



## MEMORANDUM

October 20, 2009

**To:** Senate Environment and Public Works Committee

**From:** [Congressional Research Service]

**Subject:** Terminology, Reporting, and Summary of U.S. Fossil Fuel Resources

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This memorandum summarizes the reported values for fossil fuel resources (oil, natural gas, and coal) in the United States, and provides information about the data sources and quality for various forms of fossil fuels. Because resource figures are often not directly comparable, and because many factors besides physical quantities affect the usefulness of different fuels, figures are presented for each fuel, as well as aggregate figures for all resources. This version of the memo has been updated from an October 7, 2009 version.

## Characteristics of Fossil Fuels

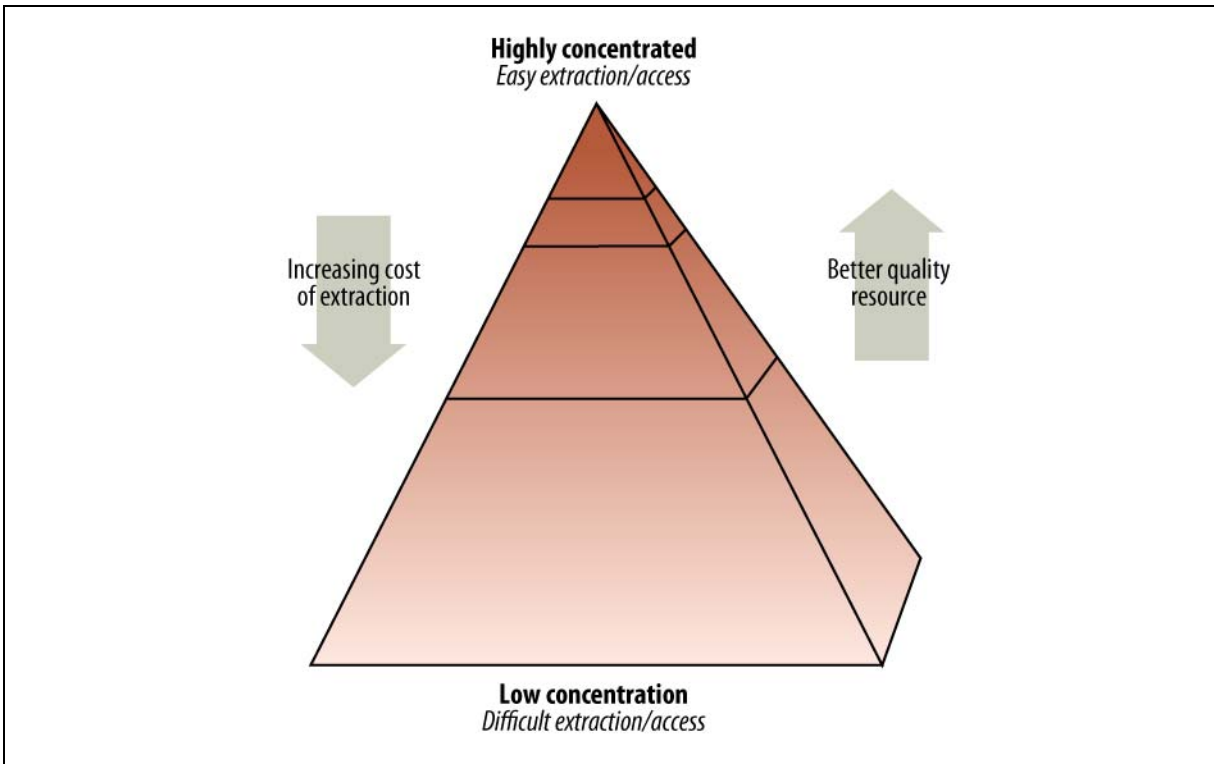
Fossil fuels are categorized, classified, and named using a number of variables. It is important to keep in mind that naturally occurring deposits of any material, whether it is fossil fuels, gold or timber, comprise a broad spectrum of concentration, quality, and accessibility (geologic, technical, and cultural). These characteristics are graphically portrayed in **Figure 1** as a resource pyramid. At the top of the pyramid are the deposits that are high-quality, and easy to access. These deposits have been generally discovered and produced first. Examples of the deposits at the top of the resource pyramid are the large oil deposits of Saudi Arabia and the enormous natural gas deposits of Qatar. Moving down the pyramid, the quality and/or accessibility declines, and production becomes more difficult and expensive. A large oil deposit in the deep waters of the Gulf of Mexico would be further down the pyramid than a comparable deposit on land because of the added expense and technology required to produce it.

It is important to note that the deposits at the bottom of the pyramid may be quite extensive. Deposits may be of poor quality or diffuse, but may occur in vast quantities. Examples of fossil fuel deposits that would be found at the bottom of the pyramid are oil shale and methane hydrates (both discussed further below). Oil shale and methane hydrate deposits contain massive amounts of oil and natural gas, but their mode of occurrence, poor accessibility, and difficult recovery make them sub-economic. The economic threshold for producing deposits further down the pyramid is, of course, partly a function of commodity price. That threshold is also moved by the development of new extraction technologies that make production feasible at lower cost.

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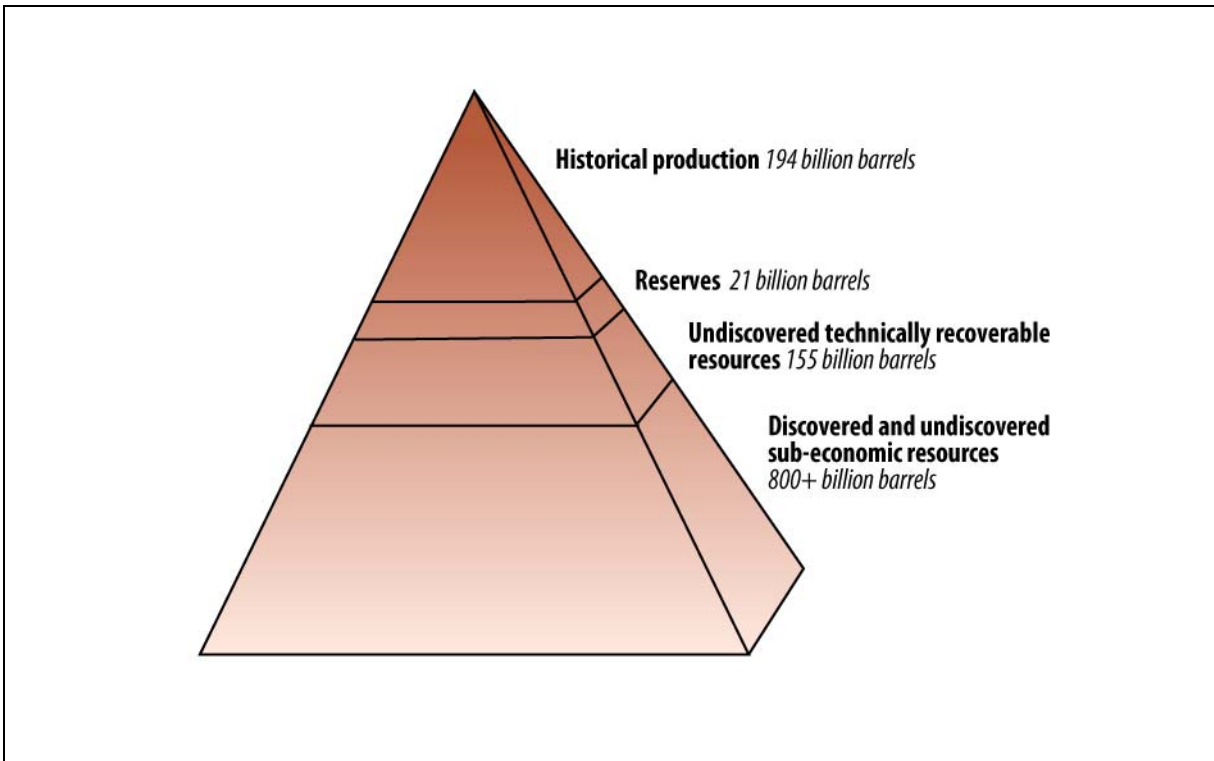
**Figure 1. The Resource Pyramid Concept**

All resources are not equal



**Source:** Michael Lardelli, *Earth as a magic pudding*, Oct 20 2008, <http://www.energybulletin.net/node/46956>, modified from Thomas Ahlbrandt and Peter J. McCabe, *Global Petroleum Resources: A View to the Future*, *Geotimes*, November, 2002, [http://www.geotimes.org/nov02/feature\\_oil.html](http://www.geotimes.org/nov02/feature_oil.html)

For U.S. oil deposits, the resource pyramid (**Figure 2**) indicates that many of the high quality, easy to find deposits have already been produced. Current proved reserves (terminology is discussed below) include many deposits that are of lower quality or with poorer access than some historical production, but which are still economic under current market conditions. As long as demand for oil continues, the exploration and production process will move down the pyramid under the influences of price (including environmental costs in some cases) and technology. Whether the vast deposits of oil shale that are lower on the pyramid will be produced depends on the price of oil, the cost of production (including environmental cost), and the availability of technology to produce it. Although this example is for oil, similar relationships exist for natural gas and coal.

**Figure 2. Resource Pyramid for U.S. Oil**

**Source:** Historical production and proved reserves figures are from Energy Information Administration, undiscovered technically recoverable resource value is from U.S. Geological Survey, and discovered and undiscovered sub-economic resources uses the lower estimate for oil shale resources from RAND as a minimum.

**Notes:** Discovered and undiscovered sub-economic resources would include poor quality or small deposits of conventional oil, some deposits of oil sands, and various other forms of oil deposits such as oil shale.

## Terminology

A search for energy statistics in the literature quickly reveals a large number of terms used to describe amounts of fossil fuels. Most of these terms have precise and legitimate definitions, and even a careful comparison of statistics for diverse forms of fossil fuels can become quite difficult to reconcile or understand. Not only do oil, natural gas, and coal occur in many diverse geologic environments, but each commodity may occur in different modes or in different geologic settings that impose vastly different economics on their recovery and delivery to market.

Examples of terms used for fossil fuel deposits (not an exhaustive list) include:

- Proved reserves
- Probable reserves
- Possible reserves
- Unproved reserves
- Demonstrated reserve base

- Undiscovered resources
- Probable resources
- Possible resources
- Speculative resources
- Potential resources
- Technically recoverable resources
- Economically recoverable resources

Definitions for several of these terms are included in the Appendix.

Two particularly important distinctions must be understood in order to gain a better understanding of fossil fuel statistics. The first key distinction is between proved reserves and undiscovered resources; the second key distinction is between conventional and unconventional deposits of fossil fuels.

## Proved Reserves and Undiscovered Resources

For oil and natural gas, a major distinction in measuring quantities of energy commodities is made between proved reserves and undiscovered resources. Understanding these terms will help avoid confusion about statistical energy data.

Proved reserves are those amounts of oil, natural gas, or coal that have been discovered and defined, typically by drilling wells or other exploratory measures, and which can be economically recovered. In the United States, proved reserves are typically measured by private companies, who report their findings to the Securities and Exchange Commission because they are considered capital assets. Because proved reserves are defined by strict rules, they do not include all of the oil or gas in a region, but only those amounts that have been carefully confirmed.<sup>1</sup> Because proved reserves are, by definition, economically recoverable, the proportion of the oil in the ground that qualifies as proved reserves grows when prices are high, and shrink when prices are low. That is, even without new discoveries, oil that may be sub-economic at \$30 per barrel becomes economic at \$60 per barrel and so the total proved reserves increase simply because price increases.

Beyond the volumes of proved reserves are deposits of oil and gas that have not yet been discovered, and those are called undiscovered resources.<sup>2</sup> The term “resource” has often been used in a generic sense to refer to quantities of energy commodities in general. We may refer to resource-rich nations, or speak about a large resource base, for example. But the term “undiscovered resources” has a specific meaning. Undiscovered resources are amounts of oil and gas estimated to exist in unexplored areas. Estimates of undiscovered resources for the United States are made by the U.S. Geological Survey for resources on

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<sup>1</sup> The Securities and Exchange Commission has recently modified their classification of reserves to include proved reserves, probable reserves, and possible reserves, adding precision of language to the degree of certainty associated with a particular volume of oil or gas, but also requiring increased attention to the terms used in energy statistics.

<sup>2</sup> The historic question is “If they are undiscovered, how do we know they exist?” The answer is that there is a probability that such deposits exist based on the geologic characteristics of a region, even if they have not been discovered yet. The exploration process is predicated on the probability that such deposits exist.

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land, and by the U.S. Minerals Management Service for resources offshore. These assessments are based on observation of geological characteristics similar to producing areas and many other factors. Reported statistics for undiscovered resources may vary greatly in precision and accuracy (determined retrospectively), which are directly dependent upon data availability, and their quality may differ for different fuels and different regions. Because estimates of undiscovered resources are based partly on current production practices, they are generally reported as undiscovered technically recoverable resources.

Another term sometimes used in the fossil fuels literature is “in-place” resources. In-place resources are intended to represent all of the oil, natural gas, or coal contained in a formation or basin without regard to technical or economic recoverability. Because only a small proportion of the total amount of the fossil fuel in a deposit is ever recovered, there are large discrepancies between technically recoverable resources and estimates of in-place resources. In-place resource estimates sometimes result in very large numbers, which may be misleading if the reader does not appreciate that the in-place volume of resource can never be completely produced or recovered.

### **The Importance of Terminology: The Example of the Bakken Formation**

Research by a USGS geologist during the 1980s and 1990s revealed that a rock formation in the Williston Basin of North Dakota, South Dakota, Montana, and southern Canada contained an abundance of hydrocarbons disbursed throughout layers of shale and sandstone.<sup>3</sup> Though the author, Dr. Leigh Price, died before publishing his results, the numbers reported were quite impressive: estimates of 271 to 503 billion barrels of oil attracted the attention of the oil industry. However, those estimates, while huge, represented “in place” oil. That is, the total volume of oil was huge, but it was disseminated throughout thousands of square miles of shale and only a small portion of that total would be recoverable. At that time, production of unconventional (or continuous) oil was not being done at large scales, so the technically recoverable volumes of oil were modest.

Subsequently, the USGS has conducted a more detailed and thorough estimate of the technically recoverable resources using modern directional drilling techniques and estimate that the Bakken Formation contains 3.65 billion barrels of undiscovered technically recoverable oil and 1.85 trillion cubic feet of undiscovered technically recoverable natural gas.<sup>4</sup> These estimates are still quite respectable, and production in the Bakken Formation is proceeding. But the gap between estimates of in-place oil and technically recoverable oil demonstrates vividly the importance of knowing what the numbers represent.

### **Conventional Versus Unconventional Oil and Natural Gas Deposits**

The first oil and gas deposits discovered consisted of porous reservoirs in geologic formations, capped by an impervious rock “trap” within which migrating fluids such as oil, natural gas, and water would accumulate. Within the reservoir, natural gas would be the least dense fluid and would have accumulated at the top of the reservoir. Oil is more dense than gas, but less dense than water and would pool in a layer below the gas cap. Below the oil and gas, water would fill the confined reservoir. This layered

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<sup>3</sup> Leigh Price, *Origins and Characteristics of the Basin-Centered Continuous Reservoir Unconventional Oil-Resource Base of the Bakken Source System, Williston Basin*, unpublished but available at <http://www.undeerc.org/Price/>.

<sup>4</sup> Richard Pollastro, *Assessment of Undiscovered Oil Resources in the Devonian-Mississippian Bakken Formation, Williston Basin Province, Montana and North Dakota*, 2008, U.S. Geological Survey Fact Sheet 2008-3021, <http://pubs.usgs.gov/fs/2008/3021/>

arrangement of natural gas, oil, and water within a reservoir is called a conventional deposit and has historically provided most of the oil and natural gas that has been produced.

In recent decades, geologists began to realize that considerable volumes of oil and natural gas exist outside conventional reservoirs in sedimentary rocks situated in geologic basins. The distribution of oil or natural gas throughout a geologic formation over a wide area, but not in a reservoir, is called an unconventional deposit (sometimes called a continuous deposit). The amounts of oil and gas contained in unconventional deposits may be very large, but recovering those deposits is sometimes difficult and expensive. An example of an unconventional oil deposit is oil sand, in which the oil is distributed widely through the sandstone formation. Recovering the oil from oil sands requires special technologies and treatments such as heating, steam flooding, or even excavation. An example of an unconventional natural gas deposit is coalbed methane. The natural gas (methane) does not exist in a discrete reservoir but is distributed throughout the pore spaces of coal. When water is removed from the coal, the gas is released and can be produced. Another type of unconventional natural gas deposit is shale gas, which is discussed below.

There is no direct correlation between the economic recoverability of a deposit and whether it is conventional or unconventional. Some conventional deposits are not economically recoverable because they are too small, too deep, or lack surface access. On the other hand, unconventional deposits such as oil sands and coalbed methane are economically recoverable in some locations. For example, coalbed methane production was 1.75 trillion cubic feet (tcf) in 2007<sup>5</sup> out of a total U.S. natural gas production of 19.3 tcf (approximately 9%), and is an important component of U.S. natural gas supply.

## Authoritative Data Sources for U.S. Fossil Fuel Reserves and Resources

Many individuals and institutions have attempted to compile and publish estimates of resources. However, the statutory responsibility for collecting and publishing authoritative statistical information on the various types of energy sources in the United States has been given to specific Federal agencies. The Energy Information Administration (EIA) was originally created as the Federal Energy Administration (FEA)<sup>6</sup> and is charged with the responsibility of monitoring and reporting U.S. energy reserves and production.

The Energy Information Administration (EIA) was created in response to the need for additional Federal initiatives to collect and disseminate energy-related information, and to evaluate and analyze this information. These needs were revealed as the United States sought to respond to the energy crises of the 1970s. The first law to address these needs was the Federal Energy Administration Act of 1974 and, over the years, many subsequent laws have contributed to EIA's evolution and growth.

[The law] Created the FEA and mandated it to collect, assemble, evaluate, and analyze energy information; provide energy information and projections to the Federal Government, State Governments, and the public; and provide Congress with an annual report summarizing these activities. It also provided FEA with data collection enforcement authority for gathering data from energy producing and consuming firms.<sup>7</sup>

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<sup>5</sup> [tonto.eia.doe.gov/dnav/ng/xls/NG\\_ENR\\_CBM\\_A\\_EPG0\\_R52\\_BCF\\_A.xls](http://tonto.eia.doe.gov/dnav/ng/xls/NG_ENR_CBM_A_EPG0_R52_BCF_A.xls)

<sup>6</sup> The Federal Energy Administration would later become the Energy Information Administration, [http://tonto.eia.doe.gov/abouteia/legislative\\_timeline.cfm](http://tonto.eia.doe.gov/abouteia/legislative_timeline.cfm).

<sup>7</sup> 1974: Federal Energy Administration (FEA) Act (P.L. 93-275, 15 USC 761)

Likewise, the responsibility for assessing onshore undiscovered technically recoverable oil and gas resources in the United States resides with the U.S. Geological Survey (USGS), in the Department of the Interior.<sup>8</sup> The USGS has conducted a number of national assessments of undiscovered technically recoverable oil and natural gas resources over several decades. The most recent complete national assessment for onshore oil and gas was completed in 1995, but USGS updates that assessment on an ongoing basis as new data become available. Responsibility for assessment of offshore undiscovered technically recoverable oil and gas resources belongs to the Minerals Management Service, also within the Department of the Interior.<sup>9</sup> EIA and USGS have similar responsibilities for evaluating the nation's endowment of coal.

In addition to purely governmental assessments, several expert groups provide perspectives on individual fuels, geographic areas, or industry sector. Some of these groups are composed of government, industry, and academic experts (e.g., the Potential Gas Committee<sup>10</sup>), expert advisory committees for federal agencies (e.g., National Petroleum Council<sup>11</sup>), independent study groups (e.g., the National Research Council, Committee on Earth Resources<sup>12</sup>), or professional societies (e.g., American Association of Petroleum Geologists<sup>13</sup> or the Society of Petroleum Engineers<sup>14</sup>). Each of these groups provides considerable expertise to the assessment and evaluation of oil and gas reserves and resources, and their reports should be taken seriously, but none have the responsibility to provide a consistent, timely statistical review of U.S. oil and natural gas resources. When using estimates generated by these expert groups, it is important to look for clear and transparent explanation of assessment methodology; in the absence of explanation, it will not be clear what is being estimated and the value and usefulness of the statistics will be diminished.

## U.S. Oil and Natural Gas Reserves and Resources

### Proved Reserves

U.S. proved reserves of oil as reported by EIA total 21.317 billion barrels.<sup>15</sup> The data are from the latest full compilation, at the end of calendar year 2007. There is generally a delay of over a year between the end of a reporting year and the compilation of the data because the process is time-consuming and quality control is essential. The EIA value for proved reserves includes both onshore and offshore reserves.

Compiling oil reserves is not a simple arithmetic exercise. Each year, volumes of individual components change significantly. Below is a list of how the reserves change during 2007 as a function of the normal exploration, production, and business processes conducted by oil companies. A more detailed description of these terms is in the Appendix.

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<sup>8</sup> <http://energy.cr.usgs.gov/oilgas/noga/>

<sup>9</sup> <http://www.mms.gov/offshore/>

<sup>10</sup> <http://www.mines.edu/Potential-Gas-Committee-reports-unprecedented-increase-in-magnitude-of-U.S.-natural-gas-resource-base>

<sup>11</sup> <http://www.npc.org/>

<sup>12</sup> <http://dels.nas.edu/besr/>

<sup>13</sup> <http://www.aapg.org/>

<sup>14</sup> <http://www.spe.org/spe-app/spe/index.jsp>

<sup>15</sup> Energy Information Administration, Data as of 12/31/2007, Release Date: 2/10/2009, [http://tonto.eia.doe.gov/dnav/pet/pet\\_crd\\_pres\\_dcu\\_NUS\\_a.htm](http://tonto.eia.doe.gov/dnav/pet/pet_crd_pres_dcu_NUS_a.htm)

- Adjustments (+,-) 65 million barrels
- Revision Increases (+) 2,278 million barrels
- Revision Decreases (-) 1,078 million barrels
- Sales (-) 811 million barrels
- Acquisitions (+) 792 million barrels
- Extensions (+) 651 million barrels
- New Field Discoveries (+) 66 million barrels
- New Reservoir Discoveries in Old Fields (+) 73 million barrels
- Estimated Production (-) 1,691 million barrels

U.S. proved reserves of natural gas, also reported by EIA for 2007 total 237.726 trillion cubic feet (tcf).<sup>16</sup> Like oil, the compilation of proved reserves of natural gas involved keeping track of several kinds of production and adjustments. The liquid components (natural gas liquids) are reported with oil production.<sup>17</sup> Total proved reserves are reported as dry natural gas and includes both onshore and offshore reserves. The following list shows a breakdown of how natural gas production is reported prior to separation into its gas and liquid components.

- Natural Gas, Wet After Lease Separation 247.789 tcf
- Natural Gas Nonassociated, Wet After Lease Separation 215.121 tcf
- Natural Gas Associated-Dissolved, Wet After Lease Separation 32.668 tcf
- Natural Gas Liquids (Million Barrels) 9.143

## Undiscovered Oil and Natural Gas Resources

As mentioned previously, the responsibility for assessing the undiscovered technically recoverable resources of oil and natural gas is split between the USGS for onshore resources, and the MMS for offshore resources. USGS and MMS use somewhat different assessment methodologies. The combined results of the onshore and offshore assessments are based on the availability of geologic data, which may be quite limited, especially for certain offshore areas. Nevertheless, the estimates are complementary and are tabulated in **Tables 1 and 2**. The USGS distinguishes between conventional and unconventional undiscovered resources and they are reported separately for oil, natural gas, and natural gas liquids. MMS reports their estimates for each offshore planning region but does not distinguish between conventional and unconventional deposits.

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<sup>16</sup> Energy Information Administration, Data as of 12/31/2007, Release Date: 2/10/2009, [http://tonto.eia.doe.gov/dnav/ng/ng\\_enr\\_sum\\_dcu\\_NUS\\_a.htm](http://tonto.eia.doe.gov/dnav/ng/ng_enr_sum_dcu_NUS_a.htm)

<sup>17</sup> <http://tonto.eia.doe.gov/cfapps/ipdbproject/docs/IPMNotes.html#p1>

**Table 1. Onshore U.S. Oil, Natural Gas, and Natural Gas Liquids**  
Undiscovered Technically Recoverable Resources (UTRR)

|                                | Oil          | Natural Gas   | Natural Gas Liquids |
|--------------------------------|--------------|---------------|---------------------|
|                                | (Bbo)        | (Tcf)         | (BOE)               |
| Conventional                   | 41.38        | 378.60        | 7.38                |
| Unconventional (continuous)    | 6.16         | 364.20        | 4.77                |
| <b>TOTAL U.S. ONSHORE UTRR</b> | <b>47.53</b> | <b>742.88</b> | <b>12.11</b>        |

**Source:** U.S. Geological Survey, Department of the Interior, 2008:  
[http://certmapper.cr.usgs.gov/data/noga00/natl/tabular/2008/summary\\_08.pdf](http://certmapper.cr.usgs.gov/data/noga00/natl/tabular/2008/summary_08.pdf)

**Notes:** Unconventional natural gas includes coalbed methane; Bbo = billion barrels of oil, Tcf = trillion cubic feet, BOE = billion barrels of oil equivalent.

**Table 2. Offshore U.S. Oil and Natural Gas**  
Undiscovered Technically Recoverable Resources (UTRR), mean values

|                                 | Oil         | Natural Gas  |
|---------------------------------|-------------|--------------|
| U.S. OCS Region                 | (Bbo)       | (Tcf)        |
| Alaska                          | 26.6        | 132.0        |
| Atlantic                        | 3.8         | 36.9         |
| Gulf of Mexico                  | 44.9        | 232.5        |
| Pacific                         | 10.5        | 18.2         |
| <b>TOTAL U.S. OFFSHORE UTRR</b> | <b>85.8</b> | <b>419.8</b> |

**Source:** Minerals Management Service, Department of the Interior, 2006:  
<http://www.mms.gov/revaldiv/PDFs/2006NationalAssessmentBrochure.pdf>

**Notes:** Bbo = billion barrels of oil; Tcf = trillion cubic feet; BOE = billion barrels of oil equivalent

The total endowment of technically recoverable oil and natural gas for the United States is obtained by summing proved reserves from EIA with the onshore and offshore undiscovered technically recoverable resources from USGS and MMS, as shown in **Table 3**.

The value for total technically recoverable natural gas (1400.49 tcf) does not include much of the newly prospective shale gas being explored in the United States. According to a 2009 report by the Potential Gas Committee, a consortium of industry, academic, and government experts, the total “future supply” of natural gas is 2,074 tcf, which includes substantial volumes of shale gas (see description of shale gas below).

**Table 3. Total U.S. endowment of technically recoverable oil and natural gas**  
(sum of EIA reserves, USGS, and MMS UTRR values)

|                      | <b>Oil</b>         | <b>Natural Gas</b> |
|----------------------|--------------------|--------------------|
|                      | <b>(Bbo)</b>       | <b>(Tcf)</b>       |
| Total U.S. UTRR      | 145.5 <sup>a</sup> | 1162.7             |
| Proved reserves      | 21.3               | 237.7              |
| Total U.S. endowment | 166.7              | 1400.4             |

**Note:** Bbo = billion barrels of oil, Tcf = trillion cubic feet

a. Represents the total of technically recoverable oil plus natural gas liquids from Tables 1 and 2.

## Sub-economic<sup>18</sup> Oil and Natural Gas Resources

### Shale Oil

After coal, shale oil represents the most abundant fossil fuel in the United States. However, despite government programs in the 1970s and early 1980s to stimulate development of the resource, production of shale oil is not yet commercially viable. The need for massive capital investment and the cost of production itself have been the major barriers. A further economic factor lies in the fact that shale oil has a unique chemical composition and, unlike conventional crude oil, cannot be distilled to produce gasoline, but would be primarily a source of other liquid middle distillate fuels such as jet fuel or diesel oil, fuels for which there is significant national demand.

In addition, production of shale oil requires large amounts of water, an important factor since most of the resource is located in water-scarce regions of western Colorado, Utah, and Wyoming. Other environmental problems include the difficulty in disposing of tailings if excavation is used as the extraction process, and the production of greenhouse gases.

In light of these difficulties, efforts to aid in the development of shale oil are focused on pilot projects to test alternative technologies of production.<sup>19</sup>

Estimates of the amount of hydrocarbon fuel in U.S. shale oil resources is highly speculative, given the small amount of development that has taken place. The Department of Energy (DOE) Office of Naval Petroleum and Oil Shale estimates that approximately 1.38 trillion barrels of shale oil are potentially recoverable from the roughly 7.8 million acres of federal oil shale.<sup>20</sup> A more conservative estimate by the RAND Corporation is that 800 billion barrels may be recoverable.<sup>21</sup>

<sup>18</sup> The amount of resources considered “sub-economic” changes with economic conditions and extraction technologies

<sup>19</sup> For more details about shale oil development, see CRS Report RL34748, *Developments in Oil Shale*, by Anthony Andrews.

<sup>20</sup> U.S. DOE, Office of Petroleum and Oil Shale Reserves, *National Strategic Unconventional Resource Model*, April 2006.

<sup>21</sup> J. T. Bartis, T. LaTourrette, L. Dixon, D.J. Peterson, and G. Cecchine, *Oil Shale Development in the United States Prospects and Policy Issues* (MG-414-NETL), RAND Corporation, 2005.

## Shale Gas

Shale gas is an emerging type of natural gas deposit, and exploration for and production of shale gas is increasing. Shale gas is currently marginally economic, and production is therefore sensitive to the price of natural gas; if natural gas prices increase, production of shale gas will increase. Shale gas is a classical unconventional type of deposit; the gas is distributed throughout the low permeability shale formations rather than accumulating in a more permeable reservoir. The occurrence of gas in this manner requires special production techniques that often involve horizontal drilling into the gas-bearing formation, followed by hydrofracturing of the rock (exerting pressure in the gas well so high that it causes brittle rock to fracture) to release the gas from the rock. The use of hydrofracturing has caused some environmental concerns arising from the injection of large amounts of water into the well, concerns about the chemical composition of the injected fluids, fears that the fractured rock will expose local water wells to non-potable waters, and the observation that some hydrofracturing jobs have apparently created small earthquakes. However, industry officials insist that any environmental concerns could be mitigated through careful production practices.

No systematic assessment of shale gas resources has been conducted for the United States, though industry and academic experts estimate that the technically recoverable volumes of natural gas from these shale deposits is very large. Recently, the Potential Gas Committee estimated that the United States has 616 tcf of “potential natural gas resources” occurring as shale gas.<sup>22</sup> The proportion of that resource that will actually be produced will depend on further development of exploration and production technology, the price of natural gas, and the ways in which states deal with potential environmental issues.

## Methane Hydrates

Another form of fossil fuel with potentially vast resources is natural gas in the form of methane hydrate. Methane hydrate (sometimes called natural gas hydrate, or just gas hydrates) are being investigated as an energy source by both DOE<sup>23</sup> and USGS.<sup>24</sup> Methane hydrate is a crystalline solid composed of methane and water which forms in porous rocks under very specific conditions of temperature and pressure. They occur most commonly offshore in the sediments or rocks of the continental shelf and slope, or in cold climates such as northern Alaska and Canada. Although considered a scientific oddity until the 1990s, methane hydrates are now known to exist in hundreds of locations around the world, often in small isolated deposits, but sometimes in massive quantities. Total worldwide in-place resources of methane hydrates are probably huge, perhaps thousands of trillion cubic feet, but hydrates have never been produced commercially. Currently efforts by the United States, Canada, Japan, India, and several other nations are aimed at developing technologies to exploit this large and widespread form of natural gas.

The mean in-place gas hydrate resource for the entire United States is estimated to be 320,000 TCF of gas, with approximately half of this resource occurring offshore of Alaska and most of the remainder occurring beneath the continental margins of the lower 48 states.<sup>25</sup> The USGS estimates that there are about 85 trillion cubic feet (tcf) of undiscovered, technically recoverable gas resources within gas hydrates in northern Alaska, and recent studies have shown that methane hydrates are more

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<sup>22</sup> <http://geology.mines.edu/pgc/index.html>

<sup>23</sup> <http://www.fossil.energy.gov/programs/oilgas/hydrates/>

<sup>24</sup> <http://energy.usgs.gov/other/gashydrates/>

<sup>25</sup> Statement of Dr. Timothy S. Collett, Research Geologist, U.S. Geological Survey, U.S. Department of the Interior, Before the House Committee on Resources Subcommittee on Energy and Mineral Resources: On Unconventional Fuels II: The Promise of Methane Hydrates, July 30, 2009.

abundant in the sediments of the Gulf of Mexico than previously believed.<sup>26</sup> Improved understanding of the occurrence and behavior of these important natural gas deposits, and improved technology for producing them, may make methane hydrates a viable source of natural gas in the future.

## Heavy Oil

Heavy oil, so-named because its specific gravity and viscosity is higher than that of light crude oil, constitutes substantial deposits of oil in Canada, Venezuela, and other parts of the world. Canada's Athabasca oil sands Venezuela's Orinoco oil sands are the largest deposits of this type. Canada's oil sands contain an estimated 173 billion barrels of technically recoverable oil and accounts for more than half of Canada's oil production. The Orinoco oil sands are estimated to contain 1.36 trillion barrels of extra heavy oil in-place, of which approximately 270 billion barrels are technically recoverable.<sup>27</sup> Oil sands generally require special production techniques such as excavation or steam flooding, and the oil produced is often limited to certain refineries equipped to handle the heavy oil. U.S. heavy oil is found in California, Alaska, and Wyoming, and is estimated to hold up to 100 billion barrels of oil in place, though production of heavy oil in the United States is declining because of the depth of the resource and the cost of production.<sup>28</sup>

## U.S. Coal Reserves and Resources

EIA is the authoritative source for coal reserves and resource estimates for the United States. EIA compiles data on coal reserves and resources from state sources and federal sources, including from work done by the USGS.<sup>29</sup> The terminology used for coal is slightly different than for oil and natural gas. The primary statistic reported by EIA is the demonstrated reserve base (DRB), which is comprised of coal resources that have been identified to specified levels of accuracy and may support economic mining under current technologies.<sup>30</sup> For the latest reporting period, calendar year 2007, the U.S. demonstrated reserve base was 489 billion short tons.<sup>31</sup> Because the United States produces and consumes about 1.2 billion short tons of coal per year, the demonstrated reserve base would appear to provide hundreds of years' supply of coal, if we continue to consume it at the same rate. However, because coal production often requires ground disturbance, especially for open-pit mining, the amount that is technically recoverable is not always available. EIA has applied an availability factor that reduces the technically recoverable amount to 262 billion short tons that would actually be available for mining.<sup>32</sup> Detailed availability studies by the USGS have indicated that, at least in some cases, the available and economically recoverable coal might be even substantially less than the technically recoverable amount. For example, in one specific case in Wyoming, 47% of the in-place coal is technically recoverable, but the economically recoverable coal is only about 6% of the in-place coal.<sup>33</sup> While these proportions may vary between 5% and 20%, depending upon the specific conditions for each coal mining area, it is prudent to

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<sup>26</sup> <http://www.usgs.gov/newsroom/article.asp?ID=2227>

<sup>27</sup> [http://www.eia.doe.gov/oiaf/aeo/otheranalysis/aeo\\_2006analysis/papers/nlf.html](http://www.eia.doe.gov/oiaf/aeo/otheranalysis/aeo_2006analysis/papers/nlf.html)

<sup>28</sup> [http://fossil.energy.gov/programs/reserves/npr/Heavy\\_Oil\\_Fact\\_Sheet.pdf](http://fossil.energy.gov/programs/reserves/npr/Heavy_Oil_Fact_Sheet.pdf)

<sup>29</sup> [http://energy.cr.usgs.gov/coal/coal\\_assessments/summary.html](http://energy.cr.usgs.gov/coal/coal_assessments/summary.html)

<sup>30</sup> <http://www.eia.doe.gov/cneaf/coal/reserves/reserves.html>

<sup>31</sup> A short ton is 2000 pounds. A metric tonne is 2204 pounds.

<sup>32</sup> <http://www.eia.doe.gov/cneaf/coal/reserves/reserves.html>

<sup>33</sup> <http://pubs.usgs.gov/of/2008/1202/pdf/ofr2008-1202.pdf>

view very large coal numbers with some caution because in-place numbers, or even recoverable numbers, may not provide a realistic assessment of the coal that could actually be produced.

## Expressing Fossil Fuels as Barrels of Oil Equivalent (BOE)

It is sometimes useful to equate the different types of fossil fuels in order to compare the energy content or to gauge the magnitude of one type of fossil fuel in terms of another. Fossil fuels may be liquid, gas, and solid; oil is a liquid measured in barrels, natural gas is a gas measured in cubic feet, coal is a solid measured in pounds or short tons, and all three types of fossil fuels vary in composition, quality, and heat content. Therefore, converting one type of fossil fuel to an equivalent amount of another is a slightly problematic calculation. For example, the energy content of coal varies by at least a factor of three depending on grade.<sup>34</sup> However, government and industry sources commonly use rule-of-thumb measures to make these conversions. For example, EIA provides a conversion tool on their web site<sup>35</sup> that assumes the following heat contents (based on U.S. consumption, 2008):

Coal: 1 Short Ton = 19,988,000 Btu<sup>36</sup>

Natural gas: 1 Cubic Foot = 1,028 Btu

Oil: 1 Barrel = 42 U.S. gallons = 5,800,000 Btu

Using these rule-of-thumb heat values, we can express natural gas and coal units in terms of barrels of oil equivalent (BOE):

Coal: 1 Short Ton = 3.45 BOE

Natural gas: 1 million cubic feet = 1,028,000,000 Btu = 177.2 BOE = 5,643 cubic feet/barrel

Using these conversion factors, we present a crude comparison of U.S. energy reserves plus resources in **Table 4**.

**Table 4. U.S. fossil fuel reserves and resources expressed as BOE**

BOE = Barrels of oil equivalent

| Fossil Fuel                              | Native units               | BOE                       |
|------------------------------------------|----------------------------|---------------------------|
| Technically recoverable oil <sup>a</sup> | 166.7 billion barrels      | 166.7 billion BOE         |
| Technically recoverable natural gas      | 1400.4 trillion cubic feet | 248.2 billion BOE         |
| Recoverable reserve base of coal         | 262 billion short tons     | 903.9 billion BOE         |
| <b>TOTAL U.S. fossil fuel endowment</b>  |                            | <b>1318.8 billion BOE</b> |

<sup>34</sup> <http://www.aps.org/policy/reports/popa-reports/energy/units.cfm>

<sup>35</sup> [http://tonto.eia.doe.gov/kids/energy.cfm?page=about\\_energy\\_conversion\\_calculator-basics](http://tonto.eia.doe.gov/kids/energy.cfm?page=about_energy_conversion_calculator-basics)

<sup>36</sup> Btu is the abbreviation for British thermal units, a common measure of heat content. One Btu is the amount of energy in the form of heat required to raise the temperature of one pound of water one degree Fahrenheit.

- a. Technically recoverable oil and natural gas includes proved reserves plus undiscovered technically recoverable resources.

## A Brief Overview of Global Fossil Fuel Resources

Reliable values for proved reserves and undiscovered resources outside the United States are less available than for the United States. The only source of data for some countries is one of the nation's ministries (energy, resource, interior, commerce, etc.), and those data may not be completely accurate because of the lack of good geologic data and assessment methodology, or because the information is purposely withheld. In fact, even if all nations wished to report their resource estimates reliably, it would not be possible to collect uniform data because different methods, accounting rules, and terminology are used in each country. Therefore, some reserve statistics reported outside the United States are not consistent with the U.S. data. Furthermore, only reserves and production statistics are reported for most nations. There has been no reliable source for estimates undiscovered oil and natural gas resources internationally since the U.S. Geological Survey completed its World Petroleum Assessment in 2000.<sup>37</sup>

Data for proved reserves and production in all countries are most reliable. Production statistics can be obtained for the Oil Producing and Exporting Countries (OPEC)<sup>38</sup> and for the Organization for Economic Cooperation and Development (OECD) countries from the International Energy Agency,<sup>39</sup> an arm of OECD. For international statistics, the EIA relies on the Oil & Gas Journal (a publication of PennWell Corporation) or World Oil (a publication of Gulf Publishing Company) for foreign oil and natural gas reserves. These energy industry trade publications monitor individual national sources for information, as described by the Oil & Gas Journal:

OGJ does not make its own estimates of a country's reserves but rather compiles the estimates of proved reserves from an annual survey of official sources, including government agencies and ministries. Since most countries do not assess their reserves annually, many of the figures in this report are unchanged from a year ago.<sup>40</sup>

World Oil summarizes their data sources this way:

World Oil's tables are produced with data from a variety of sources, including governmental agencies. Operating companies with drilling programs also contributed to this year's survey. Our survey is not scientifically randomized, and new environmental and political challenges may emerge at any time. In some cases, a country may not have responded to our surveys, in which case we might use proxies such as rig counts and third-party sources, both public and private.<sup>41</sup>

A source of global oil and gas information commonly used by a number of analysts is the BP Statistical Review of World Energy.<sup>42</sup> Some of BP's data also comes from Oil & Gas Journal and World Oil, but is supplemented with additional data:

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<sup>37</sup> U.S. Geological Survey, World Petroleum Assessment, 2000, <http://certmapper.cr.usgs.gov/rooms/we/index.jsp>.

<sup>38</sup> <http://www.opec.org/home/>

<sup>39</sup> <http://www.iea.org/index.asp>

<sup>40</sup> Marilyn Radler, Oil & Gas Journal, New estimates boost worldwide oil, gas reserves, Dec. 22, 2008.

<sup>41</sup> World Oil, Production and reserves lag as world drilling grows, September, 2008.

<sup>42</sup> <http://www.bp.com/productlanding.do?categoryId=6929&contentId=7044622>

The reserve numbers published in the BP Statistical Review of World Energy are an estimate of proved reserves, drawn from a variety of official primary sources and data provided by the OPEC Secretariat, Cedigaz, World Oil and the Oil & Gas Journal and an independent estimate of Russian oil reserves based on information in the public domain. Oil reserves include field condensate and natural gas liquids as well as crude oil. They also include an estimate of Canadian oil sands ‘under active development’ as a proxy for proved reserves. This inclusive approach helps to develop consistency with the oil production numbers published in the Review, which also include these categories of oil.

The BP Statistical Review of World Energy uses data from the World Energy Council (WEC)<sup>43</sup> for coal reserves. The WEC is a global consortium of national committees that compile energy statistics for their own country. WEC estimates for oil and natural gas reserves differ somewhat from the Oil & Gas Journal and World Oil values, but not dramatically. For the United States, the U.S. Energy Association (USEA)<sup>44</sup> is the WEC national committee, and USEA cites EIA sources for its estimates for the United States. When using any international fossil fuel statistics, users should be cognizant of ultimate sources of data among these energy data organizations.

Using the best-available data, it is possible to draw a comparison of the total endowment of fossil fuels for nations. **Table 5** includes the basic data for oil, natural gas, and coal for selected nations, with calculations of the total fossil fuels in each nation, expressed in billions of barrels of oil equivalent (billion BOE).

**Table 5. Total fossil fuel reserves of selected nations**  
(expressed in native units and as billions of barrels of oil equivalent (BOE))

|                      | <b>OIL<br/>RESERVES<sup>a</sup></b> | <b>NATURAL<br/>GAS<br/>RESERVES</b> | <b>NATURAL<br/>GAS AS<br/>BOE</b> | <b>COAL</b>                | <b>COAL<br/>AS<br/>BOE</b> | <b>TOTAL<br/>FOSSIL FUELS<br/>IN BOE</b> |
|----------------------|-------------------------------------|-------------------------------------|-----------------------------------|----------------------------|----------------------------|------------------------------------------|
|                      | (billions of<br>barrels)            | (trillion<br>cubic feet)            |                                   | (billion<br>short<br>tons) |                            | (billions of barrels)                    |
| World                | 1332.0                              | 6212.3                              | 1100.8                            | 929.3                      | 3206.1                     | 5638.9                                   |
| Saudi Arabia         | 266.8                               | 253.1                               | 44.8                              | 0.0                        | 0.0                        | 311.6                                    |
| Canada               | 178.6                               | 58.2                                | 10.3                              | 7.3                        | 25.2                       | 214.1                                    |
| Iran                 | 138.4                               | 948.2                               | 168.0                             | 1.5                        | 5.2                        | 311.6                                    |
| Iraq                 | 115.0                               | 111.9                               | 19.8                              | 0.0                        | 0.0                        | 134.8                                    |
| Kuwait               | 104.0                               | 56.0                                | 9.9                               | 0.0                        | 0.0                        | 113.9                                    |
| United Arab Emirates | 97.8                                | 214.4                               | 38.0                              | 0.0                        | 0.0                        | 135.8                                    |
| Venezuela            | 87.0                                | 166.3                               | 29.5                              | 0.5                        | 1.8                        | 118.3                                    |
| Russia               | 60.0                                | 1680.0                              | 297.7                             | 173.1                      | 597.2                      | 954.9                                    |
| Libya                | 41.5                                | 54.4                                | 9.6                               | 0.0                        | 0.0                        | 51.1                                     |

<sup>43</sup> <http://www.worldenergy.org/>

<sup>44</sup> <http://www.usea.org/>

|                           | OIL<br>RESERVES <sup>a</sup> | NATURAL<br>GAS<br>RESERVES | NATURAL<br>GAS AS<br>BOE | COAL  | COAL<br>AS<br>BOE | TOTAL<br>FOSSIL FUELS<br>IN BOE |
|---------------------------|------------------------------|----------------------------|--------------------------|-------|-------------------|---------------------------------|
| Nigeria                   | 36.2                         | 184.0                      | 32.6                     | 0.2   | 0.7               | 69.5                            |
| Kazakhstan                | 30.0                         | 100.0                      | 17.7                     | 34.5  | 119.0             | 166.7                           |
| United States             | 21.3                         | 237.7                      | 42.1                     | 262.7 | 906.3             | 969.7                           |
| China                     | 16.0                         | 80.0                       | 14.2                     | 126.2 | 435.4             | 465.6                           |
| Qatar                     | 15.2                         | 905.3                      | 160.4                    | 0.0   | 0.0               | 175.6                           |
| Brazil                    | 12.2                         | 12.9                       | 2.3                      | 7.8   | 26.9              | 41.4                            |
| Algeria                   | 12.2                         | 159.0                      | 28.2                     | 0.1   | 0.2               | 40.6                            |
| Mexico                    | 11.7                         | 13.2                       | 2.3                      | 1.3   | 4.5               | 18.5                            |
| Angola                    | 9.0                          | 9.5                        | 1.7                      | 0.0   | 0.0               | 10.7                            |
| Azerbaijan                | 7.0                          | 30.0                       | 5.3                      | 0.0   | 0.0               | 12.3                            |
| Norway                    | 6.9                          | 79.1                       | 14.0                     | 0.0   | 0.0               | 20.9                            |
| Turkmenistan              | 0.6                          | 100.0                      | 17.7                     | 0.0   | 0.0               | 18.3                            |
| Indonesia                 | 4.0                          | 106.0                      | 18.8                     | 4.8   | 16.5              | 39.2                            |
| Malaysia                  | 4.0                          | 83.0                       | 14.7                     | 0.0   | 0.0               | 18.7                            |
| Uzbekistan                | 0.6                          | 65.0                       | 11.5                     | 3.3   | 11.4              | 23.5                            |
| Egypt                     | 3.7                          | 58.5                       | 10.4                     | 0.0   | 0.1               | 14.1                            |
| Australia and New Zealand | 1.6                          | 31.2                       | 5.5                      | 85.1  | 293.6             | 300.7                           |
| India                     | 5.6                          | 38.0                       | 6.7                      | 62.3  | 214.9             | 227.3                           |

**Source:** Energy Information Administration, <http://www.eia.doe.gov/emeu/international/contents.html>

**Note:** All values are for 2007 or latest available data. Countries are listed in order of oil reserve ranking.

a. Oil and natural gas reserve numbers are from the EIA tables, using only the Oil & Gas Journal values.

Using only proved reserve numbers for the United States and other nations shows that the United States remains among the top nations in proved reserves of all fossil fuels taken together.

Values for technically recoverable oil and natural gas resources estimated by the USGS contain greater uncertainty than the statistics for proved reserves. Nevertheless, adding the estimates for undiscovered technically recoverable oil and natural gas provides a more inclusive estimate of total endowment of technically recoverable fossil fuels. **Table 6** adds technically recoverable oil and natural gas resources to the proved reserve figures of **Table 5** to provide a more complete tabulation of technically recoverable fossil fuels. Values for total fossil fuels in **Table 6** include the estimates for coal reserves in the first column but do not include any estimates for undiscovered coal resources; those data simply do not exist in any consistent form for various nations.

As an example of how such undiscovered coal resources might affect the ultimate total endowment of fossil fuels, the U.S. coal resource estimates do not include some potentially massive deposits of coal that exist in northwestern Alaska. These currently inaccessible coal deposits have been estimated to be more than 3,200 billion short tons of coal.<sup>45</sup> Only a portion of that coal would likely be technically recoverable

<sup>45</sup> Romeo M. Flores, Gary D. Stricker, and Scott A. Kinney, Alaska Coal Resources and Coalbed Methane Potential, U.S. (continued...)

even if development were pursued but, nevertheless, it suggests that other fossil fuel deposits in many parts of the world that have not been estimated or are not available for extraction.

**Table 6. Reserves of fossil fuels plus technically recoverable undiscovered oil and natural gas**

|                      | <b>Total fossil fuel<br/>proved reserves</b> | <b>Estimated<br/>undiscovered oil &amp;<br/>gas</b> | <b>TOTAL FOSSIL<br/>FUELS<sup>b</sup></b> |
|----------------------|----------------------------------------------|-----------------------------------------------------|-------------------------------------------|
|                      | (from Table 5)                               | (Billion BOE, USGS <sup>a</sup> )                   | (Billion BOE)                             |
| Saudi Arabia         | 311.6                                        | 231.3                                               | 543.0                                     |
| Canada               | 214.1                                        | 7.2                                                 | 221.3                                     |
| Iran                 | 311.6                                        | 114.3                                               | 425.9                                     |
| Iraq                 | 134.8                                        | 68.4                                                | 203.3                                     |
| Kuwait               | 113.9                                        | 4.7                                                 | 118.6                                     |
| United Arab Emirates | 135.8                                        | 16.2                                                | 152.0                                     |
| Venezuela            | 118.3                                        | 38.1                                                | 156.4                                     |
| Russia               | 954.9                                        | 293.7                                               | 1248.6                                    |
| Libya                | 51.1                                         | 10.8                                                | 61.9                                      |
| Nigeria              | 69.5                                         | 63.4                                                | 133.0                                     |
| Kazakhstan           | 166.7                                        | 33.7                                                | 200.4                                     |
| United States        | 969.7                                        | 351.5                                               | 1321.3                                    |
| China                | 465.6                                        | 28.4                                                | 494.0                                     |
| Qatar                | 175.6                                        | 12.1                                                | 187.7                                     |
| Brazil               | 41.4                                         | 79.4                                                | 120.8                                     |

a. U.S. Geological Survey, World Petroleum Assessment, 2000, <http://energy.cr.usgs.gov/WEcont/WEMap.pdf>; mean values of estimates are used for foreign countries. U.S. number is taken from values in Table 3.

b. Total Fossil Fuels in this table include the technically recoverable reserves of oil, natural gas, and coal from Table 5, plus estimates of undiscovered oil and natural gas from the USGS World Petroleum Assessment. No global estimates of undiscovered coal exist.

A meaningful comparison of the ultimate endowments of fossil fuels among nations would include the important deposits of oil, natural gas, and coal that are lower on the resource pyramid in **Figure 1**, and that might be exploited in the future given the appropriate technology, economic viability, and environmental acceptability. However, the uncertainty associated with estimates of those deposits are too great to produce meaningful comparisons. For example, the values in **Table 6** could be amended further by including estimates of oil shale or methane hydrate resources, but the final tally would have very little meaning considering the difficulties in estimating those resources. The United States has considerable amounts of fossil fuels, both conventional and unconventional, both discovered and undiscovered, that are

(...continued)

Geological Survey Bulletin 2198, 2003.

not currently economically viable. However, it is likely that other nations contain similar deposits but lack any comprehensive assessment of those resources.

## U.S. Production and Consumption of Oil, Natural Gas, and Coal

Finally, to provide some scale for the reserves and undiscovered resource values reported above, **Table 7** lists production and consumption of oil, natural gas, and coal by the United States.

**Table 7. United States Annual Consumption of Oil, Natural Gas, and Coal**

Values are for year-end, 2008

|             | Production                    | Consumption                   |
|-------------|-------------------------------|-------------------------------|
| Oil         | 1.81 billion barrels/year     | 7.1 billion barrels/year      |
| Natural Gas | 20.6 trillion cubic feet/year | 23.2 trillion cubic feet/year |
| Coal        | 1.17 billion short tons/year  | 1.04 billion short tons/year  |

**Source:** Energy Information Administration, <http://www.eia.doe.gov/>

**Notes:** Natural gas is reported on a dry basis.

## Appendix. Definition of Terms

### Reserves and Resources Terms

Definitions of terms taken from U.S. Department of the Interior, *Survey of Available Data on OCS Resources and Identification of Data Gaps*, Report to the Secretary, OCS Report MMS 2009-015, Appendix A, List of Terms Used. <http://www.doi.gov/ocs/report.pdf>

**Proved reserves.** The quantities of hydrocarbons estimated with reasonable certainty to be commercially recoverable from known accumulations under current economic conditions, operating methods, and government regulations. Current economic conditions include prices and costs prevailing at the time of the estimate. Estimates of proved reserves do not include reserves appreciation.

**Reserves.** The quantities of hydrocarbon resources anticipated to be recovered from known accumulations from a given date forward. All reserve estimates involve some degree of uncertainty.

**Reserves appreciation.** The observed incremental increase through time in the estimates of reserves (proved and unproved) of an oil and/or natural gas field as a consequence of extension, revision, improved recovery, and the additions of new reservoirs.

**Resources.** Concentrations in the earth's crust of naturally occurring liquid or gaseous hydrocarbons that can conceivably be discovered and recovered.

**Undiscovered resources.** Resources postulated, on the basis of the geologic knowledge and theory, to exist outside of known fields or accumulations.

**Undiscovered technically recoverable resources (UTRR).** Oil and gas that may be produced as a consequence of natural pressure, artificial lift, pressure maintenance, or other secondary recovery methods, but without any consideration of economic viability. They are primarily located outside of known fields.

**Undiscovered economically recoverable resources (UEER).** The portion of the undiscovered technically recoverable resources that is economically recoverable under imposed economic and technologic conditions.

**Unproved reserves.** Quantities of hydrocarbon resources that are assessed based on geologic and engineering information similar to that used in developing estimates of proved reserves, but technical, contractual, economic, or regulatory uncertainty precludes such reserves from being classified as proved.

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## Key Terms Used in Oil Statistics

Source: EIA, [http://tonto.eia.doe.gov/dnav/pet/TblDefs/pet\\_crd\\_pres\\_tbldef2.asp](http://tonto.eia.doe.gov/dnav/pet/TblDefs/pet_crd_pres_tbldef2.asp)

| Key Terms                               | Definition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-----------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Acquisitions                            | The volume of proved reserves gained by the purchase of an existing fields or properties, from the date of purchase or transfer.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Adjustments                             | <p>The quantity which preserves an exact annual reserves balance within each State or State subdivision of the following form:</p> $\text{Adjustments} + \text{Revision Increases} - \text{Revision Decreases} - \text{Sales} + \text{Acquisitions} + \text{Extensions} + \text{New Field Discoveries} + \text{New Reservoir Discoveries in Old Fields} - \text{Report Year Production} = \text{Published Proved Reserves at End of Report Year}$ <p>These adjustments are the yearly changes in the published reserve estimates that cannot be attributed to the estimates for other reserve change categories because of the survey and statistical estimation methods employed. For example, variations as a result of changes in the operator frame, different random samples or imputations for missing or unreported reserve changes, could contribute to adjustments.</p> |
| Crude Oil                               | <p>A mixture of hydrocarbons that exists in the liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities. Crude oil may also include:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Small amounts of hydrocarbons that exist in the gaseous phase in natural underground reservoirs but are liquid at atmospheric pressure after being recovered from oil well (casinghead) gas in lease separators, and that subsequently are comingled with the crude stream without being separately measured.</li> <li><input type="checkbox"/> Small amounts of non-hydrocarbons produced with the oil.</li> </ul> <p>When a State regulatory agency specifies a definition of crude oil which differs from that set forth above, the State definition is to be followed.</p>    |
| Extensions                              | The reserves credited to a reservoir because of enlargement of its proved area. Normally the ultimate size of newly discovered fields, or newly discovered reservoirs in old fields, is determined by wells drilled in years subsequent to discovery. When such wells add to the proved area of a previously discovered reservoir, the increase in proved reserves is classified as an extension.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| New Field Discoveries                   | The volumes of proved reserves of crude oil, natural gas and/or natural gas liquids discovered in new fields during the report year.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| New Reservoir Discoveries in Old Fields | The volumes of proved reserves of crude oil, natural gas, and/or natural gas liquids discovered during the report year in new reservoir(s) located in old fields.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Production, Crude Oil                   | The volumes of crude oil which are extracted from oil reservoirs during the report year. These volumes are determined through measurement of the volumes delivered from lease storage tanks, (i.e., at the point of custody transfer) with adjustment for (1) net differences between opening and closing lease inventories, and for (2) basic sediment and water. Oil used on the                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

|                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                              | lease is considered production.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Proved Reserves of Crude Oil | <p>Proved reserves of crude oil as of December 31 of the report year are the estimated quantities of all liquids defined as crude oil, which geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions.</p> <p>Reservoirs are considered proved if economic producibility is supported by actual production or conclusive formation test (drill stem or wire line), or if economic producibility is supported by core analyses and/or electric or other log interpretations. The area of an oil reservoir considered proved includes: (1) that portion delineated by drilling and defined by gas -- oil and/or gas -- water contacts, if any; and (2) the immediately adjoining portions not yet drilled, but which can be reasonably judged as economically productive on the basis of available geological and engineering data. In the absence of information on fluid contacts, the lowest known structural occurrence of hydrocarbons is considered to be the lower proved limit of the reservoir.</p> <p>Volumes of crude oil placed in underground storage are not to be considered proved reserves.</p> <p>Reserves of crude oil which can be produced economically through application of improved recovery techniques (such as fluid injection) are included in the "proved" classification when successful testing by a pilot project, or the operation of an installed program in the reservoir, provides support for the engineering analysis on which the project or program was based.</p> <p>Estimates of proved crude oil reserves do not include the following: (1) oil that may become available from known reservoirs but is reported separately as "indicated additional reserves"; (2) natural gas liquids (including lease condensate); (3) oil, the recovery of which is subject to reasonable doubt because of uncertainty as to geology, reservoir characteristics, or economic factors; (4) oil that may occur in undrilled prospects; and (5) oil that may be recovered from oil shales, coal, gilsonite, and other such sources. It is necessary that production, gathering or transportation facilities be installed or operative for a reservoir to be considered proved.</p> |
| Revisions                    | Changes to prior year-end proved reserves estimates, either positive or negative, resulting from new information other than an increase in proved acreage (extension). Revisions include increases of proved reserves associated with the installation of improved recovery techniques or equipment. They also include correction of prior report year arithmetical or clerical errors and adjustments to prior year-end production volumes to the extent that these alter reported prior year reserves estimates.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Sales                        | The volume of proved reserves deducted from an operator's total reserves when selling an existing field or property, during the calendar year.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

## Key Terms Used in Natural Gas Statistics

Source: EIA, [http://tonto.eia.doe.gov/dnav/ng/TblDefs/ng\\_enr\\_sum\\_tbldef2.asp](http://tonto.eia.doe.gov/dnav/ng/TblDefs/ng_enr_sum_tbldef2.asp)

| Key Terms                               | Definition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|-----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Dry Natural Gas                         | Natural gas which remains after: 1) the liquefiable hydrocarbon portion has been removed from the gas stream (i.e., gas after lease, field, and/or plant separation); and 2) any volumes of non-hydrocarbon gases have been removed where they occur in sufficient quantity to render the gas unmarketable. (Note: Dry natural gas is also known as consumer-grade natural gas. The parameters for measurement are cubic feet at 60 degrees Fahrenheit and 14.73 pounds per square inch absolute.)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Natural Gas Associated-Dissolved        | The combined volume of natural gas which occurs in crude oil reservoirs either as free gas (associated) or as gas in solution with crude oil (dissolved).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Natural Gas Liquids                     | Those hydrocarbons in natural gas which are separated from the gas through the processes of absorption, condensation, adsorption, or other methods in gas processing or cycling plants. Generally such liquids consist of propane and heavier hydrocarbons and are commonly referred to as condensate, natural gasoline, or liquefied petroleum gases. Where hydrocarbon components lighter than propane are recovered as liquids, these components are included with natural gas liquids.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Natural Gas Non-associated              | Natural gas not in contact with significant quantities of crude oil in a reservoir.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| Natural Gas, Wet After Lease Separation | The volume of natural gas remaining after removal of lease condensate in lease and/or field separation facilities, if any, and after exclusion of non-hydrocarbon gases where they occur in sufficient quantity to render the gas unmarketable. Natural gas liquids may be recovered from volume of natural gas, wet after lease separation, at natural gas processing plants.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Proved Reserves of Natural Gas          | <p>Proved reserves of natural gas as of December 31 of the report year are the estimated quantities which analysis of geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions.</p> <p>Reservoirs are considered proved if economic producibility is supported by actual production or conclusive formation test (drill stem or wire line), or if economic producibility is supported by core analyses and/or electric or other log interpretations.</p> <p>The area of a gas reservoir considered proved includes: (1) that portion delineated by drilling and defined by gas -- oil and/or gas -- water contacts, if any; and (2) the immediately adjoining portions not yet drilled, but which can be reasonably judged as economically productive on the basis of available geological and engineering data. In the absence of information on fluid contacts, the lowest known structural occurrence of hydrocarbons is considered to be the lower proved limit of the reservoir.</p> <p>Volumes of natural gas placed in underground storage are not to be considered proved reserves.</p> <p>For natural gas, wet after lease separation, an appropriate reduction in the reservoir gas volume has been made to cover the removal of the liquefiable portions of the gas in lease and/or field separation facilities and the exclusion of non-hydrocarbon gases where they</p> |

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|  | <p>occur in sufficient quantity to render the gas unmarketable.</p> <p>For dry natural gas, an appropriate reduction in the gas volume has been made to cover the removal of the liquefiable portions of the gas in lease and/or field separation facilities, and in natural gas processing plants, and the exclusion of non-hydrocarbon gases where they occur in sufficient quantity to render the gas unmarketable.</p> <p>It is not necessary that production, gathering, or transportation facilities be installed or operative for a reservoir to be considered proved. It is to be assumed that compression will be initiated if and when economically justified.</p> |
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