Amherst, NH – Pipeline Task Force Working Document
The Extraction and Transport of Natural Gas v. 1

What is "Natural Gas"?

Natural gas is a fossil fuel, found in sedimentary rock formations and naturally occurring underground spaces. Along with oil and coal, it arises from the decay of organic matter in anaerobic (low oxygen) conditions over geologic time, measured in millions of years, coupled with high temperatures and pressures. Fossil fuels consist of carbon-based compounds, which can come in a huge variety. Some are large, complex, heavy molecules, and some are light, simple molecules. Mostly they contain carbon and hydrogen, but the heavier forms found in oil and coal often have many other constituents such as sulfur, oxygen, nitrogen and other trace elements.

Natural gas is the lightest and simplest type of fossil fuel, consisting mainly of methane, with the chemical formula CH_4 (that is, one carbon atom and four hydrogen atoms). When burned it produces primarily carbon dioxide (CO_2) and water (H_2O). It also produces significantly less carbon dioxide than other fossil fuels when burned, for a given amount of energy produced. Compared to oil, and especially to coal, it produces lower levels of other harmful compounds that can lead to things like acid rain, and the release of radioactive elements into the environment.

The specific composition of natural gas as it comes out of the ground varies greatly, according to the specific conditions under which it formed. It is often broadly classified into "wet" gas and "dry" gas, the former containing significant amounts of heavier molecules like ethane, propane and butane, as well as carbon dioxide and nitrogen. Raw gas may typically contain anywhere from 75-95% methane. The gas may undergo processing at the wellhead, or more often at a nearby plant, to separate out the heavier compounds. Natural gas supplied to customers after processing is usually almost pure methane.

What are the Properties of the Gas that Would Flow in the NED Pipeline?

This gas would come from the Marcellus Shale formation in Pennsylvania, which also extends into West Virginia, Ohio, and New York State. Shale gas refers to natural gas trapped in small spaces, within a dense, impermeable sedimentary rock (shale). This particular rock formation is 390 million years old, and covers 100,000 square miles in a layer up to several hundred feet thick in places, about a mile down. The organic material came from marine plants and animals sinking to the oxygen-poor bed of a shallow sea.

The Marcellus shale gas has varying composition depending on location, with southern and western areas being "wetter" (more heavier compounds) and northern and eastern areas being "drier". Marcellus "wet" gas is ~75% methane with most of the rest ethane and propane, while Marcellus "dry" gas is often 95% methane or even higher. Marcellus gas in general has low levels of carbon dioxide, nitrogen and other contaminants. It seems likely that the NED pipeline would transport the eastern "dry" gas simply because it is much closer, and that little processing would be done to it before transport, though this has not yet been clearly stated in materials provided by the proposers of this pipeline. As natural gas transmission pipelines go, the

composition of the gas in NED would probably be unremarkable – mostly methane (95%+), small amounts of ethane and propane, not a lot else.

How Is the Gas Extracted?

Shales like the Marcellus contain gas in tiny spaces throughout the volume of the rock. Typically, simply drilling a hole in such rock releases only a tiny amount of gas. Significant flows can occur only when the rock is fractured, so that many of the gas-bearing spaces are breached, and there are long cracks for the released gas to flow through. As luck would have it, the Marcellus shale already has extensive natural fracturing due to geologic processes, and so is partially "primed" for gas extraction.

The second ingredient is artificial fracturing of the rock on smaller scales, to break up the rock in between the natural fractures. This is where "hydraulic fracturing" or "fracking" comes in. A mixture primarily of water and sand is forced down a well at high pressure, creating cracks in the rock. The sand is forced into these cracks and holds them open after the pressure is released, creating paths for the gas to flow. In a given volume of rock, fracking can increase the flow of gas by a very large factor.

The final, key element that has recently made shale gas economical to extract is the technology of horizontal directional drilling (HDD). This allows a single wellhead to reach many different areas of rock in a controlled, systematic fashion, further multiplying the production potential of each surface installation (see Figure 1). The Marcellus is now open to large scale exploitation, and it is the second largest currently accessible natural gas deposit on the planet. Fracking is a controversial technique, with many concerns over a variety of local environmental disruptions associated with contaminated fracking water, damage to residential wells, triggering of earthquakes and the like. The financial incentives are so great, however, that accommodations of various kinds are found and the fracking boom continues unabated.

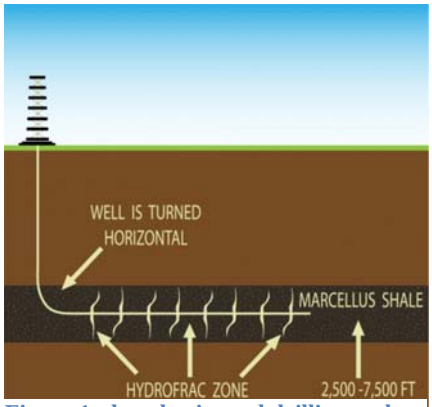

Figure 1 - how horizontal drilling and fracking work together

What Happens After the Gas is Extracted?

In a typical natural gas operation, raw gas from the well must be treated close to the wellhead before it can meet strict standards for transportation over long distances in a transmission pipeline. Certain raw gas constituents may be in liquid form under pipeline conditions, others may predispose a pipeline to rapid corrosion. Pipeline companies establish a set of standards for the gas to be transported, according to the particular characteristics of their pipeline systems, primarily to limit potential damage to their pipelines. Based on the typical standards listed in the "natural gas processing" Wikipedia page, only light processing at the source is likely to be required for eastern Marcellus "dry" gas, since it is unusually low in the contaminants of concern. The gas must then be transported to market.

At normal atmospheric pressure, natural gas has a very low energy content per cubic foot, and it would be uneconomical to transport it large distances. Therefore it must either be compressed (CNG) or liquefied (LNG) before being moved. The most economical and safest way to transport compressed gas is by pipeline, which is much safer than surface transport by road or

rail. If the gas is to travel overseas, the best way is liquefaction at low temperature for transport by tanker ships. The NED pipeline would transport compressed gas at up to 100 atmospheres of pressure, reducing the volume by up to a factor of 100. All volumes of gas quoted in the NED literature refer to gas at normal atmospheric pressure, not compressed. To transport the maximum volume of gas that is contemplated for NED, the velocity of the compressed gas in the pipeline might typically be 20-30 mph.

What Is Involved in Operating a Transmission Pipeline?

The gas does not move by itself – it must be pushed. A compression station elevates the pressure at one end of a pipeline section, and that increased pressure pushes gas downstream. As it flows, it encounters friction from the walls of the pipe. The overall effect is that a pressure gradient is set up throughout the length of the pipe section. The speed at which the gas flows and the amount of gas that is transported is directly related to this pressure gradient. The shorter the pipe segment, the higher the pressure gradient can be and the faster the gas can flow. What this means is that shorter distances between compressor stations on a long pipeline translate to higher flow rates.

One method of expanding the capacity of a pipeline to its nominal maximum rating (e.g. 2.2 billion cubic feet per day for NED) is adding more compressor stations. Typical distances between compressor stations on a major pipeline are 40 to 100 miles. These are major pieces of industrial infrastructure requiring significant tracts of land - it takes a lot of energy to push such volumes of gas through tens of miles of pipe. Sometimes it is possible to add more turbines to existing compressor stations, increasing the pressure gradient without adding new compressor stations, if doing so will not cause the gas pressure to exceed the pipeline's rated maximum pressure.

To limit hazards from leaks or ruptures, and to facilitate maintenance and repair, modern pipelines have remote controlled shutoff valves, typically every 10 miles or so. When necessary, the flow is halted and the affected segment is isolated.

Over time, pipelines can corrode, shifting earth can stress or crack welds, and contaminants could get into the system. To detect and address these and other potential problems, it is necessary to do periodic inspections of the interior of the pipe. This is often done using sophisticated versions of devices, known as "pigs" that are inserted into the pipeline and are pushed along in the gas flow. A modern gas pipeline such as NED would have multiple locations for insertion and extraction of these "pigs". Figure 2 shows an example of such a pipeline inspection gauge (pig).

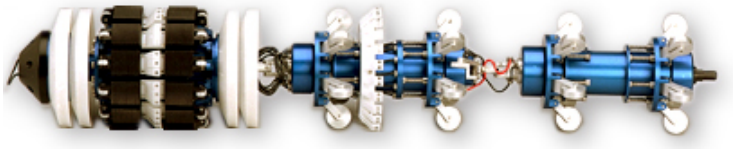

Figure 2 - pipeline inspection gauge, or PIG. Source: smartpigs.net

What happens when the gas arrives?

This depends on the content of the gas in the pipeline, and on the nature of the destination. If the gas is for residential or local business consumption through a distribution network run by a local distribution company (LDC), it must be treated to be in conformance with regulations. It may be further scrubbed and filtered, and it has mercaptan added, an odorant that gives gas its familiar smell - gas in a transmission pipeline typically does not have odorant, or has a lower concentration of such odorant. Distribution pipes run at very low pressure, no more than 20% above normal atmospheric pressure. It is possible for an LDC to tap gas from a transmission pipeline upstream from the main pipeline terminus. For example, the NED terminus is planned to be the hub in Dracut, MA, but gas could in principle be tapped by an LDC in New Hampshire as it passes through.