oil well produces 15 gallons per day; an average well in Saudi Arabia, 231,000.

GUSHERS IN TEXAS As nineteenth century oil prospectors, some of them retired whalers, continued to harpoon the Earth, strikes were made in New York, Ohio, Oklahoma, and then, Texas. Texas was a gusher, America's first world class find. If Texas had been a sovereign country, its oil riches would have placed it in the world's top ten. The state's original reserves were 6 times greater than those of India, twice as large as Brazil or Norway. Texas was big, as big as the braggadocio it came to symbolize. For the last 70 years the state has been America's leading oil producer. But production in Texas peaked in 1972 and has been declining rapidly since. According to the American Petroleum Institute, about 80% of all the oil that will ever be produced in Texas is gone. (Indeed, the state now imports about $5 billion worth of oil each year.) The Texas peak is not an anomaly. Thirty-one states produce oil and all are past their peaks. Oklahoma peaked in 1927, Colorado in 1956, Wyoming in 1970, Alaska in 1988, California in 1985.



Texas is gradually going out of the oil business.

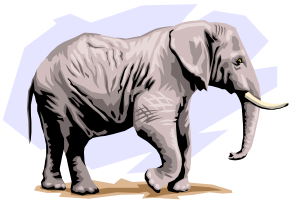
SWISS CHEESE Well, ok, if Pennsylvania and Texas are played out, why not drill more wells somewhere else? In fact, the U.S. is already one of the most thoroughly explored and drilled countries on Earth. Of the 4.6 million wells worldwide, 3.4 million have been drilled in this country. Very very few prospects remain. With the exception of the Arctic National Wildlife Refuge and a few deep water basins, we've been there and done that. From the oil industry's perspective, the U.S. is Swiss cheese.



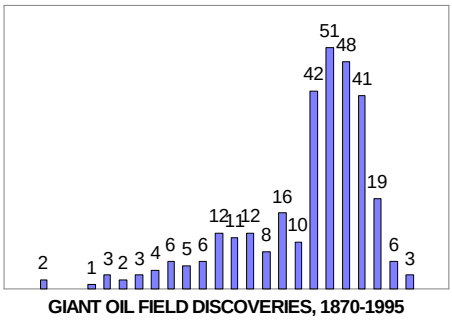
THE LAST HURRAH The oil industry employs many smart, inventive, and creative people. Many of the industry's new exploration techniques, computer software, and drilling methods are being put to good use in the Gulf of Mexico. There, the oil majors are drilling in an astounding 5,000 feet of water, with 10,000 feet soon to come. Analysts expect the Gulf to be America's last great bonanza. A mile under the ocean floor may lie 15 billion barrels. It's a lot of oil, but only as much as the nation uses every 2.5 years.

HARD ROCK CAFÉ Is there really no substitute on the petroleum menu? Our natural gas reserves wouldn't last long if we burned them in both homes and cars, but what about all that "unconventional" oil tied up in Canadian tar sands, Venezuelan heavy oil, and Colorado oil shale. Unfortunately, producing unconventional oil has more in common with hard-rock mining than with typical oil production, where you crank a valve and let if flow. The former is a slow, arduous, energy-intensive process that may never replace even a tenth of today's conventional oil. Indeed, there's some question whether oil shale yields more energy than it takes to produce it. If conventional oil is black magic, oil shale is fool's gold.

HC#99/1-1-3

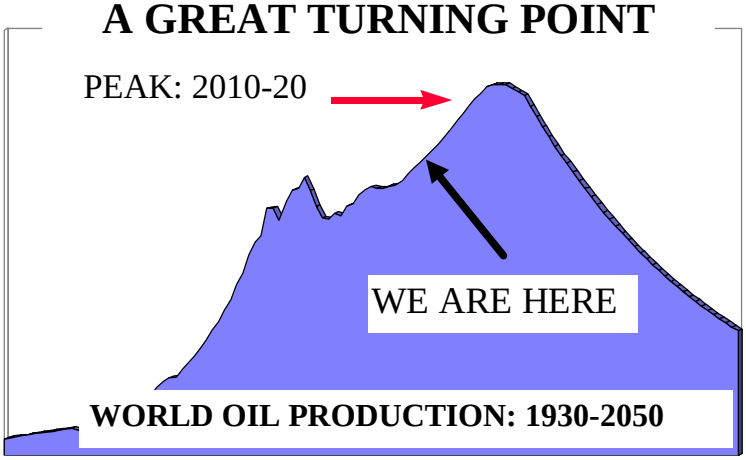


HUNTING ELEPHANTS Ghawar. Burgan. Safaniya-Khafji. Zakum. These are the strange, unfamiliar names of the four largest oil fields in the world. Oil occurs rarely in nature and when it does it's often concentrated in large amounts. About 70% of the world's petroleum is found in 370 giant fields, nicknamed "elephants" because they are so huge. Western civilization—life as we know it—is based on these elephants. In part because they are so big, the elephants were easy to find and inexpensive to produce. (To get oil out of Ghawar, for example, costs the Saudis less than $1 per barrel.) But it's getting harder and harder to find new giant fields. Indeed, many geologists believe that only a handful of elephants remain unfound.



The discovery rate for 'elephants' peaked in the 1960s. Few are left to find.

THE COMING PEAK In the same way that U.S. oil production peaked in 1970, global oil production is destined to peak during the first two decades of the coming century. Some analysts expect a peak around 2005; some suggest it will be 2010; others believe it will come as late as 2025. The exact date can't be predicted, since it will depend as much on economic and political factors as on geology. The biggest wild card? Saudi Arabia, the world's most prolific oil province. If the Saudis invest hundreds of billions of dollars they could double their output to meet expected demand. But they may decide not to double production, choosing instead to produce somewhat less oil and charge more for it. Although predicting the peak is impossible, this turning point is near.



COLLISION IN SLOW MOTION A *decline* in world oil production? The prospect seems unlikely, especially with oil prices at all-time lows. Although it's hard to imagine sharply higher oil prices during an oil glut, what seems unlikely is inevitable. The crunch may arrive suddenly. Or in slow motion. As former Energy Secretary Don Hodel says, "We're sleepwalking to disaster." When it happens, journalists will shout, "We're running out of oil." That's not true. Rather, we are running out of *cheap* oil. After production peaks oil will be readily available at a higher price, though in declining amounts, for at least 50 years. What we face is not a short-term crisis but a chronic shortfall. No one will freeze in the dark (America's reserves of natural gas and coal should last 60 years and 150 years respectively), but the transition to more expensive oil could be bumpy.

HC#99/1-1-4

GIMME THAT OIL TIME RELIGION Of course, not everyone agrees that we face an imminent crisis. (In part, it depends on how you define "imminent." Some people define it as "before I'm dead.") In 1998 *Business Week* ran a cover article on global oil. The take home: don't worry, be happy, Exxon has you covered. Energy Secretary Richardson talks hopefully about "reversing the decline in U.S. oil production." This is whistling past the graveyard. There's not that much oil left to find in the U.S. That's why the oil majors are trying to muscle in on Russia's Caspian Sea, 9,000 long miles from home. How the Caspian qualifies as "our oil" is not clear. The Chinese need it as badly as we do. Nonetheless, Henry Kissinger and Dick "Desert Storm" Cheney are lobbying to gain U.S. companies preferential treatment.

OPEC REDUX As the U.S. produces less oil, we must import more. Indeed, America *imports* more oil than any other nation *uses*. Uncle Sam's appetite is humongous, verging on gluttony. We import more than Denmark, Finland, France, Germany, Greece, Italy, Norway, Spain and Sweden collectively use. And why not, because at $10 to $15 a barrel, imported oil is a steal. The tab for 1998 will be about $50 billion, less than 1% of the nation's gross domestic product. The bargain may not, indeed can not, last. As global population and oil demand rise, more and more people will be competing for less and less oil. By 2015, only a handful of nations will be exporting significant quantities, and a revitalized Organization of Petroleum Exporting Countries, our old OPEC nemesis, will be in the driver's seat again, able to control prices at will. Since Saudi Arabia, Iran, Iraq, and Kuwait can sustain their projected production past 2020, the world will not suddenly "run out" of oil. But $10 a barrel will be a thing of the past.

REALITY CHECK Which nations have oil and which nations use it? Fully two-thirds of the world's oil is in five Muslim countries. The chart at right explains why Iraq's Saddam Hussein gets press, why the State Department frets about Iran, why the U.S. military did not leave Saudi Arabia after the 1990 Gulf War, and why we fought that war in the first place. (George Bush: "Our way of life is at stake.") America's future, Japan's future, Europe's future, China's future…all are inextricably linked to the Middle East. In the deserts of Saudi Arabia, the U.S. military is building fortified air bases. Ostensibly we are there to protect our Saudi friends. In reality, we are an occupying force protecting our access to their oil. Some Saudis are resentful of our presence, as we would be if they were building air bases in Nevada. Would we leave Saudi Arabia if asked? That's a very interesting question.

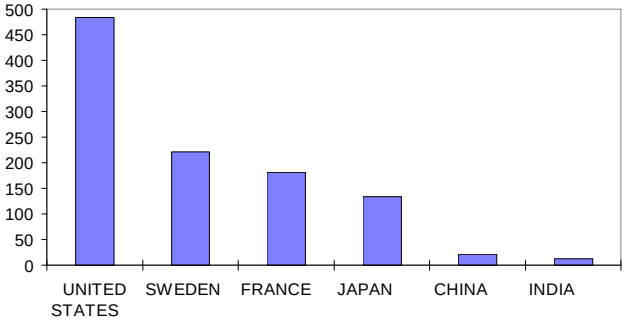
GOT OIL		USE OIL	
• SAUDI ARABIA	26%	• U.S.	25%
• IRAQ	10%	• JAPAN	8%
• KUWAIT	10%	• CHINA	5%
• ABU DHABI	9%	• RUSSIA	4%
• IRAN	9%	• GERMANY	4%
• VENEZUELA	6%	• S. KOREA	3%
• SOVIET UNION	5%	• ITALY	3%
• MEXICO	5%	• FRANCE	3%
• U.S.	3%	• ENGLAND	3%

Left, five countries in the Middle East have two-thirds of the world's remaining oil. Right, the largest oil consumers. The U.S. uses three times more than Japan, eight times more than England.

HC#99/1-1-5

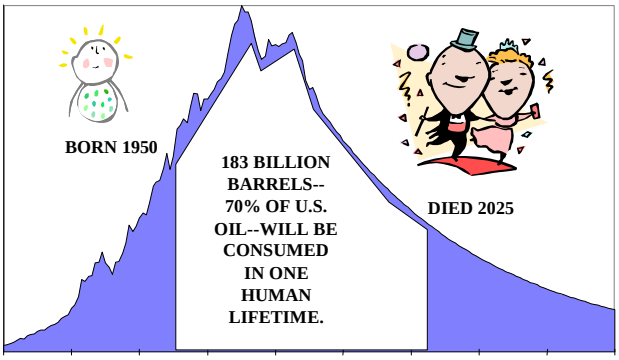
ROAD WARRIORS In 1900 oil married the automobile. Together they gave birth to a century of travel. Today oil is so thoroughly woven into the fabric of America that we can't imagine life without it. Fish don't worry about water and Americans don't worry about oil. Instead we swim in it. Think of your life: skiing on the weekend, Thanksgiving at mom's, a conference in Chicago. Middle-class Coloradans do their Christmas shopping in Minnesota at the Mall of America. Texans drive 1,000 miles to shoot a Colorado elk, hunting-and-gathering taken to new extremes. Of course, petroleum doesn't just propel us. It feeds us too. Oil is absolutely fundamental to agribusiness: the average potato travels 750 miles.

ANNUAL GASOLINE CONSUMPTION: GALLONS PER PERSON



FROM THE CRADLE TO THE GRAVE More than half the world's oil—and 70% of U.S. oil—will be consumed during a single human lifetime. That span happens to coincide with the Baby Boomer generation born after World War II. The Boomers were conceived as auto culture kicked into overdrive. As newborns, they were driven home from the hospital in a car. They grew up listening to songs like *Mustang Sally* and *Little GTO*. Getting a driver's license was their rite of passage. During their lives many Baby Boomers will drive and fly a million miles, equal to 40 trips around the globe. Magellan and Amelia Earhart were the famous circumnavigators of their day. Now every man is Magellan, every woman Amelia.

THE BABY BOOMERS' LEGACY



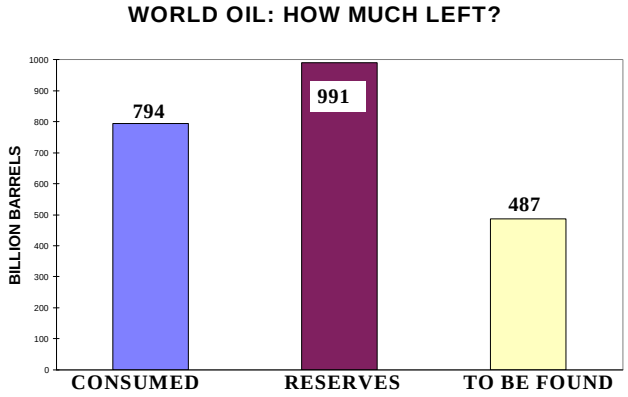
U.S. OIL PRODUCTION 1900-2080

CAR BOMB In the last fifty years the human population has doubled. In the same period, car numbers have grown *tenfold* from 50 to 500 million. Autos, in other words, are reproducing five times quicker than people. They are breeding like (VW) Rabbits. A new car is born each second.

WHO WILL FUEL CHINA? From Asia to Africa, three billion people crave the automobile lifestyle. Who can blame them? Mobility is wonderful. But Asia is oil poor. India has almost no oil and high hopes for new discoveries in the Tarim, a frontier basin in western China, have not been realized. Without large domestic reserves it will be impossible for China and India to develop an oil-intensive lifestyle. If India and China used as much oil per person as we do, world production would have to *triple*. It can't; there's not enough oil. Looking ahead, the tremendous inequities in oil distribution—and consumption—are morally troubling and militarily worrisome. As Americans continue to guzzle oil and more Asians take to the road, oil demand will eventually outstrip oil supplies. Prices will rise. Economic jousting for oil—who can pay most—is certain. Military confrontation can't be ruled out. With the U.S. using three times more oil than any other nation, future generations of young Americans may be forced to take the battlefield once more for oil.

HC#99/1-1-6

FLOW, RIVER, FLOW The global economy now consumes 74 million barrels of oil each day. That modest river moves every car in Canada, China, and Chile. Every Boeing, every Airbus. Semis, trucks, bulldozers, B-1 bombers, motorcycles, supertankers, tractors, snowmobiles…all powered by oil. Looking ahead, once Asia recovers economically, demand may increase rapidly. By 2010 most experts predict the world will be consuming 90 million barrels a day, 20% more than it does now. Sometimes between 2010 and 2020, world oil production will reach an apex, an all-time high, a *peak*. A plateau in production will be followed by a relentless inexorable decline.



The world has used 35% of its conventional oil. The reserves will be gone by 2035. By 2050, 9 billion people will use only as much oil each dav as 3 billion did in 1950.

CRYSTAL BALL GAZING If oil depletion is a slow, wasting disease, is there a quick fix, a miracle cure? There are some exciting new developments. They include technology for converting natural gas to a diesel-like fuel; horizontal drilling and 3D imagery to recover more oil from aging fields; cars powered by hybrid electric drives and by hydrogen fuel cells; telecommuting and other social changes that reduce oil consumption. All can buy time and delay the peak. None, though, will cure depletion, or greatly reduce America's dependence on imported oil. Technology shows promise, but the negative trends remain more powerful. Every day the world uses 74 million barrels and finds 15 million. Consumption up, discoveries down. Burning more than we earn--a surefire recipe for bankruptcy.

BULLS & BEARS World oil experts fall into two camps, bulls and bears. Both agree we've used 800 billion barrels. The bears think there's 1 trillion left and that production may peak by 2010. Bulls think there's 1.8 trillion left and that the peak won't come until 2020. If ten years is the only difference between them, perhaps we ought to begin planning for a world in which oil is not as abundant as it is today.

LIFE IN 2050 By 2050 nine billion people will be consuming only as much oil as three billion did in 1950. That is, there will be three times less oil per person. Oil will be more expensive. Is this a Doomsday message? Not necessarily. A more sustainable world may actually be a better place in which to live. The difficulty is getting from here to there.

WHY HAVEN'T I HEARD THIS BEFORE? Who would tell you? Exxon? Ford? Bill Clinton? *"Remember my Bridge to the 21st Century? Well, there's a big pothole on the far side. I'm sending Al over there right now to patch it up.* It's astounding that, in a country like ours, which uses 25% of the world's oil, no one is responsible for setting oil policy. The oil majors produce oil. Carmakers make cars. The Pentagon spends $50 billion a year safeguarding our "cheap" Persian Gulf imports. The U.S. Department of Energy cleans up nuclear bomb plants. If ignorance is bliss, this must be Nirvana.

HC#99/1-1-7

SOURCES This petroleum primer was written by Randy Udall, Director of the Community Office for Resource Efficiency, a nonprofit energy office in Aspen, Colorado. The co-author was Steve Andrews, Denver-based energy analyst. Our numbers and graphs were derived from U.S. Geological Survey, British Petroleum, and American Petroleum Institute reports. Oil consumption to 1997 is historical record. Depletion curves and future consumption were extrapolated from conservative assumptions and personal interviews with world oil experts, including Chuck Masters, Neil Foreman, L.F. 'Buzz' Ivanhoe, Colin Campbell, Joseph Riva, and James MacKenzie. No one can predict the future. But, on the strength of our research, America can expect a wake-up call before 2020. It could come tomorrow. Even 2020 is only 8,000 days away, which, given the stakes, isn't far.

The Authors:

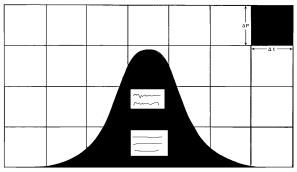
Randy Udall runs the Community Office for Resource Efficiency, a nonprofit energy office in Aspen, Colorado. He has contributed articles on energy and energy efficiency to Audubon, Sierra, the Denver Post, and Los Angeles Times. In October 1998, Udall and Andrews organized a World Oil Forum in Denver, Colorado.

Steve Andrews has been a Denver-based energy consultant and freelance writer since 1980. A graduate of Colorado College (1968), most of his work focuses on issues and opportunities in the energy consumption sector (transportation, residential and commercial), not the energy supply sector.

Randy Udall, Director
CORE
Box 9707
Aspen, CO 81612
(970) 544 9808
rudall@aol.com

Steve Andrews
3301 S. Bellaire St.
Denver CO 80222
303-759-1998 phone/fax
sbandrews@worldnet.att.net

H.C. NEWSLETTER



The M. KING HUBBERT CENTER FOR PETROLEUM SUPPLY STUDIES
located in the Department of Petroleum Engineering
Colorado School of Mines
Golden, Colorado

The Hubbert Center has been established as a non-profit organization for the purpose of assembling and studying data concerning global petroleum supplies and disseminating such information to the public.

The question of WHEN worldwide oil demand will exceed global oil supply is stubbornly ignored. The world's oil problems, timing and ramifications can be debated and realistic plans made only if the question is publicly addressed. A growing number of informed US and European evaluations put this crisis as close as the years 2000 - 2014. The formation of this center is to encourage a multi-field research approach to this subject.

For further information contact:

Hubbert Center Chairman
Prof. Craig W. Van Kirk
Head of Petroleum Engineering Dept.
Colorado School of Mines
Golden CO 80401-1887
Phone 1-800-446-9488
Fax 1-303-273-3189
Internet Address: *http://hubbert.mines.edu*

Hubbert Center Coordinator
L. F. Ivanhoe
1217 Gregory St.
Ojai CA 93023-3038

Phone 1-805-646-8620
Fax 1-805-646-5506

Notes:
This is one of the Hubbert Center's quarterly newsletters. Please retain for reference.

The views expressed by authors of Center publications are their own, and do not reflect the opinions of Colorado School of Mines, its faculty, its staff, or its Department of Petroleum Engineering.

The Hubbert Center welcomes pertinent letters, clippings, reprints, cartoons, etc.
The Hubbert Center will archive work files of recognized experts in this field.
Contributions to the Hubbert Center through the CSM FOUNDATION INC. are tax-deductible.