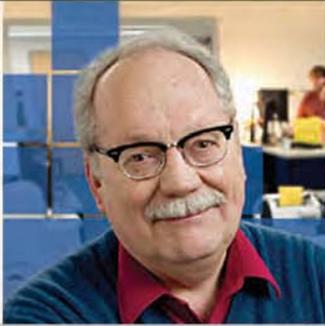




# VIEWS & VISIONS

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## The Revolution in Appalachian Shale Gas

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Dr. Carr is also a visiting professor at the China University of Geosciences in Wuhan and a consultant to the private sector and the U.S. Department of State.

His current research projects are in the areas of unconventional resources, subsurface petroleum geology and geophysics, energy systems, carbon capture and storage and developing information systems to improve public access to petroleum information and technology.

Prior to coming to West Virginia, Dr. Carr worked for the Kansas Geological Survey as chief of the Energy Research Section and as senior scientist for the Kansas Geological Survey at the University of Kansas. He was also co-director of the Energy Research Center and adjunct professor in the University of Kansas, Department of Geology. His experience also includes 13 years with Atlantic Richfield (ARCO), where he was involved in both exploration and development projects in locations including Alaska, the North Sea, East Greenland, California and Kansas.

Dr. Carr has a bachelor's degree in economics from the University of Wisconsin, a master's degree in geology from Texas Tech University and a doctorate in geology from the University of Wisconsin.

The United States has undergone a revolution in hydrocarbon production, driven by technology improvements related to technologies that were developed in the 1980s and 1990s for natural gas production from shale and other tight formations. Application of high-volume, multi-stage hydraulic fracturing and steerable horizontal drilling has enabled natural gas and hydrocarbon liquids to be economically produced from shale and other unconventional formations, and contributed to the United States becoming the world's largest natural gas producer in 2009, and to the rapid increase in oil and other hydrocarbon liquids that before the end of this decade will surpass the peak production of 1970.

During the 1970s "Energy Crisis," fear that domestic supplies of natural gas, oil and liquid hydrocarbons would run out led the U.S. government to fund research and demonstration efforts to understand the magnitude of the nation's unconventional hydrocarbon resources, and how to find and produce them.

The Unconventional Gas Research Program began in 1976, and consisted of the Eastern Gas Shales Project (EGSP) concentrated in the Appalachian region, the Western Gas Tight Sands Project (WGSP), and methane recovery from coalbeds. Research and technology development was managed by the U.S. Department of Energy (USDOE) and its predecessors through the Morgantown Energy Research Center (MERC), now part of the USDOE's National Energy Technology Laboratory (NETL). USDOE worked closely with the Gas Research Institute (GRI), established in 1976 and funded by a surcharge on interstate gas sales as approved by the Federal Energy Regulatory Commission, to manage and finance natural gas-related research and development programs.



These complementary research programs contributed directly to the revolution in production of hydrocarbons from unconventional reservoirs. DOE-funded research contributed to development of high-volume, multi-stage hydraulic fracturing, real-time steerable control of directional and horizontal drilling, new efficient drill bits, microseismic monitoring and better understanding of fracture mechanisms.

In the Barnett Shale of Texas, the GRI funded critical demonstrations of new technologies in early wells drilled by Mitchell Energy. In 1991, Mitchell Energy, with support from the federal government, drilled the first horizontal well in the Barnett. In 1998, Mitchell perfected hydraulic fracture stimulation of horizontal wells that were technical successes, but remained economic failures. However, in 2002, production from the Barnett took off and it was the most productive U.S. gas field from 2007 until 2010.

In 2007, the Energy Information Administration began reporting shale gas production, which accounted for seven percent of U.S. natural gas production. In 2013, shale gas production

accounted for almost 40 percent of production. As a result, liquid natural gas (LNG) import terminals, built to make up for the anticipated natural gas shortfall at the end of the previous century, are idle, and many have applied to become export terminals.

In late 2004, the completion of the Range Resources Corporation 1 Renz Unit well, located in Washington County, Pennsylvania, returned the focus of unconventional resource development to the Appalachian region. Production from the Marcellus has increased rapidly and surpassed the Barnett as the most productive field in the United States. Natural gas and hydrocarbon liquids production continues to increase sharply in the Marcellus and Utica-Point Pleasant in Pennsylvania, West Virginia and Ohio. As recently as 2008, gas production totaled less than 1.6 billion cubic feet per day (Bcf/d). In 2013, gas production had increased to 10.7 Bcf/d and the latest estimates place production in the three-state region at 14.6 Bcf/d. By 2019, it is expected to grow by another 33 percent, to almost 22 Bcf/d (a 1200 percent

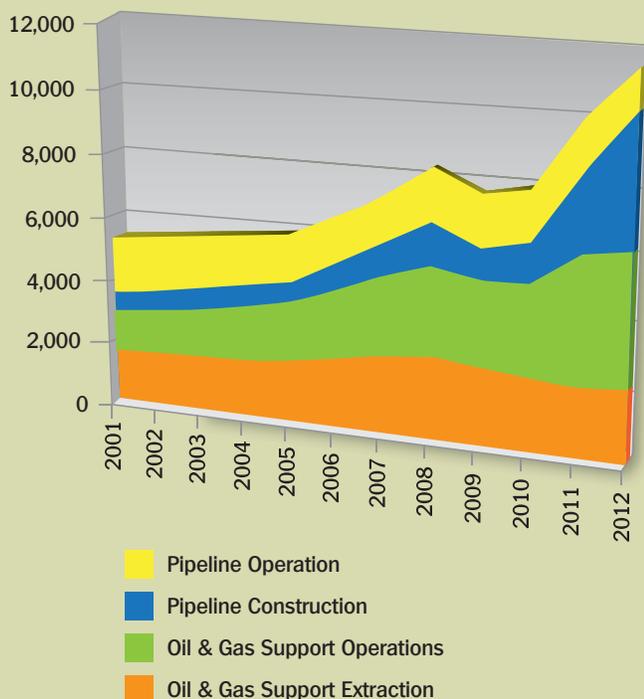
increase). As gas prices decreased in the region, producers have focused on the liquids-rich “wet gas” areas of southwestern Pennsylvania, eastern Ohio and northwest West Virginia, and liquids production in the region has doubled from 2008.

Today, unconventional wells represent less than two and one-half percent of the more than 166,000 producing wells, with multi-well pads approximately one percent of the producing locations in the region, but produce more than 95 percent of the natural gas and 50 percent of the hydrocarbon liquids. If one looks at the size of the disturbed land surface, unconventional wells compared to conventional wells produce 36 times more energy per acre disturbed.

One result of the increased shale activity since 2005 is the increase in direct employment. In West Virginia, direct employment in the oil and gas sector almost doubled and represents more than 60 percent of the growth in employment in the industrial sector, with annual wages that exceed the average by \$46,000.

The revolution in Appalachian gas and liquids has removed our regional dependence, and producers in the region need to reach additional customers to the south and west, including the LNG and hydrocarbon liquids export terminals under development on the East and Gulf coasts. While more than 50 major projects have been built in the past five years, building infrastructure capacity to process and move hydrocarbons out of Marcellus/Utica will remain a significant challenge for this decade. ▽

## West Virginia Direct Oil & Gas Industrial Sector Employment



**Industrial Sector Average  
Wage \$41,092/year**

**Average West Virginia  
Wage \$85,895/year**

**Oil & Gas jobs in WV increased from  
5,880 in 2005 to 11,524 in 2013**

**64% of the Total Increase in  
Private Sector Employment**

Source: Workforce West Virginia ([www.workforcewv.org](http://www.workforcewv.org))