Wyoming energy development in the context of the global energy economy

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Wyoming State Geological Survey

Challenges in Geologic Resource Development No. 6

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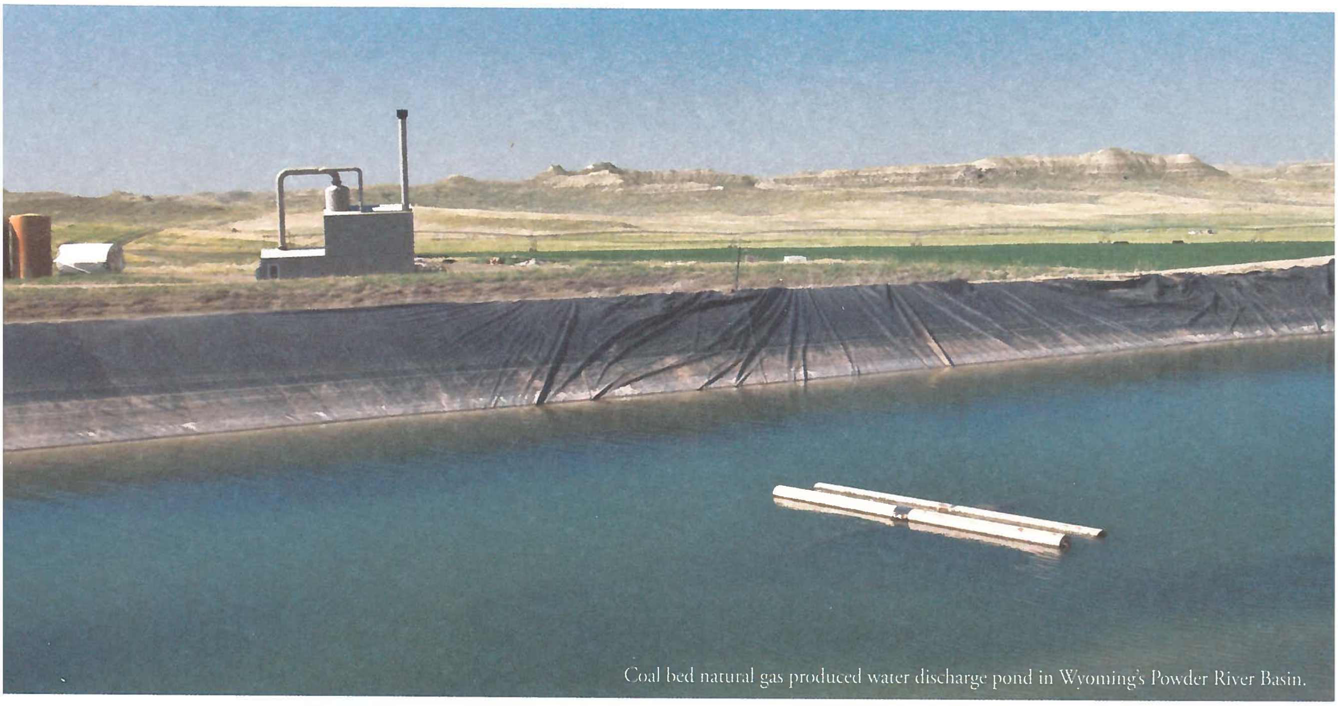

Coal bed natural gas produced water discharge pond in Wyoming's Powder River Basin.

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WYOMING ENERGY DEVELOPMENT IN THE CONTEXT OF THE *global energy economy*

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Ronald C. Surdam

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Executive summary

This report demonstrates that the boom and bust energy/economic cycles characteristic of Wyoming's past do not accurately model current and future energy activities in the state, especially revenue. In the past, global energy supply always exceeded demand, and boom and bust cycles resulted mainly from political pricing of energy commodities such as oil (for example, the 1973 oil embargo and subsequent OPEC manipulations of supply). The paradigm based on this global energy economy of the past insisted that if times were good, the bust was just around the corner. In contrast, if times were bad, good times would return sometime in the future. Most importantly, the belief developed that booms were generally short-lived and busts were longer. In terms of understanding the nature of Wyoming's future energy development, this outdated paradigm is obsolete, and continued adherence to it hinders those planning for Wyoming's future. We must look forward and understand the state's energy environment in the context of the new global energy economy.

The United States has 2.4 percent of the world's oil reserves, 3.0 percent of the world's gas reserves, and 20.0 percent of the world's coal reserves. U.S. energy consumption increased by 10.2 percent from 1995 to 2005, and the country currently uses 22.2 percent of all the energy produced in the world (about 100 quadrillion btus per year). World demand for oil, the easiest energy commodity to transport globally, exceeded supply for the first time ever in 2005, and emerging economies in India and China will ensure this trend continues.

As the global energy economy changes, so does Wyoming's. Significant decreases in commodity prices along with steady declines in production caused the state's past economic busts. Oil is a prime example: except for a minor bump in the 1980s, oil production in Wyoming decreased from 1970 to 2006, when Anadarko's successful enhanced oil recovery projects at Salt Creek and Patrick Draw (Monell unit) and increased condensate production at Jonah Field and the Pinedale Anticline led to production gains. Oil was one of Wyoming's major energy exports, along with coal and a relatively small amount of natural gas, until about 1990, when the energy scenario in the state changed dramatically, rapidly, and with little warning. Coal production increased quickly and steadily, from less than 200 million tons per year in 1990 to nearly 450 million tons per year in 2006. Natural gas production remained relatively flat (and was associated mainly with oil production) until 1995, when it increased from approximately 0.5 trillion cubic feet (TCF) to more than 2.0 TCF in 2006. Over the last decade or two, Wyoming's energy portfolio has expanded and diversified. Coal and natural gas now drive the state's economy: oil is only a minor player. Wyoming is also the nation's leading exporter of uranium.

Most importantly, Wyoming has become the number-one domestic exporter of energy over the last decade, supplying the rest of the U.S. with more than 10 quadrillion btus of energy per year. Even more astonishing is that when compared to major energy exporting nations such as Canada, Mexico, Venezuela, and Saudi Arabia, Wyoming emerges as the leading exporter of energy to the U.S.: today, one out of every ten btus used in the U.S. comes from Wyoming. Since 1970, the state's energy portfolio has grown to encompass a diverse array of resources characterized by steadily increasing production. Currently, the major constraint on production is a lack of adequate transportation options, transmission lines, and pipeline capacity. In 25 years, with appropriate infrastructure upgrades, Wyoming could produce 650 million tons of coal and 4.0 TCF of natural gas annually.

Given the facts presented above, and barring a global economic depression, how could anyone predict an economic bust for Wyoming? Instead of worrying about a bust that will not materialize anytime in the near future, Wyoming stakeholders should start planning to maximize the responsible development of energy resources, the quality of our communities, and the protection of our environment. There is no economic bust in sight: Wyoming should plan for sustained prosperity.

Introduction

In the past, Wyoming's economy – particularly state revenue derived from oil, gas, and coal production – cycled through a series of economic booms and busts. These economic oscillations occurred in a global energy environment where supply exceeded demand. Governments across the globe manipulated access to resources, causing politically-inspired energy shortages (such as the Yom Kippur War/Arab embargo) and significant spikes in energy prices from 1972 through 2000. However, as long as oil supply exceeded demand, oil remained relatively inexpensive, except for brief periods when access to oil was manipulated. Before 1972, the U.S. took advantage of inexpensive foreign oil and built the world's strongest economy. During this period, Wyoming supplied the nation with energy, but U.S. energy security did not depend on the state's energy production.

Since 2000, the global energy environment has changed drastically and irreversibly. The world energy supply/demand gap closed rapidly in the first five years of the new millennium. In 2005, global demand for oil finally exceeded supply as emerging nations such as China and India demanded more oil, stability in the Middle East crumbled, U.S. energy demand increased, refining capacity failed to expand, the rate at which new oil accumulations were discovered declined, and national oil companies appeared on the scene.

During this transition from supply exceeding demand to demand exceeding supply, Wyoming's influence on the energy situation in the U.S. increased dramatically. Wyoming is the only state in the nation capable of exporting substantial and increasing amounts of energy over the next 25 years. As long as our national infrastructure relies on fossil fuels, U.S. dependence on Wyoming and other Rocky Mountain states for conventional energy resources will only increase.

The days of cheap foreign energy are over. As recently as 1970, the U.S. was a net exporter of energy. Now, our country imports nearly 13 million barrels of crude oil per day and 4 trillion cubic feet (TCF) of natural gas per year. To believe that the capital, technology, national will and ingenuity, and tolerance for infrastructure dislocations will be available to facilitate a transition from conventional to unconventional energy sources in less than 25 years is to be unrealistically optimistic. This report suggests that as a result, Wyoming will be a major neergy provider to the U.S. for at least the next 25 years, and probably longer. In order to make good decisions about energy development, state decision-makers and residents must learn to view state resources in the context of the global energy economy.

Supply and demand imbalance

The gap between global oil production (supply) and global oil consumption (demand) has continued to narrow over the last five years (**Table 1**). The BP Statistical Review of World Energy (2006) demonstrates that between 1995 and 2005, global energy consumption increased by 23 percent (**Table 2**). In addition, every region of the world except North America increased its oil and gas reserves (**Table 3** and **Table 4**). In North America, oil reserves decreased by 31 percent and gas reserves decreased by 12 percent (**Table 3** and **Table 4**) during this period. North American gas reserves decreased despite an 18 percent increase in U.S. gas reserves (largely due to newly delineated Rocky Mountain gas reserves such as Jonah Field and the Pinedale Anticline in Wyoming; see **Table 3**). Only coal reserves increased between 1995 and 2005 in North America (**Table 5**).

In North America, the reserves to production ratio (R/P) for oil is 12 years, for gas is 10 years, and for coal is 231 years. Conversely, the Middle East has R/P ratios of 81 years for oil and 100 or more years for gas. The reserves to production ratio is calculated by dividing remaining reserves by annual production: the quotient equals the length of time the remaining reserves will last if annual production continues at the current rate and new reserves are not added. As the above data clearly show, North America's oil and gas reserve situation is rapidly becoming precarious – a real and immediate threat to our standard of living and our national security.

Table 1. World oil supply and demand, in millions of barrels of oil per day (MOPD).[1]

	2004	2005			
	Fourth Quarter	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
Supply	84.04	83.95	84.52	83.81	84.03
Demand	84.42	83.92	82.27	83.04	85.24

[1] *Includes crude oil, lease condensates, natural gas plant liquids, other hydrocarbons used as refinery feedstocks, refinery gains, alcohol, and liquids produced from nonconventional sources.*

Table 2. Global energy consumption (1995-2005).*

Region	Change, in million tons of oil equivalent (1995-2005)	Percent increase (1995-2005)	Percentage of world energy consumption (2005)
North America	294.7	11.8%	26.6%
South and Central America	96.2	25.0%	4.8%
Europe and Eurasia	203.9	7.3%	28.3%
Middle East	170.8	50.3%	4.8%
Africa	70.3	28.6%	3.0%
Asia/Pacific	1,112.5	48.1%	32.5%
Total	**1,968.7**	**23.0%**	**100%**
United States	216.9	10.2%	22.2%

**Compiled from BP Statistical Review of World Energy, June 2006.*

Table 3. The world's proved oil reserves.*

Region	Change, in billions of barrels (1995-2005)	Percent change (1995-2005)	Share of total world reserves	R/P ratio** (years)
North America	-29.5	-33.1%	5.0%	11.9
South and Central America	20.0	23.9%	8.6%	40.7
Europe and Eurasia	59.0	72.4%	11.7%	22.0
Middle East	81.2	12.3%	61.9%	81.0
Africa	42.3	58.8%	9.5%	31.8
Asia/Pacific	1.0	2.6%	3.4%	13.8
Total	**173.7**	**16.9%**	**100%**	**40.6**
United States	-0.5	-2.0%	2.4%	11.8

**Compiled from BP Statistical Review of World Energy, June 2006.*

***Reserves to production (R/P) ratio: if the reserves remaining at the end of any year are divided by production in that year, the resulting ratio equals the length of time those remaining reserves would last if production continued at that level.*

Table 4. The world's proved gas reserves.*

Region	Change, in trillion cubic meters (1995-2005)	Percent change (1995-2005)	Share of total world reserves	R/P ratio** (years)
North America	-1.0	-11.9%	4.1%	9.9
South and Central America	1.1	18.4%	3.9%	51.8
Europe and Eurasia	0.9	1.5%	35.6%	60.3
Middle East	26.8	59.0%	40.1%	100+
Africa	4.5	45.3%	8.0%	88.3
Asia/Pacific	4.3	40.8%	8.3%	41.2
Total	36.4	25.4%	100%	65.1
United States	0.8	18.0%	3.0%	10.4

**Compiled from BP Statistical Review of World Energy, June 2006.*

***Reserves to production (R/P) ratio: if the reserves remaining at the end of any year are divided by production in that year, the resulting ratio equals the length of time those remaining reserves would last if production continued at that level.*

Table 5. The world's proved coal reserves.*

Region	**Change, in million tons of oil equivalent (1995-2005)**	**Percent change (1995-2005)**	**Share of total world reserves**	**R/P ratio** (years)**
North America	19.6	3.3%	28.0%	231
South and Central America	24.2	104.8%	2.2%	269
Europe and Eurasia	-60.2	-12.1%	31.6%	241
Middle East	-0.1	-14.3%	0.4%	–
Africa	20.9	17.1%	5.6%	200
Asia/Pacific	629.0	61.9%	32.7%	92
Total	633.6	28.1%	100%	155
United States	25.5	4.6%	20.0%	240

**Compiled from BP Statistical Review of World Energy, June 2006.*

***Reserves to production (R/P) ratio: if the reserves remaining at the end of any year are divided by production in that year, the resulting ratio equals the length of time those remaining reserves would last if production continued at that level.*

Table 6. U. S. energy imports and consumption.

U.S. Energy Imports, 2005*	
Oil	634.4 million tons 4,650,152,000 barrels 25.4 quadrillion btus
Natural Gas	97.0 million tons of oil equivalent 3.8 TCF 4.0 quadrillion btus
Total energy imports	~29.4 quadrillion btus
U.S. Energy Consumption, 2004**	
Total primary energy consumption	~100 quadrillion btus

Compiled from BP Statistical Review of World Energy, June 2006.
**From Energy Information Administration data.*

For example, U.S. oil production is 310.2 million tons of oil equivalent per year and U.S. gas production is 473.1 million tons of oil equivalent per year. However, the nation consumes 944.6 million tons of oil equivalent per year in oil, and 570.1 million tons of oil equivalent per year in gas (**Table 6**). This imbalance requires the U.S. to import huge quantities of oil (more than 60 percent of the crude oil it uses annually) and lesser but significant amounts of gas (15 percent of its usage).

Currently, the U.S. consumes approximately 100 quadrillion btus of energy per year. However, the country produces only 70 quadrillion btus annually: it makes up the difference of approximately 30 quadrillion btus with foreign energy imports, including approximately 25.4 quadrillion btus in oil and approximately 4 quadrillion btus in natural gas (**Table 6**). This 30 quadrillion btus is more energy than the whole continent of South America used in 2005 (BP Statistical Review of World Energy, June 2006). The U.S. currently uses 22 percent of all the energy produced in the world.

World energy crisis

When the energy facts presented above are viewed in the context of the evolving global energy-economic framework, it is impossible to avoid the conclusion that the world is in the initial phases of a massive energy crisis. Consider world oil consumption. In 2002, the world used 79 million barrels of oil per day. By 2004, this amount had increased to 84.5 million barrels of oil per day. For each year between 2002 and 2004, world oil consumption increased by 2–3 million barrels per day.

Most discussions of the global energy crisis stress the imbalance between production and consumption, but the effect of this imbalance on world oil *reserves* is equally important. Levorsen (1967) defines *reserve* as follows: "The fundamental need of the petroleum industry is an adequate supply of its raw materials – crude oil and natural gas. Each year the 'crop' of oil and gas is completely destroyed by consumption; no 'seed' is left with which to start a new supply. Renewal of the domestic supply for any country depends almost entirely on the continuing discovery of new deposits. At any time, the recoverable petroleum in sight, which is known as the producible reserve or the proved reserve, is only that which has been discovered and developed but has not been consumed." To maintain a constant reserve base (for long-term energy stability), producers must replace oil extracted from declining fields with newly discovered reserves. At present, the world produces oil much faster than new reserves are discovered. As a result, world oil reserves currently decline by 4–5 million barrels per day each year. In practical terms, this means that to maintain its present rate of oil consumption indefinitely, the world needs to add the equivalent of Saudi Arabia's oil production (12 million barrels per day) every two years. Saudi Arabia produces 4 billion barrels of oil per year – more than any other country in the world – and has the largest oil field (the Ghawar Field) and the largest oil reserves (264 billion barrels) in the world (BP Statistical Review of World Energy, June 2006).

There is no possible way to discover new oil reserves fast enough to sate the voracious global appetite for oil and other conventional energy resources. Most importantly, the world must understand that the huge amount of unconventional energy (renewable or nonrenewable) necessary to replace conventional oil, gas, and coal will not be available for 25–30 years or more. Although these new resources may exist, the technology, capital, and industrial capacity required to take advantage of them currently does not.

Crude oil prices

From 1950–1972, crude oil prices were steady and relatively low (**Figure 1**). Because natural gas and coal prices tended to mimic crude oil prices during this period, the cost of energy on a per-btu basis was remarkably low. The 1972 Yom Kippur War oil embargo, a politically-motivated manipulation of oil supply that created a "shortage" despite the fact that real supply exceeded demand, caused the first post-World War II spike in oil prices (**Figure 1**).

From 1972 to the present, the price of oil went through a series of peaks and valleys. Although many factors influenced this trend, there is a clear relationship between unrest in the Middle East and spikes in oil prices (**Figure 1**). Until 2005, these price oscillations occurred in a global energy environment where supply exceeded demand. Beginning in 2005, global demand for energy exceeded supply as emerging economies in China and India, which both have relatively few oil and gas reserves, continued to grow by as much as 10 percent per year. This economic growth, particularly in Asia, continues to widen the disparity between oil

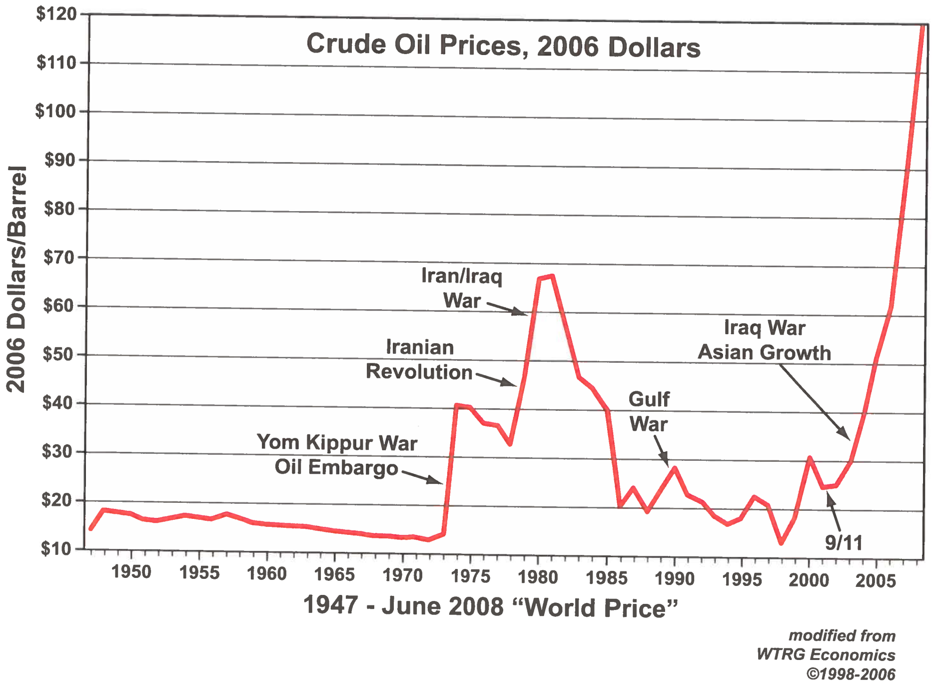
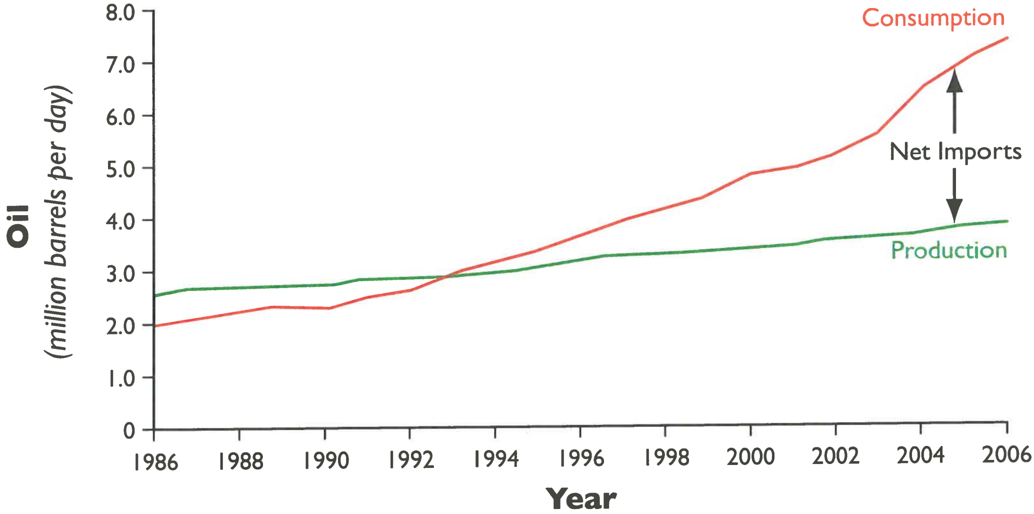


Figure 1. Global average price of crude oil from 1947 through September of 2006, shown in 2006 dollars. *Figure courtesy WTRG Economics.*

production and consumption, resulting in the present supply/demand imbalance (**Figure 2**). The new global energy environment, combined with significant unrest in the Middle East, caused oil prices to increase rapidly (**Figure 1**). For example, global oil prices in 2004 were in the $30/barrel range. In contrast, the price of oil stayed above $60/barrel in the first half of 2007, and reached a high of $75/barrel in July of 2007. By January of 2008, the price hovered between $90/barrel and $100/barrel. Now, at the beginning of July 2008, oil costs more than $140/barrel and the average price of a gallon of gasoline in the U.S. is $4.09. Prices of both commodities may increase even more. Although unrest in the Middle East may have inflated oil prices initially, emerging economies in Asia and a weak U.S. dollar are clearly sustaining elevated prices: this trend marks the end of the global era of "cheap" energy.

In 2004, Petrie Parkman and Company made some remarkable predictions about future crude oil importation (**Figure 4**), suggesting that by 2010, China's demand for crude oil would approach U.S. demand in 2004 (12 million barrels/day). Clearly, by 2015 China will import as much crude oil as the U.S. This stiff competition for oil, coupled with an energy environment where demand outstrips supply, will undoubtedly sustain or even increase already-high prices.



Source: EIA International Petroleum

Figure 2. China's oil production and oil consumption, 1986–2006. *Figure courtesy EIA International Petroleum.*

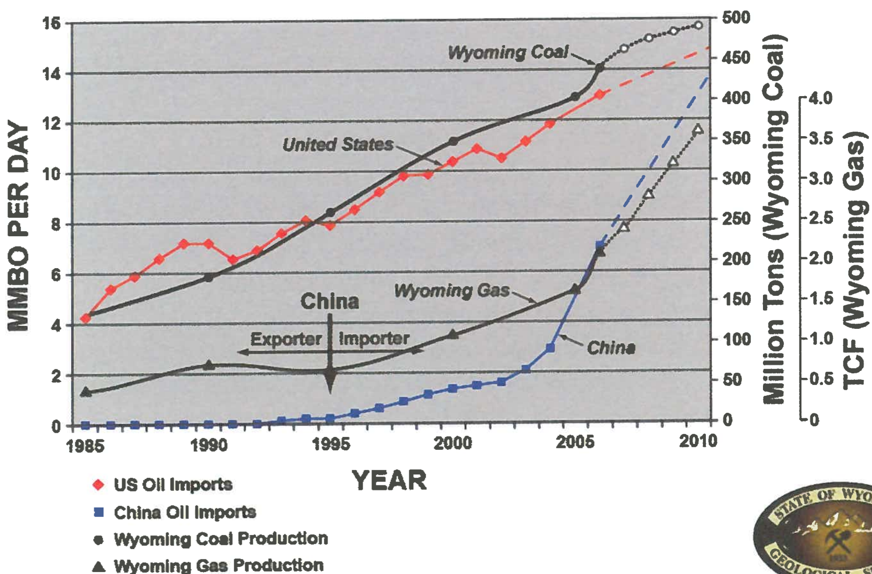


Figure 3. U.S. and Chinese oil imports from 1985–2006, with projections to 2010. Wyoming coal and natural gas production are also shown.

The age of cheap foreign energy is over, and the rules governing global energy distribution and use have changed completely and irrevocably. Unless energy companies discover the equivalent of Saudi Arabia's oil production every 2 years, the probability of skyrocketing energy costs across the globe for the next 25 years – particularly in the transportation sector – is extremely high.

Fossil fuels

Much has recently been written about replacing fossil fuels with a wide variety of alternative energy sources (non-fossil fuels). Obviously, this will probably happen some time in the future, but not in the next 20–25 years. All serious studies of global energy distribution and use have concluded that fossil fuels will continue to be our dominant energy source for the first half of this century (**Figure 4**). While it is globally imperative that conservation, efficiency, and cleaner technology be encouraged and developed, the fact remains that the world will continue to depend on fossil fuels in the near future. To maintain the current standards of living across the globe, we will need 25 to 50 percent more fossil fuel energy over the next 25–30 years (**Figure 4**).

Current Wyoming energy production

The global transition from an energy surplus to an energy deficit affected Wyoming profoundly: the state became and remains the leading domestic energy exporter in the U.S. (**Figure 5**). As the world energy economy crossed the threshold to demand exceeding supply, the value of Wyoming's energy resources increased substantially. As a direct result of increasing commodity prices, energy discovery, development, and production in Wyoming expanded dramatically. Not including electricity, Wyoming exported 10 quadrillion btus of energy (oil, natural gas, and coal) to the rest of the nation in 2006 (**Table 7**). Only ten states in the country export energy, and only five of these export more than 1 quadrillion btus (**Figure 5**). Wyoming's domestic energy exports account for 50 percent of all energy exported by states within the U.S. Most importantly, Wyoming possesses a highly diverse energy portfolio, including significant oil, gas, and coal resources. Some exporting states, such as West Virginia and Kentucky, depend on just one energy commodity (in this case, coal). Moreover, in the last 10 years Wyoming has demonstrated its ability to produce and export increasing quantities of gas and coal. Energy commodity exports from some other states are declining: West Virginia's coal exports are decreasing, as are Alaska's oil exports.

A very conservative evaluation of the global energy environment suggests that, over the next two to three decades, a worldwide imbalance between supply and demand will control energy resource pricing. As long as energy demand exceeds supply, oil, gas, and coal prices will remain high, and Wyoming's diverse energy portfolio will increase in value and sustain economic prosperity for state residents. Finally and most importantly for every U.S. citizen, the current global energy environment, along with an almost complete lack of national energy

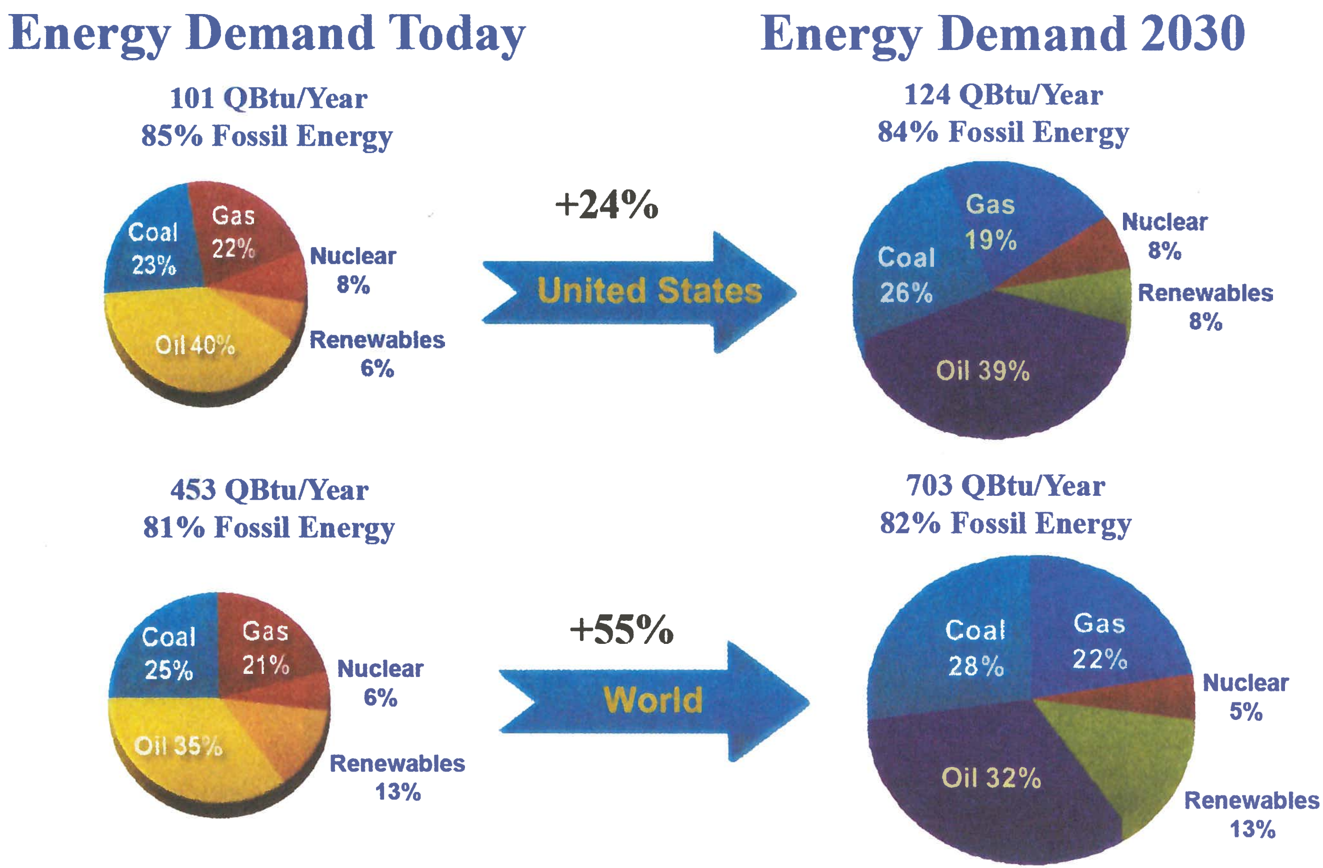


Figure 4. Current and projected (2030) energy demand for the U.S. and the world. Figure courtesy NETL. U.S. data from EIA *Annual Energy Outlook 2008 Early Release*, years 2006 and 2030; world data from IEA *World Energy Outlook 2007*, years 2005 and 2030.

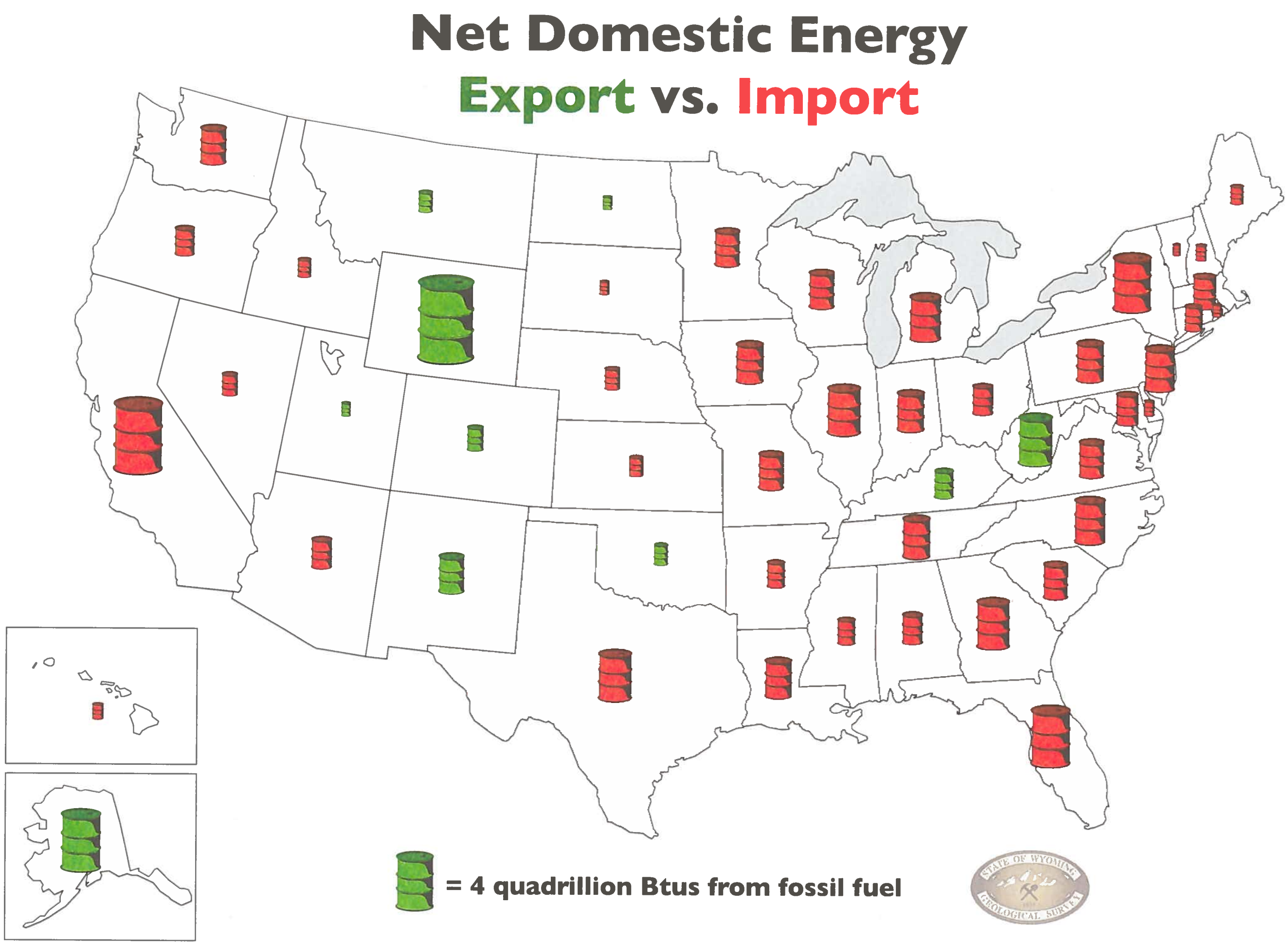


Figure 5. Map showing net energy balance for every state in the U.S.. Red barrels indicate a negative net energy balance (states that import energy), while green barrels indicate a positive net energy balance (states that export energy).

Table 7. Energy production and consumption data for six U.S. states.

State	Rank	Crude oil production		Natural gas production		Coal production		Total		Delta
		million barrels/ year	quadrillion btus	TCF/ year	quadrillion btus	MMtons/ year	quadrillion btus	Produced (quadrillion btus)	Consumed (quadrillion btus)	
Wyoming	1	52.50	0.31	2.10	2.10	440.0	8.00	10.41	0.40	10.01
Alaska	2	315.42	1.66	3.64	3.69	1.45	0.02	5.37	0.78	4.59
West Virginia	3	1.56	0.01	0.22	0.22	153.65	3.94	4.17	0.82	3.35
Louisiana	37	75.49	0.40	1.31	1.33	4.16	0.06	1.78	3.82	-2.04
Texas	46	387.68	2.04	5.99	6.06	45.94	0.68	8.77	11.97	-3.20
California	50	230.29	1.21	0.35	0.36	0	0	1.57	8.36	-6.80
Total		**1,396.65**	**7.37**	**20.32**	**20.54**	**1,166.48**	**24.59**	**52.50**	**99.87**	**-47.36**

planning, places the nation's energy security in great jeopardy. No matter what action national leaders and lawmakers take in the future, Wyoming will play a central role in domestic energy production.

Wyoming's energy potential

Both Wyoming and the U.S. have a vested interest in how much energy the state can produce in the future. Data indicate that Wyoming can probably stabilize its oil production at 60 million barrels per year (**Figure 6**). From 1985–2005, Wyoming's oil production declined from 120 to approximately 50 million barrels per year. The success of several enhanced oil recovery projects using CO_2 flooding (such as Anadarko's Patrick Draw and Salt Creek projects), along with increased condensate production at Jonah Field and the Pinedale Anticline, reversed the steady 20-year decline in Wyoming oil production (oil production increased slightly in 2006; **Figure 6**). It is reasonable to assume that Wyoming will produce at least 60 million barrels of oil per year beyond 2010.

Wyoming coal production began increasing steadily in 1970 (**Figure 7**). The ultimate constraint on coal production in Wyoming has always been transportation, not mining. However, with improved track infrastructure and rolling stock, railroads have progressively increased their hauling capacity. Concurrent increases in Powder River Basin (PRB) coal production have allowed the state to boost its coal exports. By 2010, thanks to improved road beds and larger-capacity coal cars, Wyoming should be able to produce nearly 500 million tons of coal annually (**Figure 7**). If DM&E builds an additional rail line out of the PRB, the mines could probably produce another 100 million tons of coal per year (resulting in a state production average of 600 million tons per year).

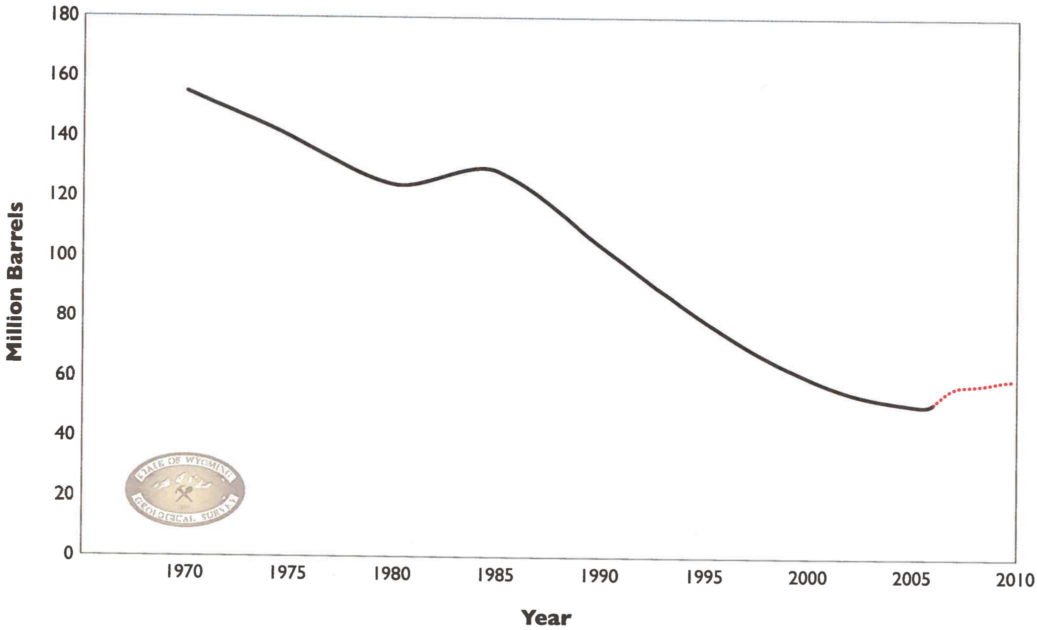


Figure 6. Wyoming oil production from 1970–2006. The red dotted line represents projected production through 2010.

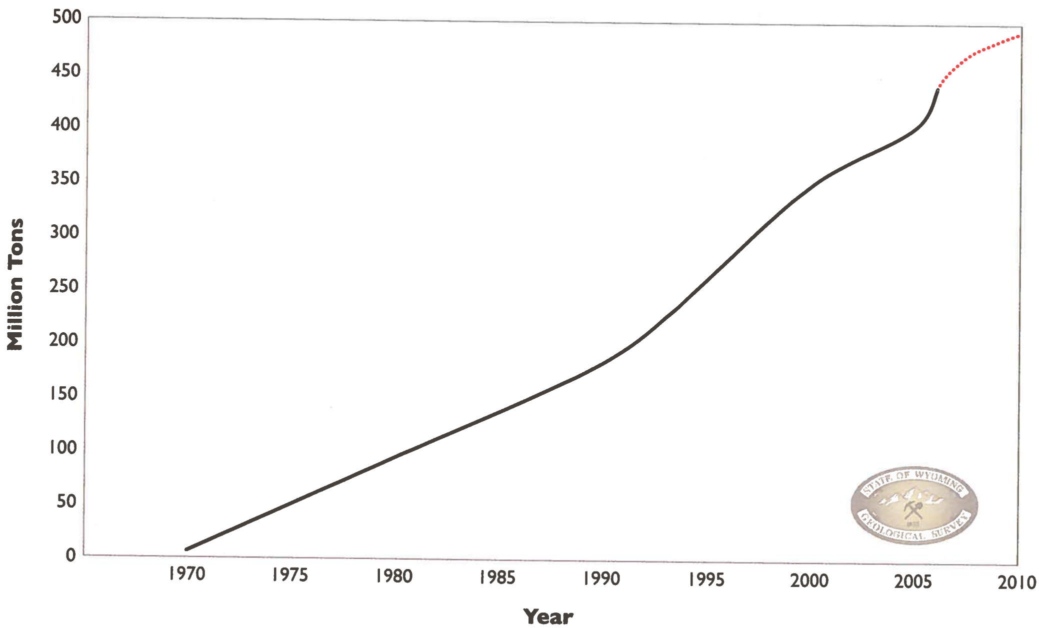


Figure 7. Wyoming coal production from 1970–2006. The red dotted line represents projected production through 2010.

Of all the energy commodities Wyoming produces, natural gas has the greatest potential to increase in the near future. Additional production can be estimated as follows. In December 2006, the Wyoming Oil and Gas Conservation Commission (WOGCC) estimated the number of gas wells that will be drilled in Wyoming from 2004–2010 (**Table 8**). These estimates are relatively conservative but realistic, as they are based in part on permitted wells; wells that will be permitted under existing or pending environmental impact statements (EIS); and industrial activities and transportation constraints. Given the production rates of typical gas wells in each of the areas shown in **Table 8**, it is possible to predict future gas production in each area and/or the total increase in Wyoming gas production from 2006–2010 (**Figure 8**). The accuracy of such predictions can be evaluated by comparing them to real production numbers from 2004 and 2005. If all permitted wells are drilled from now until 2010, Wyoming gas production could increase to 3.5 TCF per year.

New gas production from shale gas, deep gas, bypassed underpressured gas, and coal gasification were not included in the gas production figures shown in **Figure 8**. Therefore, little doubt exists that Wyoming has the potential to produce the amount of gas shown in **Figure 8** by 2010.

Table 8. Wells drilled in Wyoming (2004-2010).

Area	Actual 2004	Actual 2005	Estimated 2006	Estimated 2007	Estimated 2008	Estimated 2009	Estimated 2010	Total
Atlantic Rim CBM	34	17	7	100	150	200	200	708
PRB CBM	3,207	2,895	2,900	2,900	3,000	3,000	3,000	20,902
SW Wyoming CBM	66	84	50	50	75	100	100	525
Total CBM	**3,307**	**2,996**	**2,957**	**3,050**	**3,225**	**3,300**	**3,300**	**22,135**
Jonah	100	110	250	250	250	250	250	1,460
Misc. gas	141	95	135	115	100	100	100	786
Moxa Arch	127	122	140	125	100	75	75	764
Pinedale	111	138	200	200	225	250	250	1,374
Wamsutter	268	245	250	200	100	100	100	1,363
Wind River	90	85	95	85	75	50	50	530
Total Gas	**837**	**795**	**1,070**	**975**	**850**	**825**	**825**	**6,177**
Injection	47	24	55	25	25	25	25	226
Oil	154	206	300	250	200	175	150	1,435
Grand Total	**4,345**	**4,021**	**4,382**	**4,300**	**4,300**	**4,325**	**4,300**	**29,973**

From Wyoming Oil and Gas Conservation Commission, December 2006.

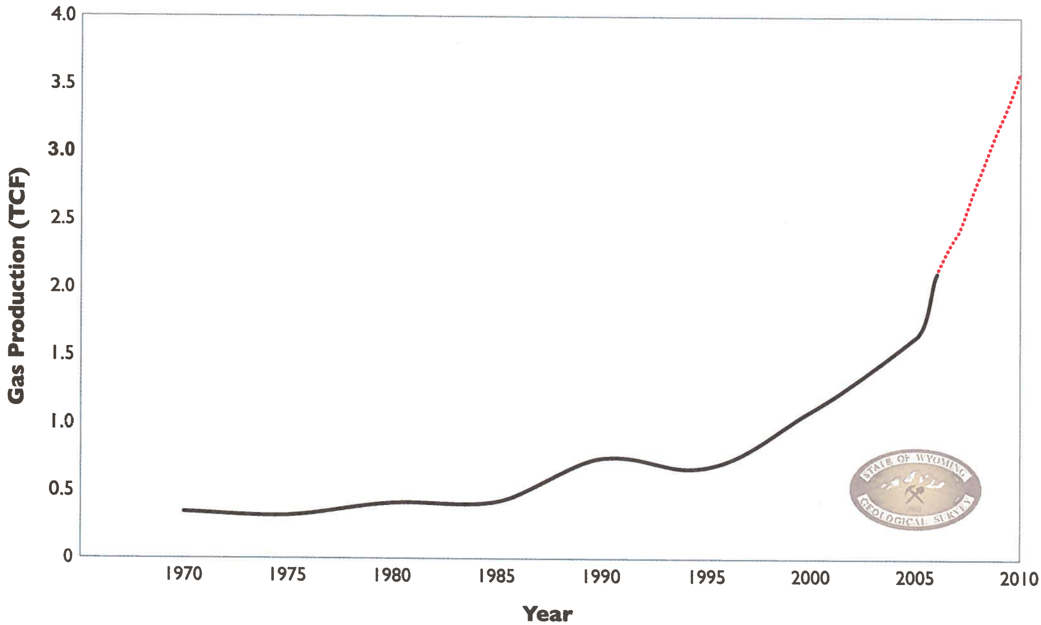


Figure 8. Wyoming natural gas production from 1970–2006. The red dotted line represents projected production through 2010.

Wyoming's huge and diverse energy portfolio, along with its low population, will ensure the state remains at the forefront of domestic energy production and exportation. Wyoming's energy contribution will increase both in quantity and in importance to national energy security.

Potential short-term constraints

The major constraint on Wyoming's energy exports is limited transportation and storage capacity (rail, pipeline, and transmission line capacity). There is no question that Wyoming could substantially increase its natural gas and coal production, and therefore its energy exports. However, existing pipelines, railways, and transmission lines are currently operating at full capacity, so increasing production at this time would not help alleviate the country's energy woes. Instead, increased production would drive the price of commodities down by creating an artificial energy surplus and a large price differential between energy from Rocky Mountain states and energy from other exporting states across the nation. This transportation bottleneck prevents Rocky Mountain states from exporting energy to areas of high demand (**Figure 9**).

Although national rhetoric regarding energy independence is increasing almost exponentially, national infrastructure to transport new energy products and/or electricity remains

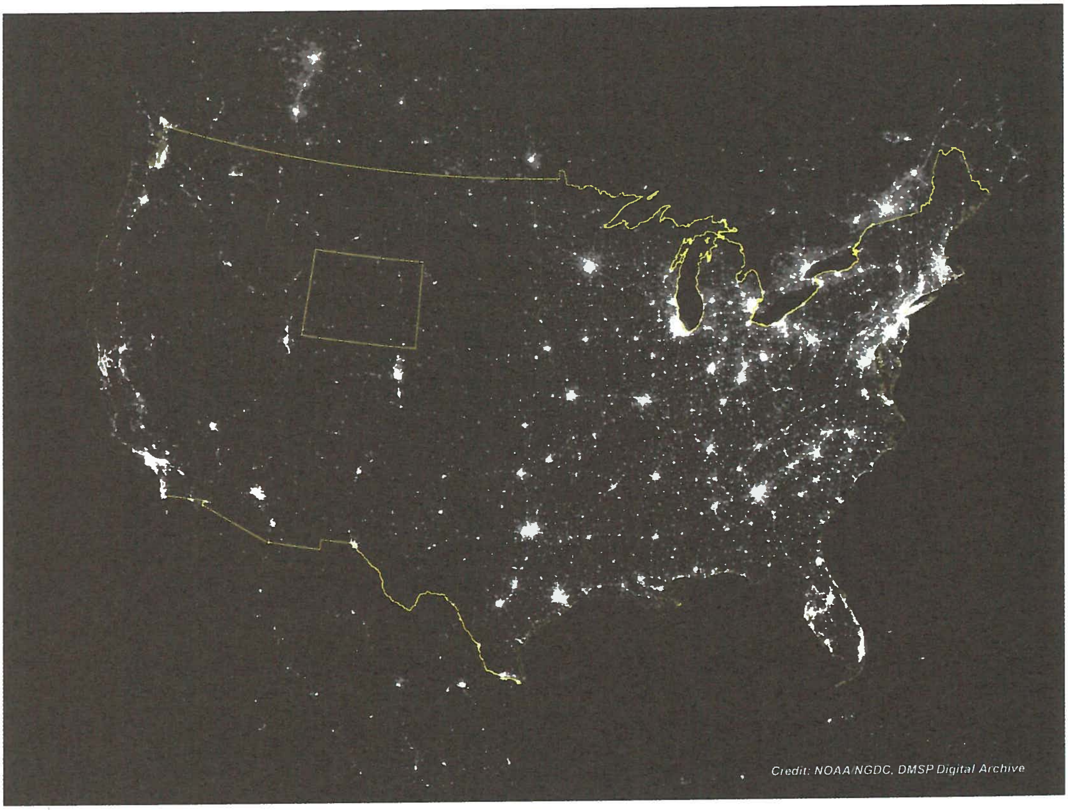


Figure 9. Satellite imagery showing the United States at night. Wyoming is outlined in yellow. This image shows a clear demarcation between areas of low and high population density.

inadequate at best and antiquated at worst. This problem has existed since 1972, and despite several subsequent national energy policies, the domestic energy transportation infrastructure remains a victim of extreme neglect.

For the first time ever in December 2007, oil prices exceeded $90/barrel and Wyoming natural gas spot prices dipped below $0.40 per thousand cubic feet (MCF). At the same time, gas processed at the Henry Hub in Alabama remained at $6.00/MCF. This devaluing of Wyoming energy resources results from the following three factors: 1) a lack of pipeline capacity exiting the state; 2) a lack of adequate gas storage in the state; and most importantly, 3) the Federal Energy Regulatory Commission (FERC) allowing new pipelines from Colorado and Utah to enter major east-west trunk pipelines in Wyoming while known major transportation constraints exist at Wyoming's borders. FERC policies fix prices at artificially low levels by dumping Colorado and Utah gas on Wyoming, creating intense competition for incredibly scarce pipeline space and driving prices down. The commission may even allow gas from the San Juan Basin of New Mexico to enter east-west Wyoming pipelines. As long as FERC keeps this up, and as long as pipeline capacity remains inadequate, the large price difference between the Opal and Henry hubs will remain as gas piles up in the west.

Without a serious long-term national plan to address energy transportation infrastructure, energy-exporting Rocky Mountain states will labor under artificial constraints, and with time, low commodity prices will chip away at exploration and production budgets, causing energy producers to leave the region. In Wyoming, small independent producers will suffer more and disappear first.

FERC must plan for the next 25 to 50 years instead of the next six months. For the welfare of the nation, we must strike a balance in the Rocky Mountain West between production and transportation. Allowing reversal of pipeline flow or converting oil pipelines to gas pipelines is not the road to energy independence, but instead a refusal to address the nation's infrastructure problem. If FERC discouraged the transport of New Mexican gas in Wyoming pipelines, demand for the gas would drive construction of much-needed new east-west pipelines.

Similarly, a lack of rail capacity from Wyoming to the East Coast has led to eastern use of Venezuelan and Colombian coal. Crude oil production in eastern Wyoming faces similar transportation constraints. Competition with Canadian synfuel from Alberta "tar sands" for north-south pipeline space through Wyoming has caused the value of Wyoming crude oil to plummet. In addition, Canadian companies now own these pipelines, along with a significant proportion of Rocky Mountain refining capacity.

If we as a nation want to optimize domestic energy production, the federal government must provide constructive leadership by addressing pressing, current energy problems such as inadequate transportation infrastructure. When the nation has the will and the federal government provides the plan, direction, and funding, energy transportation problems will be solved. These transportation problems pale in comparison to those we faced in launching the space program: the U.S. must not wait until the lights go out to address the issue. For energy-exporting states like Wyoming to reach their full potential, and for the nation to progress toward energy independence, we must ensure that transportation infrastructure keeps pace with production.

Future energy supplies

Recent discussion of future energy supplies has revolved around renewable and unconventional energy resources. Wyoming is ideally situated in this respect: the state has enormous potential for shale gas, deep gas (gas located more than 15,000 feet below ground), bypassed underpressured gas, coal gasification, and coal-to-liquid energy sources. Most importantly, the technology to exploit these unconventional energy sources is currently available. If the U.S. eventually moves to a hydrogen-based economy, coal will be used to produce hydrogen, and Wyoming has the largest coal reserves in North America. If the U.S. instead increases reliance on nuclear power, Wyoming will be ready as the number-one uranium exporter in the country. The state also has significant oil shale resources, though Colorado and Utah both have richer deposits. The new technologies required for oil shale development will probably be in place in Colorado and Utah within 25 years; however, Wyoming's oil shale deposits are thinner and not as rich, and probably will not be developed for another 20 years after that.

Wyoming also has enormous wind and solar potential, but not enough transmission lines to deliver wind and solar energy to out-of-state consumers. Concerns about environmental damage, water availability, and water quality currently constrain coal gasification, coal-to-liquids, and oil shale project permitting, and will manifest wherever exploitation of these resources is proposed in the U.S.

In the future, any new conventional coal- or gas-fired power plants, integrated gasification combined cycle plants, coal gasification plants, coal-to-liquids plants, or oil shale projects will need to geologically sequester CO_2. Again, Wyoming has excellent potential geological CO_2 sequestration sites in structural traps with saline reservoirs, depleted compartmentalized gas accumulations, and deep coal deposits. As a result, carbon regulation should encourage construction of new power plants in Wyoming.

Wyoming has huge renewable and unconventional energy resources waiting to be developed, all of which could help lessen our national dependence on foreign energy. The diversity of Wyoming's energy portfolio is truly incredible: if the nation puts politics and special interests aside and addresses the global energy crisis with logic, ingenuity, common sense, and innovation, Wyoming will play a vital role in ensuring energy security in the 21st century.

Wyoming's role in national energy security

The role of Wyoming's energy resources in the U.S. and global economies has changed drastically over the last few decades. Excluding a minor bump from 1980–1990, oil production in Wyoming declined steadily from 1970 to 2006, when production increased slightly (**Figure 6**). Wyoming's past economic "busts" resulted primarily from significant decreases in commodity prices coupled with steady declines in production. Oil was one of Wyoming's major energy exports – along with coal and a relatively small amount of natural gas (**Figures 6, 7, and 8**) – until about 1990, when Wyoming's energy environment changed dramatically, rapidly, and with little warning. Increasing concern over air quality and new federal regulations caused production of Wyoming's low-sulfur coal to increase quickly and steadily, from less than 200 million tons per year in 1990 to nearly 450 million tons per year in 2006. Even without an additional rail line to transport coal out of the Powder River Basin, Wyoming will probably produce 500 million tons of coal annually by 2010.

Natural gas production remained relatively flat (and was associated mainly with oil production) until 1995. Between 1995 and 2006, Wyoming's natural gas production increased from little more than 0.5 trillion cubic feet TCF to more than 2.0 TCF. Discovery of the giant gas fields at Jonah and the Pinedale anticline (tight gas sands), along with successful recovery of gas from coal beds in the Powder River Basin (the beginning of the coal bed natural gas industry in Wyoming), caused the jump in production. According to new well predictions by the Wyoming Oil and Gas Conservation Commission and average well performance data for the fields, Wyoming could produce as much as 3.5 TCF of gas per year by 2010.

During the last decade or two, Wyoming's energy portfolio has expanded and diversified. Coal and natural gas production now drive the state's economy: oil is only a minor player. Wyoming is also the nation's leading exporter of uranium. Most importantly, Wyoming has become the number-one domestic exporter of energy over the last decade, exporting more than 10 quadrillion btus per year to the rest of the U.S. (**Figure 5**). Even more astonishing is that when compared to all other major energy exporters (such as Canada, Mexico, Venezuela, and Saudi Arabia), Wyoming emerges as the leading energy exporter to the U.S. (**Table 9**). Over the past 18 years, Wyoming evolved from a relatively minor energy producer to the leading exporter of energy to our nation. Today, one out of every ten btus used in the U.S. comes from Wyoming. Since 1970, the state's energy portfolio has gone from including a single commodity (oil) to encompassing a diverse array of energy resources characterized by steadily increasing production. In 25 years, with upgrades of transportation, pipeline, and transmission line infrastructure, Wyoming could produce 650 million tons of coal and 4.0 TCF of natural gas annually. However, this will require an integrated national energy plan that includes substantial upgrades of the existing, antiquated national energy infrastructure and the addition of new strategic components. This task will entail huge public and private investment, federal leadership, and public cooperation.

Given the facts presented above, and barring a global economic depression, how could anyone predict an economic bust for Wyoming? On the contrary, it is possible that Wyoming's economy could expand even more. In the event of a real national energy crisis, the current constraints on energy production in Wyoming could be removed, allowing the state to maximize its energy potential.

To maintain the national economic growth rate that we have all enjoyed for decades, the U.S. requires slightly more than a 1 percent per year increase in electric power generation, or 25–30 percent more electrical generation capacity over the next 25 years. In other words, to grow successfully through 2030, the U.S. will need to build 80 new conventional coal-fired power plants the size of the Jim Bridger plant, 13 large natural gas-fired power plants,

Table 9. Top ten exporters of energy to the United States in 2006.

Rank	Country or state	Crude oil		Natural gas		Coal		Total (quadrillion btus)
		million barrels per year	quadrillion btus	trillion cubic feet per year	quadrillion btus	million tons per year	quadrillion btus	
1	Wyoming	52.93	0.28	1.75	1.77	446.74	7.96	10.01
2	Canada	648.97	3.41	3.59	3.63	1.49	0.04	7.08
3	West Virginia	1.83	0.01	0.22	0.22	152.37	3.91	4.14
4	Mexico	575.61	3.02	0.01	0.01	0	0	3.04
5	Saudi Arabia	519.40	2.73	0	0	0	0	2.73
6	Venezuela	416.83	2.19	0	0	3.07	0.08	2.27
7	Nigeria	378.51	1.99	0.06	0.06	0	0	2.05
8	Alaska	270.47	1.42	0.42	0.43	0	0	1.85
9	Iraq	201.85	1.06	0	0	0	0	1.06
10	Angola	187.25	0.98	0	0	0	0	0.98
Total		**3,253.61**	**17.08**	**6.05**	**6.12**	**603.67**	**11.99**	**35.19**

Note: total may not equal sum of components because of independent rounding. Coal imports include coal to Puerto Rico and the U.S. Virgin Islands.

Sources: Bureau of the Census, U.S. Department of Commerce, Monthly Report IM 145
EIA, U.S. Natural Gas Imports by Country
EIA, U.S. Crude Oil Net Imports by Country
EIA, Gross Heat Content of Coal Production, Most Recent Annual Estimates, 1980-2006

5 nuclear power plants, and 75,000 wind turbines, or some other equivalent combination of power sources (**Figure 10**).

How is our nation reacting to this electrical power crisis? In the last three years, 60 new power-generating projects with a combined capacity equivalent to more than 15 Jim Bridger plants have been cancelled: all but three of these projects were cancelled in 2007 (**Figure 11** and **Table 10**). Washington's inability to pass a viable energy policy and draft a coherent, definitive strategy to regulate CO_2 emissions has caused investors to pull funding for coal-fired power plants. As a consequence, the North American Electric Reliability Corporation (NERC) predicts that, in the near future, the U.S. will face an unreliable electric grid and the possibility of rolling brownouts (**Figure 12**).

The logical question is: how long would it take to build the cancelled plants along with the additional power plants required to meet the nation's need for the next 25 years? These additional facilities could consist of conventional coal-fired power plants, CO_2 capture-ready

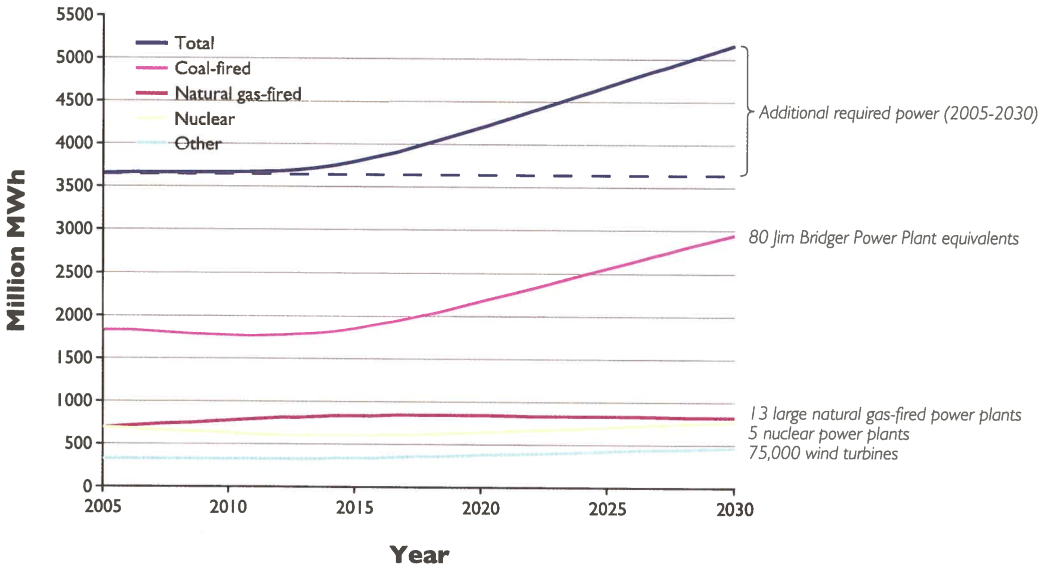


Figure 10. U.S. electrical power generation outlook for 2030. From the Department of Energy's Energy Information Administration Electric Power Annual 2006 (November 2006). <http://www.eia.doe.gov/electricity/epa/epa_sum.html>.

plants, plants that can capture and sequester CO_2, and/or some other technology that meets as-yet-unspecified standards and regulations designed by congressional lawmakers. Because of severe steel and cement shortages in the U.S., it is difficult to envision how our nation can construct essential power-generating facilities (coal-fired, gas-fired, nuclear, and wind) in less than ten years, and perhaps even in less than 20 years (**Figure 13**). Additionally, the U.S. has fallen behind in training scientists and engineers (**Figure 14**). If the country initiated an energy program similar to the Manhattan Project or the space effort of the 1960s, it would first have to contend with a dearth of qualified research, design, and construction personnel. Finally, serious construction material shortages would pose an additional challenge.

To achieve energy security, the nation desperately needs a clear and concise 25-year plan to develop energy responsibly in a carbon-constrained world. Meeting this goal will require all segments of the U.S. to make sacrifices on the order of those made during World War II. At present, it appears we lack the federal leadership, resources, and public outcry necessary to even start along the path to energy security.

Sustained prosperity in Wyoming

Under the above scenario, the value of Wyoming's diverse and plentiful energy resources can only significantly increase. To alleviate energy shortages in the U.S., it makes sense to look to those providers that have the capacity to supply additional energy resources. Wyoming is one of very few states that can significantly increase energy and power production in a relatively short time period. Under any of the national energy scenarios that have been presented by various experts, think-tanks, and government entities, Wyoming will play a central role in providing domestic energy resources to the nation. Consequently, there will be intense pressure on Wyoming over the next 25–30 years to further develop its natural resources.

It seems as though not a day passes without a newspaper quote from a Wyoming stakeholder commenting on the present economic boom and lamenting the impending, inevitable economic bust. The facts suggest that applying this "boom and bust" paradigm to Wyoming's economy, now or in the future, is fatally flawed, inaccurate, and inappropriate: general acceptance of this paradigm across the state is one of the most significant roadblocks to planning a prosperous and optimistic future for all Wyoming stakeholders.

Instead of worrying about "boom and bust" economic cycles, Wyoming stakeholders should develop a plan to maximize the responsible development of our energy resources, the quality of our communities, and the protection of our environment. There is no economic bust in sight – Wyoming should plan for sustained prosperity.

Figure 11. Power plant cancellations across the U.S. Sixty power plant projects with a combined capacity of 31,000 megawatts (MW) have been cancelled due to the current political and regulatory uncertainty surrounding CO_2 emissions. Each power plant on the map corresponds to one cancelled plant in that state. *Data: www.cmnow.org.*

Table 10. Proposed U.S. coal-fired power projects that have been cancelled in the last three years. All but three of the sixty listed projects were cancelled in 2007, and most cite political and regulatory uncertainty about CO_2 as the cause.

Company	State	Plant capacity (MW)	Action	Reason	Date
Matanuska Electric Association	AK	100	Company cancelled plans	Local opposition by elected officials over CO_2 and increased construction costs	November 2007
Southwestern Power Groups Bowie Station	AZ	600	Company cancelled to pursue natural gas	Market/economic/regulatory uncertainty regarding CO_2	September 2007
Xcel Energy	CO	300	Plans to close 2 coal-fired plants	Plans to roughly double its renewable power generation capacity by 2015	July 2007
Xcel Energy	CO	—	Plans to close 2 coal-fired plants	Plans to roughly double its renewable power generation capacity by 2015	July 2007
Xcel Energy (IGCC)	CO	600	Company shelved plans for at least 2 years	Rising construction costs and decreasing demand for coal-fired power	October 2007
Colorado Springs Utility's Ray D. Nixon Power Plant	CO	150	Company abandoned plans	Company lost financial partner	—
NRG Energy's Indian River Power Plant	DE	600	Proposal rejected by Delaware Public Service Commission	Public Service Commission ordered a feasibility study of offshore wind power	May 2007
Florida Power and Light's Glades Power Plant	FL	1,960	Proposal rejected by Florida EPA	Uncertainty surrounding costs of CO_2 regulation	July 2007
Florida Municipal Power Agency's Taylor Energy Center	FL	800	Company withdrew proposal	Florida PSC denied Glades Power Plant application	July 2007
Seminole Electric Power Cooperative's Seminole 3 Generating Station	FL	750	Proposal rejected by Florida EPA	Plant would not minimize impact on the environment and public health; plant would not serve the public interest	August 2007
Tampa Electric (TECO Energy) Polk 6 IGCC project	FL	630	Company cancelled plans	Uncertainty surrounding potential state CO_2 regulations	October 2007
Southern Company	FL	285	Company and Orlando Utilities Commission cancelled plans	Possible federal regulation of CO_2 emissions	November 2007
Idaho Power (IGCC)	ID	250	Company cancelled plans	New plan to adopt natural gas, wind, and geothermal	November 2007
Mountain Island Energy	ID	250	Company abandoned plans	—	December 2007

Table 10. Proposed U.S. coal-fired power projects that have been cancelled in the last three years. All but three of the sixty listed projects were cancelled in 2007, and most cite political and regulatory uncertainty about CO_2 as the cause.

Company	State	Plant capacity (MW)	Action	Reason	Date
Indeck Energy Service's Elwood Energy Center	IL	660	USEPA Environmental Appeals Borad reversed air permit approval	EPA found the plant lacked required emission controls	September 2006
Rentech coal to liquids plant	IL	76	Company put plans on hold indefinitely	"Pressure" on the project due to lack of a national CO_2 policy	December 2007
Steelhead Energy (IGCC)	IL	545	Southern Illinois Clean Energy Center declared inactive by EPA	Dropping coal in favor of natural gas	December 2007
Madison Power (IGCC)	IL	600	Company put plans on hold	Construction of nearby supercritical coal plant affected power demand and coal transport infrastructure	October 2007
Corn Belt Energy Corporation	IL	91	Company abandoned plans	—	March 2007
Dynegy's Baldwin Energy Complex	IL	1,300	Company abandoned plans	—	January 2007
Illinois Energy Group	IL	1,500	Company abandoned plans	Construction costs and CO_2 concerns	January 2007
Turris Coal Company	IL	35	Company abandoned project	—	January 2007
Clean Coal Power Resources (IGCC/CTL)	IL	2,400	Company abandoned project	—	June 2005
Westar Energy	KS	600	Company deferred plan	Significant increase in construction costs	December 2007
Sunflower Electric Power Corporation	KS	700	Kansas Department of Health and Environment denied air permit	CO_2 concerns	October 2007
Peabody Coal Company's Thoroughbred Generating Station	KY	1,500	Air permit denied	Inadequate air pollution control analysis	August 2007
EnviroPower/Kentucky Mountain Power	KY	525	Company abandoned plans	—	December 2007
Kentucky Pioneer Energy LLC (IGCC demo)	KY	540	Company cancelled project	—	October 2006
Alcoa	MD	950	Company cancelled plans	Economic concerns	December 2007
Twin River Energy Center	ME	700	Voters rejected plant	Coal barges would disrupt local fisheries	November 2007

Table 10. Proposed U.S. coal-fired power projects that have been cancelled in the last three years. All but three of the sixty listed projects were cancelled in 2007, and most cite political and regulatory uncertainty about CO_2 as the cause.

Company	State	Plant capacity (MW)	Action	Reason	Date
Wisconsin Public Power Inc.	MI	300	Company and City of Escanaba agreed to cancel project	High construction costs	May 2007
Excelsior Energy (IGCC)	MN	600	Failed to obtain regulatory approval	Environmental concerns	November 2007
Xcel Energy	MN	550	Company abandoned plans	—	—
Great Northern Power Development's South Heart Power Project	MT	500	Company withdrew air permit application	—	August 2007
Westmoreland and Montana Dakota Utilities' North Dakota Gascoyne	MT	175	Company failed to submit air permit application	—	September 2007
Bull Mountain Development's Roundup Power Project	MT	300	Montana regulators revoked air permit	Three lawsuits over air quality	September 2007
Dynegy and LS Power	NJ		Company cancelled plans	Pursuing natural gas	October 2007
Nevada Power Company and Sierra Pacific Power	NV	1,500	Company put plans on hold	Difficulties in regulatory review	September 2007
Tenaska's Sallisaw Electric Generating Plant	OK	880	Company cancelled plans	Not economically viable	July 2007
American Electric Power and Oklahoma Gas & Electric's Red Rock Generating Station	OK	950	Proposal rejected by the Oklahoma Corporation Commission	Failure to evaluate natural gas alternative	September 2007
TXU Corporation	TX	—	Company abandoned 8 proposed coal-fired power plants	Buyout of TXU by private equity firms	March 2007
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Table 10. Proposed U.S. coal-fired power projects that have been cancelled in the last three years. All but three of the sixty listed projects were cancelled in 2007, and most cite political and regulatory uncertainty about CO_2 as the cause.

Company	State	Plant capacity (MW)	Action	Reason	Date
TXU Corporation	TX	—	Company abandoned 8 proposed coal-fired power plants	Buyout of TXU by private equity firms	March 2007
TXU Corporation	TX	—	Company abandoned 8 proposed coal-fired power plants	Buyout of TXU by private equity firms	March 2007
TXU Corporation	TX	—	Company is abandoning 8 proposed coal-fired power plants	Buyout of TXU by private equity firms	March 2007
Tondu Corp (IGCC)	TX	—	Company abandoned plans	Rising costs and uncertain schedules for IGCC; company plans to build natural gas plant instead	June 2007
Pacific Corp (Intermountain Power coal plant expansion)	UT	950	Company abandoned plans	Six California cities that rely on the plant refused to support the expansion	
PacifiCorp's Hunter Unit 4	UT	575	Proposal rejected by Oregon Public Utility Commission	Company failed to prove a need for additional power	January 2007
Dynegy and LS Power	VA	1,600	Company abandoned plans	—	July 2007
Avista Utilities	WA	—	Company does not want to invest in new coal-fired power plants	CO_2 concerns and market economics	September 2007
Energy Northwest's Pacific Mountain Energy Center	WA	793	Application suspended by state regulators	Insufficient plans for carbon sequestration	November 2007
Pacific Corp's Jim Bridger expansion	WY	527	Company abandoned plans	CO_2 concerns	December 2007
Pacific Corp (IGCC demo)	WY	—	Company abandoned plans	CO_2 concerns	December 2007
Buffalo Energy Partners (IGCC)	WY	—	Company abandoned plans	Transmission constraints, rising construction costs, limited available technology guarantees, unsuccessful bid for funding	October 2007
Radar Acquisitions Company's Buick Coal and Power project	CO	—	Company failed to apply for air permit	Failed to find a financial backer	December 2007
NRG's Huntley Generating Station (IGCC)	NY	680	Company put plans on hold	Company must reduce costs to maintain state-awarded financial support	October 2007

Table 10. Proposed U.S. coal-fired power projects that have been cancelled in the last three years. All but three of the sixty listed projects were cancelled in 2007, and most cite political and regulatory uncertainty about CO_2 as the cause.

Company	State	Plant capacity (MW)	Action	Reason	Date
Rochester Gas and Electric's Russell Station II	NY	300	Company changed plans	Switching to natural gas, partly due to public opposition to coal	September 2007
Total plant cancellations			**60**		
Total megawatt-hours lost			**> 31,197**		

Modified from www.cmnow.org.

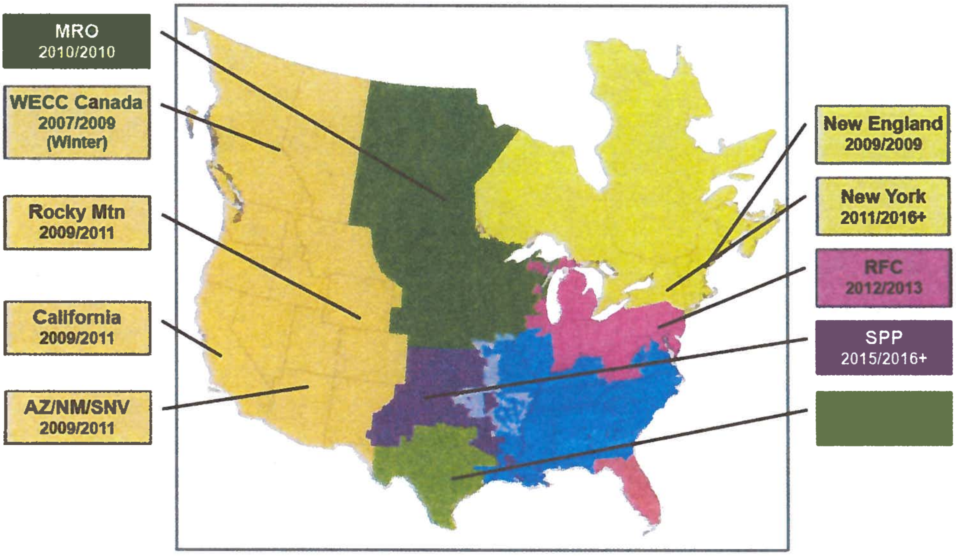

Figure 12. North American Electric Reliability Corporation long-term reliability assessment 2007 map, showing dates for potential "rolling brownouts." Modified from NERC LTRA 2007 by NETL.

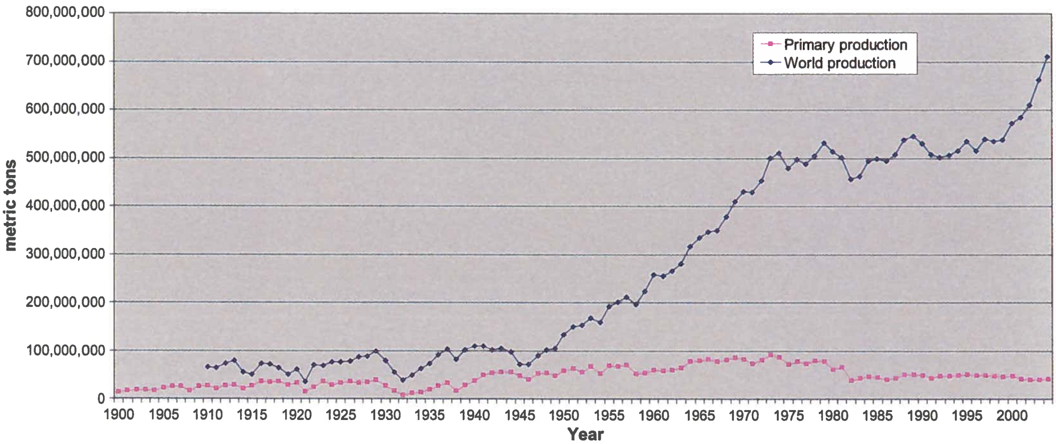

Figure 13. Global steel production (blue line), and U.S. primary steel production (pink line). From the USGS Mineral Commodity Summary (2006), <http://minerals.usgs.gov/minerals/pubs/mcs>.

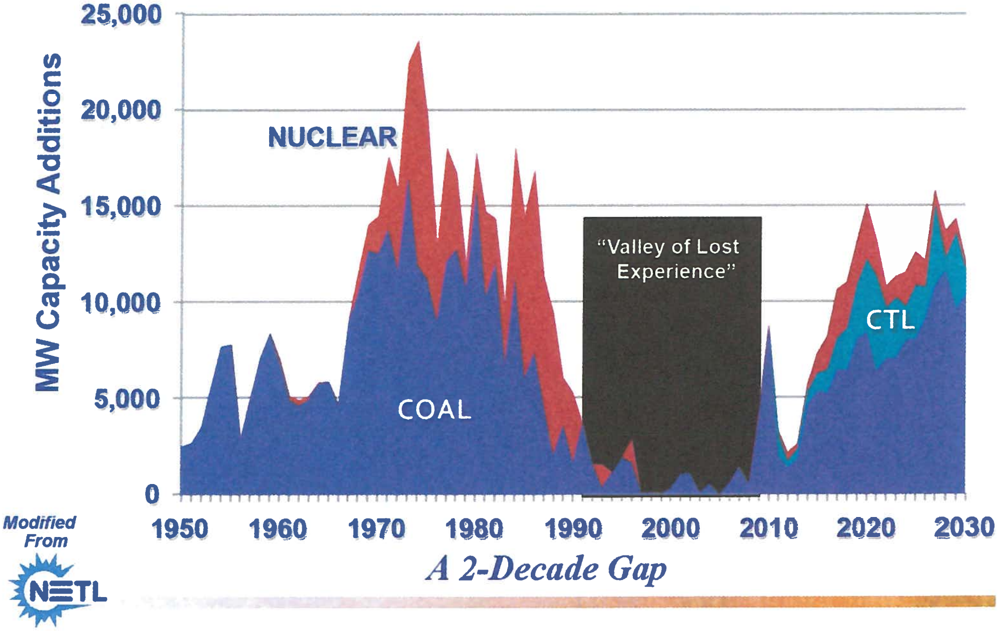

Figure 14. Diagram illustrating the gap in training scientists and engineers that currently exists in the U.S. as the country transitions from conventional coal-fired and nuclear plants to coal to liquids, coal to gas, and IGCC technology. Modified from power point presentation given by Carl O. Bauer, Director of NETL, in Cheyenne, Wyoming (2008).

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REFERENCES CITED

Bauer, C., Director, National Energy Technology Laboratory, Briefing in Morgantown, W.V., December 3, 2007.

Bauer, C., National Energy Technology Laboratory (2008), power point presentation, Tracking new coal-fired power plants, Cheyenne, Wyoming.

British Petroleum, 2006, BP statistical review of world energy June 2006, BP p.l.c, London, England, 45 p.

Chandra, M., et al., 2008, Proposed coal-fired power plants: Coal Moratorium Now <http://cmnow.org/Proposed%20Coal%20Plants.pdf >, accessed 3/10/2008.

Levorsen A. I., 1967, Geology of petroleum: San Francisco, CA, W.H. Freeman and Company, 724 p.

Likwartz, D., December 2008, personal communication.

North American Electric Reliability Corporation, 2007, 2007 Long-term reliability assessment: Princeton, N.J., NERC, 237 p.

U.S. Department of Energy, Energy Information Administration, 2007, EIA Annual energy outlook early release (Oct. 2007), Report No. DOE/EIA-0383(2008).

U.S. Department of Energy, Energy Information Administration, Office of Integrated Analysis and Forecasting, 2007, EIA International energy outlook 2007, Report No. DOE/EIA-0484(2007), 230 p.

U.S. Department of Energy, Energy Information Administration, 2008, EIA International petroleum monthly (Feb 2008), Washington, D.C.: <http://www.eia.doe.gov/ipm/>, accessed 3/10/2008.

U.S. Department of Energy, Energy Information Administration, 2008, U.S. natural gas imports by country: <http://tonto.eia.doe.gov/dnav/ng/ng_move_impc_s1_a.htm>, accessed 1/15/2008.

U.S. Department of Energy, Energy Information Administration, 2008, U.S. net crude oil imports by country: <http://tonto.eia.doe.gov/dnav/pet/pet_move_neti_a_epc0_imn_mbblpd_m.htm >, accessed 1/15/2008.

U.S. Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric, and Alternate Fuels, 2007, Electric power annual 2006: Washington D.C., 103 p. <http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html>.

U.S. Department of Energy, Energy Information Administration, Office of Energy Markets and End Use, International Energy Statistics Team, 2007, Gross heat content of coal production, most recent annual estimates, 1980-2000: <http://www.eia.doe.gov/emeu/international/RecentGrossHeatContentCoalProduction.xls>.

U.S. Geological Survey, 2006, Mineral commodity summaries 2007: U.S. Geological Survey, 199 p. <http://minerals.usgs.gov/minerals/pubs>.

WTRG Economics, 2007, Oil price history and analysis: London, Arkansas, WTRG Economics, <http://www.wtrg.com/prices.htm>, accessed 3/10/2008, Web site copyright 1996-2007 by James L. Williams.

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