Shale Gas versus Ethanol: A Water Perspective

This essay was originally published in 2012. Ron—investment manager, engineer, farmer, and landowner—examines the amount of water needed to produce the BTU equivalent of ethanol vs. natural gas.

One of the concerns often voiced by opponents of the production of natural gas from shale rock by hydraulic fracturing is that the process uses a lot of water. Websites like Water Defense[1] lay out the argument in some detail. How much water does it take to drill and frack a well? According to Chesapeake Energy, it takes between 65,000 and 650,000 gallons of water to drill a well, and 4.5 million gallons of water to hydraulically fracture the shale.[2] Call it 5 million gallons in all. That certainly sounds like a lot of water, but is it really? And how does the amount of energy we get from the expenditure of that much water compare to "green" energy like ethanol? We'll do a little math and see what we can learn. The results may surprise you.

The numbers we use are typical of a Marcellus well and are drawn from presentations published by the natural gas industry. The spacing of wells and the output of natural gas and liquids vary significantly between shale formations, but we think the Marcellus wells are a decent example to use.

A Marcellus shale well typically drains the natural gas from underneath 80 acres and uses 5 million gallons of water. How much is 5 million gallons of water? One way to look at it is to calculate how much rain would have to fall on those 80 acres to supply 5 million gallons of water. When we do the math:

$$\frac{5{,}000{,}000 \text{ gal}}{7.48 \text{ gal/ft}^3} = 668{,}449 \text{ ft}^3$$

$$80 \text{ acres} \times 43{,}560 \text{ ft}^2/\text{acre} = 3{,}484{,}800 \text{ ft}^2$$

$$\frac{668{,}449 \text{ ft}^3}{3{,}484{,}800 \text{ ft}^2} = 0.19 \text{ ft}$$

$$0.19 \text{ ft} \times 12 \text{ in/ft} = 2.3 \text{ in}$$

we conclude that 2.3 inches of rain over 80 acres are required to supply 5 million gallons of water. That's about 3 or 4 rainy days here in Pennsylvania where the annual rainfall is 35-40 inches. Put that way, 5 million gallons of water doesn't sound as impressive.

Now, how much energy is produced through the investment of these 5 million gallons of water in drilling and fracking? Data published by Range Resources[3] indicate that the average Marcellus well drilled in 2010 is expected to produce over 4 billion cubic feet (BCF) of natural gas in its lifetime (plus some liquids that we won't consider here since the quantities of liquids produced vary greatly from well to well). Since the gas well drains 80 acres, the production per acre is 50 million cubic feet (MMCF) per acre over the life of the well.

$$\frac{\text{4 BCF}}{\text{80 acres}} = \text{50 MMCF/acre}$$

The energy content of natural gas measured in British Thermal Units (BTUs) varies over a range of about 900-1050 BTUs per cubic foot. We'll use the lower end of the range and calculate the energy output per acre of the well over its lifetime: 45 billion BTUs.

$$\text{50 MMCF/acre x 900 BTU/CF = 45bn BTU/acre}$$

A gallon of gasoline contains 114,000 BTUs of energy, so the energy output of a Marcellus well per acre is equivalent to 394,736 gallons of gasoline per acre.

$$\frac{\text{45bn BTU/acre}}{\text{114,000 BTU/gal}} = \text{394,736 gal/acre}$$

We invested 62,500 gallons of water to get the energy equivalent of 394,736 gallons of gasoline out of 1 acre of land, or the equivalent of 6.3 gallons of gasoline per gallon of water used.

$$\frac{\text{5,000,000 gal}}{\text{80 acres}} = \text{62,500 gal/acre}$$

$$\frac{\text{394,736 gal}}{\text{62,500 gal}} = 6.3 \qquad \frac{1}{6.3} = 0.16$$

Invert that number and you conclude that **it takes a Marcellus shale gas well 0.16 gallons of water to generate the energy equivalent of one gallon of gasoline.**

How does ethanol compare? (We compare natural gas to corn ethanol for two reasons: 30% of the U.S. corn crop is used for ethanol production, and many of the folks who are concerned about the use of water to release natural gas think ethanol is a great "green" way to produce energy.)

Our farmer friends tell us that 25-30 inches of rainfall during the growing season are required to grow corn, we'll use 25 inches in our calculations. The U.S. Department of Agricultural data indicate that the average corn yield of an acre of farmland in the U.S. last year was 147 bushels per acre[4]; call it 150 bushels per acre. We also know that one bushel of corn yielded 2.77 gallons of ethanol in 2012[5]; we'll call it 3 gallons/bushel. So 677,724 gallons of water are required to produce 450 gallons of ethanol.

$$2.08 \text{ ft water} \times 43{,}560 \text{ ft}^2 \times 7.48 \text{ gal/ft}^3 = 677{,}724 \text{ gal}$$

$$150 \text{ bushels/acre} \times 3 \text{ gallons ethanol/bushel} = 450 \text{ gal ethanol}$$

The heat content of a gallon of ethanol is only 76,100 BTUs, so 450 gallons of ethanol is equivalent to 300 gallons of gasoline.

$$\frac{450 \text{ gal ethanol} \times 76{,}100 \text{ BTU/gal ethanol}}{114{,}000 \text{ BTU/gal gasoline}} = 300 \text{ gal gasoline}$$

Therefore, 677,724 gallons of water invested in corn production results in the equivalent of 300 gallons of gasoline via corn ethanol. Do a little more math and you conclude that **corn ethanol requires 2,259 gallons of water to produce the energy equivalent of a gallon of gasoline.**

$$\frac{677{,}724 \text{ gallons water}}{300 \text{ gal equiv gasoline}} = \frac{2{,}259 \text{ gallons water/}}{\text{gallon gas equivalent}}$$

In other words, **shale gas is 14,000 times more water efficient in the production of energy than corn ethanol.**

$$\frac{2{,}259 \text{ gal water/gal equiv gasoline}}{0.16 \text{ gal water/gal equiv gasoline}} = 14{,}118$$

We recognize that this simple comparison is by no means a complete accounting of water usage for either process. We haven't accounted for the evaporation from the fields, the runoff from the fields, or the amount of water used in the fermentation process as corn is converted into ethanol. We haven't accounted for the amount of water that comes back up a gas well, or tried to characterize the utility of the waste water from either production process. Finally, we haven't accounted for the difference in the amount of water produced by the combustion of ethanol versus the amount of water produced by burning natural gas. So there are limitations to this short discussion. Having said that, a 14,000-to-1 ratio in water efficiency is HUGE. Where water is free this may not be a concern, but if the choice is between irrigating a corn field and fracking a shale well, you get a whole lot more energy for your water investment with the shale well. We don't think this calculation has entered into the public debate over water use in the production of energy, but frankly, it should.

The comments made by Ron Muhlenkamp are his opinion and are not intended to be investment advice or a forecast of future events.

[1] http://www.waterdefense.org/the-problems/fracking

[2] http://www.hydraulicfracturing.com/Water-Usage/Pages/Information.aspx

[3] Range Resources company presentation dated February 21 2012:
http://phx.corporate-ir.net/phoenix.zhtml?c=101196&p=irol-presentations

[4] http://www.nass.usda.gov/Charts_and_Maps/A_to_Z/in-corn.asp

[5] www.fapri.missouri.edu/outreach/.../2006/biofuelconversions.pdf