A Report on Calculations of Interdependencies of Energy Production in West Virginia

This report summarizes estimates of fossil energy and water inputs to production of fossil energy resources and applies those figures to energy produced in West Virginia in 2007. Information was obtained primarily from publications of the U.S. Department of Interior (DOI), the U.S. Department of Energy and the U.S. Census Bureau. Where these publications were too broad to apply to West Virginia, such as for natural gas production, interviews with industry were used to supplement those data sources. This report is not a total life-cycle analysis in that energy consumption related to capital and material goods and transportation to end users is not included. These estimates cover on-site inputs related to physical resource extraction or production.

The following table summarizes the calculated energy inputs to fossil fuel production in West Virginia for 2007. Transportation inputs are not included due to the variability of costs associated with delivery to the end user.

ENERGY PRODUCT	ENERGY INPUTS TO PRODUCTION in 2007				
	Water (gal per unit)	**Coal (tons)**	**Electricity (MWh)**	**Natural Gas (Mcf)**	**Petroleum (bbls)**
Coal (161 million tons in 2007)	55 gallons per ton = 8.8 billion gallons	Not an input	2.2 million MWh	Not an input	1 million to 1.6 million barrels
Electricity (95,000,000 MWh in 2007)	851 gallons net per MWh = 80.8 billion gallons net use	38.4 million tons	3.6% of MWh used at power plant = 3,420,000 MWh[i]	5.9 Bcf	615,000 distillate; 46,000 residual
Natural Gas (235 Bcf in 2007)	5.6 million gallons per Marcellus well drilled = 392 million gallons	Not an input		18 Bcf	164,400 BOE for oil and gas together (drilling)
Petroleum (1.6 million bbls in 2007)	81 million gallons for secondary recovery of est. 257,000 barrels	Not an input		Not an input	

Coal: Surface and underground coal mining both consume electricity, liquid fuel, oil, lubricants and water during production. Per unit of output, analyses from the 1970s show that West Virginia surface mines consumed larger quantities of electricity than underground mines. Underground mines consumed more water during production, presumed to be due to the need to cool equipment and slightly more petroleum products.

Rates of petroleum-energy inputs for surface vs. underground coal mining are different for West Virginia-specific data published in the 1976 DOI study compared to national-level U.S. Census data for 2002. The Census data shows that surface mines consume more petroleum products per unit of output compared to deep mines. The Census figures do not include explicit information for electrical-energy consumption and is thus not fully comparable for the two reports.

Inputs to Coal Production:

- Water – 50 gallons per ton for washing (applies to all tons) + 8 gallons per ton for underground mines (for continuous miners, longwall units and outside water needs) = 8.8 billion gallons[ii]
- Electricity – Deep mine electric equipment: longwall units, continuous miner, loading machine, shuttle car, roof bolter, ratio feeder, auxiliary fan, jeeps (mantrip, mechanic, personnel), supply motor, rock duster, belt conveyer, ventilation fan, pumps, lighting, etc. Surface mine electric equipment: drill, shovels, dragline. Electricity is assumed to be used at a rate of 13,700 MWh per million tons of deep-mined coal and at a rate of 15,766 MWh per million tons of surface-mined coal.[iii]
- Natural Gas – While methane gas may be vented into the atmosphere or captured during mining it is not an input to production.
- Petroleum – Diesel fuel, engine oil and other lubricants are inputs to both underground and surface mining operations. Diesel Equipment for surface mines includes bulldozers, dump trucks and loaders. Consumption estimates vary between the two sources used for this report. According to a U.S. DOI report from 1976, petroleum products are consumed at a rate of 0.012 barrels of oil equivalent (BOE) per ton of deep-mined coal and at a rate of 0.007 BOE per ton of surface-mined coal.[iv v vi] The U.S. Census's nationwide figures for 2002 result in different rates that combine to lower total BOE: 0.012 BOE per ton of surface-mined coal and 0.009 BOE per ton of deep-mined coal.[vii] This could indicate a move toward increased electrification at deep mines and a move toward more fuel-intensive machinery at surface mines between 1976 and 2002.

Natural Gas and Oil: Energy consumed in production of natural gas and petroleum is a function of wells drilled, extraction and transmission. Because the U.S. Census-estimated figures include offshore energy consumption figures, it is believed that these numbers do not well represent inputs to production in West Virginia. Thus, rates of energy inputs were taken primarily from interviews with industry.

Drilling inputs are a function of the number of wells drilled, which does not correlate consistently with oil and gas production as wells produce at different rates. Energy inputs for drilling are the same for oil and gas, with the amount required depending on the depth of a well. A typical West Virginia well is drilled to 3,000 feet. The energy inputs calculated here are based on that depth. More precise figures could be obtained by evaluating the distribution of well depth for all wells drilled in a particular year, pending data availability.

Inputs to Gas and Oil Production:

- Water - About 220,000 net gallons per day is estimated to be used in Wetzel County via water flood extraction of oil.[viii] This is the only water flooding used in the State. Water is also a primary input in fracturing of horizontal gas wells. The typical amount of water used per well is 5.6 million gallons.[ix] Of all the gas wells in the state where drilling commenced in 2007, 70 were Marcellus wells. The estimated water used to fracture these wells is thus 392 million gallons.
- Natural Gas - Energy inputs to gas production are primarily natural gas. Natural gas is used as a fuel source to move gas from the well to gathering lines and then to transmission lines. Gas is also the primary fuel used to move gas to storage facilities, to

local distribution companies and then to final consumers. About 7.5 percent of produced gas is used to move gas from the wellhead to transmission lines. Of this amount, one percent is used to move the gas to gathering facilities, where gas is collected prior to being accepted into a larger transmission pipeline. Energy consumption as an input to the 235 billion cubic feet of natural gas produced in West Virginia in 2007 is thus 18 Bcf (18,154,000 MMBtu or 3.13 million barrels of oil equivalent).

- Petroleum - The primary input to oil and gas well drilling is diesel fuel. Energy inputs for drilling are the same for oil and gas, with the amount required depending on the depth of a well. Drilling the typical 3,000 foot well requires 3,000 gallons of diesel. While drilling itself consumes most of the fuel this level of input also covers work associated with location preparation, cementing, perforating, completion/stimulation and site remediation. With approximately 2,435 new wells drilled in West Virginia in 2007 the energy consumption associated with those wells was approximately 7.3 million gallons of diesel, which has an energy value of 953,000 MMBtu or 164,400 barrels of oil equivalent.

  Total Energy Inputs (Drilling + Extraction) = 19,107,000 MMBtu or 3.29 MMBOE. These inputs are dominated by extraction costs. Drilling inputs, although less significant, are imperfectly aligned with units of output when accounting for energy consumption in a single year. This is because the energy produced from a single well will take several years to accumulate. However, drilling can represent the cost of replacing production capacity, albeit at an increasing rate as production has increased in recent years.

  An additional 9.75 percent of produced gas is typically used to store and transport gas to its final consumer via local distribution companies. Gas extraction is emphasized in this analysis due to variability encountered in energy used to transport other fuels, particularly petroleum-based fuels. To include the energy used in final delivery would overestimate energy used to produce gas compared to other products evaluated here.

For more information on these estimates contact Christine Risch at (304)696-6251.

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[i] U.S. Department of Energy, Energy Information Administration. “Supply and Disposition of Electricity, 1995 through 2006.”
[ii] National Renewable Energy Laboratory (1999). “Life Cycle Assessment of Coal-fired Power Production.”
[iii] Ibid.
[iv] "Basic Estimated Capital Investment and Operating Costs for Coal Strip Mines", Katell, Sidney, E.L. Hemingway and L.H. Berkshire. U.S. DOI, 1976.
[v] "Basic Estimated Capital Investment and Operating Costs for Underground Bituminous Coal Mines Development for Longwall Mining", John R. Duda and E.L. Hemingway for the U.S. DOI Bureau of Mines (1976).
[vi] These rates were calculated using a consumption-weighted average price for “Other” petroleum products, which includes: asphalt and road oil, aviation gasoline, kerosene, lubricants, petrochemical feedstocks, petroleum coke, special naphthas, waxes, and miscellaneous petroleum products. Expenditure estimates provided in reports published by the U.S. DOI were converted to BOE using this price for the year evaluated.
[vii] U.S. Census Bureau, 2002 Economic Census. Mining Industry Series, Materials Summary.
[viii] This estimate is based on a 2005 interview with East Resources regarding plans to use water flooding in the short-term.
[ix] Chesapeake Energy (2010). “WATER USE IN MARCELLUS DEEP SHALE GAS EXPLORATION” Fact Sheet.