# 6

# Coal, Natural Gas, Tar Sands: More Greenhouse Gases at Higher Cost

*"Unless we free ourselves from a dependence on these fossil fuels and chart a new course on energy in this country, we are condemning future generations to global catastrophe…. So why can't we do this? Why can't we make energy security one of the great American projects of the twenty-first century? The answer is we can."*

– U. S. Senator Barack Obama,
*The Coming Storm*, April 3, 2006

**Can the other fossil fuels save the day? *No.***

- The other fossil fuels all emit greenhouse gases and increase global warming.
- Coal and natural gas cannot replace oil for transportation.
- Coal is a major source of greenhouse gases and acid rain; natural gas supplies are limited.
- Tar sands are an eco-disaster for air, land and water.
- Oil shale is one of the most environmentally destructive processes in the world; fortunately the commercial technology is not now economical.
- Investing in obsolete or destructive technologies delays our transition to clean, sustainable energy.

## Can the Other Fossil Fuels Fill the Gap?

Comedian and magician Robert Orben summed up our environmental problem in one cynical statement: "There's so much pollution in the air now that if it weren't for our lungs, there'd be no place to put it all."

There *is* more carbon and sulfur in our atmosphere than ever before. There *is* more mercury in our water than ever before. There *are* more people on the planet than ever before. And, there *are* more fossil fuels being burned than ever before.

This is no coincidence. Rather, it is the "price of progress" *within the dominant fossil-fuel paradigm*. Amazingly, all this pollution was never inevitable. We learned long ago from the Industrial Revolution that technology could advance without the sacrifice of breathable air. (For example, London banned certain uses of coal in the 20th century when it became apparent that the permanent smoke in London was too high a health price to pay for household warmth.)

In America, however, the current challenge of pollution created as a by-product of technological advancement is the outcome of a democratic system in which special-interest lobbies, such as the fossil-fuel industry, were allowed to run roughshod over the public interest.

A consequence of industrialized nations choosing to be addicted to the fossil-fuel paradigm is that we are now sitting poised at a time when global economies will deteriorate and global temperatures will gradually rise unless we finally heed the wakeup call of the energy and climate crisis.

Twenty-seven years have passed since the Iranian Revolution and the last OPEC oil shocks of the 1970s. Now, a second crisis is emerging on a global scale—a perfect storm of peak oil, geopolitical insecurity, global climate change, and China's and India's energy appetite to fuel their explosive economic growth. We have now entered the endgame of the era of cheap oil. The U.S. has one last chance to shift away from fossil fuels and to make a relatively peaceful and orderly transition to a new energy economy.

Every American business and consumer has felt the effects of high oil prices at the pump. Deep down, we all wish for one of two things: permanently lower gas prices or cheap replacements for oil that will not fundamentally change our way of life.

Frequently, the "Big Four" are touted as alternatives to oil. They are also known as the "other fossil fuels"—natural gas, coal, tar sands, and oil shale. If we want to create a sustainable energy future and reduce greenhouse gases, however, the Big Four provide *anything but* a permanent or viable solution. To solve our energy and climate crisis, government, business, and consumers must ultimately look beyond fossil fuels. In building a bridge from the end of cheap oil to a renewable, carbon-free energy future, one of the other fossil fuels—natural gas—does have a transitional role to play. Coal, tar sands, and oil shale, on the other hand, exacerbate a bad situation.

During this transition, to the extent any of the four fuels are used, it is important that they be used correctly. We cannot ever afford to see any of them as the sole permanent replacement for oil. Because they are not renewable, they will never provide long-term stability. They will neither afford protection from unpredictable market prices, nor free us from scarcity. At best, they will only defer the day and the need to construct lifeboats to escape a future *Titanic*. In sum, the other fossil fuels will never be able to completely fill the gap.

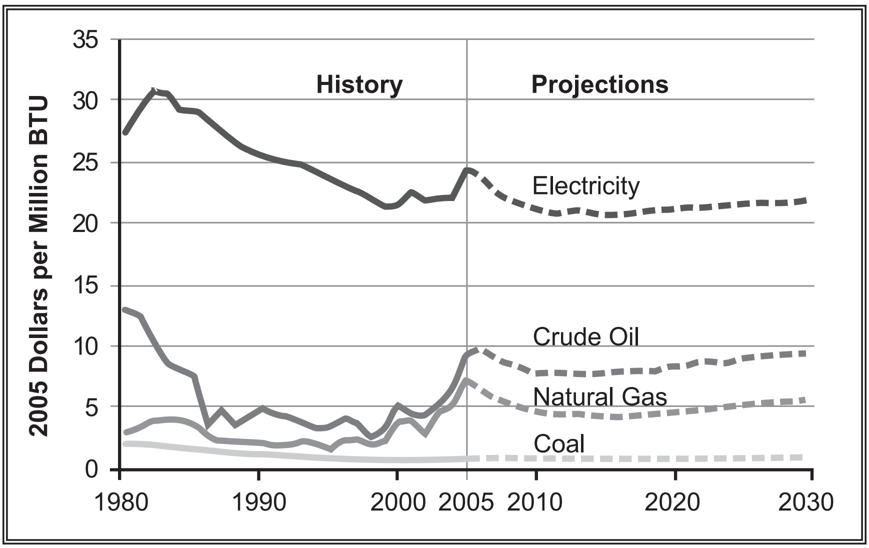
## The "Other" Fuels

Close examination reveals that coal, natural gas, tar sands, and oil shale are problematic, each in its own way, in the context of creating a healthy and sustainable energy future. Each fuel has its pros and many more cons.

The U.S. has substantial reserves of two fuels, natural gas and coal. Given these reserves, it may seem logical to conclude that we have a reasonable supply of fossil fuels at our fingertips and that we should diversify our future energy use among them. The harsh realities are that natural gas and coal cannot provide solutions to our oil supply problems because they are used primarily to generate electricity. They are not liquid fuels for transportation. Worse yet, coal poses tremendous and intractable greenhouse gas and health problems that will not be resolved by the proposed panacea of "clean coal."

Furthermore, as Figure 1 shows, reliance on oil and natural gas for electrical generation will lead only to increased energy and electricity prices over time. Even the projections in Figure 1 have proved to be woefully optimistic. Energy prices have not dropped in 2007 as predicted but have risen to historical highs across the nation.

**Figure 1. History and Projections of Energy Prices, 2005**




Source: U.S. Energy Information Administration, *Annual Energy Outlook*, 2007

If we continue our exclusive dependence on coal and natural gas while countries such as China and India, who have surging annual GDP growth, continue to increase their demand for energy, our national and global environment will suffer further serious harm, and global energy resource competition will increase.

It is very important, therefore, to analyze the repercussions of continuing down the "hard path" of the expanded reliance on fossil fuels. As Figure 2 and the subsequent discussion shows, in each case, the negatives of the other fossil fuels significantly outweigh the positives.

**Figure 2. Pros and Cons of Coal, Natural Gas, Tar Sands, Oil Shale and Petroleum**

| FUEL | PROS | CONS | COMMENTS |
|---|---|---|---|
| Coal [2] | Low cost and plentiful; easy to transport. | Produces more $CO_2$ than any other fuel; acid rain $SO_2$; smoke, ash need disposal; mining methods are destructive. | "Clean" coal extracts only $SO_2$; $CO_2$ still produced. $SO_2$ mixed with $O_2$ becomes $SO_3$ which reacts with water, becoming acid rain. |
| Natural Gas[3] | Low cost; produces less $CO_2$ than coal, oil. | Not sustainable; limited reserves. Methane, a major greenhouse gas. | If natural gas becomes the "new oil," prices will skyrocket. However, natural gas would be ideal as a transitional fuel. Cleanest fossil alternative. |
| Tar Sands ~3.5 MBD in Canada ~0.3 to 0.6 MBD in Venezuela | One of the largest reserves is in Canada, one of America's closest allies. | One of the most greenhouse polluting and least desirable forms of fossil fuel from an environmental point of view. Generally removed by strip mining. Two tons produces one barrel of oil. It requires large amounts of water. | Oil extracted from tar sands is profitable today. Canada and Venezuela possess most of the useable tar sands. |

*Figure 2 continued . . .*

*Figure 2 continued*

| FUEL | PROS | CONS | COMMENTS |
|---|---|---|---|
| Oil Shale | Estimated 1.1 trillion barrel-equivalent of oil locked in U.S. shale oil reserves. | Highly inefficient (3:1 energy output/input ratio); uses vast amounts of water; produces massive rock waste; strip mining is highly destructive; Australian shale project was shut down due to air pollution; severe groundwater concerns; shale oil contains much more $CO_2$ than petroleum; carcinogenic tailings; commercial production of 1 MBD is probably 20 years into the future.[4] | Shale oil is embedded in rock. It is extracted by retorting the rock that is saturated with kerogen by heating it to about 500 degrees Celsius and refining the extracted kerogen into petroleum. Shell has been experimenting with in situ extraction, heating the oil with electricity while the rock is still in the ground, and then transporting it for refining. Another Shell subsidiary is experimenting with a super-cold freeze-barrier around the shale while the shale deposits are heated within this "envelope." |
| Oil/Gasoline[5] | Easily extracted compared to coal, tar sands, and oil shale; produces less $CO_2$ than coal | New oil reserves are becoming scarce; large reserves located in dangerous countries; rising costs; produces $CO_2$; oil spills cause major environmental damage. | |

## Coal: One Step Forward, Two Steps Back

Coal, the most abundant fossil fuel in the U.S., is also the most detrimental to our physical health and the most destructive to the environment. Only the scarcity of oil has renewed the nation's interest in coal. Unfortunately, turning to coal (again) would be taking one step forward and two steps back. Nothing would exacerbate global warming and climate change faster than relying on coal to power electric plants in order to charge electric cars or plug-in hybrids in an "all electric world" future.

When sulfur dioxide ($SO_2$) is released during coal combustion, it reacts with oxygen ($O_2$) to create sulfur trioxide ($SO_3$). When the sulfur trioxide reacts with water, sulfuric acid forms and falls back to the earth as acid rain. Coal combustion also releases small amounts of the carcinogenic radioactive elements uranium and thorium into the atmosphere. Since coal is already used to generate 51% of our electricity, using coal to generate additional electricity to meet all, or even most, of our transportation needs would result in horrific amounts of atmospheric destruction, not to mention the amount of toxic fumes that would further pollute the air.

As Figure 3 shows, coal is hands-down the most pollution-intensive fossil fuel, emitting more $CO_2$ than oil or natural gas. With some 900 million tons of the black rock burned in the U.S. for energy every year, there are risks at every step of the coal production process: mining, preparation, transportation, and usage and combustion.

**Figure 3. Fossil Fuel $CO_2$ Emission Levels, 2004**

| **Fossil Fuel Carbon Dioxide Emission Levels (Pounds per Billion British Thermal Units of Energy Input)** | |
|---|---|
| Coal | 203,000 |
| Oil | 164,000 |
| Natural Gas | 117,000 |

Source: U.S. Energy Information Administration

For example, according to the Earth Policy Institute, "The largest source of mercury pollution is coal-fired power plants. Airborne mercury emitted by these facilities is deposited anywhere from within a few hundred kilometers of the smokestacks to across continents, far from its source." Forty-five states have warning advisories against fish consumption because of high levels of mercury in the water.

Even saltwater fish such as tuna and swordfish exceed the mercury limits deemed safe by the Environmental Protection Agency.

## Burying $CO_2$: What Goes Down, Must Come Up

Coal has two major advantages over other forms of energy: it is abundant in the U.S., and it is the cheapest fuel to produce. The world has an estimated trillion tons of mineable coal, and a quarter of it is in the U.S. The cost of delivered coal for electrical generation ranges from $1.00 to $2.50 per million British Thermal Units (BTUs). These advantages are far outweighed by the disadvantages of burning coal. It releases 9 billion tons of $CO_2$ per year, about 70% of which comes from power generation. This amounts to about a third of global $CO_2$ emissions. It also releases mercury and sulfur dioxide, causing major environmental damage to trees, aquifers, the ocean, and various animal species.

The coal industry is rallying around a new technology called Integrated Gasification Combined Cycle (IGCC). A Combined Cycle plant uses at least two thermodynamic processes to increase efficiency. The plant makes synthetic gas (a mixture of carbon monoxide and hydrogen) out of coal to fire its primary electrical generators and uses the waste heat to fuel steam boilers that drive a second set of generators. On the plus side, the technology (which is now commercial at eight plants around the world) does an admirable job of reducing sulfur, mercury, nitrogen oxides, and fly ash.

On other hand, IGCC does nothing to reduce $CO_2$. It is suggested that the $CO_2$ from IGCC plants can be isolated, condensed, and sunk in the ground or used to pressurize oil fields. It is a wide-open invitation to use more coal. Capital costs are immense—more than $1 billion per plant. While there is no general agreement on the IGCC premium over conventional pulverized coal plants, 10 to 30% is a frequently cited range. This translates into $1,400/kwh for IGCC plant construction. The cost of retrofitting conventional plants with IGCC technology is prohibitive, so it would be many, many years before it made even a slight dent in the world's footprint of coal-fired plants. Two coal-based IGCC plants are currently operational in the U.S.; nine more are cleared to be built in the next decade. To put this in context, the Chinese will build at least that number of dirty coal plants in the next three or four months.

Ironically, federal foot-dragging about emissions standards and the utility industry's own doubts are braking the pursuit of IGCC. John Hofmeister, head of Shell Oil's U.S. operations, believes, "If the 50 states have their own greenhouse gas framework, it will be chaotic . . . . " Speaking at the same October 2006 conference as Hofmeister,

> Randy Zwirn, chief executive officer and president of Siemens Power Generation Inc., said the energy industry is awaiting clear U.S. greenhouse policies, noting that his company recently surveyed U.S. utilities and found "a very high consensus" that $CO_2$ would be regulated within the next 10 years.
>
> But Zwirn said another key issue with IGCC was that utilities still have major concerns about the availability and long-term reliability of the [IGCC] technology. He said the industry view was partially colored by earlier IGCC plants that experienced startup and reliability problems.[6]

Given the indisputable health and environmental concerns that surround conventional coal production, the federal government has made research and development of "clean coal" a top priority, and IGCC plays only a part. In order to tap America's vast coal reserves, President Bush in 2001 announced his $2 billion Clean Coal Power Initiative as part of the Advanced Energy Initiative. Ten projects selected for government co-financing are in various stages of development. The winners of these grants, for the most part, are conspicuously silent about carbon dioxide.

The centerpiece of this program is the FutureGen Sequestration and Hydrogen Research Initiative. A $1 billion alliance between the Department of Energy, coal producers, and electrical utilities, it hopes to build by 2012 a 275 MW prototype plant that is coal-fired but almost "emission-free" insofar as smokestacks are concerned.

The plant will purportedly use the most modern approaches for the generation of electricity while attempting to capture and then store carbon dioxide in geological formations (known as "carbon sequestration"). The plant will also produce hydrogen and by-products for use by other industries.

Carbon sequestration, or "carbon capture and storage," refers to the process of compressing hot flue exhaust until it liquefies, transporting it by pipeline or tanker, and storing it underground in natural geological caverns or deep in the ocean floor below rock foundations.

Specific FutureGen optimistic goals include sequestering at least 90% of $CO_2$ emissions from the plant with the future potential to capture and sequester nearly 100%; proving the effectiveness, safety, and permanence of $CO_2$ sequestration; and establishing standardized technologies and protocols for $CO_2$ measuring, monitoring, and verification. It will also validate the engineering, economic, and environmental viability of advanced coal-based, near-zero emission technologies that by 2020 hopefully will produce electricity with less than a 10% cost increase compared to non-sequestered systems and also produce hydrogen at $4.00 per million BTUs (wholesale), equivalent to $0.48/gallon of gasoline.[7]

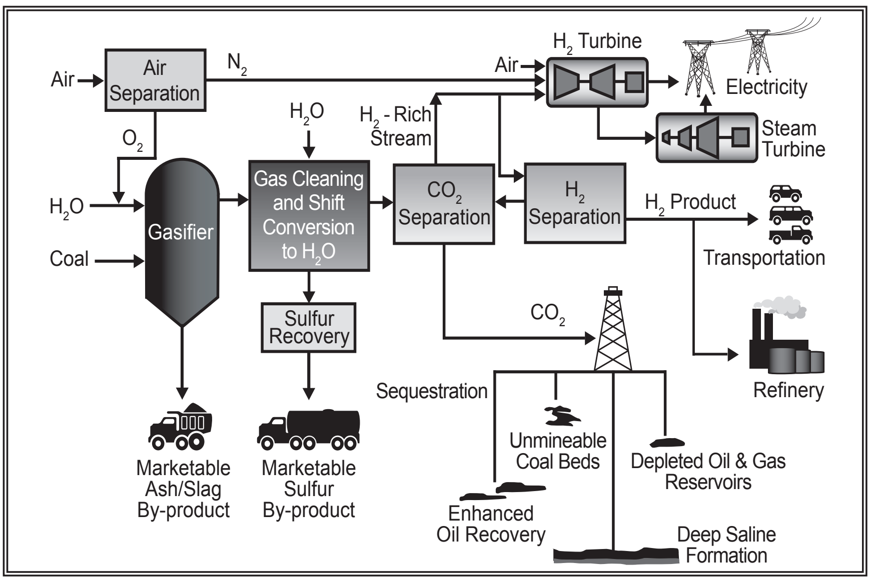
Carbon sequestration is a highly controversial technology. It represents Washington's efforts to satisfy the coal lobby and ensure coal's future in a greenhouse gas-filled world in which reducing $CO_2$ emissions will become national and global priorities. Just as the nuclear industry is marketing itself as the "solution to global warming," the coal industry is pitching "zero-emissions coal power."

We find carbon sequestration to be a highly questionable and risky possibility. If $CO_2$ were ever released from the earth years later, the results would be catastrophic. In the late 1990s, for example, several thousand people died of suffocation in East Africa when a volcanic lake belched up naturally occurring $CO_2$.

In order for carbon to be sequestrated, it must be separated from other atmospheric gases and captured in a concentrated form. There are several different methods for capturing the $CO_2$. Two technologies receiving attention are chemical absorption and gas separation membranes. Chemical absorption consists of the removal of $SO_2$ and $NO_X$, so the $CO_2$ can be absorbed using an acid-based neutralized reaction. The second method, shown in Figure 4, uses the installation of gas separation membranes: the $CO_2$ is dissolved into the membrane and then transported by a diffusion process.

Proponents suggest a variety of geologic and aqueous locations for storage: saline reservoirs, rock caverns, and coal seams and salt domes that we are unable to mine. The concept is to capture and store $CO_2$ much the way natural gas is stored. A third option is oceanic sequestration, which requires $CO_2$ to be injected into the ocean at depths of at least 1,000 meters, where it liquefies and is supposed to remain in place. One unresolved issue here is determining how bottom sediment will react with the $CO_2$. The volumes of liquefied $CO_2$ are so gigantic that it is likely it will have a serious effect on aquifers.

**Figure 4. Carbon Sequestration Process, Gas Separation Method**




Source: U.S. Energy Information Administration

Another option is terrestrial $CO_2$ sequestration, or $CO_2$ "sinks" in which soil, vegetation, agricultural lands, pastures, tundra, forests, and wetlands increase their absorption of the gas. This requires the manipulation of ecosystems to trap and hold the $CO_2$. It includes a variety of possible storage methods, including creation of fertilizers, planting forests (because trees absorb carbon dioxide for photosynthesis), and storage in soil or biomass.

One last possibility is the separation of pure $CO_2$ for possible industrial use. Despite multiple options, a 2000 National Coal Council report found that additional research and development was still necessary for $CO_2$ sequestration technologies.

The economic viability of sequestration is also a major concern, as this carbon reduction technology may increase the cost of coal-generated electricity by 60%, undercutting the economic competitiveness of coal versus natural gas and wind. "The process of capturing and sequestering a ton of $CO_2$ currently costs approximately $150 per ton. Most sources estimate that installing current technologies at power plants would significantly increase the cost of coal-generated electricity from 2.5 to 4.0 cents per kilowatt-hour. For carbon sequestration to be economically viable, the cost would have to be reduced to about $10-$20 per ton."[8] The active commercial use of CCS (carbon capture and sequestration) still remains quite distant in the future. "A system-level analysis is needed of CCS as a carbon mitigation strategy in the energy sector—one that considers the interacting effects of sunk capital investment, the economics of plant dispatch, and coal-to-gas fuel-switching."[9]

The number of high-quality sites needed for sequestration is staggering. For every ton of anthracite burned, 3.7 tons of $CO_2$ is generated. If all of the $CO_2$ generated were to be sequestrated in liquid form, it would require a volume of 12 *cubic miles* of underground space *per day*![10]

Today, carbon sequestration remains a future technology, not a current option. The facts are that carbon sequestration is unsafe, economically uncompetitive, environmentally unfriendly, and hazardous to our health and water supply. Just like burying high-level nuclear waste or deep-well injection of untreated human waste, pumping $CO_2$ underground into empty wells only defers the pollution problem to future generations. Even if the technology worked, it would have to be applied retroactively to the world's huge installed base of pulverized coal power plants, an even more expensive proposition.

Writing about sequestration in West Virginia's *Herald-Dispatch*, Abraham T. Mwaura and J. Scott Straight conclude, "This method is being touted as a potential source of raw material to take us into the hydrogen era. But as long as the source of the hydrogen is from fossil fuels, we are still stuck in an archaic energy era, instead of looking to the future with an eye on true alternative energy sources." The biggest problems associated with fossil fuels lie in the extraction process, where "toxic sludge ponds, worsened flooding, and blasting damage to property are ignored by these new technologies." The effects cannot be curbed by sequestration, and the untested effects of massive amounts of buried $CO_2$ could also come back to bite us.[11]

Coal is indeed a plentiful energy resource, but it is not a viable long-term option that will reduce greenhouse gas emissions. The Prometheus Plan requires solutions based on proven, available technologies that can make a major contribution within 10 years. Under the rosiest scenarios, so-called "clean" coal plants won't make a contribution until many decades into the future.

We believe that once carbon sequestering for any purpose is legally permitted, it will become very difficult to stop. It will become the basis for building more coal-fired plants.

## Tar Sands: A "Saudi Arabia" Next Door?

Tar sands, or oil sands, are a mixture of clay, water, sand, and bitumen, a heavy black oil, and have the viscous consistency of thick sludge.

In order to extract the oil from tar sands (also known as heavy oil), they must be mined and heated and the residue diluted. Only then can the refiners transform the newly released bitumen into a useable, albeit heavily sulfur-laden, form of petroleum.[12] It's a

> *"Coal power is America's biggest source of heat-trapping emissions, yet new investments in coal-fired power plants will keep us burning this fossil fuel for years to come. We must not allow new coal plants to sabotage the fight against global warming."*
>
> — **Barbara Freese and Jeff Deyette, Worldwatch Institute, 2006**

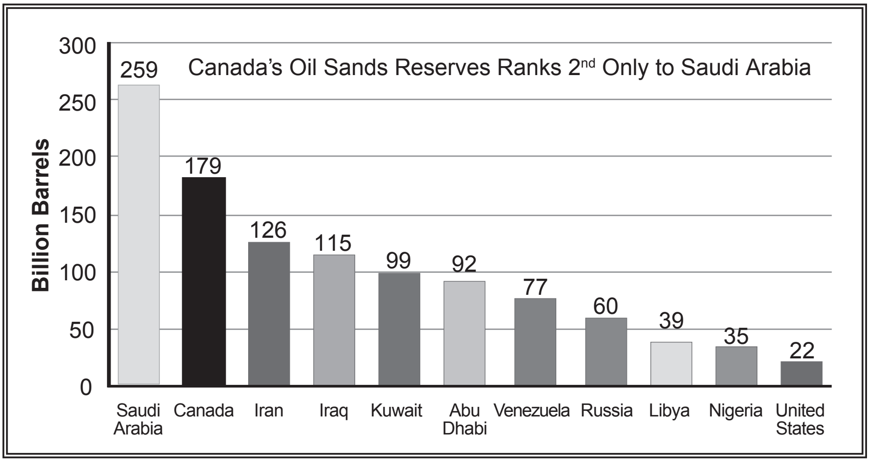
dirty, environmentally disastrous business. For every barrel of oil produced from Canadian tar sands, 170 pounds of greenhouse gases are released into the atmosphere.

The largest accumulations of tar sands in the world are found in the Athabasca deposit in Alberta, Canada, and in the Orinoco Province of Venezuela. Although there are meaningful qualitative differences between the two deposits, each holds a significant portion of the world's total tar sand resources.

Canada's Alberta Province holds the world's largest reserves of tar sands. With between 1.7 trillion and 2.5 trillion barrels, these oil sand reserves are considered second only to the conventional petroleum reserves of Saudi Arabia (see Figure 5). Of this total, however, only slightly more than 300 billion barrels, or 12-18%, are estimated to be recoverable. The U.S. imports about 9% of its daily crude oil supply from Canada, or an average of about 1.5 million barrels per day ("MBD"), including oil from tar sands.[13] Compared to Venezuelan deposits, extraction from Canadian tar sands is much more difficult because the bitumen-bearing sludge is generally colder, more viscous, and flows much more slowly.

Canadian deposits are highly attractive to the U.S. because they offer a large, secure supply located just across the border. Indeed, Canada currently supplies the largest fraction of U.S. oil imports. In 2006, Canadian tar sands operators were expected to produce more than 1.1 million barrels of synthetic oil per day, for the first time surpassing Canada's conventional oil production, which was forecasted at 1 MBD for the same period. This would boost Canada to fourth place in terms of the world's largest oil producers. Alberta is expected to produce 2.3 MBD by 2010, 3.4 MBD by 2015, and 5 MBD by 2035.[14] This increase in Alberta oil sand production would mean a decrease in U.S. oil imports from OPEC, which is in itself undeniably a good thing.

**Figure 5. Crude Oil including Oil Sands Reserves by Country**




Source: *Oil & Gas Journal*, 2004

While many experts and politicians are focused exclusively on America's need to end its dependency on Middle Eastern oil, we must pause and consider the vast environmental problems that come with heavy oil.

## Producing Gasoline and Other Products from Tar Sands

Once strip-mined or otherwise pumped up, tar sands and their oil are separated most often by steam that is created by burning natural gas. The process requires large amounts of both energy and water. While only a marginal amount of that water can be recycled, several barrels of water are required to process just one barrel of oil. In areas where water already is a scarce resource, this can pose a serious problem.

> *"Oil sands production is already one of the most environmentally destructive processes on this Earth. Imagine combining strip mining and a steelworks plant, and add in a 'tailings' lake the size of 20 city blocks. Now, add a nice big coal-fired electricity plant to the mix. Sounds great doesn't it?"*
>
> — **MurkyView.com, Canadian Environmental Blog**

Once this water is used to produce synthetic oil from tar sands, the biggest by-product by volume is toxic water stored in lakes. This creates a major risk of contaminating local water supplies, which would further stress an already tapped-out resource.

Strip-mining operations are used most frequently to extract oil sands. Production practices typically include clear-cutting thousands of acres of trees and digging out 200-foot-deep pits. This disturbance affects not only large populations of wildlife, but also air and water quality for local communities.

One of the biggest environmental concerns associated with tar sands is global warming and greenhouse gas emissions. Recovering and processing this heavy crude releases up to three times as much greenhouse gas as producing conventional crude.[15] Canada already is having trouble meeting its pledge to cut $CO_2$ emissions largely because of its heavy-oil production. In addition, oil sands also release significantly more sulfur dioxide and particulate matter, which is the leading cause of acid rain and which leads to a higher incidence of human respiratory problems.

Dr. John O'Connor, a Fort McMurray, Alberta, medical examiner, is in negotiations with Health Canada to start an epidemiological investigation that would track the public health in communities neighboring these Alberta tar sands operations. The small community of about 1,200 people that borders the tar sands operations has experienced a high number of illnesses, including leukemia, lymphomas, lupus, and autoimmune diseases. O'Connor says he is diagnosing unusually high numbers of immune disorders affecting the thyroid as well as less serious ones, such as rheumatoid arthritis and skin rashes. He also treated five people in the community who died recently from a rare, almost always fatal cancer that should occur only once in every 100,000 people. This increase in illness is a key indicator of the emerging public health concerns associated with oil sands production.[16]

## Oil Shale: Expensive, Environmentally Disastrous, and Far in the Future

Oil shale generally refers to any sedimentary rock that contains kerogen, a tarry material even more challenging than bitumen to convert to oil. The kerogen is generally separated from the rock by a high temperature process called retorting. This can be done by heating the pulverized rock in a retort, or *in situ* by drilling holes in the shale and driving the oil out by hot steam injection and/or initiating a flame front to drive the kerogen to the surface. The kerogen then must be processed as in a refinery to add hydrogen and remove contaminants such as sulfur and nitrogen.

While the U.S. may not have the largest deposits, it still holds a respectable amount of oil shale—about 60-80 billion barrels, most of which are concentrated in Utah (19-32 billion barrels), Alaska (19 billion barrels), Alabama (6 billion barrels), California (5 billion barrels), and Texas (5 billion barrels). Oil shale is not by any measure the way to improve the environment because it is significantly dirtier than conventional oil and far more expensive to produce.

A study entitled, "Effects of Oil Shale Waste Disposal on Soil and Water Quality," published in the journal *Chemical Speciation and Bioavailability,* discovered that the soil and groundwater surrounding the oil shale tailings (what is left over from drilled or mined oil shale reserves) became acidified and were filled with heavy metals and sulfates, including carcinogenic substances.[18]

Those who strongly support oil shale development base their arguments primarily on the nation's need to end dependency on imports of foreign fuels. However, critics look at life cycle and

> *"Oil shale, coal gasification or coal liquefaction—the last of the fossil-fuel sources as the world's supplies of oil and natural gas are depleted—require 20 to 50 times more water to produce an equivalent amount of energy, compared to oil and gas."*
>
> **— Kevin Hall, *Energy Reporter*, November 2005**[17]

environmental impacts as well. Byron King sums up the big picture problems with oil shale as follows:

> After you retort the rock to derive the kerogen (not oil), the heating process has desiccated the shale. Sad to say, the volume of desiccated shale that you have to dispose of is now greater than that of the hole from which you dug and mined it in the first place. Any takers for trainloads of dried, dusty, gunky shale residue, rife with low levels of heavy metal residue and other toxic, but now chemically activated crap? Well, it makes for enough crap that when it rains, the toxic stuff will leach out and contaminate all of the water supplies to which gravity can reach, which is essentially all of 'em. Yeah, right. I sure want that stuff blowin' in my wind. Add up all of the capital investment to build the retorting mechanisms, cost of energy required, cost of water, costs of transport, costs of environmental compliance, costs of refining, and you have some relatively costly end product.[19]

When the price of oil spikes, interest in oil shale revives. Investors lost billions on an attempt to move mountains (literally) in western Colorado in the 1980s. While a few shale experiments are now operating around the world, scalable technology remains many decades distant. Even if the environmental problems could be overcome, oil shale would not make a meaningful contribution for at least 30 years. We need solutions much sooner than that.

## Natural Gas: Everyone's Transitional Fuel

Natural gas accounts for about one-fifth of total U.S. energy production, most of which is used to generate electricity. A large portion of the nation already relies on gas, but it may be possible to expand the use of gas, thereby decreasing reliance on foreign oil and reducing energy costs. However, in 2005, the U.S. had only about 204 trillion cubic feet of domestic natural gas reserves—at its 2005 annual consumption rate of about 22 trillion cubic feet, enough to last only about nine years.

Some experts claim there are sufficient reserves of natural gas to fuel the world for decades. Estimates of world natural gas reserves vary widely, from 3,000 to 9,000 trillion cubic feet. Given international concerns over declining energy resources, it is surprising that even the oil and gas companies do not have precise estimates of these reserves. According to geologists, the most commonly agreed world reserve estimate is 6,040 trillion cubic feet, which represents around 50 years' worth of natural gas at current global consumption levels.

According to *Oil and Gas Journal* data on "World Natural Gas Reserves by Country as of January 1, 2005," 10 countries control 78.9% of these reserves. The top five natural gas nations—Saudi Arabia, Iran, Venezuela, Nigeria, and Iraq—are geopolitical hot spots where supplies are subject to risks and disruptions (see Chapter 3). Completely relying on natural gas to replace oil, therefore, does not significantly enhance U.S. energy security or independence.

Furthermore, we must keep world supply trends in mind. From 1977 to 1987, 9,000 new gas fields were uncovered throughout the world. By 1997, only 2,500 additional fields had been found. In the Gulf of Mexico, the number of drilling rigs increased by 40% between April 1996 and April 2000, but production remained flat because the newly discovered fields tended to be smaller. Also, because of new technology, natural gas fields tend to be depleted faster than just five years ago, with the newer wells averaging a 56% depletion rate during the first production year.

## LNG Is Highly Explosive

Transportation of natural gas is an expensive and high-risk process, especially for natural gas vehicles that run on liquefied natural gas (LNG). Currently, there are around four million natural gas vehicles around the globe. Although popular in Western Europe, they are most commonly found in Argentina and Brazil. As of March 1, 2007, the U.S. Department of Energy calculated that the nationwide average price of natural gas was still lower than the nationwide average price of gasoline. At that time, gasoline was selling for $2.30/gallon, and natural gas was priced at $1.94/GGE (gallon of gasoline equivalent).[20]

LNG is made by refrigerating natural gas to -260˚F to condense it into a liquid. This is called liquefaction. The process removes most of the water vapor, butane, propane, and other trace gases that are usually included in ordinary natural gas. The resulting LNG is usually more than 98% pure methane. When cold LNG comes in contact with warmer air, it creates a visible vapor cloud from condensed moisture in the air. As it continues to get warmer, the vapor cloud becomes lighter than air and rises. When the vapor mixes with air, it is flammable only when the mixture is between 5% and 15% natural gas. When the mixture is less than 5% natural gas, it doesn't burn. When the mixture is more than 15% natural gas, there is not enough oxygen for it to burn.

As a liquid, LNG is not explosive. LNG vapor will explode only in an enclosed space within the flammable range of 5-15%. On the plus side, LNG is produced both worldwide and domestically at a relatively low cost and burns cleaner than diesel fuel. Since LNG has a higher storage density than compressed natural gas for heavy-duty vehicle applications, it is a more viable alternative to diesel fuel. In addition, LNG in heavy-duty natural gas engines produces significantly lower emission levels than diesel.

The possibility of major accidents is of great concern. LNG undergoes a rapid transition to vapor, especially when spilled on water. When suddenly disbursed over water, the volume of the LNG instantly expands by a factor of 600, resulting in a physical explosion that poses a hazard for structures and people close to the site of the incident. The explosion may not initially involve combustion, but a subsequent inferno is almost always assured after contact with an ignition source. When LNG is spilled on water, heat is transferred from the water to the LNG. This results in a rapid transformation of liquid to gas, releasing a large amount of energy.

Compressed natural gas can also be used for transportation. It has been used to fuel taxi cabs, UPS delivery vans, postal vehicles, street sweepers, and transit and school buses. Natural gas is available outside of North America, but not via pipelines. It can be imported to the U.S. in the form of LNG, but this method of transport is highly controversial.

Because LNG occupies only a fraction (1/600) of the volume of natural gas, it is transported more economically over long distances and can be stored in larger quantities. Certainly, LNG is a price-competitive source of energy that could help meet future economic needs in the U.S. To date, there are six LNG terminals in the U.S.—in Kenai, Arkansas; Everett, Massachusetts; Cove Point, Maryland; Elba Island, Georgia; Lake Charles, Louisiana; and Penuelas, Puerto Rico.[21] To date, no catastrophic accidents have occurred at these terminals. Even operating at full capacity, however, they are capable of importing only 3% of U.S. natural gas consumption.

If natural gas vehicles are ever to have a material effect on the transportation market, we'll need to establish a national natural gas fuel infrastructure virtually from scratch. Because natural gas vehicles cannot be purchased or fueled as conveniently as gasoline-powered cars, the way to boost demand would be to significantly reduce costs. The best way to reduce costs would be to increase demand. It's a Catch-22 that can be resolved only by getting the federal, state, and local governments involved by offering short-term incentives to buyers of natural gas vehicles and by supporting U.S. Department of Energy efforts to promote "clean cities" programs based on governmental purchase and use of natural gas vehicles.[22]

Many advocates of alternative energy see natural gas as a means to shift from oil to hydrogen and renewable energy. They see it as the only viable transition fuel that can buy time as the U.S. switches from dependency on foreign crude to cheap, renewable, and clean energy sources, especially in the transportation sector. Given a choice between natural gas and oil, liquefied natural gas, obviously, would be the preferred liquid fuel.

Aside from the risks of accidents, however, the major problems with natural gas are that the U.S. has only limited domestic reserves, much of the foreign reserves are located in high-risk areas of the world, and natural gas prices tend to move with oil prices, promising future high prices for natural gas.

Any move to make natural gas the "new gasoline" would, therefore, be a colossal mistake and would simply replace one foreign addiction with another.

In sum, none of the big four other fossil fuels—coal, natural gas, tar sands, or oil shale—offers a viable long-term, economically sound, or environmentally friendly solution for generating electricity in ways that simultaneously decrease U.S. dependency on foreign energy resources *and* reduce greenhouse gas emissions. Fortunately, the penultimate resource for cheap, efficient, non-polluting, and commercially available electrical power generation is literally "blowing in the wind." The advantages of wind power along with other sustainable sources of energy are discussed in Chapter 11.

## Notes and References
## Chapter 6: Coal, Natural Gas, Tar Sands

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