

ENGAGING ADULTS IN SCIENCE AND ENERGY



Pennsylvania State University

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Engaging Adults in Science and Energy

Marcellus Matters

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This text was compiled on 08/26/2026

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Glossary

Detailed Licensing

Licensing

*A detailed breakdown of this resource's licensing can be found in **Back Matter/Detailed Licensing**.*

1: PROCESS OF SCIENCE

The Process of Science

Understanding the process of science is critical to understanding what science can and cannot say. Science is a process of exploration and discovery. Science is not static but can change and deepen with new evidence. In this lesson, you will learn about the way scientists build consensus, deal with uncertainty, determine correlation vs. causation, present evidence and conclusions, and the language of science.

Learning Outcomes

By the end of this lesson, you should be able to:

- understand program goals, requirements, and the rules of engagement.
- identify the components of the scientific process.
- differentiate between what science can and can't say.
- evaluate assumptions and their importance to interpretations/conclusions (general and specific, related to data).

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1.1: Energy and your Life

Please watch the following video from [Switch Energy Project](#). (2:12)

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1.2: What is Science?

Science is:

- A way of learning about the world?
- A body of agreed-upon knowledge about how our world works?
- The practice of making observations and testing ideas with evidence?
- A process of challenging, improving and revising our understanding of how our world works?
- A system of checks and balances to ensure accuracy?
- An iterative process or work in progress that builds upon prior investigations and refines ideas?
- A democratic process that moves forward by building consensus?

The answer is “all of these—and more.” It is almost easier to say what science is NOT than to define what science is.

So what is NOT science?

Science is not a collection of static facts. Facts are knowledge about how our world works produced by science, but science itself is the process of exploration and discovery about how the world works. Science involves asking questions, formulating ideas, making observations, gathering and interpreting data, challenging assumptions, and revising ideas based on the data.

Science is not conducted in an arbitrary and uncontrolled manner. It is systematic and requires careful, deliberate and organized procedures.

Science is not a process that results in definitive answers. Scientific ideas and understanding can change and deepen with new evidence. Advances in technology may offer new insight that leads to modification of scientific ideas and understanding. For example, though the idea that continents once fitted together and were torn apart was first proposed in the 16TH century, it was the advent of seismometers and magnetometers in the 1950s and 60s that provided the insight which eventually led to the theory of plate tectonics that was only widely accepted by the geologic community in the 1970s.

Science is not about proving truth. “Science is not about immutable laws but provisional explanations that get revised when a better one comes along,” says Daniel Willingham, a professor of psychology at the University of Virginia (Willingham, 2011). That revision is not a weakness but a strength, he adds, as acknowledging and accepting new data strengthens those explanations.

Science is not quick. The development of scientific knowledge usually takes a long time. Scientists spend a lot of time rechecking and duplicating their observations, carefully writing up their results and then publishing them. Science also is iterative—meaning it circles back on itself so that useful ideas are built upon and used to learn even more. This often means that successive investigations of a topic lead back to the same question, but at deeper and deeper levels. Consider our knowledge of how biological inheritance works. In the mid-1800s, Gregor Mendel showed that inheritance is particulate—that is, characteristics are passed along in discrete chunks. In the early 1900s, Walter Sutton and Theodor Boveri (among others) helped show that those particles of inheritance, today known as genes, were located on chromosomes. Experiments by Frederick Griffith, Oswald Avery, and many others soon elaborated on this understanding by showing that it was the DNA in chromosomes which carries genetic information. And then in 1953, James Watson and Francis Crick, again aided by the work of many others, provided an even more detailed understanding of inheritance by outlining the molecular structure of DNA. Still later in the 1960s, Marshall Nirenberg, Heinrich Matthaei, and others built upon this work to unravel the molecular code that allows DNA to encode proteins. And it doesn't stop there. Biologists have continued to deepen and extend our understanding of genes, how they are controlled, how patterns of control themselves are inherited, and how they produce the physical traits that pass from generation to generation.

Science is not a solitary pursuit. Most discoveries are made by teams of researchers. While a single scientist may work alone, he/she is still dependent upon the work of scientists who have gone before and the community of scientists that review and validate the discoveries.

Science is not a process that is totally objective. Scientists like all people have values and biases that can influence what they do, how they do it and what they conclude. Scientists rely on the scientific community to review their work—in a process known as peer review—to minimize biases and validate scientific work and understanding.

Science is not a process that is perfect. Scientists can and do make mistakes—sometimes inadvertently and sometimes purposefully. Just as in any field, there are scientists with integrity and scientists without integrity.

Check Your Understanding

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1.2.1: Building Consensus and Peer Review

As noted previously, science is an ongoing or cumulative process that builds upon prior results or findings. Consensus develops as results are continuously confirmed with evidence, and alternative ideas are proven to be inaccurate. An idea, called a hypothesis, becomes well established when it is accepted by a majority of scientists who are respected in that field. Scientific consensus—that is, accepting established results—forms around what scientists judge as the most probable hypothesis. The ideas on which there is consensus form the starting point for additional research. Sometimes this research expands and solidifies the points of consensus and other times, as was the case with Albert Einstein’s work, new work overturns the fundamental idea upon which the scientific community had reached consensus.

Building uniform scientific consensus takes time— years, decades and even centuries. Scientists have to observe, investigate, gather data, examine other research and repeat their experiments. They have to consider alternative explanations and debate their research and conclusions. They have to explain their data and methods. They also have to publish their results, so that others can examine their data, methods and conclusions.

How scientists report their findings is critical to the process of building consensus. The gold standard for scientists is “peer-reviewed journals.” To be published in a peer-reviewed journal, a piece of scientific work is reviewed by other knowledgeable scientists who are neither personal associates nor collaborators with the scientist submitting the work. The reviewers critique the work—that is, analyze and evaluate the methods, reasoning and results—and make a recommendation that the work be accepted for publication, returned to the author for revision, or rejected outright. Most journals enlist the voluntary help of other scientists in the field to judge the merit of the science being submitted for publication. The journals themselves choose the reviewers, and typically, reviewers are anonymous. If you are an active scientist who publishes, then part of the expectation is that you will spend some of your time as a peer reviewer. The reviewers add their own credibility to the work and increase the respectability of the journal. The peer-review process works to minimize the effects of human bias and error in the scientific process.

Just because a paper has been peer reviewed does not mean it is correct beyond all doubt. Sometimes the problem may be the personal bias of the reviewers—although having a number of different reviewers can help with this. Sometimes the problem may be the science, which initially looked solid but which over time turns out to be flawed.

This is what happened with a widely cited paper by Andrew Wakefield, a British researcher, who in 1998 published a paper in *The Lancet*, a highly respected journal, suggesting a link between autism and the measles-mumps-rubella (MMR) vaccine typically given to children between the ages of 12 and 18 months of age. Wakefield based his concerns on a study he and other researchers had conducted of 12 children. The paper and a press conference held by Wakefield made headlines around the world and may have led to an uptick in childhood diseases once nearly wiped out as some parents feared having their children vaccinated.

In 2010, however, *The Lancet* retracted the Wakefield paper amid charges of conflict of interest and ethical misconduct by Wakefield and also questions about his research since no other labs had been able to replicate Wakefield’s results. Wakefield’s medical license also was revoked.

Unfortunately, peer review is not a good way to catch scientists who deliberately fabricate or manipulate data. Reviewers can only assess whether a scientist used reasonable techniques and whether their conclusions logically follow from the data reported. Detecting fraudulent data can only be done by other researchers carefully replicating the work of others. This is why the reporting of research methods and raw data are an important part of the scientific process.

While “peer review” is the gold standard, there are other avenues open to scientists wishing to report their work. They can publish in journals that are not peer-reviewed, self-publish reports, and more recently, publish on websites and blogs. However, the absence of peer review should raise serious concerns about the work and the conclusions being reported. You should check the author’s or authors’ background to find out why the report was not published in a standard peer-reviewed journal and look for similar work by others that is published in a peer-reviewed journal. As science journalist Maggie Koerth-Baker writes, peer review is “a first line of defense. It forces scientists to have some evidence to back up their claims, and it is likely to catch the most egregious biases and flaws....Journals that don’t have peer review do tend to be ones with an obvious agenda” ([boingboing](#)).

Checking a scientist’s background and credentials also is critical in determining expertise. Scientists may have broad interests, but expertise only in a very narrow field. Koerth-Baker notes how some journalists pursuing the Fukushima nuclear accident asked nuclear engineers—experts on nuclear power plants—to comment on the human health consequences of the disaster. Just because a scientist has expertise on one area does not mean he/she can speak with authority in other areas even those that

seem closely related.

1.2.2: Science and Uncertainty

The desire for certainty is a powerful human emotion, and dispensing with uncertainty is a prime motivation for many endeavors and decisions. But even when we seemingly put uncertainty at bay—we choose a career, our elected officials tighten legislation to address pollution, the Federal Reserve Board lowers interest rates to spark economic activity—we never know how those decisions or actions will turn out. Whether we like it or not, uncertainty is ever present.

Many of us, however, tend to think science provides definitive answers. After all, science explains why and how things happen. Science solves problems. Scientists make predictions about our future.

But much as we may want scientific findings to be definitive, they are not. Scientists do not operate with 100 percent certainty. Findings are based on probabilities. New evidence can invalidate predictions and even modify well-accepted understandings. In many respects, uncertainty is critical for science because it spurs scientists to engage in further investigation and research.

It is important to understand that scientific uncertainty does not mean the science is flawed. Rather it means an absence of certainty and in science, it's okay to have uncertainty. Scientists do not expect that every finding will be the last word. More often, those findings are just the beginning.

However, the lack of certainty often causes problems when science and emotion collide. It can paralyze policy makers and elected officials contemplating legislation. They need certainty to convince the public of the rightness of the proposed action—particularly if the decision involves economic pain.

The following from the [Union of Concerned Scientists](#), a science-based nonprofit with more than 400,000 members, speaks to science and uncertainty:

In science, there's often not absolute certainty. But, research reduces uncertainty. In many cases, theories have been tested and analyzed and examined so thoroughly that their chance of being wrong is infinitesimal. Other times, uncertainties linger despite lengthy research. In those cases, scientists make it their job to explain how well something is known. When gaps in knowledge exist, scientists qualify the evidence to ensure others don't form conclusions that go beyond what is known.

Even though it may seem counterintuitive, scientists like to point out the level of uncertainty. Why? Because they want to be as transparent as possible and it shows how well certain phenomena are understood.

Decision makers in our society use scientific input all the time. But they could make a critically wrong choice if the unknowns aren't taken into account. For instance, city planners could build a levee too low or not evacuate enough coastal communities along an expected landfall zone of a hurricane if uncertainty is understated. For these reasons, uncertainty plays a key role in informing public policy.

1.2.3: Science and Rationality

We like to think of ourselves as rational beings: faced with a decision or choice, we evaluate the options objectively and logically and proceed with the one that makes the most sense or is most practical. But research is showing that rather than behaving rationally, we are “predictably irrational,” as behavioral economist and Duke University Professor Dan Ariely says. What he means is our behavior and decisions are far more related to our emotions and values than to reasoning and logic.

One of Ariely's experiments that demonstrates this involves a fake medication or placebo to combat pain. In this experiment, Ariely's research team gave pain relievers to participants recruited for the research study (in actuality, the pills were Vitamin C). One pill had a high price tag while one was cheap. The experiment revealed that the more expensive pill was measured to be more effective at combating pain than the less expensive one. Remember: the pills were Vitamin C, not known as a pain reliever.

Video: Dan Ariely - Why Do Placebos Work? (6:03)

Another scientist who is studying the role of beliefs and values on shaping perception is Dan Kahan, Yale University. He was curious about why some people are skeptical about several issues around which there is scientific consensus. His study involved 1,500 participants who were asked about whether “most expert scientists agree with the statement, most expert scientists disagree with the statement, or expert scientists are divided in their views” on three issues including whether global climate change is occurring, whether nuclear power waste can be disposed of safely and whether carrying concealed handguns will reduce violent crime.

What Kahan and his research group discovered was that participants' values played the most significant role in their evaluations of scientific information. If people were uncertain about global climate change, for instance, then they choose the statement that “most expert scientists are divided in their views” on climate change, and they found reasons to reject those with opposing viewpoints. Similarly, participants against carrying concealed weapons rejected any information suggesting this might deter or reduce violent crime. In other words, people downplay or discount those expert scientists whose views differ from theirs while seeking experts whose views support or conform to theirs.

Even one or two contrary voices is enough to convince us that the science is unsettled if that supports our values and viewpoints. This is because as Willingham says, “We want our beliefs to be accurate—to align with what is really true about the world—and we know that science is a reliable guide to accuracy....But this desire to be accurate conflicts with other motives, some of them unconscious. People hold beliefs to protect important values. People also hold beliefs that are rooted in their emotions. Because we want to see ourselves as rational beings, we find reasons to maintain that our beliefs are accurate” (Willingham, 2011).

Cognitive scientists have a term for this—biased assimilation. What that means is that we evaluate information selectively. If information agrees with what we think or believe, we tend to value it for affirming our positions. If information disagrees with what we think or believe, we tend to dismiss it. We also hold very different standards for evaluating information that agrees with our positions and information that challenges our positions.

This is not to say that we are incapable of acting rationally or engaging in rational and logical decision-making. But it does explain some of why there can be public disagreement over areas from childhood vaccinations to climate change where scientific consensus exists.

1.2.4: Science and the Media

In March 2006, Harper's Magazine published "Out of Control: AIDS and the Corruption of Medical Science," in which journalist Celia Farber alleged doctors and the National Institutes of Health were covering up problems with current AIDS treatments and collusion between medical science and pharmaceutical companies that make antiretroviral drugs to treat AIDS. She described vitamin- and nutrition-based programs underway in several African countries that were successfully combating AIDS.

Farber is an AIDS denialist. She doesn't believe that the human immunodeficiency virus (HIV) causes acquired immune deficiency syndrome (AIDS). She also subscribes to the idea that antiretroviral drugs (ARV) cause rather than treat the virus.

She is not alone in her views. There are others who deny that HIV causes AIDS. They include former South African president Thabo Mbeki who suspended use of ARVs while in office. AIDS denialists also include a handful of scientists, one of whom is a Nobel Prize winner for work in DNA.

But scientific consensus, based on more than three decades of research throughout the world, is that HIV causes AIDS. Thousands of scientists, medical researchers, directors of research institutions and scientific academies, Nobel prizewinners and physicians have accepted that conclusion.

Given that consensus, how is it that the views of a few denialists garner so much attention?

John Moore, a Cornell University medical researcher who studies AIDS, says that dissent is normal and occurs "for any argument put forward by humans, be it scientific, political or the best shade to use for the bathroom wallpaper". In his view, the existence of dissent, however, should not be considered evidence of cracks in consensus or indications prevailing views are wrong.

The existence of dissent and denialists also does not mean that both sides should be given equal time and equal weight in public debate or on the airwaves—particularly if one side represents only a very small number of voices. Cornelia Dean, a science reporter for The New York Times, criticizes this practice because it does what Moore says—suggests the two sides are equally strong and compelling "even if one side is much weaker than the other—or even if there hardly is another side at all" (Dean, pp. 49-50).

Today's media landscape also allows for dissent to have a louder voice than perhaps it should. Internet-based, 24-7 access to information has led both to the decline of mainstream media and the rise of an unprecedented number of media choices. On the surface, access to a variety of media might seem like a good thing as consumers can now tailor their news to their own interests.

But while we have access to more information than we have ever had in the history of humankind, we can find media today—websites, blogs, videos—that support rather than challenge our viewpoints. In other words, we can listen to, watch, or read media that allow us to affirm what we already think or believe. Finding a news source we agree with allows us to claim we are informed while steering clear of information that contradicts or challenges our understandings.

Niche media also enables what Leah Ceccarelli, University of Washington, describes as "manufactured controversy" or "manufactroversy." These manufactroversies claim "disagreement [that] doesn't exist inside the scientific community...to achieve specific political ends" (Ceccarelli, 2008). The public, in other words, is convinced of scientific controversy even though the science is settled.

It is important to keep in mind that not many news organizations have journalists with science backgrounds, and that can impact news stories about science. In a study that compared original scientific papers with how they were presented in the media, University of Maryland Professor Jeanne Fahnestock found examples where journalists had overstated claims of certainty and rarity, were selective in use of information and watered down statements scientists made that hedged drawing definitive conclusions (Fahnestock, 1986).

Gavin Schmidt, Columbia University, notes that the science that journalists focus on is often at the cutting edge and may not stand the test of time. From his podcast "[Scientists Say](#)":

Most of the science news we hear about is based on papers that have just come out in a few high-profile journals that specialize in big, splashy results, but if those results were already commonly accepted, they wouldn't have got into those journals to begin with. So we have a paradox: the work that the media supposes all scientists agree on is precisely the work that is on the edge of the uncertainties, most likely to be contested, and might in fact be completely wrong.

To identify which media have the best handle on science reporting, borrow from peer review:

- Check out reporters' backgrounds. National Public Radio, for instance, includes bios of reporters.
- Also look for reporters whose beat is science or energy. They are likely to have more in-depth knowledge. Several Pennsylvania news organizations have been writing about the Marcellus play for years.
- Read news media from other parts of the country with shale plays and identify the reporters that cover oil and gas
 - Media organizations in Texas and Oklahoma, for instance, have different takes on energy because oil and gas is a part of their history and culture, Dr. Gavin Schmidt, Columbia University - "Scientists Say"

1.2.5: References

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1.3: Thinking Like a Scientist

These Three Facts Will Make You Think Like a Scientist

By Dan Satterfield

[AGU Blogosphere: These Three Facts Will Make You Think Like a Scientist](#)

Critical thinking is harder than you think. Our minds are actually predisposed against it, but learning to reason is a necessity if you want to make good decisions. Failing to learn the basic skills of critical thought can be expensive, or even lead to making YouTube videos like the ones I am interspersing through this blog post!

Here are three things that, in my humble opinion, will make you a better critical thinker. If you have suggestions of your own, or a better way of putting it, I'm all ears!

1. **Anecdotal evidence is not scientific truth.**

We are hardwired by evolution to learn the first time not to stick our hand in a burning flame, and perhaps that is why we are so susceptible to ascribing anecdotal evidence as truth. Experience can help you avoid removing yourself from the gene pool before you're able to reproduce, but it can also fool you into believing things that are not so. Correlation is not causation, but it does beg for some real research into the issue. In other words, anecdotal evidence begs scientific testing to find out what the truth really is.

2. **Confirmation Bias messes with your mind.**

We all suffer from confirmation bias (CB) and must allow for it. David McRaney has a short and simple definition in his excellent book *You Are Now Less Dumb*:

The Misconception: Your opinions are the result of years of rational, objective analysis.

The Truth: Your opinions are the result of years of paying attention to information which confirmed what you believed while ignoring information which challenged your preconceived notions.

The weather forecasts in the *Farmers Almanac*, and political pundits like Rush Limbaugh thrive on confirmation bias. So do vitamin companies and the homeopathic medicine crowd, and a classic example is the horoscope in your local paper. Congratulations, just knowing you suffer from CB is the first step to beating it! The second step is asking tough questions about new information, and the reliability of the source. For instance, Oklahoma Senator Jim Inhofe made his millions selling fossil fuels (you know: oil, black gold, Texas tea), but he insists that climate change is a hoax perpetrated by a worldwide conspiracy of scientists. Ask yourself which is more reasonable: thousands of scientists secretly faking research, or the opinion of every major scientific body on the planet? Keeping a secret is hard, just ask the National Security Agency (NSA). Confirmation bias is why millions believe the senator, instead of those who studied atmospheric physics. It also made him a lot of money because thousands also paid (to reinforce their preconceived notion) \$17.56 for the hard cover of his book! Trust me, when I say there is a lot more real science in David McRaney's book.

3. **Science Never Proves Anything, But Scientific Method Is Mankind's Greatest Invention.**

Scientific method relies on common observations and reproducible experiment. If something is labeled as a scientific theory then it **MUST** be possible to design an experiment that **COULD** prove it wrong. If you can't do it, then you have a belief instead of a theory. Don't get fooled by one pretending to be the other. By the way, your belief may or may not be accurate, it's just not science. If an experiment is conducted (A reproducible experiment that anyone can do), and it shows a theory is wrong, then it's wrong. The reason Einstein's relativity, and Darwin's natural selection are the foundation of their respective sciences is easy to understand; thousands of attempts to falsify them have failed, and

thousands of observations indicate their theories are right. Sources count as well. Analyze them carefully, and if an image is not sourced, alarm bells should go off. The same thing should happen if someone is telling you something about science, and they have virtually no background in that particular field. That's especially true if it is contrary to what you read in text books etc. To sum it all up, the words of Richard Feynman say it best. "The first principle of science is to not fool yourself, and you are the easiest person to fool!"

If we want to "think like a scientist" it usually means forcing ourselves to think rationally, which is not something humans are very good at without a lot of training. Humans are also not very good at observing the absence of something and recognizing the importance of absence. Humans are good at collecting a dataset that supports what they already believe to be true, but this is an unscientific habit. In order to think scientifically, people need to look for data that contradicts their mental model.

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1.4: Correlation vs. Causation

There is much confusion in the understanding and correct usage of correlation and causation. It is easy to make the assumption that when two events or actions are observed to be occurring at the same time and in the same direction that one event or action causes the other. As shown in the 2nd video below, an increase in ice cream consumption in the summer is correlated with increased cases of polio also occurring in the summer. Therefore, eating ice cream causes polio. Or another example: as ice cream sales increase, the rate of drowning deaths increases sharply. Therefore, ice cream consumption causes drowning.

Correlation is an action or occurrence that has a direct link to another action or occurrence; however, this link does not automatically mean that the change in one is the cause of the change in the other. Establishing causality is harder and involves the use of experiments where there are both controlled and independent variables. When the results of these experiments are certain and predictable, causation is established. So, beware, just because two things occur together does not mean that one is the cause of the other.

Video: How Ice Cream Kills! Correlation vs. Causation (5:26)

Video: Correlation vs. Causality: Freakonomics Movie (1:29)

Many normal human beings are not intuitively able to understand the true meaning of correlation and causation. The takeaway message is: When somebody tells you about a relationship between two things, call them A and B, here are the questions you should ask before you agree that there really is a relationship:

1. How often do A and B occur together?
2. How often does A happen without B also happening?
3. How often does B happen without A also happening?
4. How often do neither of them happen?

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1.5: Reading Plots

Below is a plot showing two datasets at once. The bars show the price of natural gas (right y axis) in the United States as a function of time from January 2007 until November 2011. The circles connected by a line shows the number of Marcellus well permits issued in Clearfield County, PA, (left y axis) from January 2007 until January 2012. Take a look at the plot, and see what conclusions you can draw from it. Then let's discuss it together.

Graph of Clearfield County well permits issued 2007-2012

Clearfield County PA 2007-2012

Credit: [PA Department of Environmental Protection, Oil and Gas Reports](#)

When I look at a plot I have never seen before, I have a mental checklist in my head that helps me read its information. Here it is:

Where did this data come from?

The data for well permits issued came from [Pennsylvania's Department of Environmental Protection](#) website.

Here's a screenshot of what you get when you go through the web form entering times for which you'd like to view numbers of permits issued for Marcellus wells:

Above is a plot showing two datasets at once. The bars show the price of natural gas (right y axis) in the United States as a function of time from January 2007 until November 2011. The circles connected by a line shows the number of Marcellus well permits issued in Clearfield County, PA, (left y axis) from January 2007 until January 2012. Take a look at the plot, and see what conclusions you can draw from it. Then let's discuss it together.

Screenshot of chart showing number of permits issue for natural gas wells in 2011

Screen Shot: Numbers of Permits Issued for Marcellus Wells

Credit: [Pennsylvania Department of Environmental Protection, Oil and Gas Reports](#)

Which one is easier to make sense of, the line on my plot or this data table? I hope you agree that my plot is clearer. This is why scientists often make plots from their data. It is often easier to spot a trend, see a relationship, or make sense of all your observations with a plot that conveys information in a visually logical way.

The data concerning price of gas at the well head came from the United States Energy Information Administration website. Here is a screenshot from their page.

Graph of U.S. Natural Gas Wellhead Price

Price of Gas at the Well Head

Credit: [United States Energy Information Administration](#)

Chart of US Natural Gas Wellhead Price 1973 - 1992

Screenshot: U.S. Natural Gas Wellhead Price (Dollars per Thousand Cubic Feet)

Credit. [U.S. Energy Information Administration](#)

I like the organization of this web site a lot better than the one produced by the DEP because it has both the plot as well as the

data table used to make the plot. In general, I do not dispute data that is posted on government websites (have a .gov address) nor do I dispute data that comes from a peer-reviewed publication, especially if I do not have the expertise to evaluate the data itself. Even scientists trust each other and rely on each other to publish truthful data to the best of their ability. We have to. Nobody can be an expert in all fields.

Okay, back to the plot.

What are the plot axes?

In this plot the x axis is calendar years and I can see from the number of bars and data points that this is monthly data. There are two y axes with different numbers and labels. It is important to make sure I know which data goes with which one. On the left it says “well permits issued” and the range goes from zero to 30. On the right it says “price at the well head per thousand cubic feet” and the range goes from \$0 to \$11.

What does the data show?

When I look at the legend, I see that the circles connected by a line belongs to the left y axis and concerns permits issued. I see that the bars belong to the right y axis and correspond to gas price. From about 2007 to early 2009 there were a handful of permits issued and from early 2009 until the end of the plot, number of permits issued fluctuates quite wildly month by month going as high as 25 and sometimes dropping to 0. The price of gas reached a high of nearly \$11 in mid 2008 but since then has been around the neighborhood of \$4.00 - \$4.50.

What is the person who made this plot trying to tell me?

You will hear people say things like “the data speaks for itself,” but in my experience that is never true. People make plots to visualize data but also to tell a story. In this case, why did I put those two datasets together on one plot? I did it because I wanted to see if there was a similar trend followed by both the price of gas as well as by number of permits issued. What do you think? Having just completed an exercise about correlation, what are some questions you could ask about this data if you wanted to try to convince somebody else that these two observations are or are not related to each other? If you were going to collect more data to try to confirm or disprove the idea that gas price and permits issued are related, how would you go about it? What would you look for?

1.6: Understanding Science: Big Ideas and Language

Science is a democratic process that moves forward by building consensus.

But what is it, really? According to dictionary.com, science is the “systematic knowledge of the physical or material world gained through observation and experimentation.” That’s right. Science is a human endeavor. It is the way we objectively try to make sense of our world and build a framework that allows us to understand how things work. It is important to realize that science is an ongoing work in progress. However it is just as important to realize that science builds upon prior results of science. Once a consensus has been reached by a majority of scientists who are respected in that field, usually that problem isn’t considered an interesting avenue of research anymore. This is an important point because sometimes when the prevailing scientific results of the day are unpopular politically or with certain advocacy groups, persuasive individuals with great oratorical skills can convince the general populace that controversy exists when in fact there is none (Ceccarelli, 2008).

Scientists try to collect data that will distinguish between competing ideas.

They are naturally skeptical and looking for ways to disprove a hypothesis. Here are some important points. A hypothesis that can’t be tested is not useful. Data that support multiple hypotheses is not very useful. Collecting more of the same data that supports your favorite hypothesis is not good enough. Good science involves an active search for observations and data that will disprove a hypothesis.

Scientists make observations and collect data in a careful, organized, and systematic way to test their ideas.

This is where the work comes in. Scientists spend a lot of time rechecking and duplicating their observations, carefully writing up their results, and then publishing them.

Scientific work that is peer-reviewed and published is more likely to be accepted by other scientists.

Peer review is a way that science is validated inside the scientific community. Most journals as well as funding agencies enlist the voluntary help of other scientists in the field to judge the merit of the science being submitted for publication. The journals themselves choose the reviewers. If you are an active scientist who publishes then part of the expectation is that you will spend some of your free time as a peer reviewer. Just because a paper has been peer reviewed does not mean it is correct beyond all doubt (Koerth-Baker, 2011). In fact, peer review is not a good way of catching deliberate fraud. But it does provide a check on sloppy work, or work that has failed to test a hypothesis in a useful way. (Koerth-Baker, 2011) For me, if I see that a paper has been published in a standard journal then I know it has gone through peer review. If someone claims that a self-published report has been peer-reviewed then I hear an alarm bell because I wonder what that really means. To reiterate, peer review does not guarantee infallibility but the absence of peer review means you should check the author’s background to find out why the report wasn’t published in a standard peer-reviewed journal.

Helen Quinn, former president of the American Physical Society, wrote a nice piece in Physics Today in 2008 about how the language scientists use can be misinterpreted by the general public. The table below is a summary of many of her points:

word/ phrase	what the public means	what a scientist means
believe	Usually it's a statement of faith or else a statement of uncertainty, as in "I believe it will rain today, but I'm not sure."	"Scientists believe . . ." means that all the evidence collected so far supports this viewpoint and furthermore opposing viewpoints have no evidence to support them. It's basically analogous to a regular person stating a fact they know.
theory/ hypothesis	guess, hunch	a complex construct of well-tested observations that describes some part of how the world works as well as predicts it.
error	something that is wrong	margin of variability given the limits as to how precise you could possibly be
uncertainty	not sure, don't know	the limit of the state of the art knowledge given a complex system or not enough data

1.7: Exercise 1 - Oklahoma Earthquakes (Words and Positive Probability)

Please read the article below from the Christian Science Monitor about seismicity in Oklahoma. We have underlined several words that express uncertainty. **After reading, please complete the activity on the next page.**

Oklahoma earthquake: How oil extraction shifts the ground beneath us

By David J. Unger, Correspondent / March 27, 2013

Oklahoma's largest recorded earthquake may have been the result of injection wells used for disposing wastewater from oil extraction, according to a new study by researchers at the University of Oklahoma, Columbia University and the US Geological Survey.

Their findings challenge the state's own geological survey, which concluded the 5.7 magnitude earthquake was likely "the result of natural causes."

The 2011 event in Oklahoma is the largest earthquake linked to wastewater injection, according to the study, published Tuesday in the journal *Geology*.

"There's something important about getting unexpectedly large earthquakes out of small systems that we have discovered here," said study co-author Geoffrey Abers, a seismologist at Columbia University, in a press release. His conclusion is that "the risk of humans inducing large earthquakes from even small injection activities is probably higher" than previously thought.

The oil and gas industry downplays the threat, noting that manmade earthquakes have been known for some time, from dam building to geothermal projects. Precautions can be taken to mitigate the risk.

"To date all the evidence indicates that properly located injection wells will not cause earthquakes," wrote Reid Porter, a spokesman for the American Petroleum Institute, in an e-mail.

One potential complication is that in the central and eastern part of the US, many faults are not well-mapped, according to Eliza Richardson, professor of geophysics at Penn State University. "Sometimes a well is drilled and put into action, and nobody realizes there is a fault nearby until the swarms of earthquakes start happening," Ms. Richardson wrote in an e-mail.

The oil and gas industry uses the wells to dispose of large amounts of wastewater produced in conventional oil extraction, as well as in hydraulic fracturing. Toxic mixtures of salt water (brine), chemicals, heavy metals, and radioactive material are pumped deep underground into porous rock formations where, in theory, they cannot contaminate underground sources of drinking water.

Sometimes the process is used to aid in the extraction of oil. Over time, the buildup of fluid can cause nearby faults to slip. "When you overpressure the fault, you reduce the stress that's pinning the fault into place and that's when earthquakes happen," said Heather Savage, a geophysicist at Columbia University and a co-author of Tuesday's study, in a press release.

The connection between human activity and seismic activity can be difficult to pin down. It's particularly complex in the Oklahoma case where the area was subject to 17 years of wastewater injection without incident. Typically, any dramatic increase in seismic activity will occur within months or a year of deep underground injection.

"It's not easy to make the connection, but the connection is very possible," said Steve Horton, research scientist at the University of Memphis' Center for Earthquake Research and Information. "Time will kind of tell."

Some 144,000 wells are associated with oil and natural gas production in operation in the US, according to the Environmental Protection Agency, which regulates the construction, operation, permitting, and closure of injection wells. These wells -- most of which are in Texas, California, Oklahoma, and Kansas -- inject over 2 billion gallons of brine every day.

As oil production continues to increase in the US, geologists are concerned about the potential seismic implications.

"[I]t makes sense to point out that there are many injection wells in this country that have never had any seismicity associated with them," Richardson of Penn State wrote in an e-mail. "And it is also true that Oklahoma has had moderate-sized earthquakes in the past that have not been associated with injection wells. However, those points should not be a reason to ignore the potential hazards that human activities can cause and **most likely** are continuing to cause in this case."

1.7.1: Activity

Positive Probability

For each of the underlined phrases or words in the Oklahoma Earthquake article (reproduced below), please assign a number between 1 and 100 to describe the positive probability you think is being associated with that word. For example, if you think the phrase “almost certain” means 90% certain, write down the number 90. Or, for example, if you think the phrase “almost certain” means 50% certain, write down 50. For example, if you think “cannot” means that there is zero chance of it happening, write down the number 0. Or if you think “cannot” means there is still a 5% chance that it might happen, write down the number 5.

- May
- Concluded
- Likely
- Probably
- Will not Cause
- Cannot
- Can cause
- Can be
- Very possible
- Most likely

Answer available at the end of this section.

Answers

Positive Probability

ANSWER: There are no right or wrong answers. However, below is a plot that compares the probability values a scientist assigned to the words in the Oklahoma Earthquake article, to the values assigned by a group of non-scientists. The dots in red are the values assigned by the scientist. The dots in white are the values assigned by the non-scientists. Sometimes dots plot on top of each other so that's why it looks like not all rows have the same number of responses. Please note, scientists disagree too! With this in mind, the values assigned by the scientist for this exercise, may differ from the values another scientist might assign.

plot of probability values based on table above

Plot of probability values assigned to words

Credit: Eliza Richardson

1.8: Exercise 2 - Scientific Evidence and Conclusions (Gas Safety)

Science is the practice of making observations and testing ideas with evidence; it involves asking questions, gathering data, challenging assumptions and revising ideas based on data. Let's consider the scientific conclusions that may be drawn from this report from Gas Safety Incorporated:

[Report to the Clean Air Council on June 8, 2012 Field Inspection and Methane Sampling Survey of Parts of Leroy, Granville and Franklin Townships, Bradford County, Pennsylvania.](#)

After reading the report, proceed with the exercise that follows.

1.9: Check Your Understanding

Check Your Understanding

1. List 4 attributes of science.

Answer available at the end of this section.

2. True or false: Science is about proving truth.

Answer available at the end of this section.

3. True or False: Science is a perfect process.

Answer available at the end of this section.

4. What is the "gold standard" for scientists to disseminate their research findings?

Answer available at the end of this section.

5. Explain why scientific uncertainty does not mean the science is flawed.

Answer available at the end of this section.

6. According to the plot, what is the relationship between the number of chickens in the U.S. and Major League Baseball players' salaries?

chickens vs MLB salaries graph

- A. The increase in players' salaries is linked to the increase in the number of chickens
- B. The increase in players' salaries caused the increase in the number of chickens
- C. There is no relationship between players' salaries and the number of chickens
- D. The increase in the number of chickens and increase in players' salaries reflect changes in the U.S. economy

Answer available at the end of this section.

Answers

Check Your Understanding

Possible Answers:

1. A way of learning about the world
2. A body of agreed-upon knowledge about how our world works
3. The practice of making observations and testing ideas with evidence
4. A process of challenging, improving and revising our understanding of how our world works
5. A system of checks and balances to ensure accuracy
6. An iterative process or work in progress that builds upon prior investigations and refines ideas
7. A democratic process that moves forward by building consensus

Check Your Understanding

False. Science is not about immutable laws but provisional explanations that get revised when a better one comes along.

Check Your Understanding

False. Scientists can and do make mistakes—sometimes inadvertently and sometimes purposefully. Just as in any field, there are scientists with integrity and scientists without integrity.

Check Your Understanding

The gold standard for scientists is "peer-reviewed journals." The peer-review process works to minimize the effects of human bias and error in the scientific process. Unfortunately, peer review is not a good way to catch scientists who deliberately fabricate or manipulate data. Detecting fraudulent data can only be done by other researchers carefully replicating the work of others. This is why the reporting of research methods and raw data are an important part of the scientific process. Checking a scientist's background and credentials also is critical in determining expertise.

Check Your Understanding

Scientists do not operate with 100 percent certainty. Findings are based on probabilities. New evidence can invalidate predictions and even modify well-accepted understandings. In many respects, uncertainty is critical for science because it spurs scientists to engage in further investigation and research.

Check Your Understanding

C. *There is no relationship between players' salaries and the number of chickens.*

Accuracy

A measurement result is considered accurate if it is judged to be close to the true value.

Belief*

When the public hears the word “believe,” non-scientists think of a statement of faith or else a statement of uncertainty as in “I believe it will rain today, but I’m not certain.” When scientists say, “We believe” in the context of scientific research, it means that all the evidence collected so far supports this viewpoint and furthermore, opposing viewpoints have no evidence to support them. “Scientists believe” is basically analogous to non-scientists stating a fact that they know.

Data

Information, either qualitative or quantitative, that has been collected.

Causation**

One event is the result of the occurrence of the other event. This is also referred to as cause and effect. Beware: Just because two things occur together does not mean that one caused the other. Correlation** A statistical measure that describes the size and direction of a relationship between two or more variables. A correlation between variables, however, does not automatically mean that the change in one variable is the cause of the change in the values of the other variable. Example: Height and weight are correlated. Taller people tend to be heavier than shorter people. In contrast, both the price of gas and the number of Facebook users have gone up in the past years, but gas prices are not causing the number of Facebook users to increase.

Error

Margin of variability given the limits as to how precise you could possibly be.

Evidence

Data that has been shown to be valid.

Hypothesis

A proposal intended to explain certain facts or observations.

Peer review***

A peer review is an in-depth critique of assumptions, calculations, extrapolations, alternate interpretations, methodology, and acceptance criteria employed, and of conclusions drawn in the original work. Peer reviews confirm the adequacy of the work. Peer review is expert (including national/international perspectives on the issue), independent, external, and technical. Most importantly, peer reviews must be carried out by independent reviewers who are experts in the technical issues relevant to the projects under review. Such reviewers must be highly qualified and independent in order to evaluate credibly the scientific and engineering merit of the work

Precision

Precise measurements are ones in which there is very little spread about the average measured value. Precision depends only on the extent of random errors – it gives no indication of how close results are to the true value.

Prediction

A prediction is a statement suggesting what will happen in the future, based on observation, experience or a hypothesis.

Repeatable

A measurement is repeatable if the original experimenter repeats the investigation using same method and equipment and obtains the same results.

Reproducible

A measurement is reproducible if the investigation is repeated by another person, or by using different equipment or techniques, and the same results are obtained.

Theory*

For scientists, a theory is a complex construct of well-tested observations that describe some part of how the world works as well as predict how the world works. Scientific theories are not guesses or hunches.

True value

This is the value that would be obtained in an ideal measurement with no error.

Uncertainty

The limit of the state-of-the-art knowledge given a complex system or not enough data. Also the interval within which the true value can be expected to lie, with a given level of confidence or probability, e.g. "the temperature is $20\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$, at a level of confidence of 95 %.

Validity

Appropriateness of the investigative procedure to answer the question being asked. For example, an investigation to find out whether methane found in a water well was from drilling would not be valid if it did not check for other possible sources of the methane.

Valid conclusion

A conclusion supported by valid data, obtained from an appropriate experimental design and based on sound reasoning.

Resources

*Helen Quinn, "Belief and Knowledge – A Plea About Language," Physics Today, January 2007

**[Australian Bureau of Statistics](#)

***Definitions from [AQA](#) except for "peer review" which is adapted from the National Academies Press.

1.11: Resources

Ceccarelli, L. 2008, Manufactroversy: The Art of Creating Controversy Where None Existed, <http://scienceprogress.org/2008/04/Manufactroversy/>

Koerth-Baker, M., 2011, Meet Science: What is Peer Review? <http://boingboing.net/2011/04/22/meet-science-what-is.html>

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Satterfield, Jim, "These three facts will make you think like a scientist," <http://blogs.agu.org/wildwildscience/2013/09/01/three-things-that-will-m...>

Smedslund, J. 1963, The Concept of Correlation in Adults, Scandinavian Journal of Psychology, Vol 4, 165-173.

Issued well permits data: Pennsylvania's Department of Environmental Protection website: http://www.depreportingservices.state.pa.us/ReportServer/Pages/ReportView.aspx?/Oil_Gas/Permits_Issued_Count_by_Well_Type_Monthly

Price of gas at the well head data: United States Energy Information Administration website: <http://www.eia.gov/dnav/ng/hist/n9190us3m.htm>.

1.12: Summary

Science is the process of exploration and discovery about how the world works. Science involves asking questions, formulating ideas, making observations, gathering and interpreting data, challenging assumptions, and revising ideas based on the data. Science is systematic and requires careful, deliberate and organized procedures. Scientific ideas and understanding can change and deepen with new evidence. The development of scientific knowledge usually takes a long time. Scientists spend a lot of time rechecking and duplicating their observations, carefully writing up their results and then publishing them. Science also is iterative—meaning it circles back on itself so that useful ideas are built upon and used to learn even more. Most scientific discoveries are made by teams of researchers. While a single scientist may work alone, he/she is still dependent upon the work of scientists who have gone before and the community of scientists that review and validate the discoveries. Science is not a process that is totally objective. Scientists like all people have values and biases that can influence what they do, how they do it and what they conclude. Scientists rely on the scientific community to review their work—in a process known as peer review—to minimize biases and validate scientific work and understanding. Science is not a process that is perfect.

2: ENERGY CHOICES FOR PA AND THE US

Overview

Pennsylvania is a major energy state. It is one of the largest producers of electric energy, and sends fully one-third of all the power it produces to surrounding states. In just a few years it has become the second-largest producer of natural gas in the U.S. Regionally, Pennsylvania is one of the larger wind-producing states in the eastern U.S.

You might think that all of this is because Pennsylvania has one of the largest economies in the U.S. and a rich energy resource base. All of this is true. But compare a state like Pennsylvania with California, another state with a large economy and rich energy resources. Unlike Pennsylvania, California has to import much of its electricity from other states. While California has significant oil and gas wealth, it is not a major producer of either (California is the third-largest on-shore oil producer, but its oil output pales in comparison to Texas, Alaska and the Gulf of Mexico.)

Two states with very large economies and significant energy resources have made two very different sets of decisions. Why? What factors come into play when individual states or the U.S. set their energy use priorities? In this lesson we'll look at how different energy resources are used in Pennsylvania and across the U.S. and identify some of the ways in which these resources differ from one another.

Please watch the following video.

Energy Choices: The SWITCH energy prime (2:51)

[2.1: Introduction](#)

[2.2: A Little Light Physics of Energy](#)

[2.3: Energy Efficiency and Energy Content of Different Fuels](#)

[2.4: Visualizing Energy Use in the United States](#)

[2.4.1: Sankey Diagram Questions](#)

[2.5: Comparing Energy Sources](#)

[2.5.1: Cost](#)

[2.5.2: Air Pollution](#)

[2.5.3: Energy Return on Investment](#)

[2.5.4: Safety](#)

[2.6: PA Energy Choices](#)

[2.7: Energy Pricing](#)

[2.8: Are We Running Out of Oil?](#)

[2.9: Glossary of Energy Terms](#)

[2.10: Resources](#)

[2.11: Summary and Final Tasks](#)

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2.1: Introduction

Energy is linked to mobility, national wealth, climate change and wars. We want energy that is cheap, reliable and environmentally benign, but we forget there are no magic bullets and at this point in time, no single energy source alone meets all three criteria. Understanding energy systems is critical to making informed decisions about everything from deciding which household appliances to buy and where to locate power plants to incentivizing use of natural gas and drafting national energy policies.

Most of us take our energy-intensive lifestyles for granted—unless the electricity goes off or gas prices reach \$4 a gallon—but the commercial production of energy is relatively recent. Just 80 years ago, few rural residents had electricity. Similarly, our demand for petroleum only exceeded national production beginning in the 1950s.

It should come as little surprise that in the past 25 years, energy consumption by primary energy source (oil, hydro, coal, gas and nuclear—to name a few) has increased throughout the world. Worldwide, electricity generation has doubled since 1980—a similar doubling is projected by 2030, according to the International Energy Agency's World Energy Outlook. What may be surprising is who is driving that increase.

Electricity consumption in the U.S. and Europe has stayed reasonably flat over the past couple of decades and, as a percentage of world consumption, has actually fallen nearly 10 percent since 1990. In the U.S., the current rate of growth of electricity consumption is about zero—attributable to a combination of a sputtering economy and energy-efficiency/conservation awareness and programs. Still, U.S. electricity use in 2010 was more than 13 times greater than electricity use in 1950, according to the U.S. Energy Information Agency.

The growth in demand is largely from developing countries where millions and millions of people do not have access to electricity. China's consumption is growing at about 10 percent a year. Between 2006 and 2010, China doubled its electric power system. Projections are that a similar doubling will occur in the next few years. India is embarking on similar electrification with a rate of growth of electricity consumption of about 5 percent. Estimates are that by 2030, India will have increased its power consumption fivefold.

Graph of total energy consumption 1965–2013 in North America, South America, Europe and Eurasia, Africa, China, Asia (not including China)

Total Energy Consumption (1965 – 2013) of North America, South America, Europe/Eurasia, Africa, China, and Asia (not including China)

Source: Data obtained from [BP Statistical Review of World Energy](#)

Three main fuels dominate the global energy picture: oil, natural gas and coal. While OPEC—the cartel of oil-producing nations—gets a lot of press, those countries produce only about a third of oil consumed. North America, Russia, the United Kingdom and Norway together produce about what OPEC produces in a year. The remainder of world oil production comes from a large group of small producers – primarily Asian countries and former Soviet states.

OPEC is not as big a player in the natural gas market. The largest gas producers in the world are Russia, the U.S. and Canada, which together produce a little less than half of the world's supply of natural gas.

The U.S. has more coal than any other country in the world. This is good news for large electricity consumers since about 40 percent of U.S. electricity generation comes from coal, but bad news for the environmentally-minded who are concerned about greenhouse gases and other emissions, particulate matter and heavy metals such as mercury. Recent federal regulations placing restrictions on a large group of pollutants (including emissions of carbon dioxide and other heat-trapping gasses) seem likely to shutter some coal-fired generation plants—and thereby, reduce some emissions. Demand for coal, however, is likely remain strong, particularly as China and India ramp up electricity generation.

Check Your Understanding

List the 4 attributes of an ideal energy resource.

Answer available at the end of this section.

Answers

Check Your Understanding

1. *Affordable*
2. *Available*
3. *Reliable*
4. *Clean*

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2.2: A Little Light Physics of Energy

When physicists talk about “energy,” they are talking about the “ability or capacity to do work.” Physicists, in a triumph of circular logic, define “work” as a change in energy. To normal people, “work” involves a large range of tasks involving heat or motion – everything from getting out of bed to powering a cruise ship. Virtually every aspect of our daily lives involves “work” and therefore energy in some form. To measure the total amount of work done (and thus the total amount of energy utilized), physicists use the joule (J). In the United States and United Kingdom, the British thermal unit (Btu) is also commonly used. The Btu is technically defined as the amount of energy required to heat one pound of water by one degree Fahrenheit. There are approximately one thousand Joules in one Btu. Power is the rate at which work is done and is measured in watts (W) or joules per second.

In the non-physics world, however, energy is a derived demand—that is, people don't really demand energy. Instead they demand goods and services that require energy to be produced or provided.

In the world of physics, there are several forms of energy including:

- **Mechanical energy** which involves motion and changes in speed
- **Chemical energy** which arises from breaking or changing the bonds between molecules which occurs when fossil fuels are burned
- **Thermal energy** which arises from vibrations on an atomic level and which creates heat
- **Electrical energy** which is the movement of charged particles and is associated with batteries and electrical currents
- **Nuclear energy** which holds the nucleus of an atom together

Energy can and often does change from one form into another. For instance, a car battery, which is a form of chemical energy, produces the electrical energy needed to run headlights. Similarly, a diesel locomotive burns diesel fuel to produce the electrical energy needed to drive the engine's wheels.

Complex processes—such as the process of producing electrical energy through the combustion or burning of fossil fuels—typically require several energy transformations or conversions.

In a simple combustion turbine at a power plant, for example, some fuel—such as coal or natural gas—is burned. This breaks the molecular bonds and produces chemical energy. This chemical energy is used to heat water, producing steam or thermal energy (which is why plants that burn fossil fuels are sometimes referred to as “thermal” plants). The steam then turns a generator, producing mechanical energy, which in turn, creates electrical energy. A nuclear power plant works exactly the same way, except the energy to heat water comes from nuclear reactions (fission – the breaking apart of an atom's nucleus) rather than from combustion of fuel.

Diagram of a turbine generator within a thermal power plant

Figure 1: In a thermal power plant, fuel is burned to generate steam, which turns a turbine to generate electricity.

Source: [U.S. Energy Information Administration \(EIA\)](https://www.eia.doe.gov)

The first law of thermodynamics, also known as conservation of energy, describes these transformations. It states: Energy can neither be created nor destroyed; it can only change in form.

But any time an energy conversion occurs, some energy is lost and typically as heat. Think about the heat light bulbs give off or the heat a car engine gives off after being driven. This is the second law of thermodynamics, which says basically that what you get out of an energy conversion is always less than what you put in.

To return to the power plant, for every unit of fuel that is burned, only about one-third comes out as electric power—which would seem to violate the first law of thermodynamics (the energy content of the input fuel should equal the energy output). So where did the other two-thirds go?

Most of the energy is lost as heat since the steam simply escapes into the atmosphere, which is why large power plants require immense cooling towers. The heat lost out of the cooling tower plus the electricity output of the plant is just about equal to the energy input. Put another way, in terms of capturing thermal energy to turn it into electricity, most of our power plants operate at

about 35 percent efficiency.

Newer technologies can reduce the amount of waste heat. Combined-cycle plants capture the exhaust gas and use it to run a second turbine. Combined heat-and-power (CHP) plants use the exhaust gas to heat building spaces or water.

Keep in mind these guiding principles of energy conversion:

- No energy process is completely reversible since some of the energy is lost.
- A machine whose input is mechanical energy can create useful energy (usually electrical energy) with minimal losses. Examples include hydroelectric dams, wind turbines and alternators.
- A machine whose input is thermal energy can never be 100 percent efficient at creating useful energy. Examples including the burning of fossil fuels, nuclear power plants and internal combustion engines.

Check Your Understanding

1. True or False: The first law of thermodynamics states: energy can neither be created nor destroyed; it can only change form.

Answer available at the end of this section.

2. In the United States and United Kingdom, the British thermal unit (Btu) is used to measure energy utilized. Define Btu.

Answer available at the end of this section.

3. Suppose you have a 500-watt light bulb that is powered by burning coal. If the coal is transformed into electricity with perfect efficiency, how long would the bulb have to burn before it consumed one ton of coal?

- A. 1.4 years
- B. 5.4 years
- C. 10 years
- D. 14 years

Answer available at the end of this section.

Answer available at the end of this section.

4. Now assume that the 500-watt bulb is powered by coal that is converted to electricity with 35% efficiency. How long would the bulb have to burn before it consumed one ton of coal?

- A. Nearly 3 months
- B. Nearly 6 months
- C. Nearly 1 year
- D. Nearly 2 years

Answer available at the end of this section.

Answers

Check Your Understanding

True

Check Your Understanding

The Btu is technically defined as the amount of energy required to heat one pound of water by one degree Fahrenheit.

Check Your Understanding

Check Your Understanding

The answer is A:

Why the answer is A:

We need to determine the total Btu content of one ton of coal, and determine how much electricity could be produced with that many Btu's. From Table 1, we see that one ton of coal has 20.7 million Btu of energy. Since the coal is transformed to electric energy with perfect efficiency, each kWh generated requires 3,412 Btu of coal. The number of kWh of electricity that can be produced from one ton of coal at perfect efficiency is:

Do the Math

$(20.7 \text{ million Btu}) \div (3,412 \text{ Btu per kWh}) = 6,069 \text{ kWh}$ of electricity.

The light bulb uses electricity at a rate of 500 Watts, or 0.5 Kilowatts. To find the amount of time that the light bulb will run, given 6,069 kWh of electric energy, we divide the total amount of energy by the rate at which the bulb uses energy.

Bulb running time = $6,069 \text{ kWh} \div 0.5 \text{ kW} = 12,133$ hours. There are 8,760 hours in one (non-leap) year, so the bulb would run for 1.4 years (just shy of eighteen months) on one ton of coal.

Check Your Understanding

The answer is B, nearly 6 months.

The explanation:

Again, we need to determine the total Btu content of one ton of coal, and determine how much electricity could be produced with that many Btu's. But this time we need to determine how many Btu's are required to generate one kWh of electricity if the conversion of coal to electricity is only 35% efficient. In other words, we need to use Equation 2 to figure out the heat rate of the coal power plant.

Do the Math

Equation 2: Heat rate = (ideal heat rate)/efficiency = $(3412 \text{ Btu/kWh})/\text{efficiency}$. Plugging in the efficiency of 0.35 (35%), we get a heat rate of:

Heat rate = $(3412 \text{ Btu/kWh})/0.35 = 9,750 \text{ Btu/kWh}$.

Thus, our coal power plant requires 9,750 Btu's worth of coal to produce one kWh of electricity. The number of kWh of electricity that can be produced from one ton of coal at 35% efficiency is thus:

$(20.7 \text{ million Btu}) \div (9,750 \text{ Btu per kWh}) = 2,123 \text{ kWh}$ of electricity.

The light bulb uses electricity at a rate of 500 Watts, or 0.5 Kilowatts. To find the amount of time that the light bulb will run, given 2,123 kWh of electric energy, we divide the total amount of energy by the rate at which the bulb uses energy.

Bulb running time = $2,123 \text{ kWh} \div 0.5 \text{ kW} = 4,246$ hours, or just shy of six months.

2.3: Energy Efficiency and Energy Content of Different Fuels

Remember that energy is the “ability or capacity to do work,” where “work” is defined as a change in energy. Energy is measured in a variety of units including calories, kilowatt hours (kWh), British Thermal Units (Btu). Power is measured in watts (or joules per second) and is the rate at which energy is generated or used.

Fuels are converted into useful energy according to their heat content. The heat content of a fuel is normally measured in Btus. One Btu is the amount of energy required to raise the temperature of one pound of water (about a pint) one degree Fahrenheit. The relative efficiency of a fuel or technology is summarized in the “heat rate” – the amount of fuel required to generate one kilowatt-hour (kWh). As might be expected, not all fuels are created equal. Comparison of fuels is possible by converting them into useful energy according to their heat content as measured in Btus.

Equation 1: Heat rate = Btu/kWh

Under ideal conditions, in which the energy input is equal to the energy output, the heat rate is equal to 3,412 Btu/kWh. But not all energy-conversion processes are ideally efficient. So Equation 1 must be modified to account for these inefficiencies.

Equation 2: Heat rate = (ideal heat rate)/efficiency = (3412 Btu/kWh)/efficiency

Table 1 summarizes the average heat content of several familiar fuels. These numbers are averages because variations in the quality can affect the efficiency with which these fuels can be converted into useful energy.

Table 1: Heat (energy) contents of fuels

Fuel	Amount	Heat Content (Btus)
Oil	1 barrel*	5,800,000 (138,095/gal)
Natural gas	1 cubic foot	1,026
Coal**	1 ton	20,700,000
Gasoline	1 gallon	124,000
Electricity***	1 kWh	3,412
Diesel or heating oil	1 gallon	139,000
White oak (20% moisture content) fn	1 cord	27,000,000

Credit: Source: [U.S. Energy Information Administration](#)

* 1 barrel of oil = 42 gallons.

** Heat content of coal is an average of bituminous coals. Lignite (brown coal) will have a lower heat content. Anthracite will have a higher heat content.

*** The number for electricity assumes perfectly efficient conversion of fuel into electricity.

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2.4: Visualizing Energy Use in the United States

The economy of the United States needs roughly one hundred quadrillion Btu's to function each year. One quadrillion – the number 10 followed by fifteen zeros (10,000,000,000,000,000) sounds like a huge number, and it is. 100 quadrillion Btu's is enough energy for a few hundred million trips to the moon, or to light tens of billions of light bulbs for an entire year.

How different energy sources power different parts of the U.S. economy can be visualized using an energy flow diagram or “Sankey Diagram” like the one from the Lawrence Livermore National Laboratory shown in Figure 2. The diagram looks complicated, but once you get the hang of it you'll see that it contains an incredible amount of information. Watch the video below to gain a better understanding of how to read the diagram.

How to read an LLNL energy flow chart (Sankey diagram) (3:02)

Sankey Diagram

Let's start with the left-hand side of the diagram. Each of the colored boxes represents a specific fuel, like natural gas, coal or hydropower. (Electricity is not a “fuel” in and of itself but is generated using other fuels, which is why electricity does not appear alongside the other fuels on the left-hand side of the diagram.) The size of the boxes represents the amount of each fuel used in the U.S. economy each year, and the numbers in the boxes represent the number of quadrillion Btu's of each fuel used. For example, in 2015 the U.S. used about twice as much natural gas as coal (15.7 quadrillion Btu of coal versus 28.3 quadrillion Btu of natural gas). Thus, the size of the natural gas box is larger than the size of the coal box.

Sankey diagram showing how energy flows through the U.S. economy.

Figure 2.4.1: Copy and Paste Caption here. (Copyright; author via source)

Moving from left to right in the Sankey diagram, the paths coming out of each fuel box illustrate how each fuel is used to power the U.S. economy in one of five ways:

- Generation of electric power (which is then used in buildings for heating, cooling, lighting and other uses)
- Residential: Use in homes, for example for heating and cooking
- Commercial: Use in businesses, for heating/cooling buildings
- Industrial: Use in factories and manufacturing facilities
- Transportation: Use for cars, buses, planes and so forth

The size of each of the paths describes how much of each fuel is used in each sector of the U.S. economy. The number next to each path shows the number of quadrillion Btu of each fuel is used in each economic sector. For example, if you follow the five paths out of the natural gas box you will see the following:

- 9.99 Quadrillion Btu of natural gas are used to generate electricity
- 4.75 Quadrillion Btu of natural gas are used in households
- 3.3 Quadrillion Btu of natural gas are used to in commercial buildings
- 9.36 Quadrillion Btu of natural gas are used in factories and manufacturing
- 0.92 Quadrillion Btu of natural gas are used in transportation

The Sankey diagram thus tells you that around two-thirds of the natural gas used in the U.S. every year goes to power plants and industry, while very little natural gas is used to fuel cars, buses and trucks.

As a point of comparison, look at the boxes for nuclear and petroleum. What differences do you spot in how these fuels are used in the U.S. economy, relative to natural gas? We can see that there is only one path coming out of the nuclear box, which goes directly to the electricity generation box. This means that all nuclear fuel used in the U.S. goes into power plants. (This should not come as a big surprise – we don't see nuclear-powered cars on the road.) Looking at the paths coming out of the petroleum box, we can see that most of the oil used in the U.S. economy goes either to industrial boilers or for transportation fuel. Very little oil is used in buildings (some people and buildings still use furnaces that run on fuel oil) and even less is used to generate electricity.

Finally, the right-hand part of the Sankey diagram reveals an awful truth about the U.S. energy system: it is incredibly wasteful. Our power plants, cars and buildings just do not use energy very efficiently. You can see this in the two gray boxes on the right-hand side of the Sankey diagram. The darker gray box at the bottom labeled 'Energy Services' shows how much of the fuel from coal, oil, natural gas, wind, and so forth is actually put to useful work to move cars, light buildings and so forth. The lighter gray box labeled 'Rejected Energy' captures how much energy we waste because we use highly inefficient technologies in our power plants, cars and buildings. Looking at the amount of 'Rejected Energy' (59.1 quadrillion Btu) versus 'Energy Services' (38.4 quadrillion Btu), we can see that we waste about 60% of the fuel that we use to power the U.S. economy every year. The biggest waste comes from generating electricity (where we waste about two-thirds of all the fuel we put into power plants) and from transportation (where we waste around 80%).

2.4.1: Sankey Diagram Questions

Please refer to the Sankey diagrams for Washington and Pennsylvania to answer the knowledge check questions. For consistency, the 2012 Sankey diagram for the U.S. is also provided for comparison.

Sankey diagram for the United States for 2012

2012 Sankey diagram for Washington State

2012 Lawrence Livermore National Laboratory

Washington State Sankey diagram

2012 Sankey diagram for Washington State

2012 Lawrence Livermore National Laboratory

Pennsylvania State Sankey diagram for 2012

2012 Sankey diagram for Pennsylvania state

2012 Lawrence Livermore National Laboratory

Check Your Understanding

Q1: Compared to Washington State, is Pennsylvania's energy mix more or less similar to the energy mix of the U.S. as a whole?

Answer available at the end of this section.

Q2: Identify the biggest source of energy used in electricity production in Pennsylvania, Washington and the US as a whole?

Answer available at the end of this section.

Q3: Is a greater proportion of total energy wasted in Washington or Pennsylvania? How do these states compare to the U.S. as a whole?

Answer available at the end of this section.

Answers

Check Your Understanding

Compared to the U.S. as a whole, Pennsylvania is very similar. Like the U.S. as a whole, Pennsylvania relies primarily on a mix of fossil fuels (natural gas and coal) and nuclear energy for electric power generation and oil for transportation. Washington on the other hand relies principally on hydropower for electricity generation.

Check Your Understanding

In Washington the biggest energy source for electricity production is hydro power. In Pennsylvania and the US as a whole, it is coal.

Check Your Understanding

In Washington about 2/3 of all energy is wasted. In Pennsylvania the percentage is very slightly smaller (65% versus two-thirds). In the U.S. as a whole the percentage of energy wasted is around 61%.

2.5: Comparing Energy Sources

We use a lot of different fuels because, unfortunately, there is not a single “best” energy source. Fuels differ greatly on economic costs, environmental impacts, and ease with which they can be harvested. In this section we’ll compare energy sources for electric power generation along a number of different criteria. We’ll focus on power generation because we use the greatest diversity of fuels for electricity and because the power sector has been a major target of environmental regulation over the last several decades.

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2.5.1: Cost

The most obvious place to start comparing energy sources is cost. We all want electricity to be cheap (and in many states electric utilities are mandated by law to choose the cheapest fuel available, regardless of environmental impact or any other criteria). Power plants have construction and operational costs, and these are very different for plants that use different types of fuels. A range of illustrative construction costs for power plant technologies is shown in Figure 3, while a range of illustrative operational costs is shown in Figure 4.

Schematic showing Comparative Construction Costs for Power Plant Technologies. CHP is Combined Heat and Power.

Figure 3: Comparative Construction Costs for Power Plant Technologies. CHP is Combined Heat and Power.

Source: Data from [U.S. Energy Information Administration \(EIA\)](#).

Schematic of Comparative Operational Costs for Power Plant Technologies. CHP is Combined Heat and Power

Figure 4: Comparative Operational Costs for Power Plant Technologies. CHP is Combined Heat and Power.

Source: Source: Data from [U.S. Energy Information Administration \(EIA\)](#).

So, which fuel source for power plants is cheapest? Looking at Figures 3 and 4, this is a hard question to answer. Some technologies (like wind, solar and nuclear energy) have high construction cost but low operational cost. Others have low construction cost but higher operational cost (like coal and natural gas). So which is cheaper to build – a natural gas plant or a wind farm?

Often times the construction cost and fuel cost is combined to get a single measure of “average” cost per unit of electricity produced. In the electricity business this is sometimes called a “levelized cost.” These average costs for various power generation technologies are shown in Figure 5. Note that these are pure engineering and fuel costs – they do not include the social costs of any environmental damage associated with electricity production and do not include any explicit subsidies like tax credits.

Schematic of Average Cost of Electricity for Different Technologies. CHP is Combined Heat and Power.

Figure 5: Average Cost of Electricity for Different Technologies. CHP is Combined Heat and Power.

Source: Data from the [U.S. Energy Information Administration \(EIA\)](#).

2.5.2: Air Pollution

Power generation technology options also differ widely on how much they can pollute the air, at least without appropriate environmental controls in place. A big part of the reason for the number of regulations and policies put in place that penalize power plants burning fossil fuels (and reward power generated from wind and solar) is the large social cost of air pollution. Emissions of oxides of sulfur and nitrogen degrade air quality in cities, and emissions of carbon dioxide contribute to global climate change. A comparison of some of the air quality impacts of power generation technologies is shown in Table 2.

Table 2: Emissions of Sulfur Dioxide (SO₂), Oxides of Nitrogen (NO_x) and Carbon Dioxide (CO₂) from Power Generation Using Differ

Fuel Source	SO ₂	NO ₂
Coal	50	6
Natural Gas	0	2.5
Petroleum	3	20
Wind/Solar	0	0
Nuclear	0	0

The air emissions figures in Table 2 don't really present the whole environmental impact, however – they just measure how much pollution comes from the plant's smokestack. Any fuel, however, has to be harvested from the ground (or sun or sky), possibly refined to remove impurities, and transported. All of these other stages of the "life cycle" of fuels for power generation have environmental impacts. Compared to the environmental impacts of burning fuel in a power plant, however, most of these other life-cycle impacts are probably pretty small. Figure 6 shows an example for Pennsylvania's power grid. The figure shows the contribution of the life cycle of different fuels to the total quantity of greenhouse gases emitted in Pennsylvania (one of the largest electricity-producing states in the U.S.). More than 80% of the greenhouse-gas emissions from electricity production in Pennsylvania is due to the burning of coal in power plants. Mining, processing and fuel transportation impact Pennsylvania's environment in other ways but add very little to the overall quantity of greenhouse gases.

Pie graph showing Contribution of Different Activities to Greenhouse Gas Emissions in Pennsylvania's Electricity Generation Sector.

Figure 6: Contribution of Different Activities to Greenhouse Gas Emissions in Pennsylvania's Electricity Generation Sector.

Energy Information Administration

2.5.3: Energy Return on Investment

It takes energy to get energy. Drilling a natural gas well, stringing a power line or erecting a wind farm all require energy. One popular measure of how much energy we get for the energy we use in development is called the “Energy Return on Investment.” For each unit of energy spent to develop the following resources, you could get back...

- 10 to 100 units of energy from petroleum
- 70 to 80 units from coal
- 30 to 35 units from wind
- 15 to 20 units from natural gas
- 15 to 20 units from nuclear
- About 5 units from solar PV
- About 5 units from Canadian tar/oil sands
- A bit more than 1 unit from biodiesel or corn ethanol

(Note that the source of these calculations is [American Scientist: Revisiting the Limits to Growth After Peak Oil \(2009\)](#))

The U.S. has clearly been spoiled by coal and oil! These energy resources, for all of their other costs and problems, are incredibly dense in energy and have historically been easy to extract. As traditional oil reserves are dwindled and we turn to unconventional formations, the Energy Return on Investment calculation may change.

2.5.4: Safety

Yet another dimension along which energy sources differ is safety, both to workers and to the general population. Data on safety in the energy industry, particularly outside of the U.S. and Europe, is very hard to come by but what data does exist globally is presented in Figure 7.

Bar graph showing Comparative Global Production and Death Rate for Major Energy

Figure 7: Comparative Global Production and Death Rate for Major Energy

Sources. Data from the OECD World Health Outlook and Paul Scherer Institute

Perhaps unsurprisingly, coal and oil exhibit the highest death rates for all energy sources for which data was available. On a per-Btu basis, some of the safest energy sources have historically been wind and solar (in part because they represent a very small share of global energy production), natural gas and perhaps surprisingly nuclear.

2.6: PA Energy Choices

This section of the lesson discusses the energy choices that one state, Pennsylvania, has made and how those choices are changing with the advent of unconventional natural gas drilling in the state and in the region.

The material on this page asks you to review and compare the following documents:

1. U.S. Energy Information Administration, [Pennsylvania State Energy Profile](#)
2. The Sankey diagrams for Pennsylvania and the United States as a whole, which you saw in the previous segment of this lesson. The Sankey diagrams are a useful way for us to compare energy choices in Pennsylvania with those of the United States as a whole.
3. “[Dash for Gas, 21st Century Style](#),” an article describing some of the forces driving interest in unconventional natural gas production.

As you read the Pennsylvania State Energy Profile, make sure that you review the highlighted points in the front of the document and the longer description of Pennsylvania energy in the second half of the document (after all of the pages of data and statistics).

Pennsylvania is a major energy-producing state, second only after Texas (we'll see a lot of comparisons between Pennsylvania and Texas in this section of the lesson). The state is a leader in virtually all forms of energy production and conversion, with the exception of crude oil production. Its position as a major producer of natural gas has happened with astonishing speed. As recently as five years ago, natural gas production in Pennsylvania was a drop in the bucket as compared with states like Texas and Louisiana. Now, Pennsylvania is the second-largest gas producer (second only after Texas). Even with the recent decline of the coal industry in the U.S., Pennsylvania still remains in the top five coal-producing states, and is the only major producer of anthracite coal, which has high value for industrial use.

Not all of Pennsylvania's energy choices have been based on exploiting fossil energy resources. The state is one of the larger wind energy producers in the eastern United States, and is the second largest nuclear power producer in the country. Because of the ready availability of very cheap natural gas, the state's electric power sector is in the process of shutting down coal-fired power stations in favor of those running on natural gas. If you look at the Sankey diagram for Pennsylvania for 2012, you'll see that the state used a bit more than twice as much coal as natural gas for power plant fuel (900 trillion BTU of coal versus 410 billion BTU of natural gas, and if you go back a decade there was virtually no natural gas used for power generation in Pennsylvania). But by 2015, the use of natural gas for power plants in Pennsylvania was about equal to the use of coal. This shift has been driven by a number of factors, including changes in markets for electric energy favoring gas-fired technologies and the emergence of natural gas so cheap that it has pushed coal from its long-held place as the most economical fuel for power plants.

Pennsylvania's mix of energy sources is very close to that of the United States as a whole. Comparing the Sankey diagrams for the U.S. and Pennsylvania, there are very few major differences. Pennsylvania uses a little larger share of nuclear power in its electricity generation mix than the U.S. as a whole, and uses less biomass in industry and for transportation.

An important aspect of Pennsylvania's energy choices is the state's position as a major energy supplier to other states along the eastern seaboard. Fully one-third of all electricity generated in Pennsylvania is moved over long-distance power lines to other states. Within the past several years Pennsylvania has become a large natural gas exporter to New England and to states in the southern Mid-Atlantic region. While not a major crude oil producer, Pennsylvania is a major refining center, providing gasoline and diesel fuel for regional consumption.

2.7: Energy Pricing

Everyone likes to complain about energy prices or their monthly utility bill. Ultimately, energy is like any other product or service; prices are largely determined by the forces of supply and demand.

Most energy resources are traded in large quantities on *commodity* or *wholesale* markets. These markets operate similarly to stock exchanges. Someone wanting to buy or sell large quantities of oil or natural gas, for example, would go to the New York Mercantile Exchange or NYMEX, just as you would go to the stock exchange if you wanted to buy a share of stock in Apple or General Motors. End-use consumers (homes and businesses) generally do not buy directly from these exchanges because the exchanges require trading in very large volumes. (An oil contract on the NYMEX requires you to buy 1,000 barrels or 42,000 gallons and to pick up the oil in Cushing, Oklahoma.) Instead, end-use consumers purchase energy from various types of retail sellers (who would then purchase their supplies from the wholesale market). Gas stations and electric utilities are examples of these retail sellers. Retail prices are most often higher than wholesale prices, sometimes by substantial amounts. The retail price of energy commodities depends on transportation and delivery costs, as well as on how shrewdly retailers can find the best bargain on the wholesale market.

Oil and coal are global commodities that are shipped all over the world. Thus, global supply and demand determines prices for these energy sources. Events around the world can affect our prices at home for oil-based energy such as gasoline and heating oil. Oil prices are high right now because of rapidly growing demand in the developing world (primarily Asia). As demand in these places grows, more oil cargoes head towards these countries. Prices in other countries must rise as a result. Political unrest in some oil-producing nations also contributes to high prices – basically, there is a fear that political instability could shut down oil production in these countries. OPEC, the large oil-producing cartel, does have some ability to influence world prices, but OPEC's influence in the world oil market is shrinking rapidly as new supplies in non-OPEC countries are discovered and developed.

Natural gas is not as widely traded globally, since it is not easily transported across oceans. The North American gas market (U.S. and Canada) is relatively isolated from the rest of the world. Thus, increasing demand for natural gas in Asia, or political unrest in gas-producing nations, does not really affect our natural gas prices very much. This is why natural gas prices have been falling so rapidly – increased supply has not been matched with any increases in demand. If the U.S. and Canada were to start exporting natural gas to Europe or Asia (in the form of *liquefied natural gas* or LNG), that would probably increase the price of natural gas in the U.S., though experts disagree on how much.

Electricity pricing has undergone rapid changes over the past decade. Until the mid 1990s, the electricity industry was very tightly regulated and electric rates were set by state regulators. Utilities priced power based on the costs of providing service to each customer (plus some profit for the utility company), and these prices required explicit approval by state regulators. With the advent of electricity deregulation in the 1990s, about half of the U.S. states, including Pennsylvania, loosened regulatory restrictions on electricity pricing to encourage competition between electric generating companies and utilities. Your electric bill is broken down into two parts: prices for generation (energy) and delivery (wires, or “transmission and distribution” of electricity). The wires charges continue to be regulated and set by the state Public Utility Commissions. Generation prices are determined through regional wholesale electricity markets where many companies compete to sell electricity to utilities. The electricity market that serves Pennsylvania, PJM Interconnection, is the largest in the world, in terms of number of customers served. Generators from as far west as Chicago and as far south as North Carolina compete to sell electricity to utilities and consumers in the Mid-Atlantic region.

2.8: Are We Running Out of Oil?

Our transportation systems are highly dependent on petroleum. High and volatile prices for oil (and at the pump) naturally give rise to suggestions that oil production has peaked, or that we are running out of oil. Concern over oil supplies is not new. In fact, historical projections suggest that the world has “almost run out of oil” at least five times in the past century. Here are some examples:

- “The world will run out of oil in 10 years.” - U.S. Bureau of Mines (1914)
- “The world will run out of oil in 13 years.” - U.S. Department of the Interior (1939 and 1950)
- “The world will run out of oil and other fossil fuels by 1990.” - Paul Erlich, *Limits to Growth* (1973)
- “The world will run out of oil in 2030, and other fossil fuels in 2050.” -Paul Erlich, *Beyond the Limit* (2002)

In the 1950s, a geologist named M. King Hubbert looked at oil production data from all of the major oil-producing countries in the world (at that time). Based on his statistical analysis of the data, he projected that U.S. oil production would peak in the 1970s and that world oil production would peak during the first decade of the 21st century. These projections came to be known as “Hubbert’s Peak.” And it turns out that Hubbert’s projections were highly accurate – U.S. oil production did peak in the 1970s and the collection of oil-producing countries that Hubbert originally studied did see their collective oil production peak in the early 2000s. So maybe Hubbert had a point, and maybe there is something to the “peak oil” paranoia.

The reality of the “amount of oil” is more complex. When Hubbert made his predictions in the 1950s, the oil industry was still in its technical infancy. Most oil production came from so-called “elephant” oil fields, tremendously large reservoirs of easily-accessible oil. To imagine what these “elephant” fields were like, think about the theme song to the *Beverly Hillbillies*, when Jed Clampett shoots a hole in the ground and oil comes spouting up. The elephant oil fields that represented most oil production during Hubbert’s time were basically like “Jed Clampett oil.” What Hubbert was predicting was really the decline in Jed Clampett oil.

While Hubbert was right about Jed Clampett oil, his analysis did not consider the advances in technology that would make extraction of oil possible from less-accessible reservoirs. Nor did he consider that a rise in the price of oil would make oil extraction from so-called “unconventional” reservoirs profitable enough to undertake. Deepwater drilling (like in the Gulf of Mexico), the Canadian oil sands, and even extraction of oil from shales via hydraulic fracturing in North Dakota are all examples of unconventional oil production.

In fact, most geologists now believe that the amount of unconventional oil is much larger than all of the Jed Clampett oil fields put together. A recent study from University of California at Berkeley estimated that the world has used up only about 5% of known technically recoverable oil reserves.

The reality is not that we are “running out of oil,” but rather that we are transitioning from a period of easily-accessible oil at low prices to an era of increasingly unconventional production, which has higher costs. Companies will not try to develop these unconventional resources unless consumers are willing to pay the price (economic and environmental) or governments heavily subsidize oil production or consumption. So far, the world has found a way to consume plenty of \$100 per barrel oil. At some point, unconventional oil exploration will get so expensive that consumers will look to lower-cost alternatives. Oil will price itself out of the market before the world truly runs out. The increasing popularity of hybrid vehicles, electric vehicles, bicycle transportation in urban areas and even natural gas vehicles are examples of such a shift, even if government policies are required to affect the decisions that consumers make.

Sheik Ahmed Zahi Yamani, the longtime Saudi oil minister and a key founder of OPEC, has perhaps summed up the world oil market the most nicely. He said, “The stone age came to an end, not for lack of stones, and the oil age will end, but not for lack of oil.”

Watt (W)

The unit of electrical power equal to one ampere under a pressure of one volt. A Watt is equal to 1/746 horse power.

Kilowatt (kW)

One thousand watts.

Kilowatt hour (kWh)

A measure of electricity defined as a unit of work or energy, measured as 1 kilowatt (1,000 watts) of power expended for 1 hour. One kWh is equivalent to 3,412 Btu.

Megawatt (MW)

One million watts of electricity.

Gigawatt (GW)

One billion watts or one thousand megawatts.

Energy

The capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Most of the world's convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means in order to accomplish tasks. Electrical energy is usually measured in kilowatt hours, while heat energy is usually measured in British thermal units (Btu).

***Power**

The rate at which energy is converted or utilized. The most common unit of power is the Watt, which is equal to one Joule per second or one one-thousandth of a Btu per second.

Heat content

The amount of heat energy available to be released by the transformation or use of a specified physical unit of an energy form (e.g., a ton of coal, a barrel of oil, a kilowatt hour of electricity, a cubic foot of natural gas, or a pound of steam). The amount of heat energy is commonly expressed in British thermal units (Btu). Note: Heat content of combustible energy forms can be expressed in terms of either gross heat content (higher or upper heating value) or net heat content (lower heating value), depending upon whether or not the available heat energy includes or excludes the energy used to vaporize water (contained in the original energy form or created during the combustion process). The Energy Information Administration typically uses gross heat content values.

British thermal unit

The quantity of heat required to raise the temperature of 1 pound of liquid water by 1 degree Fahrenheit at the temperature at which water has its greatest density (approximately 39 degrees Fahrenheit).

Btu conversion factor

A factor for converting energy data between one unit of measurement and British thermal units (Btu). Btu conversion factors are

generally used to convert energy data from physical units of measure (such as barrels, cubic feet, or short tons) into the energy-equivalent measure of Btu. (See [British Thermal Unit Conversion Factors\(link is external\)](#) for further information on Btu conversion factors.)

The following table contains some Btu conversion factors for several common energy sources.

Fuel	Amount	Heat Content (Btu)
Oil	1 barrel ^a	5.8×10^6
Natural Gas	1 cubic foot	1,026
Coal	1 ton	2.07×10^7
Gasoline	1 gallon	124,000
Residual Oil	1 barrel	6.29×10^6
Electricity	1 kWh	3,412
Diesel or Heating Oil	1 gallon	139,000
Propane	1 gallon	91,000

Btu per cubic foot

The total heating value, expressed in Btu, produced by the combustion, at constant pressure, of the amount of the gas that would occupy a volume of 1 cubic foot at a temperature of 60 degrees F if saturated with water vapor and under a pressure equivalent to that of 30 inches of mercury at 32 degrees F and under standard gravitational force (980.665 cm. per sec. squared) with air of the same temperature and pressure as the gas, when the products of combustion are cooled to the initial temperature of gas and air when the water formed by combustion is condensed to the liquid state. (Sometimes called gross heating value or total heating value.)

Quad

Quadrillion Btu, or 10^{15} Btu.

Quadrillion

The quantity 1,000,000,000,000,000 (10 to the 15th power).

Joule (J)

The meter-kilogram-second unit of work or energy, equal to the work done by a force of one newton when its point of application moves through a distance of one meter in the direction of the force; equivalent to 107 ergs and one watt-second. One Btu is approximately one thousand Joules. The Joule is the preferred unit for measuring energy or heat content in much of the world where the metric system is used; the United States and the United Kingdom use the British Thermal Unit (Btu).

Primary energy

Energy in the form that it is first accounted for in a statistical energy balance, before any transformation to secondary or tertiary forms of energy. For example, coal can be converted to synthetic gas, which can be converted to electricity; in this example, coal is primary energy, synthetic gas is secondary energy, and electricity is tertiary energy.

Energy-use sectors

A group of major energy-consuming components of U.S. society developed to measure and analyze energy use. The sectors most

commonly referred to in EIA are: residential, commercial, industrial, transportation, and electric power.

Thermal

A term used to identify a type of electric generating station, capacity, capability, or output in which the source of energy for the prime mover is heat.

Thermal efficiency

A measure of the efficiency of converting a fuel to energy and useful work; useful work and energy output divided by higher heating value of input fuel times 100 (for percent).

***Heat rate**

Specifically for electric power plants, the heat rate measures the efficiency with which fuel is converted to electric energy. The heat rate takes units of Btu of primary input energy per kWh of electric energy produced. A power plant with 100% thermal efficiency would have a heat rate of 3,412 (since the heat content of one kWh of electric energy is 3,412 Btu). The given heat rate of a power plant can be converted to a thermal efficiency by dividing 3,412 by the heat rate. For example, a power plant with a heat rate of 8,000 Btu per kWh would have a thermal efficiency of $3,412/8,000 = 0.43$ (i.e., 43% thermal efficiency).

Capital cost

A term referring to the fixed costs of constructing an energy project. Capital costs may include materials, labor, land and financing costs.

***Operating cost**

The cost of operating a plant once it has been constructed. Components of operating cost include fuel, labor and maintenance costs.

Levelized Cost of Energy (LCOE)

The average sales price (per energy unit, such as \$ per MWh of electricity or \$ per million Btu of natural gas) from an energy project over its lifetime that results in the project breaking even, i.e., recovering all capital and operating costs.

Electric power grid

A system of synchronized power providers and consumers connected by transmission and distribution lines and operated by one or more control centers. In the continental United States, the electric power grid consists of three systems the Eastern Interconnect, the Western Interconnect, and the Texas Interconnect. In Alaska and Hawaii, several systems encompass areas smaller than the State (e.g., the interconnect serving Anchorage, Fairbanks, and the Kenai Peninsula; individual islands)

Fossil fuel steam-electric power plant

An electricity generation plant in which the prime mover is a turbine rotated by high-pressure steam produced in a boiler by heat from burning fossil fuels.

Combined cycle unit

An electric generating unit that consists of one or more combustion turbines and one or more boilers with a portion of the required energy input to the boiler(s) provided by the exhaust gas of the combustion turbine(s).

Combined heat and power (CHP) plant

A plant designed to produce both heat and electricity from a single heat source.

Solar Photovoltaic Cell

An electronic device consisting of layers of semiconductor materials fabricated to form a junction (adjacent layers of materials with different electronic characteristics) and electrical contacts and being capable of converting incident light directly into electricity (direct current). An integrated assembly of photovoltaic cells is referred to as a photovoltaic module or panel.

Solar thermal power generation

A solar thermal technology that uses a modular mirror system that approximates a parabola and incorporates two-axis tracking to focus the sunlight onto receivers located at the focal point of each dish. The mirror system typically is made from a number of mirror facets, either glass or polymer mirror, or can consist of a single stretched membrane using a polymer mirror. The concentrated sunlight may be used directly by a Stirling, Rankine, or Brayton cycle heat engine at the focal point of the receiver or to heat a working fluid that is piped to a central engine. The engine then acts as a conventional steam-powered turbine to generate electricity.

Nitrogen oxides (NO_x)

Compounds of nitrogen and oxygen produced by the burning of fossil fuels. NO_x compounds are among the “criteria pollutants” regulated under the Clean Air Act. These compounds have been associated with acid rain and the formation of ground-level ozone (smog) in urban areas.

Sulfur oxides (SO_x)

Compounds containing sulfur and oxygen, such as sulfur dioxide (SO₂) and sulfur trioxide (SO₃). Sulfur dioxide is one of the “criteria pollutants” covered under the Clean Air Act; it historically has been associated with acid rain.

Greenhouse gases

Those gases, such as water vapor, carbon dioxide, nitrous oxide, methane, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride, that are transparent to solar (short-wave) radiation but opaque to long-wave (infrared) radiation, thus preventing long-wave radiant energy from leaving Earth's atmosphere. The net effect is a trapping of absorbed radiation and a tendency to warm the planet's surface.

*Cushing, Oklahoma

An oil pipeline hub and major storage area for crude oil, located in central Oklahoma. It is the settlement point for the West Texas Intermediate crude oil futures contract on the New York Mercantile Exchange (NYMEX).

Henry Hub

A natural gas pipeline hub on the Louisiana Gulf coast. It is the delivery point for the natural gas futures contract on the New York Mercantile Exchange (NYMEX).

Wood conversion to Btu

Converting cords of wood into a Btu equivalent is an imprecise procedure. The number of cords each household reports having burned is inexact, even with the more precise drawings provided, because the estimate requires the respondent to add up the use of wood over a 12-month period during which wood may have been added to the supply as well as removed. Besides errors of memory inherent in this task, the estimates are subject to problems in definition and perception of what a cord is. The nominal

cord as delivered to a suburban residential buyer may differ from the dimensions of the standard cord. This difference is possible because wood is most often cut in lengths that are longer than what makes a third of a cord (16 inches) and shorter than what makes a half cord (24 inches). In other cases, wood is bought or cut in unusual units (for example, pickup-truck load, or trunk load). Finally, volume estimates are difficult to make when the wood is left in a pile instead of being stacked. Other factors that make it difficult to estimate the Btu value of the wood burned is that the amount of empty space between the stacked logs may vary from 12 to 40 percent of the volume. Moisture content may vary from 20 percent in dried wood to 50 percent in green wood. (Moisture reduces the useful Btu output because energy is used in driving off the moisture). Finally, some tree species contain twice the Btu content of species with the lowest Btu value. Generally, hard woods have greater Btu value than soft woods. Wood is converted to Btu at the rate of 20 million Btu per cord, which is a rough average that takes all these factors into account.

Resources

[U. S. Energy Information Administration\(link is external\)](#)

**Seth Blumsack, Department of Energy and Mineral Engineering, Penn State*

2.10: Resources

[U.S. Energy Information Administration](#)

Research-based information on different energy sources and uses; energy forecasts; energy and the environment; state information; maps

[U.S. Department of Energy](#)

Science-based information on energy sources, energy uses, energy efficiency

[Database of State Incentives for Renewable Energy](#)

Compilation of incentives and policies promoting renewable energy and energy efficiency

[The Nature Conservancy Pennsylvania](#)

Reports and fact sheets on natural gas pipelines, Marcellus Shale; maps showing existing and projected wind turbines

[Switch Energy Project](#)

Videos about different energy topics

[National Energy Technology Laboratory - Role of Alternative Energy Sources: Natural Gas Technology Assessment](#)

Study discussing natural gas as an option for meeting the country's energy needs with identifying of environmental and cost aspects of natural gas power

[Electrocity](#)

ElectroCity is an online computer game that lets players manage their own virtual towns and cities. It's great fun to play and also teaches players all about energy, sustainability and environmental management in New Zealand.

[Energites](#)

EnerCities is an online elearning game for young people to experience energy-related implications. The goal of the game is to create and expand virtual cities dealing with pollution, energy shortages, renewable energy etc. The game is web-based and suitable to play on low-budget computers. You will need to download Unity game platform.

2.11: Summary and Final Tasks

Summary

This lesson has been focused on understanding energy use in Pennsylvania and the United States, including basic energy vocabulary (such as BTUs and watts); data sources for energy consumption by state; and Sankey diagrams for visualizing energy flows through a state or national energy economy. Apart from the United States being a major energy producer and consumer, we saw the following things from comparing Sankey diagrams and reviewing energy data from the U.S. government:

- The United States as a whole is heavily dependent on fossil energy (coal, oil and natural gas) for virtually every aspect of economic activity, including fueling our cars and powering homes and businesses.
- Some segments of the economy are more heavily invested in certain energy sources. Transportation in the United States, for example, is heavily dependent on oil while the power generation sector uses hardly any oil.
- While the United States as a whole relies heavily on fossil energy, this is not true of all states individually. Washington, for example, uses a lot of hydroelectricity and very little coal or natural gas.
- Pennsylvania's mix of energy resources is very close to that of the United States as a whole.

The energy choices that we have made have been driven largely by economics, convenience and available technology. Coal dominated electric power production for so many years because it was inexpensive to mine, very dense in energy content and easy to transport and store. Transportation still relies primarily on petroleum for many of those same reasons. While the price of oil and gasoline fluctuates (sometimes wildly), petroleum-based fuels can be easily moved around and have a high energy content. Major changes in energy use can happen, but are easier to achieve in some areas of the economy than others. Natural gas has easily equaled coal in use for power generation within the span of a few short years, because of the emergence of cheap natural gas for fuel and the ability to use existing power lines to move gas-fired electricity instead of coal-fired electricity. Replacing oil completely in our nation's energy system is a challenge because it would require technological change on a much larger scale – not only would everyone in the country need to replace their cars at great cost, but new delivery and retailing systems would be needed.

Please watch "Avoid the Energy Abyss" (Powering the Planet) (4:17)

3: CONSTRUCTIVE CONVERSATIONS

Overview

This lesson focuses on having constructive conversations about contentious topics. And as everyone knows, Marcellus Shale and Natural Gas Development definitely qualify as contentious topics. One of the reasons we are having this lesson toward the beginning of the class, is that it helps to set the stage for how we talk with other people about Marcellus Shale and any other divisive topic. The strategies discussed in this lesson, such as active listening, really shape how you might engage with other people when talking about this topic. Moreover, the skills that we will discuss are applicable to any topic in any domain of life, from work to family life to scientific topics, like Marcellus Shale.

This is the only lesson that doesn't focus on the scientific issues involved in Marcellus Shale. Instead this lesson provides a framework for understanding conflict management. Most of the other sessions in this class focus on the science to help you understand topics like geology, energy use, water, community and environmental and economic impacts, and so forth. However, Marcellus Shale is a very complex and divisive issue and it's hard to talk about these substantive science related questions if you don't trust who you are talking with. Also, if you think that the process you are engaging in is lousy, that it's stacked toward one side or the other, or there's no chance for public input and so forth, it is difficult to engage in a successful dialogue. So the substance is really just one part of that triangle. People and relationships are the other part of that triangle. Just understanding the science of Marcellus Shale isn't enough to help people make informed decisions. This lesson focuses on the people and relationships component of conflict management.

Main Topics

- Rationale for discussing constructive conversations within a class on the science of Marcellus Shale
- Difference between debate and dialogue
- Three skills for having constructive conversations, which are active listening, mediating, and reframing

Learning Outcomes

By the end of this lesson, you should be able to:

- Illustrate an understanding of active listening.
- Compare position and interest.
- Demonstrate constructive conversation skills around contentious issues.

3.1: Rules of Engagement

3.2: It's Not About the Nail

3.3: Why 'Constructive Conversations'?

3.4: Moving from Debate to Dialogue

3.4.1: Debate, Dialogue and Deliberation

3.4.2: Facilitating Deliberation

3.5: Key Skills for Constructive Conversations

3.5.1: Active Listening

3.5.1.1: Active Listening Strategies

3.5.1.2: Active Listening Activity

3.5.1.3: Try Active Listening Yourself

3.5.2: Mediating and Reframing

3.5.2.1: Mediating Role

3.5.2.2: Reframing- Moving from Positions to Interests

3.5.2.3: Reframing the Question- Public Issues Forum

3.5.2.4: Questions to help people articulate interests and solutions

3.5.2.5: Mediating and Reframing Activity

3.6: Resources

3.7: Summary

3.1: Rules of Engagement

- **Stay focused** on the topic and questions being discussed.
- **All ideas** are accepted; seek to learn from divergent perspectives.
- **Encourage and support** different points of view.
- **Listen actively**; respect others and think carefully about what they are saying - **NOT** whether or not you agree.
- **Conversations** are about inquiry and **NOT** for advocating a position or point of view.
- **Focus on** issues and interests, **NOT** positions or personalities.
- **Focus on** positive/constructive outcomes.
- **Only one person** speaks at a time; don't interrupt.
- **No side conversations.**
- **Respect** time boundaries.
- **When in doubt**, ask for clarification.
- **Recognize** that everyone shares responsibility for the success of this effort.

Remember, rules of engagement create not only effective learning environments but also enhance communication in any setting.

3.2: It's Not About the Nail

There is a common tendency for people, when someone is sharing a problem or concern with them, to skip the listening phase and jump to the possible solutions. Instead of listening, they rush to help the person solve the problem and identify a solution, because taking the time to listen does not seem valuable or necessary. People may think listening takes too much time or that it's not valuable or necessary when the problem is so obvious and pressing—like solving environmental problems or figuring out how to alleviate unemployment and poverty. However, it's crucial to learn how to listen because listening lays the groundwork or foundation for being able to solve problems in a way that is collaborative and respectful. No one will accept your proposed solution if they don't think that you have heard and understood their viewpoint.

This video below shows the distinction between listening and solving problems in a very humorous way. Of course, there are times when someone just needs to solve the problem and remove the nail, so to speak. But in most cases, people's more fundamental need is to be heard. Once we feel that we've been heard by our family members, neighbors, co-workers, or fellow citizens—that they genuinely understand where we are coming from—then we are ready to start thinking about solutions.

It's Not About The Nail (1:41)

When a listener sees something out of the ordinary or hears a trigger word, it is easy to jump to a conclusion. Here, he sees the nail but ignores her words, her tone of voice, her pleading eyes, and quickly determines the solution—get rid of the nail. He rushes to fix what to him is obvious but to her has nothing to do with what she is attempting to communicate to him. She wants him to hear and feel her emotional pain. He finally does when he says “that sounds really hard” and she melts with relief and then attempts to kiss him.

3.3: Why 'Constructive Conversations'?

You may find yourself in situations where you disagree with someone you are talking to about Marcellus Shale or where you are with people who are disagreeing about Marcellus Shale. Handling these situations wisely requires a special set of skills. You will need to know how to help people really listen to and learn from each other, to discover common ground (things they both care about), and to articulate what really matters to them so they can find mutually agreeable solutions. Communities will be better able to make informed decisions about Marcellus Shale if they have a complex understanding of issues AND if they can understand the basis for people's viewpoints.

Situations where people fundamentally disagree:

- Conflict
- Polarized positions
- Inability to find agreed-upon solutions

At some point, all of us find ourselves in situations where people fundamentally disagree. These situations are characterized by conflict, polarized positions, and an inability to find agreed-upon solutions. Moving conversations beyond conflict and polarized positions requires skills in:

Moving conversations beyond conflict and polarized positions requires skills in:

- Listening to and learning from each other
- Finding common ground
- Looking for solutions that satisfy all

The diagram below offers a framework for thinking about managing conflict. The **substance** (top of triangle) is critically important. In this course, “substance” means understanding the science of Marcellus Shale and unconventional gas development, including all the accompanying issues such as energy use, water safety, and community impacts, among others. However, it is difficult to talk about the substance if the **process** in which you are engaging is lousy—for example, if certain groups are excluded or privileged, if the public is kept in the dark or has little opportunity to shape decisions that affect them, if people perceive the decision makers aren’t hearing their concerns. Finally, people and relationships are essential to managing conflict. It’s also difficult to talk about the substance if we don’t trust or feel respected by the people with whom we are interacting.

Framework for Thinking about Conflict Management

Triangle: top corner reads substance, what are the issues?, bottom right corner reads process, how do you get there?, bottom left corner reads, people/relationships, who is involved and what is the dynamic between them?

Compiled by Grace Wildermuth.

In sum, understanding the substantive issues (the science) is necessary but insufficient for handling and making informed decisions about complex, divisive social-scientific issues. We also need to learn how to relate to people who disagree with us. That is where skills in active listening and mediation come in. You will learn about these topics in a later section of this lesson.

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3.4: Moving from Debate to Dialogue

A central idea in constructive conversations is moving from debate to dialogue. You can see from the first cartoon, the way that many people experience debate. They feel as though they are under attack and being hit over the head with other people's words. In debate, it's more of a competition, where one person is viewed as right and the other is viewed as wrong. The 2nd cartoon depicts a situation where the goal is to listen and learn from one another and to identify where there is commonality and opportunity for finding solution.

Moving from Debate to Dialogue: The Idea

Debate cartoon. While person is talking, another person is "clubbing" another person over the head with words.

Debate. Credit: Igor Kopelnitsky.

Dialogue cartoon, people sitting around a table.

Dialogue. Credit: Tim Casswell.

It is important to emphasize that there is a time and place for debate. There are facts about Marcellus Shale and there is also misinformation about Marcellus Shale. Dialogue doesn't mean that there are no facts and anything goes. However, while it is important to dispel myths, it is more important to learn how to talk to one another. The goal of dialogue is to create better understanding so that people can find mutual solutions. Dialogue does not mean having to agree with the other person's position. It doesn't mean that everyone comes to think the same way, but rather people are understanding what other people's positions are and why they hold them.

The following quotation explains what dialogue is not:

"Dialogue is not a way to talk an issue to death. Dialogue is not consensus building. Dialogue provides a better understanding of other's viewpoints, but it does not necessarily create agreement. What it ensures is that any remaining disagreement is based on real differences, not on misunderstanding or mistrust. Dialogue does not replace debate or decision making, it precedes them."

Credit: Rosell, S. A., & Gantwerk, H. (2010). *Moving beyond polls and focus groups*. In D. Yankelovich & W. Friedman (Eds.), *Toward wiser public judgment* (pp. 110-128). Nashville, TN: Vanderbilt University Press.

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3.4.1: Debate, Dialogue and Deliberation

The video below juxtaposes dialogue and debate. Note that there is a time and place for debate. There is misinformation that needs to be challenged and debunked. People do not get to make up their own facts and reality and expect that they will go unchallenged. The important point is that before we can start debating issues such as Marcellus Shale, people must feel heard and respected, and that requires dialogue..

Dialogue Versus Debate (7:07)

The table below summarizes the key differences between debate, dialogue, and deliberation.

Debate, Dialogue, & Deliberation

Debate	Dialogue	Deliberation
Compete	Exchange	Weigh
Argue	Discuss	Choose
Promote option	Builds relationships	Make choices
Seek majority	Understand	Seek overlap
Persuade	Seek understanding	Seek common ground
Dig in	Reach across	Framed to make choices
Tight structure	Loose structure	Flexible structure
Express	Listen	Learn
Usually fast	Usually slow	Usually slow
Win/lose	No decision	Common ground
Community division	Enhanced trust	Legitimacy and buy-in

Credit: Adapted from [Discovering Common Ground: Missouri Communities Deliberate Community Development](#), University of Missouri Outreach and Extension (p. 9).

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3.4.2: Facilitating Deliberation

Suggested Questions for Facilitating Deliberation

The following questions are useful for stimulating deliberation on contentious community issues.

Questions that connect the issue to real life concerns:

- Could you illustrate how this is touching the lives of most of us in the community?
- What makes the issue real for us?
- What evidence do you see that this is something that is important to all of us?
- Can you illustrate how this issue touches people up and down the economic ladder?

Questions that ask individuals to weigh the costs and consequences of each choice until they have begun to hear others' perspectives and to acknowledge conflicting values:

- What might be the results of your choice on others?
- How might your choice be different if you were poor? Wealthy? A worker?
- Could you identify those things that are important to us that seem to be clashing?

Questions that ask people to weigh the costs they are willing to accept in order to achieve the results they want:

- Can you live with the consequences?
- What costs are at stake and can we live with them?
- Would you give up ____ in order to achieve ____?
- What are the trade-offs you are or are not willing to make?

Questions that probe each person's statement until others can understand what he or she believes should be done and why he or she thinks it should be done:

- What does that mean to you?
- Why does this choice appeal to you?
- What is important about taking this direction?
- Can you give an example of how that might work out? What might happen?
- Why do you feel we should move in this direction?

Questions that encourage the speaker to make a connection between the actions he or she would advocate and what is important to him or her:

- Could you live with the actions?
- Would you be willing to have that action apply to everyone?
- What is most valuable to you or to those who support that action?
- If we did what you suggested, could you illustrate how that might play out in your life?

Ask questions that invite others to respond to what has just been said:

- What did you hear?

- Could someone tell a story that illustrates what was just said?
- Did that pull anyone's chain?
- What do you feel drives the action that was just illustrated?

Questions that give the individual an opportunity to identify what they have heard that reveals a shared understanding of the problem, a new option they have created, or costs the group cannot accept:

- What actions did you hear that seemed most important to all of us?
- What actions would best accomplish this?
- Suppose we can't have everything, is there some action we could all live with?
- Have we come to some understanding or developed a political will to support certain actions?
- What are those actions?

Credit: Worksheet adapted from Kettering ([www.kettering.org\(link is external\)](http://www.kettering.org(link_is_external))) & the National Issues Forum Institute ([www.nifi.org\(link is external\)](http://www.nifi.org(link_is_external)))

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3.5: Key Skills for Constructive Conversations

Discussing controversial issues like Marcellus Shale development can lead to disagreement and conflict. Yet we need to talk about these issues or we can't move toward solutions that will be supported and carried out. We can use some basic tools to create productive, constructive discussions that will help us identify the areas in which we agree, those in which we disagree, and what kinds of actions we can accept. When involved in these conversations, we have to pay attention to how we communicate with others. Communication skills – both verbal and non-verbal (body language) – are critical skills for being part of good conversations and helping others have good conversations.

Active Listening is one of the most important communication skills. We think faster than we speak, so our minds tend to wander when someone else is speaking, and we start to construct our own response as we wait for them to finish, potentially missing important information. Active listening requires us to concentrate on the speaker, listen for ideas, and control our own internal voice that is crafting what we will say next. As someone else is speaking, ask yourself these questions: *What is the speaker's main point? What are they trying to tell me?*

Mediation is also an important component because it provides a neutral party to help people come to a place of understanding and agreement. Mediating is helping other people listen to and learn from each other.

Reframing helps to move from positions to interests. It is a technique that restates or paraphrases a speaker's statement and makes it more easily heard by the listener(s). Reframing helps to move the conversation beyond debate, away from questions with yes/no answers, by getting to the feelings and bottom line interests of the speaker. It can start a discussion about multiple options that can meet common needs, and the advantages/disadvantages of each option (for example, for or against Marcellus Shale), to articulate what their interests are (underlying needs, desires, concerns, fears).

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3.5.1: Active Listening

What is Active Listening?

Active listening is a process where the listener responds in a conversational manner back to the speaker. They place their attention on the speaker and they feed back their perceptions of the speaker's feelings and the content of what they said. When you are actively listening, you're thinking about what the person is telling you and what their point of view is that they are trying to get across. Please watch this video about how to improve your listening skills.

How To Improve Your Listening Skills (4:54)

The three the main techniques for active listening are paraphrasing, clarifying and summarizing.

- **Paraphrasing** is restating the speaker's thought, in your own words. For instance, "I think you're saying that..." or "It sounds like you're saying ...". This is so they know you understand, or don't understand, in which case they can clarify for you.
- **Clarifying** involves asking questions to make sure that you understand. For example, "Can you give me an example of that?" or "You just said that such and such is important, can you help me understand what that means to you?"
- **Summarizing** is accurately and briefly summarizing the intent of their message. For instance, "I think the main ideas here are ...".

Active Listening Guidelines

- Put the focus of attention on the speaker
- Paraphrase and clarify
- Summarize
- Don't discuss your own reactions or give well-intentioned comments like, "I know what you mean.", "Oh yeah, that same thing happened to me.", or "I don't agree because..." This is not a time to articulate your own view points or turn the attention back to yourself.
- Don't ignore the speaker's feelings
- Don't pretend that you understand their meaning if you don't. It's perfectly fine to ask for clarification. For example, "What did you mean by...?" or "Can you tell me more about...?"
- Don't ignore the non-verbal content. People's body language, facial expressions, gestures, pitch, tone, can give you clues about what they are thinking and feeling.
- Don't think about what you will say next. (Probably the hardest guideline to follow) It seems it is our default response when we are getting into a rather heated conversation with somebody, we're just holding our breath until we can get a chance to insert our opinion, and that is the opposite of

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3.5.1.1: Active Listening Strategies

The following table includes examples of questions for active listening. These questions will help the other person articulate, elaborate on, and clarify their statements and to know that they have been heard, whether or not you happen to agree with them.

Statements That Help The Other Person Talk

Statement	Purpose	Do This	Examples
Encouraging	- To convey interest - To encourage the other person to keep talking	- Don't agree or disagree - Use neutral words - Use varying voice intonation	"Can you tell me more?"
Clarifying	- To help you clarify what is said - To get more information - To help the speaker see other points of view	- Ask questions - Restate wrong interpretation to force speaker to explain further	"When did this happen?"
Restating	- To show you are listening and understanding what is said - To check you meaning and interpretation	Restate basic ideas, facts	"So you would like for your parents to trust you more. Is that right?"
Reflecting	- To show that you understand how the person feels - To help the person evaluate his/her own feelings after hearing them expressed by someone else	Reflect the speaker's basic feelings	"You seem very upset."
Summarizing	- To review progress - To pull important ideas, facts and feelings together - To establish a basis for further discussion	Restate major ideas expressed, including feelings	"These seem to be the key ideas you have expressed..."
Validating	To acknowledge the worthiness of the other person	- Acknowledge the value of their issues and feelings - Show appreciation for their efforts and actions	"I appreciate your willingness to resolve this matter."

Credit: Ann K. Hennings, WSU Area Extension Coordinator, Washington State University, Lincoln/Adams County Extension. Permission to use obtained from Judy Saul, Kittitas Co.

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3.5.1.2: Active Listening Activity

Please take a few minutes to watch the two humorous videos below, then write a short two minute essay.

Bad Listeners (2:52)

Everybody Loves Raymond Uses Active Listening - from Parent Effectiveness Training (2:58)

Check Your Understanding: Two Minute Essay

Take a few minutes to reflect on each of the videos above. Consider why each video was either a good example or a bad example of active listening and explain why. Keep in mind the three techniques and the guidelines presented on previous pages in this lesson.

Click for Answer available at the end of this section.

Answers

Check Your Understanding: Two Minute Essay

Answer:

Video #1:

In your response you should have noted that Sheldon

- *Was not focused on Leonard, the speaker*
 - *Nonverbal cues we're only about himself, i.e., no eye contact*
 - *Dismissed Leonard's attempt to talk because it didn't affect him personally*
 - *Initially did not acknowledge that Leonard was even speaking and continued to sound frustrated that Leonard wanted to talk at all*
- *Interrupted Leonard repeatedly*
 - *Kept taking back control of the time clock not giving Leonard time to speak*
 - *Talked over Leonard*
- *Conveyed no interest in what Leonard was saying*
 - *Did not restate Leonard's basic concerns or paraphrase Leonard's words; instead stated "beats me" or "I hear you brother" or "it sucks to be you"*
 - *Did not reflect back Leonard's basic feeling to indicate understanding*
 - *No attempt to validate the worthiness of Leonard's problems*
 - *Did not use voice intonations or questions such as "can you tell me more?" to provide encouragement for Leonard to keep talking*
- *Judgment: made assumption that Leonard's problem was simple, i.e., "blonde women"*

Note that Leonard:

- *States, "Is it possible we're having two different conversations?"*
- *Through the use of a chess time clock attempted to provide avenue for each to listen to the other*
- *Made a sincere effort to listen and reflect back to Sheldon*
- *In total frustration, gives up trying to have a conversation*

Video #2

- *Raymond walks into a situation where his wife is interrogating their daughter and getting nowhere and encourages her to use active listening skills*
- *Although she attempts, Raymond interrupts and points out that she should reflect back and not be judgmental—two important active listening skills, paraphrasing and non-judgmental*
- *Raymond then takes over and does the following:*
 - *Gets down on his daughter's level and makes direct eye contact—this demonstrates interest and full attention on her*
 - *Demonstrates empathy by recognizing and stating to his daughter the reasons behind her feeling of anger*
 - *Reflects that the giraffe was still special to his daughter even though she wasn't playing with it*
 - *Takes ownership that mommy and daddy made a mistake by not asking their daughter before giving the giraffe to Michael*
- *Outcome:*
 - *The daughter wants to fix the giraffe and give it to Michael*
- *Following:*
 - *Raymond:*
 - *Acts pompous—he's the fixer*
 - *Is not empathetic to his wife—"Don't worry, you'll get it."*
 - *Then uses empathy stating his wife feels inadequate*
 - *She rejects the "active listening crap"*

Example of effective active listening:

Leadership Training - Active Listening (2:21)

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

[View this YouTube Video online](#)



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3.5.1.3: Try Active Listening Yourself

Using active listening skills, engage in a conversation with another person about Marcellus Shale. If possible, involve a third person to watch the time and provide feedback.

Question for discussion:

What do you think should be done about Marcellus Shale?

Process:

- Person A answers question (2 minutes)
- Person B paraphrases Person A's answer (2 minutes)
- Person B answers question (2 minutes)
- Person A paraphrases Person B's answer (2 minutes)
- Person C watches time, provides feedback

When paraphrasing, **do not share your own opinion**. This is not a back-and-forth discussion. This is purely meant to be an exercise in active listening, so put your own thoughts and feelings on hold. Refer to [Active Listening Techniques](#).

Take notes:

Take simple notes while listening to help jog your memory for summarizing/restating. This will help to:

- quiet the voice in your head
- begin to reframe or neutralize emotion
- ensure that you can remember what you want to restate

Debrief questions:

- How did it go?
- How well were you able to paraphrase the other person's views?
- How well were you able to 'turn off your own brain' to listen?
- 3rd person (if included): What did you see the partners do particularly well? Struggle with?

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3.5.2: Mediating and Reframing

Mediating

The second skill for constructive conversations is mediating. A mediator is an impartial person who can help people with opposing views to find commonality, agreement, and/or understanding. People taking this class, and most people, citizens, are not formal mediators, but all of us at some point find ourselves in a situation where we may be trying to help people find common ground, whether it's two friends at a bar or people at church or the workplace or one's family.

The idea is to use active listening skills to understand two or more people and seek areas of common ground. And again, the key capabilities here are listening, paraphrasing, looking for underlying issues, and where people differ and where they agree. In one of the later activities we'll get into this mediating role.

Reframing

The key goal for a mediator is to help people move from positions to interests, this is called reframing. Look at the cartoon below. First think about what this indicates about the difference between positions and interests. Positions are specific solutions and that is usually what people articulate and what people focus on. But the interests are what's underlying that, so with this iceberg metaphor, it's the interests that are under the water that you can't see. And those are really what you need to try to understand and articulate and unearth.

So again, a position is a specific solution whereas interests are the why, the underlying motivations, hopes, concerns, desires, and worries

Interests motivate people. They are the silent movers behind the hubbub of positions. Your position is something you have decided upon. Your interests are what causes you to so decide. Behind opposed positions lies shared and compatible interests, as well as conflicting ones.

- Fisher and Yuri

For example, a woman who had developed cancer early in her life from exposure to chemicals had a strong position against Marcellus. Her position had everything to do with her interests. She was very concerned about the safety risks because of her personal experience. In this case, her interests would not be apparent unless you take the time to learn about what experiences influenced her position.

Check Your Understanding - Two-Minute Essay

What does this graphic suggest about the difference between positions and interests? Take two minutes and type your answer in the area below. Click Check Answer to see some of the ideas you should have mentioned.

Positions and Interests cartoon

Positions vs. Interests

Credit: Johnny Goldstein

Check Answer available at the end of this section.

Answers

Check Your Understanding - Two-Minute Essay

Answer:

- We tend to focus on people's positions because these are easily visible. They are easy to identify; people come right out and say them. For example, "I'm for

X" or "I'm against Y."

- *If we want to find out what is motivating someone to take a particular position, we have to find out what their interests are. These are less visible and not something that people readily articulate.*
- *Underneath every position lies a set of interests that needs to be uncovered.*
- *Interests are the underlying reasons that a person holds a particular position.*

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3.5.2.1: Mediating Role

Mediator

A mediator is an impartial person, who can help people with opposing views to find commonality, agreement, and/or understanding.

Schematic that illustrates a mediator helping people with different views

A mediator and four people, each with a different view

Compiled by: *Grace Wildermuth*

Idea

The next time you are with two or more people who are discussing something about which they disagree, take on the role of mediator. Step back from your own viewpoint and seek instead to help the others in your group understand where the other person is coming from. This could be in person or on social media such as Facebook. Use active listening skills (or the equivalent of these skills expressed in writing) to help two or more people find areas of common ground. What did you do? What worked? What didn't work?

Key skills

Listening, paraphrasing, looking for underlying issues, where they differ, where they agree.

3.5.2.2: Reframing- Moving from Positions to Interests

Reframing

It's crucial to understand that each person, or group, has multiple interests. Some will overlap and others will conflict. When we focus on positions, there is only one solution. However, when we focus on interests, you can discover multiple solutions. That is really how you can start to make a breakthrough in helping people find common ground. Those multiple solutions might meet one or more interests of the different parties. Take a few minutes to watch this video to gain a better understanding of how to reframe before moving on.

Mediation skills: reframing (3:44)

When reframing, we are trying to help people move from their fixed, intransigent positions to discovering and articulating their interests. One of the classic examples of distinguishing positions from interests is from Fisher and Ury's book, *Getting to Yes*.

Consider the story of two men quarreling in a library: one wants the window open and the other wants it closed. They bicker back and forth about how much to leave it open — a crack, halfway, three quarters of the way. No solution satisfies them both.

Enter the librarian. She asks one why he wants the window open. "To get some fresh air," he replies. She asks the other why he wants it closed. "To avoid the draft," he answers. After thinking a minute, she opens a window in the next room, bringing in fresh air without a draft.

Although this example is simplistic, it illustrates how a third party can help people reframe the issue. That is, by shifting the focus from their position (what should be done) to their interests (their underlying concerns), you can come up with a solution that satisfies both.

Disagreement about opening a window

	Position	Interest	Solution
Person A	Open Window	Wants fresh air	Open a window in the next room
Person B	Close Window	Does not want a draft	Open a window in the next room

Another example is from a case study of how a mediator facilitated land-use planning on Vancouver Island (in John Forester's book, *Mediation in Practice*). There were many stakeholders involved in deciding how to use land on the island, including governmental representatives; environmentalists; people from forestry, mining, agriculture, and tourism sectors; employers; companies; First Nations groups; and so on. They were at an impasse. The position of several sub-groups was that they wanted 29% of the land to be protected. The negotiations had a breakthrough these sub-groups were able to articulate that what they really cared about was making sure that the protected areas were contiguous, rather than scattered around the island. Once they moved from the 29% position to the contiguous protected areas, they were able to come up with a solution that satisfied multiple parties.

One example of positions versus interests on issues related to Marcellus Shale is a statement such as, "I don't want drilling in my community." That's a position. But an underlying interest might be, "I want to have places to hunt and fish." Another position might be, "Drilling will create jobs." The interest here might be, "I'm worried my kids won't be able to find work." When we focus on what people really care about, like having places to hunt and fish or being able to find work, it opens up possibilities for finding multiple solutions.

Disagreement about drilling

	Position	Interest	Solution
Person A	Drilling will ruin the environment.	Wants places to fish and hunt	Find ways to ensure that wildlife and land are protected.

	Position	Interest	Solution
Person B	Drilling will create jobs.	Does not want children to move away to find work	Find ways to strengthen the local labor market.

There are particular kinds of questions you can ask that will help people articulate their interests. First, don't ask for their proposed solution. Instead find out what they care about. Essentially what you want to do is ask "Why?"—but without using that exact word. You're not asking for justification of their position, like, "why do you feel that way?" This isn't an accusatory kind of question; rather, you're probing for the needs, hopes, fears, and desires that are behind, or underneath, their position. Maybe they're worried about providing for their family or disrupting the quality of life in their community; maybe they are attached to their land that's been in their family for generations, and so forth. A few questions you can ask to help people move from positions to interests include the following:

- What concerns, worries upsets, bothers, or frustrates you about ____? (Example: the rig on your neighbor's property)
- What is your basic concern in wanting ____? Example: drilling banned or your land leased
- What do you fear might happen if ____? Example: Gas companies are not testing water before drilling.
- What do you hope will happen if ____? Example: Truck traffic is restricted.
- What do you really care about?
- What is important to you about ____?
- What will your solution help you accomplish?
- What leads you to believe that your solution will get at what you need?

This is what we call reframing. An example of a position question is, "How much of the land will be available for drilling?" This question can only have an answer that is a number: 2/3, 15%, 60%. That is a very narrow solution. An interest question is more open-ended. For example, "What kind of zoning would help us create jobs, while preserving the quality of our streams and water supply?" In this instance, you're not asking for a fixed number, you're talking about rules for zoning or other land use issues and so forth. The focus here is on meeting the underlying needs of all parties. The questions that you ask in a mediating position can help people get past their articulated solutions to looking at their underlying interests.

Position → the solution you have decided upon → one solution

Interests → the underlying motivations, hopes, concerns, desires, worries that led you to your position → multiple solutions

"Interests motivate people; they are the silent movers behind the hubbub of positions. Your position is something you have decided upon. Your interests are what cause you to decide....Behind opposed positions lie shared and compatible interests, as well as conflicting ones." (Fisher & Ury, p. 41)

3.5.2.3: Reframing the Question- Public Issues Forum

About 75 people attended a public issues forum on Marcellus Shale in Centre County on April 14, 2012. Public Issues Forums provide an environment to work through complex and controversial issues in a way that allows us to get to the heart of what is important to each person.

Public Issues Forums are designed to encourage people to consider different perspectives and to wrestle with the trade-offs and consequences inherent in each approach. An explicit goal of any forum is to have those who attend come to a better understanding of why people with different viewpoints see the issue in the way they do; another is to discover areas of common ground for moving forward.

An important start for the conversation is an issue book, which frames the development of the Marcellus Shale not as an either/or position (i.e., should we impose a moratorium?) but as a series of potential approaches each with their own potential actions. A local Task Force developed these approaches based on surveys, conversations with Centre County residents, and other information from diverse sources. Although the four approaches overlap, they do suggest different underlying interests, priorities and trade-offs to consider.

Approach 1. Pursue economic opportunity for all.

From this perspective, we should position ourselves to take full advantage of the economic potential of the Marcellus Shale for our families, businesses and communities. The new wells are already resulting in more jobs, more income, a boost in local business and higher tax revenues for the state. Responsible investments of this new wealth could benefit all of us, now and for generations to come.

Approach 2. Protect health and safety.

From this perspective, the serious risks associated with shale gas drilling require us to put safety first every step of the way. There are signs of harmful consequences to human health and safety and to our water, air and land. We need to learn more about the immediate and long-term impacts of Marcellus wells so that we can make responsible decisions about their development and whether or not it's safe to drill them at all.

Approach 3. Preserve our communities.

From this perspective, we must protect our quality of life by acting now to minimize the negative aspects of the Marcellus Shale on our communities. The dramatic increase in development is straining the housing market, roads, public services, parks and wildlife areas, and even relationships. We need to address these local issues to preserve the resources and heritage of our towns and rural areas.

Approach 4. Achieve energy security.

From this perspective, the Marcellus Shale offers a critical opportunity to take our energy future into our own hands. Development of this abundant source of natural gas has the potential to lower utility bills and support more fuel-efficient transportation. Natural gas also gives us the time we need to replace our declining fossil fuels with solar, wind and other renewable energy to guarantee energy security for our children and grandchildren.

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3.5.2.4: Questions to help people articulate interests and solutions

What kinds of questions help people articulate their interests?

Don't ask for their proposed solution (this is probably what they will tell you first off); first find out what they *care* about. Ask “why”, not asking for *justification* of position, but for needs, hopes, fears, desires *behind* their position (from Fisher & Ury). For example, a person may be worried about being able to provide for their family, disrupting their quality of life, or losing land that has been in their family for generations.

- What concerns/worries/upsets/bothers/frustrates you about ____ (the rig on your neighbor's property)?
- What is your basic concern in wanting ____ (to ban drilling; to lease your land)?
- What do you fear might happen if ____ (gas companies don't test water before drilling)?
- What do you hope will happen if ____ (truck traffic is restricted)?
- What do you really care about?
- What is important to you about ____?
- What will [your solution] help you accomplish?
- What leads you to believe that [your solution] will get at what you need?

What kinds of questions help people identify solutions?

Once people have articulated their interests, pose questions that can help them identify multiple ways (solutions) to meet those interests (reframing).

- Position question: How much of the land will be available for drilling?
- Interest question: What kind of zoning would help us create jobs while preserving the quality of our streams and water supply?
- Focus is on meeting underlying needs of all parties.

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3.5.2.5: Mediating and Reframing Activity

This activity involves both mediating and reframing. It generally works best if people aren't totally on the same page. When persons A and B pretty much agree with one another, it kind of falls flat. So to really experience mediating, you would want to find people that have differing perspectives in some way. You can also have people switch roles so that other people get a chance to play the mediating role. The mediator can refer to the questions in the gray box to help them move from positions to interest, summarize, clarify, and so forth.

First, identify common ground and differences. And then secondly, shift from their positions to their interests. Were they able to get at the why of their proposed solutions, and what were some of the reasons for their positions. It can be difficult to get past the contrived nature of these role plays, but I would say that to get anything out of it, you just have to suspend disbelief and play along. So even if that means people taking positions that they don't hold-- and that could actually be a really good exercise for people to try to make an argument for a position that is different from their own-- that is also really good for perspective taking.

Activity

Invite two people to engage in a conversation about Marcellus Shale. Using active listening skills, play the role of mediator.

Question for discussion:

What do you think should be done about Marcellus Shale?

Process

Mediator uses active listening skills (paraphrasing, summarizing, clarifying) and other questions to:

- Help A and B talk to one another
- Help A and B identify commonalities, differences
- Help A and B identify interests behind positions

Refer to questions below as a guide.

- What concerns/worries/upsets/bothers/frustrates you about ____ (the rig on your neighbor's property)?
- What is your basic concern in wanting ____ (to ban drilling; to lease your land)?
- What do you fear might happen if ____ (gas companies don't test water before drilling)?
- What do you hope will happen if ____ (truck traffic is restricted)?
- What do you really care about?
- What is important to you about ____?
- What will [your solution] help you accomplish?
- What leads you to believe that [your solution] will get at what you need?

Debrief Questions

For the Mediator

- How did you do?
- What skills did you use?
- Were you able to get at the 'why' of their proposed solutions?
- What were the reasons for their positions?
- What was the most challenging part of mediating?

For Persons A and B

- How did having C there affect your conversation?
- What did mediators say or do to help you to identify common ground and differences?
- What did mediators say or do to help you shift from positions to interests?

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3.6: Resources

Fischer, R., Ury, W., & Patton, B. (1991). *Getting to YES: Negotiating agreement without giving in* (2nd ed.). New York: Penguin Books.

Rosell, S. A., & Gantwerk, H. (2010). Moving beyond polls and focus groups. In D. Yankelovich & W. Friedman (Eds.), *Toward wiser public judgment* (pp. 110-128). Nashville, TN: Vanderbilt University Press.

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3.7: Summary

We have practiced active listening skills, mediating, and reframing from positions to interests. These skills are useful for discussing controversial issues and managing conflict in conversations, whether it's about Marcellus Shale, other science topics, or other divisive issues that you may encounter in your daily life. Consider how you see yourself applying these strategies to situations in real life, at work, with your families. Lastly, consider how you see yourself applying what you learned to issues related to Marcellus Shale. How might you bring people together to do that with you?

For example, one person that completed this course wanted to start a breakfast group that would meet to discuss Marcellus Shale. They met for over two years. Another person started a group that met at a bar once a month to discuss Marcellus Shale. It wouldn't necessarily have to be starting a group, it could be anything, like getting people together for a community cleanup, or to count the number of trucks that are coming through, or writing letters to the editor, etc.

Once you become well practiced in active listening, mediating and reframing, these are skills that you will be able to use in your interactions with people in your community. One of the best ways to promote more civil conversations is by modeling that yourself. We can't control how other people communicate and engage with us, but we can become a model and inspire others to communicate respectfully with others. That can be done partly through active listening, mediating, and reframing. And again, just understanding the science of Marcellus Shale isn't enough to help people make informed decisions. Their relationships and the process are also important, and that's where the skills you have learned in this lesson come into play.

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4: GEOLOGY AND SEISMIC TESTING

Overview

Geology! The word brings to mind dinosaurs, earthquakes, volcanoes, and, depending on how old you are, either Pierce Brosnan or The Rock. Geology encompasses all of these things (with the exception of Brosnan and The Rock), and much more. Simply put, geology is the study of earth processes through time. According to astronomers and physicists, the earth is 4.5 billion years old! A lot has happened in that time, and humanity has existed for only the smallest part of it.

The purpose of this lesson is to give you a general understanding of geologic principles, as a foundation for further lessons in this course. How do we know what we know about the earth? How do people know where to drill for oil? Where does oil and gas come from? These are just a few of the questions we will answer here.

Learning Outcomes

By the end of this lesson, you should be able to:

- Comprehend the basic geological history of the area and the resulting natural resources.
- Gain an appreciation for geologic scales like time, depth, and distance.
- Understand the process of locating oil and gas reservoirs, and the associated uncertainties.

4.1: Check Your Understanding

4.2: Time

4.3: From the Earth to a Grain of Sand

4.3.1: The Structure of the Earth

4.3.2: Rocks

4.3.3: The Rock Cycle

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4.3.5: Sedimentary Rocks

4.3.6: Assessment

4.4: Energy

4.4.1: Oil and Natural Gas

4.4.2: How do geologists find oil and natural gas?

4.4.3: Environmental Costs to Extraction

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4.5: Glossary of Geologic Terms

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4.1: Check Your Understanding

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4.2: Time

One of the most difficult concepts to internalize when just beginning to study geology is **time**. Humans live in a relatively fast-paced world. We watch the seconds tick by, live through semesters, and mark the passage of years with anniversaries. We sometimes go back hundreds of years when thinking about historical events, or even occasionally thousands of years when examining early human history. Geology, however, often works on time scales of millions of years. Geologists call this 'deep time'.

Take some time to explore, [Chronozoom](#), a tool being developed by earth scientists at the University of California, Berkeley. This tool puts different time scales in perspective of each other, and within the largest time scale: the universe. The bar along the top shows time in millions of years ago (ma), or thousands of years ago (ka). Because the timeline is in terms of the past, the present is 0 at the far right, while the number of years ago extends to the left. Above the time bar on the top left, you can select the time scale you want to look at: Cosmos, Earth, Life, Pre History, and Humanity. From the Cosmos time scale, click on 'Humanity' on the top left to get a sense of how briefly humanity has existed in the grand scheme of things.

Now let's focus on the geologic time scale. In Chronozoom, double click on the appropriate box within the 'Earth and Solar System' box. You'll see that the length of the geologic time scale extends a little beyond 4500 Ma (or 4.5 billion years), the age of the earth. Most geologists focus on the largest box to the far right, the Phanerozoic Eon, or the last 540 million years. This is because the earth is constantly changing, and finding rocks or environments to study from beyond this time, while not impossible, is difficult.

Now that you have a sense of where geologic time fits into the universe, and where human time fits into geologic time, take a look at this geologic time scale published by the Geological Society of America (GSA). This chart is read from the bottom right (oldest) to the top left (youngest). In geology, time is always represented with the oldest object of interest (rock, fossil, event) at the bottom, and the youngest at the top. This is because when you examine a sequence of rocks, if there has been no deformation, the oldest rock will be on the bottom, and the youngest will be on the top. This is called the Principle of Superposition, and we'll talk about it in more detail in a bit.

Geologic Time Scale
GSA Geologic Time Scale

Source: Geological Society of America

On the left of each major section (Cenozoic, Mesozoic, Paleozoic, Precambrian) is a small column that says AGE (Ma). 'Ma' means 'millions of years ago'. The earliest anatomically human remains are somewhere between 90 and 190,000 years old, and the oldest recorded human history is 5 thousand years old. Society as we know it kicked off in the Pleistocene epoch, at the very end of this time scale.

To give you a sense of the time scales over which the earth changes, here are some points of interest. See if you can find them on [Chronozoom](#)!

- First single-celled organisms 4 Ga
- Multi cellular organisms 3 Ga
- First plant life 700 Ma
- Land animals ~430 Ma
- Dinosaurs went extinct 65 Ma
- Appalachian Mountains stopped growing 220 Ma
- Himalayas began to form 55 Ma
- Earliest hominids (not anatomically modern humans) ~6 Ma
- Eruption of Mt Vesuvius (destruction of Pompeii) 0.0019 Ma (1.9 thousand years ago)

Example of time scales:

- Universe (14 billion years)
- Geologic time (billions of years)
- Mountain building (100 million years)

- Human existence (~100 thousand years)
- Mammals (83 million years)

Stop and think about it

What are a couple of the oldest events you can think of? Where do they fall on this time scale?

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4.3: From the Earth to a Grain of Sand

With a planet as old, large, and complex as the Earth, it's no wonder we have so many different focuses within geology! Most geologists start out with the same general geology background, that they then apply to their fields of choice.

Goals

By the end of this section you will:

1. Understand the overall structure of the Earth;
2. Be able to identify and explain the four basic principles of geology; and
3. Know which observations geologists use to identify a sedimentary rock, and what those observations mean for the history of the rock.

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4.3.1: The Structure of the Earth

Since we humans live on the very surface of the Earth, we do not tend to think too much about what is beneath the basements of our homes and workplaces. The Earth is nearly 8000 miles in **diameter** (almost 13,000 km), the distance you would travel if you went straight through the earth to the exact opposite point on the globe. If you traveled through the earth this way, you would pass through many different layers, the temperature would get as hot as the surface of the sun, and you would see things no human eyes have ever seen before!

Schematic showing and labeling earth layers
Layers of the Earth

Compositional Layers

The Earth has different compositional and mechanical layers. Compositional layers are determined by their components, while mechanical layers are determined by their physical properties.

Information about the compositional layers

Layer	Definition	Depth
Crust	The outermost solid layer of a rocky planet or natural satellite. Chemically distinct from the underlying mantle.	0-100km silicates
Mantle	A layer of the Earth (or any planet large enough to support internal stratification) between the crust and the outer core. It is chemically distinct from the crust and the outer core. The mantle is not liquid. It is, however, ductile, or plastic, which means that on very long time scales and under pressure it can flow. The mantle is mainly composed of aluminum and silicates.	100-2900km iron and magnesium silicates
Core	The innermost layers of the Earth. The Earth has an outer core (liquid) and an inner core (solid). They are not chemically distinct from each other, but they are chemically distinct from the mantle. The core is mainly composed of nickel and iron.	2900-6370km metals

Mechanical Layers

The mechanical layers of the Earth are differentiated by their strength or rigidity. These layers are not the same as the compositional layers of the Earth, such as the crust, mantle, and core, though sometimes the boundaries fall in the same places.

Information about the mechanical layers

Layer	Definition	Depth
Lithosphere	The outermost and most rigid mechanical layer of the Earth. The lithosphere includes the crust and the top of the mantle. The average thickness is ~70km, but ranges widely: It can be very thin, only a few km thick under oceanic crust or mid-ocean ridges, or very thick, 150+ km under continental crust, particularly mountain belts.	0-100 km
Asthenosphere	The asthenosphere is underneath the lithosphere. It is about 100km thick, and is a region of the mantle that flows relatively easily. Reminder: it is not liquid.	100-350 km Soft plastic *note: The mantle is not liquid!
Mesosphere	The mesosphere is beneath the asthenosphere. It encompasses the lower mantle, where material still flows but at a much slower rate than the asthenosphere.	350-2900km stiff plastic

Layer	Definition	Depth
Outer Core	A layer of liquid iron and nickel (and other elements) beneath the mesosphere. This is the only layer of the Earth that is a true liquid, and the core-mantle boundary is the only boundary of Earth's layers that is both mechanical and compositional. Flow of the liquid outer core is responsible for Earth's magnetic field.	5100-6370 km solid

You may be wondering how it is that layers of the Earth can be liquid, or 'plastic'. When we describe these properties of the layers of the Earth, it is important to remember that the Earth moves and changes on very long time scales. Something that appears to be solid on a short time scale can, in fact, be liquid. Glass is an example of an 'amorphous solid' – a material that is neither liquid nor solid. Over long periods of time glass can flow, forming (for example) windowpanes with thick bottoms and thin tops in old buildings. The mantle is like this. When it is under stress for long periods of time, it can flow. Due to the incredibly high temperatures and pressures near the center of the Earth, the outer core is liquid iron and nickel, while the inner core is solid. The motion of the liquid outer core is what gives Earth its magnetic field. Take a look at how temperature in the earth change with depth.

Graph of temperature vs depth (earth layer)

Temperature with depth in the Earth

The image above of the layers of the Earth is very simplified. Much in the way that we can use a stick figure to represent a person but lacks all of the detail, a wealth of information is missing in order to highlight the general distinctions between the layers of the Earth. It's important to remember that these systems are incredibly complex. If you're interested in learning more about the different layers of the Earth and how we know where they are, check out the [United States Geological Survey](https://www.usgs.gov/) website!

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4.3.2: Rocks

If you've never thought about them before, you could easily think that all rocks are the same. By this point in the course, you'll know that is not the case! Rocks are aggregates of minerals. A mineral is an inorganic, crystalline solid. This means that it has a regular, repeating series of molecules that ultimately determine its form. Quartz is an example of a very common mineral. Another is halite, commonly known as table salt! You can have very large quantities of a particular mineral, and even very large single crystals of minerals. Once you have more than one mineral together though, you've got a rock. There are three broad categories of rocks. They are Igneous, Sedimentary, and Metamorphic.

Igneous Rocks

Igneous rocks start as molten material that cools and solidifies. If you've ever seen granite, it was once super heated liquid! When this liquid is beneath the surface of the earth, it's called **magma**. Once it reaches the surface, perhaps as an eruption, it is called **lava**. Lava cools very quickly, since the temperature of the surface (let's say 32 degrees Fahrenheit, or zero degrees Celsius) is significantly cooler than the lava, which can be more than 1000 degrees F! This rapid cooling is called **quenching**, and is how glass-like rocks, like obsidian, form. Bringing material as hot as lava to the surface is somewhat like sticking a red-hot iron into a pot of water. Igneous rocks can (and often do) cool beneath the surface of the earth, the molten material moving up from the mantle but never making it to the surface. Other times they **extrude** at the surface, either at **mid-oceanic ridges** or **hotspots**.

The igneous rocks in this picture form what is called a pahoehoe (pronounced pah-hoy-hoy) flow, or a smooth, undulating, ropey texture.

Igneous rocks
Igneous Rocks at Craters of the Moon National Monument

Sedimentary Rocks

Sedimentary rocks are made up of grains that break off of other rocks through a process called weathering. When rocks are exposed to rain, wind, temperature changes, roots, and some chemicals, they can be broken down into their basic components. **Physical weathering** breaks off grains of rock, while **chemical weathering** breaks rocks down into more basic elemental components. Putting vinegar onto baking soda is a good example of this. These grains can come from other sedimentary rocks, from igneous rocks, or from metamorphic rocks. Grains are transported downstream, eventually settling in a basin, or low energy environment (for example a lake or an ocean). Over time, as more sediment is deposited, layers of sediment are buried deep enough to be **lithified**, or turned to stone. Because features of the environment are preserved in the sediments, we can tell something about where the rock was deposited. For example, a rock with leaf fossils preserved must have been formed in a slow, stagnant environment - one in which the leaves would not be disturbed or moved away. Sedimentary rocks are all about what remains. Black shales, organic rich sediments from which we extract oil and gas, form in deep marine settings, where there is very little energy and there is very little oxygen to decompose the organic material that gets deposited. More on that in a bit!

The sedimentary rocks in this picture have been tilted.

Sedimentary Rocks
Sedimentary Rocks in Utah

Metamorphic Rocks

Metamorphic rocks are rocks that have been deformed. They have been heated or squashed or buried (which often means they are both heated and squashed), which can cause minerals in the rocks to recrystallize. Metamorphic rocks form in places where change is happening: they can form in mountain belts (**collision zones**) where rock is compressed or buried, along fault planes, along **subduction zones**, next to magma pockets as the neighboring rock is cooked, to name a few. Marble is metamorphosed limestone (a chemical sedimentary rock). Slate was once used as the backing of chalkboards. Any type of rock can be metamorphosed, including metamorphic rocks!

It's hard to tell why a rock is considered metamorphic from a photo and out of context. In this picture, the rocks in the foreground were baked by a large igneous intrusion, and bleached by superheated water.

Metamorphic rock
Metamorphic Rock in Alta, Utah

Each of these rock types relies on the others in some way.

Take a few minutes to watch this fun video that describes the three types of rock and how they are connected.

Geology Kitchen: The 3 Types of Rocks (8:35)

Activity: Make a concept map!

Think about the interaction between igneous, sedimentary, and metamorphic rocks, and spend a few minutes drawing a picture that draws attention to relationships between these rocks. After you've given it a go, check out the concept map below! What is different between your concept map and this one? Do these differences surprise you?

Click here for solution. available at the end of this section.

Answers

Activity: Make a concept map!

Enter image and alt text here. No sizes!

The Rock Cycle Credit: [USGS](#)

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4.3.3: The Rock Cycle

The concept map below describes **the rock cycle**. As you can see, each of the rock types is related to the others through different physical and chemical processes. How does this translate to the world outside? Mountains can expose igneous, sedimentary, and metamorphic rocks to weathering and erosion. Grains of sediment (or boulders!) break off of these exposed rocks, and, thanks to gravity, move downhill either in a stream bed or by rolling. This travel causes further breakdown of the sediment, which eventually reaches the ocean. The sediment, once deposited in an ocean basin, gets buried by other sediment, and compacted into a sedimentary rock. If it's buried deep enough, or if the basin becomes part of an **orogen**, it can be metamorphosed, becoming a metamorphic rock. Eventually, the rock can either become exposed through sea level fall or mountain-building, where it starts the journey back to the ocean again, or it can be recycled back into the mantle at a subduction zone, perhaps one day returning to the surface as an igneous rock. The following concept map shows the rock cycle in terms of earth processes. New material comes from mid-ocean ridges and volcanoes; it is weathered, deformed, compacted and cemented, until it is recycled back into the mantle at a subduction zone.

Schematic of the rock cycle

The Rock Cycle

[USGS](#)

At this point you may be thinking to yourself 'how *does* a sedimentary rock, formed in an ocean, get to be in a mountain range? And if rocks are constantly being weathered, extruded, or squashed, shouldn't the earth be changing constantly?' And you'd be right! The earth is made up of distinct **tectonic plates**. Where they move towards each other either mountain belts or **subduction zones** form. Where they move away from each other **mid-ocean ridges** form. These plates move individually and very, very slowly. Sometimes these movements are slow and steady. Other times, the plate gets stuck, and that slow and steady motion builds up over hundreds of years, releasing all at once in a devastating earthquake, like the 2011 Tohoku Oki earthquake in Japan. Events like earthquakes and volcanic eruptions - obvious changes to the earth's surface - can happen over a matter of minutes or hours, but the **recurrence interval** of these events can be hundreds to thousands of years.

Check Your Understanding!

Take a couple of minutes to watch the video below to learn how plate tectonics, volcanoes and earthquake are related.

Plate Tectonics (2:42)

Did you notice that a majority of earthquakes and volcanic events occur at plate boundaries?

[Take a look at the mountain ranges of the world.](#) Most of them (though not all) are along active plate boundaries. Some old mountains, like the Appalachian Mountains of the eastern United States, show where plate boundaries used to be, but are no longer. As the plates move, where they interact with each other they build up **stress** and **strain**. Stress is the push, pull, or shear felt by a material when subjected to a force (in this case, another tectonic plate). Strain is the change in shape due to a stress. When enough force builds up, the friction keeping the two plates in place is overcome and the strain energy is released, often all at once. This is an earthquake!

As a result of the sudden release of energy, large waves move through the earth: P-waves, or primary waves; S-waves, or secondary waves, and surface waves. P-waves are compression waves. These waves arrive at detectors first, and can move through the entirety of the earth to be recorded by seismic detectors on the far side. S-waves arrive second (as you may have guessed). S-waves are transverse waves and cannot pass through liquid. Careful observations of seismic waves at the far sides of earthquakes are how we know the outer core of the earth is liquid! Surface waves are the slowest of the three, do not penetrate below the crust of the earth, and cause motion at the surface, bringing down buildings and causing damage.

Schematic of P wave and S wave movement through rock

Movement of P waves and S waves through rock

Credit: USGS

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4.3.4: The Principles of Geology

There are several basic principles that geologists use to figure out the history of a rock:

1. Uniformitarianism
2. Original horizontality
3. Superposition
4. Cross-cutting relationships
5. Walther's Law

Uniformitarianism

The principle of uniformitarianism states that processes that alter the earth's crust are the same processes that occurred millions of years ago. Furthermore, the results of processes today are the same as the results of the same processes millions of years ago. This means that we can take our observations of processes that occur today, and observations of the results and know the process that formed it when we see that same result in the rock record. For example, you can look in a stream and see ripple marks in the sand, formed by the flow of water over the sand. If you see ripple marks in the rock record, you can know that a similar process was at work.

A person on a stream bank looking at a stream. There are ripple marks in the sand, formed by the flow of water over the sand.

A geologist contemplates the ripples formed in a mountain stream in Idaho.

Nooreen Meghani 2015

Original Horizontality

The principle of original horizontality states that sediment is deposited horizontally. This is sometimes easier to envision with liquids: imagine pouring water into a cup. The surface of the water is perfectly flat - horizontal. If you dump that water into a bowl, the surface remains flat. Now imagine that you have a jello mixture in the bowl - if you chill it and it solidifies, and then pour a different color on top, You have the two flat layers of jello, one on top of the other. This is similar to how sedimentary rocks form. As water moves sediment from high regions, like mountains, to low regions, like the ocean, the energy of the system decreases until the sediments are deposited in a basin, like a lake or an ocean. More sediment is deposited on top, and over time the whole **sequence lithifies** (sort of like the jello did in the fridge). The rocks remain horizontal until a force acts on them, pushing (or pulling) them out of their original orientation.

Laws of original horizontality (1:22)

Check Your Understanding

The rocks in this image are sandstone (a sedimentary rock). What do you think is part of their history?

Sedimentary rock
Sedimentary rocks in Utah

Nooreen Meghani 2015

Superposition

This principle states that a sequence of rocks in their original orientation will have the oldest rock on the bottom and the youngest rock on the top. A simple way to think about this is that for something to be on top of something else, for example in order to put

a book on top of a table, the table has to be there. If the table isn't already there and you put the book down, it falls to the floor (and note! The floor had to be there for the book to land on it.). The same is true of rocks. In order to deposit a sandstone on top of a limestone, the limestone has to already be there. Knowing this, geologists can figure out the relative ages of rocks on top of each other.

Image of rocks. A, b, c, d, e, f

Cross-Cutting Relationships

Similarly to the principle of superposition, a rock must already be in place to be cut by a fault, igneous intrusion or erosion. By carefully examining which rock units are cut by faults or intrusions, or which rock units have been weathered, geologists can further determine the relative ages of rocks.

Image of rocks: three are cut, the rocks on top are not

Walther's Law

Walther's law is a little different from the previously discussed geologic principles, but it is just as important. Instead of dealing only with relative time, Walther's law deals with relative space through time. Walther's law states that depositional environments that are laterally adjacent on the surface of the earth will also appear in succession in a stratigraphic sequence. If there is **something missing, there is missing time, or an unconformity**.

Okay, that was a lot to take in. Let's break it down, starting with laterally adjacent and depositional environments. If two things are right next to each other, they are laterally adjacent. A depositional environment is simply a place sediment can be deposited. Different types of sedimentary rock form in different depositional environments, so geologists can often figure out what existed at a particular place millions of years ago. Some examples of depositional environments include meandering river, delta, beach, lake, swamp, shallow marine, and deep marine. So what are laterally adjacent depositional environments? Two depositional environments are considered laterally adjacent if you can walk from one to the next without anything in between. (If there IS something in between, that something is the laterally adjacent environment!) Imagine that your kitchen has a door to an outside porch, and your porch is just one step above your grassy back yard. You can walk from the kitchen to the porch without encountering the grassy backyard. That means your kitchen and the porch are laterally adjacent. Can you get from your kitchen to the grassy backyard without encountering something else? Nope, you have to cross the porch to get the yard. The kitchen and the yard are **not** laterally adjacent. The image below shows typically laterally adjacent depositional environments.

Enter image and alt text here. No sizes!

Dispositional environment schematic

By Mikenorton - Own work, CC BY-SA 3.0, [Wikimedia](#)

Changes in depositional environments are driven by changes in **base level**, or the elevation of the terminal body of water (often, but not always sea level!). When base level changes, the depositional environments shift to achieve a new equilibrium. If sea level falls, you might shift the depositional environment image to the right. However, you can't move the mountains, so you end up stretching out the environments in between the mountains and the ocean. Where you once had a delta, now you might have a meandering river. If, instead, you raise sea level, you would move the ocean to the left, squishing the environments in between. The result could be a delta where you once had a meandering river. Think of the beach as the main focus: If the beach moves towards where the ocean used to be, sea level has fallen and your sediments **prograde**. If the beach moves away from where the ocean used to be, sea level has risen and your sediments **regress**.

How did you do? If you got some wrong, go back to the depositional environments image and imagine putting the second environment on top of the first. If you have to move the second environment toward the ocean, sea level has to fall. If you have to move the second environment toward the mountains, sea level has to rise.

Now imagine that you have a section of rock. Here's what a geologist would see of the five examples above. The direction of depositional environment change moving up-sequence (oldest to youngest) tells you about the change in the environment, which in turn tells you about the change in base level. Using the image to show adjacent depositional environments, do you think base level rises or falls in this sequence of rocks?

Image - three examples of depositional environments with tie points to show spacial correlations. One high base level, one medium base level, and one low base level, with arrows between them to show which way base level is moving

The information a geologist can get about depositional environments and the rise and fall of sea level through time lets her know where the oil-bearing sedimentary rocks might be!

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4.3.5: Sedimentary Rocks

Because we are ultimately focusing on oil and gas formation, let's take a closer look at sedimentary rocks. Oil and gas typically form in sedimentary rocks, and get trapped in the **pore space** within the rocks. But first, how do we get from loose sediment like we might see in a stream or on the beach to solid rock?

There are many different types of sedimentary rocks. Geologists differentiate between them by making observations about **composition**, **texture**, and **grain size**. **Composition** is what the rock is made out of. Sedimentary rocks can be clastic, chemical, or biologic. Clastic sedimentary rocks are composed of individual minerals, like quartz or feldspar, and fragments of other rocks (these are called lithic fragments). These rocks contain grains that can range from large cobbles or boulders to smaller than the unaided eye can see. Chemical sedimentary rocks form through precipitation, typically when water cools or evaporates, leaving the minerals behind. Halite, the mineral name for salt, forms when salt-rich water evaporates, leaving the salt behind. Biologic sedimentary rocks are either composed of fragments (or the whole) of living creatures, or they are formed by biologic processes. Coal is an example of a biologic sedimentary rock.

We'll focus on clastic sedimentary rocks, since that's where oil and natural gas most commonly form. Below is a schematic of the depositional environments in which sedimentary rocks form. One way to think about depositional environments is by the size of the sediment at that location. Notice that sedimentary rocks and the flow of water often go hand in hand - this is because sediment is commonly transported by water. As sediment is moved, it weathers. A large boulder that breaks off of a mountainside becomes smaller and smaller as it collides with other boulders, forming gravel in mountain streams, and sand on beaches. Eventually, the smallest fragments of the boulder might make it out to the deep ocean, settling to the ocean floor when there is no longer enough energy in the flow of water to keep the sediment moving.

schematic of the main sedimentary depositional environments

Schematic showing the main sedimentary deposition environments

Credit: [Wikipedia](#)

In order for a sedimentary rock to form, the deposited sediment must be **preserved**. Burying the sediment with other sediment usually does this (sand is heavy!). Eventually the buried sediment is **lithified** (converted into a rock) through **compaction** and **cementation**. Compaction is a physical process that involves compressing loose grains. Cementation is a chemical process in which dissolved ions precipitate in the space between grains, forming a "bridge" between the previously loose grains and binding them together.

Check Your Understanding

Oil and natural gas are typically found in a sedimentary rock called shale. Shale is formed at very low energies, and of very fine-grained sediment. In which depositional environment do you think it is likely to form?

Answer available at the end of this section.

Answers

Check Your Understanding

Deep Marine

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4.3.6: Assessment

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4.4: Energy

What is energy? What kind of energy do we extract from the earth? How do we find it?

Goals

By the end of this section you will:

1. Have a thorough understanding of the requirements to form oil and natural gas reservoirs, from deposition to formation of the reservoir;
2. Be able to explain the processes geologists use to locate oil and natural gas reservoirs; and
3. Have an appreciation for the environmental costs of oil and natural gas extraction.

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4.4.1: Oil and Natural Gas

Oil and natural gas typically form in **sedimentary** rocks. When carbon-rich organic material, like leaves, are deposited terrestrially in water with a low oxygen content (stagnant water), it may not fully decay. Think about swamps and bogs! If this happens and sediment is deposited on top, a coal bed can form. Many of the largest coal beds in the world are a result of huge **Devonian** and **Carboniferous** swamps. Similarly, oil and gas are formed when organic material is deposited in deep marine sediments. In marine deposits the organic material is mostly **phytoplankton**, microscopic animals that convert sunlight into energy. When they die and settle to the ocean floor some of this energy remains in the form of carbon molecules in their bodies. Other elements that settle to the ocean floor are nitrogen, oxygen, and hydrogen. All of these molecules mix with very fine grained sediment and form an organic-rich 'ooze'. As sediments continue to be deposited, burying the ooze (remember burial is vital to preservation!), the weight of the overlying sediment will cause an increase in temperature and pressure, which will in turn lithify the ooze. It also provides enough energy for the carbon and hydrogen molecules to bond, forming hydrocarbons: oil or natural gas. The temperature, pressure, and type of organic material determine whether oil or gas is formed. Relatively lower temperatures and pressures form oil, while higher temperatures and pressures form gas.

graph showing depth below surface vs. relative amount of petroleum formed.

Figure 1: The relationship between depth of burial, temperature and the relative amount of crude oil and natural gas formed from Type II kerogen in an area with a geothermal gradient of about $35\text{ }^{\circ}\text{C km}^{-1}$

Source: [OpenLearnWorks](#)

Once oil and gas are formed, they are able to migrate through open spaces in rock called **pore space**. The spaces within a rock that are unoccupied by **solid** material. These include the space between grains, fractures, vesicles, and voids formed by dissolution. Geologists look for a **trap**, or **impermeable** rock that can catch migrating oil and gas. When pore spaces are well connected, a rock is considered to be relatively permeable, since it is easy for liquids to flow through it. An impermeable rock will have therefore have a low connectivity of pore spaces. The rock that the oil or gas resides in below the impermeable rock is called the **reservoir rock**, while the rock the oil and gas formed in is called the source rock. Sometimes, the source rock and the reservoir rock are the same - it just depends on where the impermeable rock layer is. Shale makes a good reservoir rock because the pore spaces are so small that oil and natural gas become trapped within and can't migrate out. In fact, the very low permeability of shale is why **hydraulic fracturing, or fracking**, is the preferred method to extract the oil and gas from natural gas-rich layers like the Marcellus Shale. Fracking is the process of injecting liquid at very high pressures into a rock. The pressure causes any weak sections of the rock to break, forming pathways for the oil and gas to escape.

4.4.2: How do geologists find oil and natural gas?

Geologists use a lot of the information that you now have to locate oil and natural gas. First, geologists think about where oil and gas form. We know that they form rocks like shale, which form in deep marine environments. So, a geologist would start out by looking for shale. There are a couple of ways to go about this.

One way is to look at the rocks exposed at the surface of the earth. By making a geologic map and extrapolating what we find at the surface beneath, we can form a reasonable guess about what rocks are below. One problem with this is that oil and gas can be far beneath the surface, and it's possible that faults or folds could exist below that we cannot see at the surface. Here's an example of a geologic map that shows rock units at the surface, and the cross section that was made based on the data collected at the surface.

Another way to find out what's below the surface is to drill a core through the earth. Cores can be thousands of feet long, and provide a snapshot of what exists beneath a particular point. By drilling several cores miles apart, geologists can correlate the rock units and create an image of what exists and where below the surface. Combining this information with rocks exposed at the surface, which can give clues about rock orientations below, can be a powerful tool in locating oil and gas. This generalized geologic cross section provided by Penn State's Marcellus Center for Outreach and Research (MCOR) was created based on information from cores that were drilled across Pennsylvania. Once you have an idea of what the big picture is, you can figure out where the particular rock type you're looking for might be. Walther's law is particularly important here, because you can get a sense of which direction in the rock unit you need to move to get to the rock you want.

Check Your Understanding

If you want to find a shale and your section of core looks like this, should you move up section or down section? Remember that older rocks are on the bottom, and younger rocks are on top. OR two cores, with correlations between them. Which way is the basin?

beach - meandering river - braided river: Answer - down in the core. This progression has depositional environments that are getting progressively 'shallower', and shale is found in a very deep marine depositional environment.

A third way to get an idea of what is below the surface is to run a seismic survey. Remember from the very beginning of the geology lesson that a Seismologist is a geologist who studies earthquakes, and the properties of elastic waves through the earth. Earthquakes create natural waves that move through the earth, and by recording them seismologists can study the earthquake itself in addition to the properties of the different layers of the earth. It's in large part thanks to earthquakes that we know the outer core is liquid!

In a seismic survey a human-generated wave is sent through the earth using a thumper truck, dynamite, or simply a hammer (the more energy in the wave, the farther it will go before dissipating). Just as P-waves can pass through the entirety of the earth (if they have enough energy) and S-waves cannot pass through liquids, different rocks interact with the waves caused by thumper trucks in different ways. Depending on the properties of the rock, the thumper-truck wave can either pass through, be reflected, or some combination of the two. In a seismic survey there will be a point source for the wave (the place the wave comes from) and a number of 'geophones' set up around the point source that 'listen' for the reflections of the waves when they come back to the surface. The length of time it takes for the wave to return depends on the properties of the rock that reflects it and how deep the rock is.

Schematic Diagram of Seismic Study

Schematic diagram of seismic study, from Chesapeake Energy Corporation.

Credit: Chesapeake Energy Corp

Seismic surveys can't tell you precisely what types of rock are below the surface, but they can give you an idea of what the structures below the surface are. Here's an example of the data that comes out of a seismic survey.

Each solid line drawn in and labeled represents a particular stratigraphic surface, which we haven't discussed in this course.

For more information on stratigraphic sequences, including what they are and how to identify them, visit the [SEPM \(link is external\)](#) website, or the website of Dr. Steve Holland at the University of Georgia, [UGA Stratigraphy Lab\(link is external\)](#). When looking at seismic data, it's important to remember that the Y-axis represents time: How long it took for the wave to go from the source to the layer to the geophone. Seismic data also includes a number of 'echoes', or doubled seismic reflectors. These are identifiable by a series of perfectly duplicated lines, and they form when the wave bounces inside a layer before coming out. Usually only the first of these represents a real surface in the rock.

Uncertainties

Each of these methods for identifying what's going on beneath the surface of the earth comes with its own set of uncertainties. Figuring out what's going on beneath the surface is a little like putting together a puzzle while blindfolded: we only know the shapes of the pieces we touch, and we can't see the whole picture. We have to use all the tools and technology at our disposal in order to make the best picture of what's below the surface that we possibly can based on what we know. Even then, the interpretation could be missing information, or could be wrong. Notice how the seismic data interpretation was correlated with a core (this is the information directly beneath the well symbol). Seismic data and cores often are taken together: By taking a core sample, geologists can identify with more certainty which of the seismic reflectors represents a surface or a change in rock type, and by taking a seismic survey, geologists can extend their interpretation of the core to get a much bigger picture without having to do more drilling.

Schematic of Generalized Geologic Cross Section Showing Marcellus Shale in Western Pennsylvania
Generalized Geologic Cross Section Showing Marcellus Shale in Western Pennsylvania

Credit: Marcellus Center for Outreach and Research

Check Your Understanding

Using the graph of peak oil and gas depths, where should we drill for oil?

(overlay lines on the image above at the peak oil and peak gas zones, ~2800 and 4000m, straight line to the surface, curve across the top to show likely drilling locations)

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4.4.3: Environmental Costs to Extraction

How we extract oil and natural gas today will be covered in more detail later, but we'll talk about some of the costs now. When we remove material from the earth, there are consequences: Every action has a reaction, every cause has an effect. When we drill we affect systems at depth and at the surface, sometimes disrupting delicate balances and causing dramatic changes to ecosystems.

Less-obvious types of pollution

Some extraction removes vegetation at the surface, exposing dirt and sediments to the elements and allowing them to be easily eroded away. This leads to a type of pollution called turbidity, where the pollution isn't a chemical, it's the sediment itself. It clouds the water, causing less sunlight to get through. This affects microscopic organisms that rely on sunlight, and since those organisms are at the very base of the food chain, the ramifications of sediment pollution extend all the way to the top. In addition, the influx of sediment can cause a rapid increase in deposition rates. This means that areas where there isn't necessarily a lot of sediment settling out of the water might experience a much higher rate, clogging riverbeds or dams, and potentially changing the flow of a river dramatically.

Human induced earthquakes – injection wells

The environmental costs of extracting energy-resources are numerous, with varying degrees of severity. A recent consequence of increased oil and gas activity is human-induced seismicity. These earthquakes range from very small to as large as an earthquake you might expect in California. Although some earthquakes have been associated with oil and gas extraction, the largest earthquakes are usually the result of injection wells (sometimes called disposal wells), wells that are used to dispose of waste waters used in drilling. Injection wells involved much higher pressures than typical extraction wells, and this high pressure can re-activate old faults deep in the crust. Severe damage has been caused in some towns as a result.

Activity

Read this article from Forbes on earthquake hazards associated with drilling: [Thanks To Fracking, Earthquake Hazards In Parts Of Oklahoma Now Comparable To California](#).

After reading, think about how you would answer the questions below. Click 'Answers' to see how your thoughts compare to the answers provided.

1. Is the increase in earthquake hazard in Oklahoma really due to fracking?
2. Compare the map of earthquakes associated with oil and gas with a map of recent earthquakes published by the United State Geological Survey (USGS) – how common does it seem like earthquakes are in Ohio? [USGS Oklahoma Earthquakes](#)

Answers available at the end of this section.

Methane emissions: Legacy Oil and Gas Infrastructure

Sometimes the environmental costs are not apparent until many years later. When it comes to drilling, many states suffer from abandoned oil and gas infrastructure that was neither documented when originally installed, nor plugged/cleaned up when extraction ended. Pennsylvania, home to some of the largest and earliest oil fields, has an estimated 300,000+ **orphan** and **abandoned** oil and gas wells, the vast majority of which have unknown locations. Part of the reason so many wells are 'missing' is because there were no regulations regarding oil and gas drilling until the 1950s – people didn't have to report well locations. Because the oil was relatively shallow in Pennsylvania, it was pretty easy to extract. Regular people would drill in their back yards or on their farms, using the oil or gas to heat their homes until it ran out. Similarly, small companies would drill in an area until it ran dry, and then move on, or eventually go bankrupt. Since plugging wasn't required in the early days of the oil and gas industry, most of these wells serve as conduits from shallow oil and gas fields to the surface. It's been estimated that nearly 7% of Pennsylvania's methane emissions are from these legacy wells (Kang et al., 2014, *Direct Measurements of methane emissions*

from abandoned oil and gas wells in Pennsylvania, PNAS, v.111 n.51:18173–18177), and there are some who think that may be an underestimate.

Methane emissions: Plugged Wells

In addition to unplugged wells, plugged wells are also a large contributor to methane emissions. The plug on a well lasts only as long as its weakest component, which in modern plugs is usually the cement. Cement has a lifespan of about 30 years, which means that even if all the wells were plugged, each plug would need to be replaced, or at the very least reassessed, every 30 years – at least until the technology improves.

Want to learn more about orphan and abandoned oil and gas wells? Check out [Marcellus Matters](#) and [PA Oil and Gas Mapping](#)([link is external](#)). for more information. We are still reliant on fossil fuels, and mining and drilling is the only way to get them. It's worth remembering that getting them likely has a larger price over time than simply what we pay at the pump.

Answers

Activity

1. *Like most things, this is a little more complicated. Although fracking certainly contributes to the increase in earthquakes in Oklahoma, Dr. Conca notes that the culprit is most likely wastewater injection, which changes the pressure systems at depth and can allow for things to move that wouldn't otherwise. Wastewater is created both at fracking sites and at regular drill sites, so there are multiple culprits.*
2. *For the last three years, there have been 585, 890, and 518 earthquakes per year. Seems like earthquakes are pretty common now! But from 1978 to 2008, Oklahoma experienced less than 2 earthquakes a year.*

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4.4.4: Assessment

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Appalachian Basin*

A long-lasting sedimentary basin that existed in the area of the present-day mid-Atlantic states. Rocks deposited in the basin range from early Cambrian through early Permian age (540-295 million years old). The Appalachian basin is known for its abundant coal, oil and natural gas deposits.

Basin

A topographic or structural low area that generally receives thicker deposits of sediments than adjacent areas; the low areas tend to sink more readily, partly because of the weight of the thicker sediments; the term also denotes an area of relatively deep water adjacent to shallow-water shelf areas.

Bedding

Sedimentary layers in a rock. The beds are distinguished from each other by grain size and composition, such as in shale and sandstone. Subtle changes, such as beds richer in iron-oxide, help distinguish bedding. Most beds are deposited essentially horizontally.

Black shale*

Variety of shale relatively rich in organic material and most likely formed in an oxygen-depleted environment.

Clay

A family of platy silicate minerals that commonly form as a product of rock weathering. Also, any particle smaller than 1/256 of a millimeter in diameter.

Compaction

Occurs when the weight of overlying material compresses more deeply buried sediment. Along with cementation, this process converts sediments to solid rock.

Crust

The rocky, relatively low density, outermost layer of the Earth.

Devonian*

A geologic period within the Paleozoic Era. The Devonian spans from 416-359.2 million years ago and was the period of Earth's history when land plants first appeared, fish species became numerous and diverse, and the first animals crawled from the sea to walk on dry land.

Diagenesis

A group of processes that cause physical and chemical changes in sediment after it has been deposited and buried under another layer of sediment. Diagenesis may culminate in lithification of sediment, turning it into solid rock.

Earthquake

A sudden ground motion or vibration of the Earth. Produced by a rapid release of stored-up energy along an active fault.

Epicenter

The point on the Earth's surface located directly above the focus of an earthquake.

Erosion

Removal of material by water, wind, or ice.

Fault

A fracture in the Earth along which one side has moved in relative to the other. Sudden movements on faults cause earthquakes.

Formation

A rock formation is a body of rock of considerable extent with distinctive characteristics that allow geologists to map, describe, and name it.

Fracture

Any break in rock along which no significant movement has occurred.

Impermeable

Rock or sediment that does not allow passage of water or other fluids.

Induced seismicity*

Earthquakes that occur due to human activity.

Intensity

One way to measure the strength of an earthquake. Intensity measures of the affects of an earthquake on buildings and the reactions of people. Compare with magnitude.

Isotope

Different forms of a single element that have the same number of protons but different numbers of neutrons in their nuclei. Some radioactive isotopes are unstable and shed nuclear particles over time until they become stable. For instance, unstable isotopes of uranium break down to become lead.

Joint

A narrow crack in rock along which there has been no significant movement of either side. Joints commonly form in parallel sets.

Limestone

A sedimentary rock made mostly of the mineral calcite (calcium carbonate). Limestone is usually formed from shells of once-living organisms or other organic processes, but may also form by inorganic precipitation.

Lithification

The conversion of loose sediment into solid sedimentary rock. Several processes, including compaction of grains, filling of spaces

between grains with mineral cement, and crystallization act to solidify sediment.

Magnitude

A measure of the total amount of energy released by an earthquake.

Marcellus Shale*

Organic rich black shale that formed from mud deposited in the Appalachian Basin 384 million years ago. The Marcellus contains relatively abundant organic material derived from the remains of plankton living in the waters of the shallow sea that filled the Appalachian Basin at that time. Over time, some of the organic material has been converted to natural gas.

Mud

Wet clay and silt-rich sediment.

Mudstone

A very fine-grained sedimentary rock formed from mud.

Normal fault

A fault that drops rock on one side of the fault down relative to the other side.

Permeability

The ability of a rock or other material to allow water or other fluids to flow through its interconnected spaces. Permeable bedrock makes a good aquifer, a rock layer that yields water to wells. See porosity.

Plankton

Generally tiny animals or plants that live floating in water.

Porosity

The percentage of open spaces (pores) in rock or soil. When these spaces are interconnected, water, air, or other fluids can migrate from space to space. Interconnected spaces make the soil or bedrock permeable.

Reservoir rock*

A highly porous and permeable rock, such as sandstone, that collects hydrocarbons produced by source rocks.

Sand

Loose particles of rock or mineral (sediment) that range in size from 0.0625 - 2.0 millimeters in diameter.

Sandstone

Sedimentary rock made mostly of sand-sized grains.

Seismic

Refers to earthquakes.

Sedimentary

Sedimentary rocks are formed from pre-existing rocks or pieces of once-living organisms. They form from deposits that accumulate on the Earth's surface. Sedimentary rocks often have distinctive layering or bedding.

Shale

Sedimentary rock derived from mud. Commonly finely laminated (bedded). Particles in shale are commonly clay minerals mixed with tiny grains of quartz eroded from pre-existing rocks.

Silt

Loose particles of rock or mineral (sediment) that range in size from 0.002 - 0.0625 millimeters in diameter. Silt is finer than sand, but coarser than clay.

Siltstone

A sedimentary rock made mostly of silt-sized grains.

Source rock*

A rock that has generated hydrocarbons from organic material deposited along with the sediment comprising the rock.

Weathering

Weathering includes two surface or near-surface processes that work in concert to decompose rocks. Both processes occur in place. No movement is involved in weathering. Chemical weathering involves a chemical change in at least some of the minerals within a rock. Mechanical weathering involves physically breaking rocks into fragments without changing the chemical make-up of the minerals within it. Mechanical weathering includes processes such as water in cracks freezing and expanding, or changes in temperature that expand and shrink individual minerals enough to break them apart.

Resources

* definition by Chuck Anderson, Penn State University

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5: SHALE DEVELOPMENT ENGINEERING

Overview

Here's where you will introduce your lesson. What will we learn, how does it connect with what we may have already covered, what can you expect content-wise?

Include the main topics of the lesson here. This can be included in the text or be a bulleted list.

Learning Outcomes

By the end of this lesson, you should be able to:

- Define fracking and its components.
- Summarize the stages of oil and gas extraction.
- Summarize the history of the oil and gas industry and associated regulations.

5.1: Introduction

5.2: The Phases of Exploration, Leasing, Drilling and Production

5.3: Exploration Phase

5.4: Leasing Phase

5.5: Drilling and Production Phase

5.5.1: Drilling Operations

5.5.2: Fracking and Production Phase

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5.1: Introduction

Technology and engineering are significant aspects of exploration for and production of hydrocarbons. Although there are risks associated with drilling and producing hydrocarbons from the subsurface, regulation, proper engineering, and inspection combine to make the process as safe as possible. Still, members of the public commonly perceive these risks as unacceptable and some continue to oppose further development of shale gas. The present lesson explores the timeline of development for drilling a typical shale gas well in Pennsylvania and outlines the components required for selecting a suitable site and drilling and completing one or more wells from a single well pad, as well as outlining the role of regulation in limiting the risk of accidents, spills, and other potential hazards.

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5.2: The Phases of Exploration, Leasing, Drilling and Production

Table 5.1 provides an outline of the procedures and operations required to locate, drill, and complete a typical unconventional well in Pennsylvania, while Figure 5.1 indicates the average time required for each phase.

Table 5.1: Outline of procedures and operations required to locate, drill and complete a typical unconventional well in Pennsylvania.

Exploration Phase (the geology)	Leasing Phase (the people and contracts)	Drilling Phase (the engineering and inspection)	Production Phase (the engineering and infrastructure)
1. Basin scale assessment (data analysis, available well information)	1. Identifying "sweet spots"	1. File for and receive Permit from state regulators (plan for drilling)	1. Production and takeaway of hydrocarbons(gathering lines)
2. Seismic data acquisition and interpretation	2. Approaching landowners/owners of mineral rights	2. Site preparation and plan for drilling, including safety plan	2. Site restoration
	3. Securing a block of leases	3. Rig setup and drilling operations(water access)	
		4. Cementing and wellbore integrity considerations (geophysical logs)	
		5. Hydraulic fracturing operations	
		6. Well completion and testing	

Extraction Timeline

Figure 5.1: Outline of the average time required for each phase of exploration, leasing, drilling, and production for a typical shale gas well in Pennsylvania.

Source: [Pennsylvania Marcellus Shale Workforce Needs Assessment](#)

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5.3: Exploration Phase

Aspects of the exploration phase are entertained in Lesson 1. [The U.S. Geological Survey](#) now routinely assesses petroleum potential for various basins or "plays" worldwide and publishes their assessments with estimates for total reserves of different types including the Marcellus Shale ([U.S. Geological Survey Information Relevant to the U.S. Geological Survey Assessment of the Middle Devonian Marcellus Shale of the Appalachian Basin Province, 2011](#)).

Industry exploration teams acquire all data available for a certain geologic basin in order to assess the prospects for economic deposits of hydrocarbons (oil, natural gas liquids, and/or natural gas). In the continental U.S., most basins have been explored and drilled for decades, if not longer, and the Appalachian Basin is no exception. In fact, shallow Appalachian Basin strata in Pennsylvania were first drilled and produced in 1859. In addition to compiling and analyzing drilling and production records and geophysical (downhole) logs available from individual wells, industry will also acquire seismic surveys or contract with service companies to run such surveys for the purpose of understanding the complexities of subsurface structure and stratigraphy. For the Marcellus Shale Play, note that these seismic surveys are not done for the purpose of locating the Marcellus Shale horizon or detecting hydrocarbons per se; the most important reason such surveys are done is to identify impediments to drilling, including through-going faults or other features that could possibly cause problems with extending long lateral production strings (so-called "horizontals" that could extend over 2 miles away from the drill site; this will be discussed a bit later in this lesson) in the subsurface unit from which hydrocarbons will be produced. These seismic surveys are now typically 3-D, providing large swaths of coverage of the subsurface for interpretational significant cost (e.g. can exceed \$300,000 per square mile in rough terrain).

After assessing the available data, industry will then decide whether to lease in the "play." Sometimes, however, leasing precedes careful assessment if it appears that delays will cause lease costs to increase significantly and/or availability of territory will be limited as the result of a frenzy of leasing by other companies. Of course, in the latter case, a company may lease territory that they may never drill should it not be prospective economically.

5.4: Leasing Phase

Leasing privately held mineral rights is a complex process. The U.S. is nearly unique in having private ownership of mineral rights. In most countries, the government holds rights to mineral extraction. In the United States, the oil and gas leasing process is not regulated and takes the form of a legal contract between the landowner (the lessor) and the operator (the lessee). The purpose of a lease or a purchase contract is to convey the rights of exploration and production to an oil and gas development company. The ultimate goal of the leasing process is to produce an agreement between a landowner and an operator in which mineral rights are leased to the operator in exchange for a recurring rental payment and royalties from any oil or gas produced on the land. It is almost always the case that a "land man" representing an operator approaches the landowner. Since lease agreements involve significant amounts of money and are complex, one should obtain advice from an attorney who has expertise in mineral transactions and Pennsylvania Oil and Gas Law. Since producers have detailed knowledge of the best location to drill for oil and gas, as well as a large number of potential lessors, they tend to have the upper hand in oil and gas negotiations.

Importantly, the property owner has rights as regards the surface and protections afforded by state laws. Surface owners leasing subsurface minerals can, through a well-constructed contract, protect crops, livestock, buildings, personal property, access and any other aspects of their surface holding for the duration of a lease. Although lessees will often accept significant revisions to their standard lease or sales contract, they can reject them.

A lease does not necessarily entitle an energy company to drill on a property. The company must first obtain a permit from the state regulatory authority (in PA this is the Department of Environmental Protection), which requires a detailed plan for drilling a specific target formation. The permit insures regulatory protections and makes the drill site subject to inspections.

5.5: Drilling and Production Phase

Permitting

A permit is required prior to beginning operations. Once a permit is issued, a company has one year to begin drilling or the permit expires. If drilling is begun but not completed within 16 months, the permit will expire. There are many stipulations for the permit application outlined in the Regulations for Oil and Gas Wells included in the [2012 Oil and Gas Act--Act 78 and 78a](#) most recently amended in October, 2016. Act 78a specifically applies to unconventional (e.g. shale gas) wells. These stipulations include, but are not limited to, erosion and sediment control, protection of water supplies, surveys and identification of abandoned wells, handling of drill cuttings and fluids, and site restoration.

Marcellus shale drillsite in Central PA
Figure 5.5.1: Marcellus Shale drillsite in Central Pennsylvania

Source: [Marcellus Center for Outreach and Research \(MCOR\), Penn State](#)

Drillsite and Drilling Operations

Most producing companies do not own or maintain their own drilling rigs and must lease rigs from a drilling or service company. For shale gas drilling in Pennsylvania, heavy duty rigs are required to handle long (heavy) drillstrings for deep drilling. These cost upwards of \$250,000/day to lease and are usually top-drive rigs (Fig 5.5.1) that are capable of "walking" short distances in order to drill multiple holes on one pad (see 5.5.5). Drill pad arrangements and drilling rigs can be confusing to the uninitiated. There are many working parts with names (e.g., rathole, cathead, doghouse, etc.) and purposes that may seem obscure. But these are industry standard and many of them are designed for safety and containment of fluids and gases encountered downhole during the drilling operation.

Components of a typical drillrig and setup numbered and labeled

Figure 5.5.2: Components of a typical drillrig and setup 1. Crown Block and Water Table 2. Catline Boom and Hoist Line 3. Drilling Line 4. Monkeyboard 5. Traveling Block 6. Top Drive 7. Mast 8. Drill Pipe 9. Doghouse 10. Blowout Preventer 11. Water Tank 12. Electric Cable Tray 13. Engine Generator Sets 14. Fuel Tanks 15. Electric Control House 16. Mud Pump 17. Bulk Mud Components Storage 18. Mud Pits 19. Reserve Pits 20. Mud Gas Separator 21. Shale Shaker 22. Choke Manifold 23. Pipe Ramp 24. Pipe Racks 25. Accumulator

Source: [OSHA](#)

For a description of individual components, the reader should consult the illustrated glossary of typical drilling equipment at the drill site that can be found at [OSHA](#) (see Fig 5.5.2). A few of the key components will be discussed in the text as they relate to the drilling and completion of operations.

In order to prevent spilled fluids from penetrating into the ground, drillsites are protected by an impermeable pad with raised edges (Fig. 5.5.4). Even minor spills must be reported to PA DEP. Fluids flowing from the subsurface during drilling and post-drilling operations are stored temporarily in tanks on the pad. Storage in open, lined ponds was initially common practice but no longer used.

Impermeable pad laid down before rig and other equipment is installed

Figure 5.5.3: Impermeable pad laid down before rig and other equipment is installed. Three cages are future sites for drill holes with conductor casing already installed.

Tank that temporarily stores fluids from subsurface during drilling and post-drilling operations

Figure 5.5.4

There is a geologic rationale to the layout of holes to be drilled on a drillsite. Figure 5.5.5 shows six completed wells on a former pad (now restored and covered with gravel). These producing wells are very close together at the surface and illustrate the position of the vertical parts of the wells by a drilling rig that can drill one well and "walk" a few feet to drill another. The Marcellus

Shale horizon increases with depth towards the southeast from its shallowest level in northwestern Pennsylvania. (Fig. 5.5.6). Conventional vertical wells alone cannot tap sufficient hydrocarbons from this relatively thin shale unit to be economic. Thus, an unconventional strategy must be used that combine a vertical wellbore, drilled to about 1000 feet above the target horizon, followed by a bend and horizontal segment that is drilled along the target horizon; in this case, the target is typically the most organic-carbon-rich horizon near the base of the Marcellus Shale (Fig. 5.5.7). Note that the well is "cased" to protect groundwater resources from fluids and gases coming up the well from deeper horizons. Ultimately, most of the casing is cemented, particularly in the shallow zone of fresh water (typically from the surface to 500 to 1000 feet) to fill in the "annulus" (void space) around the casing and further protecting against contamination of shallower horizons by migrating fluids. We discuss this aspect further in a later section.

Completed well with workers on site

Figure 5.5.5: Completed Marcellus Shale wells in Tioga County, PA. Pad has just been cleared and wellheads connected (water tanks from fracking operation surround pad).

Map outlining depth of marcellus shale base

Figure 5.5.6: Map of Appalachian Basin showing depth to the base of the Marcellus Shale. The wet gas/dry gas boundary is a function of the maximum burial temperature experienced by the shale during its history. Wells to the south and east of the boundary recover only methane (so-called "natural gas").

Source: [Marcellus Center for Outreach and Research \(MCOR\), Penn State](#)

schematic of typical marcellus shale well showing and describing different parts

Figure 5.5.7: Schematic of typical Marcellus Shale well showing vertical segment with protective casing, kick-off point for going from vertical to horizontal drilling, and horizontal segment (producing interval) in lower part of Marcellus Shale.

Source: [Marcellus Center for Outreach and Research \(MCOR\), Penn State](#)

So, back to why the vertical wells are spaced and have the orientation that they do. Some time ago, Professor Terry Engelder at Penn State University showed that there are natural fractures in the subsurface within the Marcellus Shale that have a similar orientation across the Appalachian Basin. There are two major sets of fractures, which Dr. Engelder called J1 and J2. Examples of these intersecting fracture sets are shown in Figure 5.5.8. Without getting into the details of how these formed, suffice it to say that they are presently oriented relative to certain principal stress directions such that the J1 fractures, which are more closely spaced and oriented Northeast-southwest, will open somewhat if pressurized fluids are pumped along horizontal lengths of tubing placed perpendicular to them. This is the rationale for the pattern of drilling shown in Figure 5.5.9.

Natural fractures

Figure 5.5.8: Natural fracture sets J1 (coming out of the picture toward you) and J2, nearly perpendicular to J1 that have nearly the same orientation over the entire Appalachian Basin.

Photo courtesy of T. Engelder

Diagram illustrating typical orientation of lateral segments of well

Figure 5.5.9: Diagram illustrating the typical orientation of lateral segments of Marcellus Shale wells. The gray area represents a square mile of area. The white box at the center represents a well pad with six wells drilled. The vertical wellheads are arrayed as in Fig. 5.5.5, with the horizontals drilled in a "pitchfork" array to be perpendicular to the J1 fracture set (black squiggly lines). Regional stresses are shown as arrows.

12 images representing process flow of hydraulic fracturing job

Figure 5.5.10: Steps in drilling, fracking and completion of a typical shale gas well.

Source: "[Evaluating the Environmental Implications of Hydraulic Fracturing in Shale Gas Reservoirs](#)," ALL Consulting, 2008

5.5.1: Drilling Operations

We have, so far, outlined the exploration, leasing, permitting, and site design for drilling Marcellus Shale wells in Pennsylvania. Now we need to develop an understanding of the drilling process and the protections against environmental impacts that are implemented during that process.

A first step in preparing the surface for the drill hole is to install "structural casing" which is a large diameter conduit that is usually dug or pounded in to shallow depth to protect loose near-surface formations (prevent caving into the hole) and to enable circulation of drilling fluid.

Drilling requires a drill string that can be added in segments (typically 30-feet) as the hole deepens with a durable "bit" (the part that grinds up the rock) at the bottom. The bit must be sufficiently strong and hard because if it fails the entire drill string needs to be "tripped" back to the surface (pulled up and taken apart in 30-foot sections) in order to replace the broken or worn bit with a new one. Bits vary in design, but either a roller-cone bit with three rotating cones or a fixed cutter bit is used commonly. The steel cones or fixed cutting surfaces are studded with harder tungsten carbide or even diamonds to improve abrasion and durability. Quartz, a typical component of sedimentary rocks, and steel have about the same hardness such that an all steel bit would not cut rock effectively. The drill string needs to have considerable strength and is suspended from the rig at the surface (the string is actually in tension rather than compression, otherwise it would likely fail; in other words drilling rock is not like the bit on the end of your wood drill that you apply pressure to so that it penetrates deeper into the wood. In addition, there must be some sort of fluid circulation in the hole around the drill bit for at least three reasons: 1) to cool the bit and provide lubrication; 2) to lift cuttings (the rock fragments formed during drilling) to the surface (otherwise they would clog the hole and jam the drill string); and 3) to counteract the higher potential gas pressure in deeper horizons that would cause the well to "blow out."

In the shallower part of a hole drilling must be done with air or fresh water or fresh-water mud to prevent contamination of the shallow fresh water aquifers. Generally, the salt content (salinity) of fluids trapped in small voids (called pores) in sedimentary strata increases with depth from near-surface drinking-water quality (less than 1000 parts per million dissolved solids), to waters that, at least in the Appalachian Basin, may have nearly 10 times the salt content of ocean water (ocean water averages about 35,000 parts per million dissolved solids). Deeper in the well, the fluids circulating in the hole must be more and more dense so that their weight will counteract the pressure of gases encountered during drilling that will attempt to rise up the hole. These fluids are actually "mud", a mixture of water, clays, and, commonly a dense mineral called "barite." Drillers monitor subsurface pressure while drilling and constantly adjust the mud density to match the pressure. The "Driller", who is in charge of the progress of drilling in the hole, sits in the "doghouse" surrounded by instruments that monitor downhole conditions, weight-on-bit, and mud weight, and with a clear view of operations on the rig.

The process of actually drilling a well begins with drilling in and setting the "conductor casing" which is the largest diameter casing in the wellbore. Casing must meet certain strength standards (API, American Petroleum Institute sets these) and is fabricated from strong, low-carbon steel. This casing helps to maintain borehole stability and prevent contamination of surface aquifers and to protect against shallow gas. The conductor casing provides a connection for the installation of the casing head and blowout prevention stack. This casing will be set to some depth (usually 500 to 1000 feet in PA, mandated to extend to 50 feet below the last "fresh" water), and will be cemented from its shoe (bottom flange) to the surface to prevent migration of gas or fluids along the outside of the casing where there is a gap between the casing and the surrounding formation. Subsequent strings of casing (surface, intermediate, and production casing) have decreasing diameters and are hung inside the conductor casing to isolate water from producing formations and to control well pressures during drilling and production.

The size of the bit used to drill vertical holes decreases with depth. Casing (hole) diameter decreases with depth in a typical shale gas well. Surface casing is set to provide blowout protection, isolate water sands, and prevent lost circulation (drilling fluids flowing into low-pressure, porous formations). Intermediate casing provides protection from deeper low-pressure zones, if they occur, and hydrocarbon producing zones that are encountered before the target horizon. Production casing is the last string installed, and is set in the horizontal part of the hole (5.5 inch diameter) and is designed to protect production tubing, which has lower crush strength than steel casing or is perforated itself as the conduit for hydrocarbons from the producing zone. Production tubing, essentially a liner, would typically extend from the producing zone to the surface inside the other casing strings.

From the "kick-off" point, a different drilling technique is used, with a special drill collar and "mud motor" that can bend at a maximum angle of 3 degrees. Thus, it takes some vertical distance to actually go from the vertical hole to a horizontal segment, typically about 1000 feet. The mud motor is driven by a special formulation drilling mud pumped at high pressures through the motor system, causing the bit to rotate. However, the speed of rotation is slower (about 50 rpm) than for the vertical

drillbit because of the eccentric nature of the angled system, which would cause excessive wear if rotation rates were greater. Interestingly, in this string there is a telemetry system with magnetic sensors that can transmit position information to the surface and a total natural gamma radiation detector that allows "geosteering" through a shale formation. Geosteering means that this drilling system can be operated remotely (possibly from a thousand miles away) and guided by a geologist rather than the "driller" through the zone in the target formation that is deemed most productive of hydrocarbons.

All of the casing strings must be centered in the hole (practically and by regulation). This is accomplished by strategically space "centralizers" that are attached to the outside of the casing. The centralization is critical to the later cement job such that specially formulated cement will ideally fill the "annulus" (the void between the formation and the casing) equally to prevent gaps that could facilitate upward hydrocarbon migration of hydrocarbons to the surface and/or to penetrate shallow horizons and migrate laterally into drinking water sources. Note that poor centralization of casing was one of the significant factors in the failure of the BP "Macondo Well" in the Gulf of Mexico in 2010.

Cementing is performed on each string of casing. The American Petroleum Institute (API) recommends different cement formulations, depending on downhole conditions (temperature, pressure, presence of sulfide). The cement is mixing and send down the inside of the casing, followed by a "wiper plug" that pushes the cement downward, through the casing shoe, and up the outside of the casing (the annulus) towards the surface. The volume of cement used is calculated for the depth of the casing string and the average annulus spacing and, by practice and regulation, cement must appear at the surface to provide assurance that the annulus is filled. The cement, by regulation (see DEP Requirements Chapter 78), must be allowed a minimum of 8 hours to set, during which there can be no other operations in the well that might disturb the casing, and must reach a required minimum compressive strength of 1200 psi within 72 hours.

There are certain downhole logs that can evaluate the efficacy of cement emplacement. These are generally referred to as "cement bond logs" (CBL) and have the capability of sensing the degree of fill and bonding to both the casing and formation. The CBLs are sonic logs that are run through the casing strings and can be interpreted in terms of the transmission of sound waves through solids. If there are gaps between cement and either the casing or the formation or fluids present in these gaps certain sound waves will not propagate through them and will not be detected by the logging tool. Such logs are not infallible, but are critical to evaluating cement jobs that protect against environmental impacts on the environment—either contamination of fresh-water aquifers or direct emissions of greenhouse gases to the atmosphere.

The casing and proper cementing constitute the barriers to leakage of hydrocarbons and other fluids to the surface. The main barrier to direct blowout of high-pressure fluids and hydrocarbons from the well during drilling is the "blowout preventer" which, at the top of the casing string, prevents pressured gases from blowing out during drilling operations.

5.5.2: Fracking and Production Phase

Once the drilling of the well and emplacement of the casing is completed, the next phase aims to initiate and enhance the production of hydrocarbons from the well. This phase includes perforation of the production casing and hydraulic fracturing of the reservoir rock surrounding the lateral. Initially, the lateral production casing is perforated by spaced charges sent down on a wireline (a "perf gun"). The small explosions penetrate the steel casing, providing an avenue for the later high-pressure fluids that will help open fractures in the reservoir rock to allow hydrocarbons to flow into the production casing and into the well to be produced at the surface. The perforation is done in relatively short segments, as is the hydraulic fracturing that follows; these are called "stages." Laterals can exceed 2 miles in length, but cannot cross under a lease held by another company. The longest lateral to date in the Appalachian Basin was completed in the Utica Shale, which underlies the Marcellus Shale by several thousand feet, in Ohio by Eclipse Resources and is 18,544 feet long consisting of 124 stages!

Once all stages are "perfed" the well must be hydraulically fractured ("fraced" or "fracked"). Fracking involves pushing fluids at high pressure into the lateral, stage by stage. Deeply buried shale formations are dense and nearly impermeable to flow of fluids and gases. The hydrocarbons that occur in the shale are trapped in tiny "pore" spaces that are generally isolated from one another in the rock matrix. These hydrocarbon-bearing pores must be connected in some way in order to allow the hydrocarbons to flow to the well. This is where fracturing comes into play.

In Marcellus Shale operations the fluid used for hydraulic fracturing is usually water containing a variety of additives. Water is rather incompressible, so that it can be pumped from the surface by large volume pumps to depths of thousands of feet while maintaining pressure great enough to open fractures in the rock around the lateral (connecting those pore spaces), with the hydraulic fracturing fluid penetrating the casing where perforations were made earlier. The pressurized fluid locally counteracts the great pressures exerted on rock at depth by the overburden and causes fractures to open, most likely those pre-existing joints that are oriented perpendicular to the lateral. However, once the fluid pressure drops, the fractures will close again because of the overburden pressure, so the fractures must be "propped" open somehow to keep them open and allow hydrocarbons to flow more easily to the well. "Proppants", such as fine-grained quartz sand or ceramics, are added to the hydraulic fracture fluid as it is pumped down the well and end up being forced into the fractures that form to act as small wedges to hold the fracture open on a microscopic scale. The hydraulic fracturing fluid additives mentioned before give the water both a viscosity to carry the sand particles into the well and the formation while minimizing frictional resistance to flow. Thus, the typical Marcellus Shale fracs are called "slick-water fracs." One may actually see the nature of the additives used in individual wells by visiting "FracFocus.com." Until recently, this site was favored as a data repository. Note that Pennsylvania DEP is currently developing its own site and requirements (mid-2016), partly because of the difficulty of data searches and incomplete reporting on the industry-supported FracFocus platform.

There are significant safety considerations during a hydraulic fracturing job because of the high pressures being applied. The volume of water required for fracking is also significant, with an average of about 4.5 million gallons used per well through 2014 for Marcellus Shale wells. Hydraulic fracturing initially required low-salinity water because the chemical additives would not work effectively with salinities over about 20,000 ppm (2%). So most of the water was fresh water pumped from streams and rivers. Industry developed large impoundments to store this water strategically for frac jobs in areas of rapid well drilling. However, over the past several years, additives have been modified to allow use of water of higher salinity, which means that wastewater can be mixed with fresh water leading to less freshwater withdrawal. Huge volumes of water must still be stored on site. Also, after fracking there is a period of "flowback" during which excess water returns to the surface. Interestingly, for Marcellus Shale wells, only about 15 to 30% of the volume of water that is pumped down the hole returns to the surface. It appears that the shale "imbibes" the water. In addition, the water returning to the surface is far more saline than that used in fracking. Flowback can occur over a period of a year after completion of a well and the late-stage water returning can have a salinity as great as 10 times that of seawater. The flowback water can contain toxic substances, including radium (a radioactive element) and various trace metals, so treatment and proper disposal are important considerations. This aspect of water handling is detailed in a previous "module" in this course. During the flowback phase any natural gas coming to the surface is typically "flared" to the atmosphere (methane is combusted to prevent dangerous buildups). These flares can be seen at night.

Once the fracking is completed, wells can be put online, as long as there is pipeline access (see earlier "module" on pipelines) and gathering lines are built to the wellsite. Pressure is controlled at the wellhead so that gas can flow into the lines. There is a water separator as well, and any water produced with the gas is siphoned off and held in a tank on the restored pad. These tanks must be emptied periodically by truck. The gas produced by each well is monitored by gage in order to determine royalties to be paid to leaseholders. Effectively, an area of one square mile (640 acres) can be drained by six wells on one pad in a pitchfork layout. This is far better than conventional well production (vertical only) for which there would be one pad and well for each 16 to

32 acre plot with much more surface impact for infrastructure.

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6: UNDERSTANDING PIPELINE REGULATION, CONSTRUCTION AND LAND IMPACTS

Overview

Surging natural gas production throughout the United States, as a result of unconventional well development, has ushered in a wave of pipeline development projects designed to increase delivery capacity from areas of production to market. As a result, many communities throughout the country are experiencing a significant level of natural gas pipeline development. In this lesson you will learn about the role pipelines play in transporting natural gas to market along with the various considerations related to pipeline construction and operation, including:

- Pipeline Basics
- Pipeline Construction and Related Pipeline Infrastructure
- Rights-of-way and Easement Agreements
- Pipeline Safety

Learning Outcomes

By the end of this lesson, you should be able to:

- Appreciate the societal benefits and costs associated with pipeline development.
- Recognize the various steps involved in pipeline construction.
- Understand the concept of pipeline easements and basic terminology associated with easement agreements.
- Discuss issues related to pipeline safety and the leading causes of pipeline failures.

6.1: Pipeline Basics

6.1.1: Types of Gas Pipelines

6.1.2: Regulatory Oversight

6.1.3: Compressor Stations

6.2: Pipeline Construction Steps

6.2.1: Installing a Pipeline

6.2.2: Lowering the pipe into the trench

6.2.3: Laying pipe across streams or rivers

6.2.4: Exercise 1

6.2.5: Restoring the pipeline's pathway

6.3: Right-of-Way and Easement Agreements

6.3.1: Exercise 2A

6.3.2: Negotiating a Right-of-Way Agreement

6.3.3: The Easement Agreement

6.3.4: Value of Rights-of-Way

6.4: Pipeline Safety

6.4.1: Pipeline Failure Causes

6.4.2: Safety Precautions

6.4.3: Exercise 2B

6.5: Check Your Understanding

6.6: Summary

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6.1: Pipeline Basics

Natural gas pipelines crisscross the United States, moving nearly a quarter of the nation's energy from the well head to market. With the increase in natural gas production in the US, there is a need to build more pipeline capacity to deliver this new supply to end users. As a result, communities throughout the country are experiencing an increased level of natural gas pipeline development. As of the writing of this course (August 2016) about 3,000 miles of interstate natural gas pipeline are being proposed in the Northeastern and Mid-Atlantic region in the US. Combined, the proposed projects would have the ability to move an additional 16.8 billion cubic feet of natural gas per day plus 120,000 barrels per day of natural gas liquids out of the Appalachian basin. Most of these projects are expected to be completed and operational by 2018–2020. The maps below indicate the location of proposed 'greenfield' natural gas and natural gas liquid pipelines in the Eastern US. 'Greenfield' refers to new pipeline being proposed in newly acquired right-of-ways, as opposed to pipeline upgrades or expansion of existing systems.

Map indicating sights of proposed Greenfield pipeline project along the east coast of the U.S.

East Coast map of the proposed Greenfield Project with wells drilled

November 25, 2015 Marcellus Center for Outreach and Research

Map showing pipelines for the proposed Greenfield project in Pennsylvania without wells

Map of Pennsylvania indicating proposed Greenfield pipeline projects.

November 25, 2015 Marcellus Center for Outreach and Research

Pipelines are generally buried underground, although they may have associated surface facilities such as valves, metering stations, pig launchers, pig receivers, or compressor stations. When studying proposed pipeline projects, it's important to understand the benefits and associated costs that pipelines represent:

Penn State Extension

Natural Gas Pipeline Benefits	Potential Impacts from Pipelines
Safe, cost effective transportation	Environmental impacts during construction and operation
Energy and consumer products produced from natural gas 63% of American homes used natural gas 25% of electricity generation in the US is from natural gas - Feedstock for food products, pharmaceuticals, plastics and resins	Safety and human health concerns
Nearly 100% of natural gas consumed in US is transported via pipeline	Impairment of viewsheds and landscape
	Negative impact to property values and future use of the land

Check Your Understanding

True or False:

Pipeline upgrades or expansion of existing pipeline systems are referred to as "Greenfield" pipelines.

Answer available at the end of this section.

Answers

Check Your Understanding

False: "Greenfield" pipelines refers to new pipelines being proposed in newly acquired right-of-ways, as opposed to pipeline upgrades or expansion of existing systems.

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6.1.1: Types of Gas Pipelines

Essentially, three major types of pipelines occur along the transportation route: gathering lines, the interstate pipeline, and the distribution system. Gathering lines are small-diameter pipelines (2–20 inches) that move natural gas from the wellhead to a natural gas processing facility or an interconnection with a larger mainline pipeline. Transmission pipelines are wide-diameter (20–48 inches), long distance pipelines that transport natural gas from producing areas to market areas. Interstate pipelines are 8–24 inches in diameter and carry natural gas across state boundaries—in some cases, clear across the country.

Intrastate natural gas pipelines operate within state borders and link natural gas producers to local markets and the interstate pipeline network. Although an intrastate pipeline system is defined as one that operates totally within a state, an intrastate pipeline company may have operations in more than one state. As long as these operations are separate—that is, they do not physically interconnect—they are considered intrastate and are not jurisdictional to the Federal Energy Regulatory Commission (FERC).

The type of pipeline—whether it's a gathering line or interstate transmission line—placed on a landowner's property, influences the amount of surface disturbance (i.e., larger areas are disturbed when installing larger diameter pipelines) and determines whether eminent domain is possible and who provides regulatory oversight.

Natural Gas Liquids Pipeline

Natural gas production in parts of the Appalachian basin, especially in western Pennsylvania, Ohio, and West Virginia, are rich in natural gas liquids such as ethane, propane, and butane. These liquids are generally separated from the natural gas stream and shipped in dedicated natural gas liquids pipelines. Within the federal regulatory framework, natural gas liquids pipelines fall under the Interstate Commerce Act and are regulated the same as oil pipelines. This means that proposed gas liquids pipelines do not go through the FERC review process and, importantly, do not receive federal eminent domain authority. Natural gas pipelines, on the other hand, are covered by the Natural Gas Act and go through the FERC process. The key factor in determining which regulations are followed is whether or not the product is liquid at standard pipeline pressures.

Check Your Understanding

Q1:

True or False: An intrastate pipeline system is one that operates totally within state borders, that links natural gas producers to local markets and to the interstate pipeline network. In some circumstances, however, an intrastate pipeline company may have operations in more than one state. As long as these operations do not physically interconnect they are considered intrastate and are not jurisdictional to the Federal Energy Regulatory Commission (FERC).

Answer available at the end of this section.

Q2:

What differentiates gathering lines, distribution lines, and transmission lines?

Answer available at the end of this section.

Q3:

True or False: Natural gas liquids such as ethane, propane, and butane and natural gas (methane) flow through the same pipelines.

Answer available at the end of this section.

Answers

Q1:

True

Q2:

- Gathering lines are small-diameter pipelines (2–20 inches) that move natural gas from the wellhead to a natural gas processing facility or an interconnection with a larger mainline pipeline.
- Transmission pipelines are wide-diameter (20–48 inches), long distance pipelines that transport natural gas from producing areas to market areas.
- Interstate transmission pipelines are 8–24 inches in diameter and carry natural gas across state boundaries—in some cases, clear across the country

Q3:

False: Natural gas liquids are generally separated from the natural gas stream and shipped in dedicated natural gas liquids pipelines. Within the federal regulatory framework, natural gas liquids pipelines fall under the Interstate Commerce Act and are regulated the same as oil pipelines. This means that proposed gas liquids pipelines do not go through the FERC review

6.1.2: Regulatory Oversight

Major interstate pipelines and pipelines within Pennsylvania are under the jurisdiction of federal or state regulatory agencies. In 2011, the Pennsylvania legislature passed Act 127 (the Gas and Hazardous Liquids Pipelines Act) expanding the Pennsylvania Public Utility Commission's (PUC) authority to include non-public utility natural gas gathering lines. Specifically, the PUC now has the authority to enforce federal pipeline safety laws as they relate to natural gas gathering lines within the Commonwealth. Act 127 also requires the PUC to maintain a registry of pipeline operators within Pennsylvania and to recover the costs of enforcement by yearly assessments on pipeline operators.

The Pennsylvania [Department of Environmental Protection \(DEP\)](#), [Office of Oil and Gas Management](#), provides oversight of certain aspects of pipeline development in the Commonwealth via environmental protection laws that include the Clean Streams Law and the Dam Safety and Encroachments Act.

[The Federal Energy Regulatory Commission \(FERC\)](#) has authority over the location, construction, and operation of interstate pipelines. The FERC review process for new interstate pipelines includes an environmental assessment, review of route alternatives, and interfacing with landowners and the public. FERC also regulates the abandonment of interstate pipelines and sets rates that carriers charge for interstate transmission of natural gas.

Once federally regulated, interstate natural gas pipelines become operational, safety is regulated, monitored, and enforced by the [U.S. Department of Transportation](#) (DOT). Within DOT, the [Pipeline and Hazardous Materials Safety Administration \(PHMSA\)](#) is responsible for enforcing proper design, construction, operation, maintenance, testing, and inspection standards.

Required Reading

[An Interstate Natural Gas Facility on my Land? What Do I Need to Know?](#)

Check Your Understanding

Q1:

What authority does PA Act 127 give the Pennsylvania Public Utility Commission (PUC)?

Answer available at the end of this section.

Q2:

Major interstate pipelines and pipelines within Pennsylvania are under the jurisdiction of federal or state regulatory agencies. Identify the pipeline jurisdiction of the following regulatory agencies. Also indicate which agency has the right to enforce eminent domain:

- Federal Energy Regulatory Commission (FERC)
- Pennsylvania Department of Environmental Protection (DEP), Office of Oil and Gas Management (OOGM)
- U.S. Department of Transportation (DOT)
- Pipeline and Hazardous Materials Safety Administration (PHMSA)

Answer available at the end of this section.

Answers

Q1:
In 2011, the Pennsylvania legislature passed Act 127 (the Gas and Hazardous Liquids Pipelines Act) expanding the Pennsylvania Public Utility Commission's (PUC)

authority to include non-public utility natural gas gathering lines. Specifically, the PUC now has the authority to enforce federal pipeline safety laws as they relate to natural gas gathering lines within the Commonwealth. Act 127 also requires the PUC to maintain a registry of pipeline operators within Pennsylvania and to recover the costs of enforcement by yearly assessments on pipeline operators.

Q2:

- FERC has authority over the location, construction, and operation of interstate pipelines and can enforce eminent domain under the following conditions: if FERC approves the project and no agreement with the landowner is reached, the company may acquire the easement under eminent domain (a right given to the company by statute for FERC authorized use) with a court determining compensation. In Pennsylvania, eminent domain or right of condemnation generally only applies to interstate transmission lines, or lines moving gas longer distances between two or more states. In other states the power of eminent domain may be given to all intrastate gathering and distribution pipeline companies under a 'common carrier' provision.
- DEP, OOGM provides oversight of certain aspects of pipeline development in the Commonwealth via environmental protection laws that include the Clean Streams Law and the Dam Safety and Encroachments Act
- Once federally regulated, interstate natural gas pipelines become operational, safety is regulated, monitored, and enforced by the DOT
- PHMSA is responsible for enforcing proper design, construction, operation, maintenance, testing, and inspection standards for pipelines

6.1.3: Compressor Stations

Please watch this video about how a compressor station works.

How a compressor station works (3:59)

Components of a Compressor Station

Natural gas enters a compressor station through station yard piping and is passed through scrubbers and filters to extract any liquids and remove solids or other particulate matter that may be in the gas stream (Figure 3). Once the natural gas stream has been cleaned, it is directed through additional yard piping to individual compressors. Computers regulate the flow and number of units that are needed to handle the scheduled system flow requirements. Most compressor units operate in parallel, with the individual compressor units providing the needed additional pressure, before directing the gas back into the pipeline with full operational pressure restored. When the required boost in pressure is very high, several compressor units may be operated in stages (serially) to achieve the desired pressure in stages.

A separator

A separator filters out liquids, solids, and other particulate matter that may be in gas stream.

National Fuel Gas Midstream Corporation

Compressor stations are an integral part of the natural gas pipeline network that moves natural gas from individual producing well sites to end users. As natural gas moves through a pipeline, distance, friction, and elevation differences slow the movement of the gas, and reduce pressure. Compressor stations are placed strategically within the gathering and transportation pipeline network to help maintain the pressure and flow of gas to market.

Workers in hard hats walking into a compressor station

Workers walking into a compression station

Penn State Extension

As natural gas is compressed, heat is generated and must be dissipated to cool the gas stream before leaving the compressor facility. For every 100 psi increase in pressure, the temperature of the gas stream increases by 7–8 degrees. Most compressor stations have an aerial cooler system to dissipate excess heat (an “after” cooler). The heat generated by the operation of the individual compressor units is dissipated via a sealed coolant system similar to an automotive radiator.

In wet gas areas, or areas that produce natural gas liquids (NGLs), changes in pressure and temperature cause some of the liquids to drop out. The liquids that drop out are captured in tanks and trucked off site. The liquids captured are called natural gasoline or drip gas, which is often used as a blend in motor gasoline.

Most compressor stations are fueled by a portion of the natural gas flowing through the station, although in some areas of the country, all or some of the units may be electrically powered primarily for environmental or security reasons. Gas-powered compressors may be driven by either conventional piston engines or natural gas turbine units. There are site design and operational differences, as well as unique air and sound emissions, between these competing compressor engine technologies.

There may be one or more individual compressor units at a station, which can be out in the open, or more often, housed in a building to facilitate maintenance and sound management. Newer units are often housed one per building, but there may be multiple units in one large building. Compressor buildings generally incorporate insulated walls, shielded exhaust systems, and advanced fan technology to dampen sound. Newly constructed compressor buildings may incorporate these features where local, state, or federal regulations require noise mitigation.

Inside a compressor building.

Inside compressor building.

Penn State Extension, Marcellus Education Team

Compressor station yards for gathering lines are often larger than transmission line compressors due to multiple pipelines coming into the complex, and sometimes, additional equipment needed to filter and remove liquids from the gas stream. Other components of a compressor complex include backup generators, gas metering equipment, gas filtration systems, and system monitoring and safety controls. There may also be odorization equipment to add mercaptan, which provides the distinctive sulfurous odor to natural gas.

Diagram of a compression station yard

Compression station yard

Courtesy of Spectra Energy

Please refer to Penn State Extension Publication '[Understanding Natural Gas Compressor Stations](#)' to learn more about the types of compressor stations, regulatory oversight, safety and landowner and community considerations.

Required Reading

[Understanding Natural Gas Compressor Stations](#)

Check Your Understanding

Why are compressor stations an integral part of the natural gas pipeline network?

Answer available at the end of this section.

Answers

Check Your Understanding

Compressor stations are an integral part of the natural gas pipeline network that moves natural gas from individual producing well sites to end users. As natural gas moves through a pipeline, distance, friction, and elevation differences slow the movement of the gas, and reduce pressure. Compressor stations are placed strategically within the gathering and transportation pipeline network to help maintain the pressure and flow of gas to market.

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6.2: Pipeline Construction Steps

Video: Typical Stages of Pipeline Construction (3:25)

After a pipeline operator obtains the required permits and satisfies the regulatory requirements, construction of the pipeline may begin. Surveying of the intended route is completed, both aerial and land based, to ensure that no surprises arise during actual assembly of the pipeline.

Piping being installed in ground

Pipeline being installed.

Dave Messersmith

Pipeline Construction Process

- Planning route, surveying
- Permitting
- Acquiring the right of way (ROW)
- ROW is cleared
- Topsoil removed, trench dug
- "Stringing Pipe"
- Pipe is welded and contoured
- Pipe is lowered into trench
- Pipe is placed underground and site is restored

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6.2.1: Installing a Pipeline

Installing a pipeline is much like an assembly line process, with sections of the pipeline being completed in stages. First, the path of the pipeline is cleared of trees, boulders, brush, and anything else that may prohibit the construction. Once the pipeline's path has been cleared sufficiently to allow construction equipment to gain access, topsoil from both the permanent and temporary easement is removed and stockpiled along the edge of the temporary easement, taking steps to avoid compaction during removal and stockpiling. Topsoil may also be referred to as A or Ap horizon, the soil layers at the surface. On agricultural land where clearing is not necessary, topsoil removal is the first construction activity. Sections of pipes are then laid out along the intended path—a process called “stringing” the pipe. These pipe sections are typically from 40 to 80 feet long and are specific to their destination—that is, certain areas have different requirements for coating material and pipe thickness.

After the pipe is in place, trenches are dug alongside the laid-out pipe. These trenches are typically 5 to 6 feet deep. In certain areas, however, including road crossings and bodies of water, the pipe is buried deeper. Soil from trenching is stockpiled separately from the topsoil stockpiles, again taking steps to avoid compaction. Once the trenches are dug, the pipe is assembled and contoured. This includes welding the sections of pipe together into one continuous pipeline and bending it slightly, if needed, to fit the contour of the pipeline's path. Coating is applied to the ends of the pipes (the coating applied at a coating mill typically leaves the ends of the pipe clean, so as not to interfere with welding), and the entire coating of the pipe is inspected to ensure that it is free from defects.

stringing pipes

Stringing pipe

Dave Messersmith

workers contouring a pipe

Contouring or bending pipe to fit the contours of the landscape

Dave Messersmith

a pipe after being contoured and welded

Pipe ready to be placed underground after contouring and welding. Note the epoxy coating applied to the welds/pipe joints.)

Dave Messersmith

6.2.2: Lowering the pipe into the trench

Once the pipe is welded, bent, and coated, it can be lowered into the previously dug trenches. This is done with specialized tracked construction equipment acting in tandem to lift the pipe relatively uniformly and lower it into the trench. After the pipe has been lowered into the ground, the trench is filled in carefully to ensure that the pipe and its coating do not incur damage. The last step in pipeline construction is the hydrostatic test, which consists of filling the pipe with water at pressures higher than will be needed for natural gas transportation, through the entire length of the pipe. This serves as a test to ensure that the pipeline is strong enough and absent of any leaks or fissures before natural gas is pumped through the pipeline.

pipe being lowered into the ground

Lowering pipe into the trench.

Photo courtesy of FERC

same section of right-of-way during construction (left) and ready for topsoil to be placed back over surface (right)

Same section of right-of-way during construction (left) and ready for topsoil to be placed back over surface (right)

Dave Messersmith

This page titled [6.2.2: Lowering the pipe into the trench](#) is shared under a [CC BY-NC-SA 4.0](#) license and was authored, remixed, and/or curated by Marcellus Matters ([John A. Dutton: e-Education Institute](#)) via [source content](#) that was edited to the style and standards of the LibreTexts platform.

6.2.3: Laying pipe across streams or rivers

Laying pipe across streams or rivers can be accomplished in one of two ways. Open-cut crossing involves the digging of trenches on the floor of the river to house the pipe. Then, the pipe itself is usually fitted with a concrete casing, which both ensures that the pipe stays on the bottom of the river, and adds an extra protective coating to prevent any natural gas leaks into the water. Alternatively, a form of directional drilling may be employed in which a “tunnel” is drilled under the river through which the pipe may be passed.

Google Earth image of an area where pipe was placed under water

Google Earth image of an area where pipe was placed under water

Google Earth

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6.2.4: Exercise 1

Exercise 1

Given the brief description on the two most common ways to construct a pipeline across a river or stream (open trench or horizontal directional drilling); compare and contrast the potential environmental impacts of each construction method.

Answer available at the end of this section.

Answers

Exercise 1

1. *Open Trench: Open trench technology causes physical disruption of the waterway and nearby riparian areas. While these disturbances can be managed to reduce impacts, open trench technology has the potential to disrupt water flow and cause sediment to be dislodged and carried downstream. Additionally, the trees and shrubs in the riparian areas on both side of the waterway need to be cut and removed during open trench construction which can increase the amount of sunlight hitting the waterway, increasing water temperatures. This can be especially important in small cold water streams.*

2. *Horizontal Directional Drilling (HDD): HDD is often the construction method that causes the least environmental impact to the waterway and riparian areas on both sides of the waterway. However the process often requires a larger footprint on each side of the waterway for the HDD related equipment. Also, the HDD process utilizes a water-clay mixture to lubricate the drill string and return cuttings. This introduces the risk of producing an 'inadvertent mud return' or leaking the drilling mud through shallow rock fissures into the waterway. There are also some site specific limitations to using HDD technology such as the approach and departure angles leading to and from the waterway and the distance of the horizontal bore.*

6.2.5: Restoring the pipeline's pathway

Once the pipeline has been installed and covered, efforts are taken to restore the pipeline's pathway to its original state, or to mitigate for any environmental or other impacts that may have occurred during the construction process. This often includes replacing topsoil, fences, and anything else (including removing debris and reseeded) that may have been removed or disturbed during the construction process. Significant soil compaction often results from pipeline construction equipment traffic in the easement and excavation and replacement of soil. This can result in reduced crop yields on agricultural soils and reduced tree growth on forested soils for several years. Steps should be taken to minimize soil compaction throughout the construction process and to mitigate compaction during restoration. Such steps include using only low-ground-pressure construction equipment and ceasing operations when soils are wet and most susceptible to compactive forces. After replacement of subsoil material in the trench and grading of the easement, the entire area should be deep ripped to a depth of 16 inches to loosen the exposed subsoil. On agricultural soils any rocks pulled to the surface during ripping should be collected and removed. The stockpiled topsoil should then be replaced over the easement, again taking steps to avoid compaction. The replaced topsoil should then be loosened by deep ripping to a depth of 16 inches, and, on agricultural soils, any rocks brought to the surface should be collected and removed. Recovery of full productivity of agricultural soils can sometimes be accelerated by incorporating compost or manure in the topsoil.

an area that was recently restored after pipe installation

Restored right-of-way. Note the area is maintained as herbaceous vegetative cover and not allowed to revert to tree and shrub growth. The ROW is maintained as open space for the benefit of inspection, leak detection, maintenance and emergency response.

Dave Messersmith

Required Reading

[Evaluation of Reclamation Efforts from Pipeline Right of Way Construction Using the Cornell Soil Health Test](#)

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6.3: Right-of-Way and Easement Agreements

What Is a Pipeline Right-of-Way?

A pipeline right-of-way is a strip of land over and around natural gas pipelines where some of the property owner's legal rights have been granted to a pipeline operator. A right-of-way agreement between the pipeline company and the property owner is also called an easement and is usually filed in the county Register and Recorders Office with property deeds. Rights-of-way and easements provide a permanent, limited interest in the land that enables the pipeline company to install, operate, test, inspect, alter, repair, maintain, replace, and protect one or more pipelines within the designated easement. The agreement may vary the rights and widths of the right-of-way, but, generally, the pipeline company's rights-of-way extend 25 feet from each side of a pipeline unless special conditions exist. These easements can be both permanent and temporary, with temporary easements granting the pipeline company additional space for construction.

Right of Condemnation or Eminent Domain:

In Pennsylvania, eminent domain or right of condemnation generally only applies to interstate transmission lines, or lines moving gas longer distances between two or more states. In other states the power of eminent domain may be given to all intrastate gathering and distribution pipeline companies under a 'common carrier' provision.

Individual gathering lines (pipelines running between well sites, compressor units, and metering stations) are not subject to eminent domain in Pennsylvania, and the pipeline operator must negotiate easements with each individual landowner along the pipeline route.

A provision in Pennsylvania law does allow operators of a "public utility" to use eminent domain to secure pipeline easements. In the event of an eminent domain proceeding, the landowner will be compensated by the court or regulatory authority at a fair market value for the easement.

Property Use Restrictions:

If you are negotiating a right-of-way easement on your property, you should be aware of the pipeline operator's guidelines for property use and construction near natural gas pipelines and equipment. Generally, property owners are prohibited from installing any structures, storing anything that could be an obstruction, or planting trees or shrubs within the right-of-way. Unauthorized building or planting in the pipeline right-of-way is known as right-of-way encroachment. Normal gardening and agricultural activities are generally acceptable. However, you should never dig or construct anything within the easement without first having a pipeline representative mark the pipeline, stake the right-of-way, and explain the company's construction guidelines. Activity on the pipeline easement can also create additional dangers if the pipeline trench has not been properly compacted, fully refilled, and depth of covering maintained at the required thickness.

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6.3.1: Exercise 2A

Exercise 2A

Right-of-way contracts, also known as easement agreements, are negotiated between the landowner and the pipeline operator, granting the operator the right to construct, operate and maintain the pipeline on the property. If a natural gas pipeline were being planned on your property, what are some of the points regarding the easement agreement you would want to discuss and clarify with the land agent?

Answer available at the end of this section.

Answers

Exercise 2A

There are a number of points a landowner should consider when negotiating a natural gas pipeline easement agreement. Many of these points will be discussed in the following section. At the end of the section you will have the opportunity to review your answer in Part A and make any changes or additions based on what you learned.

6.3.2: Negotiating a Right-of-Way Agreement

Easement agreements are formal legal agreements granting the operator long-term use of the right-of-way. A change in ownership of the property does not alter the easement agreement, especially if the easement agreement or a memorandum of the easement agreement is filed on record. Because easement agreements are legally binding contracts, landowners are encouraged to have the contract reviewed by an attorney who is knowledgeable in oil and gas law and experienced in reviewing right-of-way agreements before entering into any contract. Experienced oil and gas lawyers can also be immensely helpful in the negotiation of the easement agreement.

Basic Negotiation Suggestions

- Do not feel pressured to sign anything
- Many points in the contract can be negotiated
- Everything should be in writing
- Talk to your neighbors, share information
- Limit the agreement as possible
- Talk to an accountant
- See legal review

Required Reading

[Landowners Resource Guide for Pipeline Easements and Rights-of-Way](#)

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6.3.3: The Easement Agreement

hand holding an easement agreement and map of the property
Easement Agreement

Credit: Dave Messersmith

The Easement Agreement

- Is a contract between property owner (Grantor) and pipeline operator (Grantee)
- Provides Grantee permanent easement for constructing, operating, maintaining, repairing...
- Is filed in Register and Recorder's Office
- Uses addenda to modify and limit the agreement

Many aspects of a pipeline easement are negotiable. Typically, a pipeline representative will present the landowner with a preprinted agreement. This document can serve as a starting point for a two-way negotiation, or it can be fully accepted or rejected by the landowner. You can make changes to the easement by creating an addendum that is approved by both parties. Most easements are negotiated by an independent contractor, generally known in the industry as a "landman" (regardless of the person's gender). Having this third-party independent contractor involved can complicate and confuse the communication with the pipeline company that will be the owner of the easement rights. Below is a sampling of considerations that may be included in a pipeline agreement or addressed with an addendum:

- Width of the permanent easement and time line for completion of construction
- Definition of the terms and width of any temporary construction easement
- Identification of any independent contractors and subcontractors that the pipeline company will use and make the pipeline company responsible and liable for all acts on your property by independent contractors and subcontractors
- Requirement of the pipeline company to indemnify the land owner from the acts and omissions of the independent contractors and subcontractors as well as those of the pipeline company
- Requirement of the pipeline company to pay property tax rollback penalties associated with pipeline development on your property
- Definition and limitations of access to both permanent and temporary easements
- Payments for trees, crops, etc., damaged during the installation of the pipeline
- Reseeding of easements and what types of grasses and other improvements, including the amount of time following completion of construction for surface restoration to be completed
- Identification of all stream crossings, statement of methods of stream crossings, and requirement for restoration of stream crossings after construction
- Specification of the "double ditch" method of topsoil removal during construction so that the topsoil can be placed back on the surface (not at the bottom of the trench) during site restoration
- Requirement that the landowner be provided an "as-constructed" survey of the easement with an official seal by the surveyor within a stated period of time following completion of construction
- Replacement or installation of fencing and gates (with materials specification), including which gates will have locks and the kinds of the locks to be used
- Limitation of the number of keys or number of people with lock combinations
- Identification of an actual person at the pipeline company who will be landowner's contact, with immediate notice to the landowner when this person is replaced (Require the pipeline company to give 30 days' notice to landowner of any such change in contact person or related contact information.)
- Definition of access post-construction to the easement with specific method and location of all access roads and methods
- Prohibition or limitation of surface appurtenances to the pipeline
- Requirement of minimum depth of soil from surface to top of buried pipeline and requirement that this minimum depth be maintained at all times
- Termination of the lease automatically by nonuse of installed pipeline for a stated number of days
- Definition of "abandonment" of the pipeline as a termination of easement event and requirement of the pipeline company to remove all abandoned pipelines

- Requirement of prior landowner consent for any assignment of the easement to another party
- Limitation of the easement to one pipeline of a stated diameter, with no right to install additional pipelines and no right to increase the diameter of the pipeline
- Definition of substances that can be transported in the pipeline (e.g., flowback and/or produced water can be as environmentally dangerous as can unscented natural gas)
- Requirement of the same post-construction restoration of surface for pipeline repairs as for original construction
- Right to seek surface damages for pipeline repairs as for the initial pipeline installation
- Confirmation whether gas to be transported will be scented or unscented
- Permanent and temporary easements by metes and bounds descriptions and with official surveys, pre-construction and post-construction (as-built survey)
- Alternative dispute resolution method that provides the cheapest, quickest, and least burdensome way to resolve conflicts between landowner and the pipeline company
- Surface uses, if any, by the landowner that will be prohibited in the easement and statement of these limitations in the easement
- Scope of the easement specified so that the pipeline operator is limited in its activities on your property

It's important to note that these examples are not an exhaustive listing of all terms, conditions and addenda that may be negotiated by a landowner. The list is meant to provide general examples that are commonly observed.

Required Reading

[Oil and Gas Pipeline Easement Checklist](#)

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6.3.4: Value of Rights-of-Way

Payments to landowners for granting right-of-way easements can vary significantly between pipeline operators, type of pipeline, and from location to location. Most payments for gathering lines involve a set dollar amount per linear foot (or per “rod,” which is 16.5 feet). In Pennsylvania, easement agreements for gathering lines have ranged from less than \$5.00 to more than \$25.00 per linear foot. Payments to landowners for interstate transmission pipelines are generally based on a value per disturbed acre and can be highly variable based on the prevailing property values in the area.

Easement payments may include restitution for damages to timber, crops, etc., or damages may be paid over and above the quoted value per foot or per acre. It’s important for the landowner to know exactly what is being offered and whether this offer includes damages. Some pipeline operators will also offer a “signing bonus” (a fixed dollar amount for signing an easement agreement) in addition to the payment per linear foot. Be sure to get the amount and terms of payments in writing before signing an easement agreement. Many pipeline companies use “bank drafts” that may look like a negotiable check but often will have stated conditions and limitations that prevent release of funds to the easement grantor. Study bank drafts carefully for all stated conditions and limitations on payment of the agreed funds.

Financial Considerations

- Payment terms
- Is it an option for an agreement?
- Easement income and damage may be taxed differently
- Consult with an accountant

Legal Counsel

- Always have an attorney review any contracts or agreements **before** you sign them

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6.4: Pipeline Safety

To ensure the efficient and safe operation of natural gas pipelines, pipeline operators routinely inspect their pipelines for corrosion and defects. This is done through the use of equipment known as pigs. Pigs are robotic devices that are propelled down pipelines to evaluate the interior of the pipe. Pigs can test pipe thickness and roundness, check for signs of corrosion, and detect leaks and other defects along the interior of the pipeline that may either impede the flow of gas or pose a safety risk for the operation of the pipeline. Sending a pig down a pipeline is fittingly known as “pigging” the pipeline.

Diagram of a pipeline pig

Diagram of a pipeline pig

By BonGoggle (talk) - self-made, CC BY-SA 3.0, [Wikipedia](#)

Bar graph of national gas transmission reported injuries from 1993-2012

National Gas Transmission Incidents: Injuries (1993-2012). While incidents are rare there is a slight trend of increasing numbers of transmission line incidents over the past several decades. The jump in injuries from these incidents in 2010 was due primarily to the San Bruno CA incident.

Data from the US Department of Transportation (DOT), Pipeline and Hazardous Materials Safety Administration (PHMSA).

In addition to inspection with pigs, a number of safety precautions and procedures are in place to minimize the risk of accidents. A few of the safety precautions associated with natural gas pipelines include:

- Aerial patrols: Planes are used to ensure that no construction activities are taking place too close to the route of the pipeline, particularly in residential areas. Unauthorized construction and digging is the primary threat to pipeline safety in many areas.
- Leak detection: Natural gas detecting equipment is periodically used by pipeline personnel on the surface to check for leaks. This is especially important in areas where the natural gas is not odorized.
- Gas sampling: Routine sampling of the natural gas in pipelines ensures its quality and may also indicate corrosion of the interior of the pipeline or the influx of contaminants.
- Preventive maintenance: This involves the testing of valves and the removal of surface impediments to pipeline inspection.
- Emergency response: Most pipeline companies have emergency response teams that train for the possibility of a wide range of potential accidents and emergencies.

Required Reading

[Damage Prevention Guide for Excavators, Homeowners and Farmers](#)

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6.4.1: Pipeline Failure Causes

System Type: Gas Distribution

The causes of serious pipeline incidents during gas distribution, broken down by percentage, are 4.2% corrosion, 26.3% excavation damage, 11.1% incorrect operation, 7.6% material/weld/equipment failure, 6.5% natural force damage, 25.2% other outside force damage, and 19.1% all other causes. The pie graph below illustrates this breakdown.

Pie graph of gas distribution serious incident causes, as explained.
Serious Incident Cause Breakdown 10 Year Average (2008-2015)

[U.S. DOT Pipeline and Hazardous Materials Safety Administration \(PHMSA\)](#)

System Type: Gas Transmission

The cause of serious pipeline incidents during gas transmission, broken down by percentage, are 7.3% corrosion, 26.8% excavation damage, 17.1% incorrect operation, 19.5% material/weld/equipment failure, 14.6% other outside force damage, and 14.6% all other causes. The pie graph below illustrates this breakdown.

Pie graph of gas distribution serious incident causes, as explained.
Serious Incident Cause Breakdown 10 Year Average (2008-2015)

[U.S. DOT Pipeline and Hazardous Materials Safety Administration \(PHMSA\)](#)

The US DOT, Pipeline and Hazardous Materials Safety Administration (PHMSA) is responsible for maintaining industry inspection standards and incident investigation. The leading causes of gas distribution pipelines, primarily in urban and suburban areas, are excavation damage and other outside force damage. These lines are often placed in and around areas that will see construction activity in the future and increase the likelihood of damage from excavation or other outside forces. Transmission lines on the other hand are often constructed in rural areas where excavation is less frequent per mile of pipeline, and therefore excavation damage is less likely. The leading cause of incidents in transmission lines are failures due to materials, welds, or equipment.

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6.4.2: Safety Precautions

Odorization

Natural gas is a colorless, odorless gas, so an odorant, typically mercaptan, is added to the gas stream as an additional safety mechanism. Odorization of natural gas, in Interstate and gathering transmission systems, is regulated under Title 49, part 192 of the Federal Code of Regulations. This code requires transmission lines in highly populated areas (Class 3 and 4 locations) to be odorized. High-consequence areas are subject to added layers of regulation to ensure public safety. “Class location” is a term used in the regulations to denote the population density surrounding the pipeline. Class location is determined by the number of dwelling units within 220 yards in a sliding mile of the pipeline. Classes 3 and 4 are those locations with 46 or more buildings or a building occupied by 20 or more persons at least five days a week for ten weeks (schools, community centers, etc.). Transportation pipelines in Class 1 and 2 locations—rural areas with fewer than 46 buildings per sliding mile—are exempt from the odorization regulations. On a practical basis, gas that is odorized for a Class 3 or 4 location “upstream” will retain some level of odorant in the gas stream as it travels through Class 1 and 2 areas.

Class Locations

Most PHMSA and/or state regulatory agency inspection protocol are based on the pipelines ‘class location’. Class 3 and 4 areas are places where there would be greater human injury potential from a pipeline incident and require a more vigorous inspection regime. Class locations are checked routinely and revised based on new residential development occurring in an area.

Note

Class Locations are:

- Determined by number of buildings within 201m on each side of pipeline per 1.6km
 - **Class 1 location** - 10 or fewer buildings
 - **Class 2 location** - more than 10 less than 46
 - **Class 3 and 4 locations** - more than 46 buildings and buildings with occupancy (churches, schools, etc.)
- Added layers of regulation in higher consequences areas

Pipeline Identification

Pipeline markers are located along the path of a gas pipeline. These markers identify the general location of the pipeline and list the products transported, the operator’s name, and the emergency contact number. Pipeline markers do not identify the exact location of the pipeline, so it is critical that landowners contact the One Call System before any excavation near the pipeline easement. This is also why landowners should insist in their negotiations with pipeline companies that the landowner receive an “as built” survey showing the precise location of the as-constructed pipeline within a stated period immediately following the completion of pipeline construction.

pipeline marker samples

Pipeline Markets

U.S. DOT Pipeline and Hazardous Materials Safety Administration

Right-of-Way Maintenance

Pipeline operators will regularly conduct aerial and ground inspections to check right-of-way conditions, test for leaks, install and maintain pipeline makers, and clear brush that restricts access to the right-of-way or visibility during inspections. Rights-of-way are kept clear of trees, brush, and other obstructions so the pipeline operator can safely operate, inspect, maintain, and repair

its pipelines. The easement usually provides for ingress and egress rights to the pipeline company. This can create problems for landowners who keep cattle, horses, and other animals on land across which an easement runs. The pipeline company may come onto the easement without prior notice and without care to keep all gates shut, except for entering and leaving the property.

6.4.3: Exercise 2B

Exercise 2B

Review your answers to [Exercise 2A](#). Now that you have completed this section on Rights-of-Way and Easement Agreements; would you change, add or modify any of your answers?

Answer available at the end of this section.

Answers

Exercise 2B

While there are no 'right' and 'wrong' answers to this question, a landowner should attempt to limit and clarify the easement agreement as much as possible using addenda. The most common addenda specify the location and dimensions of the pipe and right-of-way (a map of the property specifying the location of the easement may be included), the terms and conditions for construction and site restoration, access to the property during the life of the pipeline – including maintenance and repairs, and clearly defined terms regarding compensation for the easement and damages. Lastly, everything should be in writing and reviewed by an experienced oil and gas attorney prior to the landowner signing the contract.

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6.5: Check Your Understanding

Take a few minutes to answer the questions below to check your understanding of the lesson content.

Q1: Societal Benefits and Costs

There are societal benefits and costs associated with natural gas pipelines. What are some of these?

Answer available at the end of this section.

Q2: Steps Involved in Construction

Installing a pipeline is much like an assembly line process, with sections of the pipeline being completed in stages. Describe, in order, the steps involved in pipeline construction.

Answer available at the end of this section.

Q3: Easements and Terminology

Acquiring a right of way (ROW), also known as an easement, is a necessary step in the construction of a pipeline. Describe what rights a ROW provides to the landowner and the pipeline company.

Answer available at the end of this section.

Q4: Safety and Failures

A. To ensure the efficient and safe operation of natural gas pipelines, pipeline operators routinely inspect their pipelines. What mechanisms do pipeline companies use to help ensure safety?

Answer available at the end of this section.

B. PHMSA is responsible for maintaining industry inspection standards and incident investigations of pipeline failures. It tracks the causes for distribution lines and transmission lines. The #1 cause for each type of line is the same. Identify this primary cause as well as other causes of pipeline breakdown.

Answer available at the end of this section.

Answers

Q1: Societal Benefits and Costs

You should consider that natural gas pipelines are a safe and cost effective transportation method to supply the 63% of American homes that use natural gas, support the 25% of US electrical generation, and its use as feedstock for pharmaceuticals, plastics, resins, and food products such as grain and oilseed milling. In contrast, natural gas pipelines have environmental impacts during construction and operation, can have negative impacts to property and land values including view sheds and landscape, and can have safety and human health concerns.

Q2: Steps Involved in Construction

1. Planning route, surveying
2. Permitting
3. Acquiring the right of way (ROW)
4. ROW is cleared
5. Topsoil removed, trench dug

6. "Stringing Pipe"
7. Pipe is welded and contoured
8. Pipe is lowered into trench
9. Pipe is placed underground and site is restored

Q3: Easements and Terminology

A pipeline right-of-way is a strip of land over and around natural gas pipelines where some of the property owner's legal rights have been granted to a pipeline operator. A right-of-way agreement between the pipeline company and the property owner is also called an easement and is usually filed in the county Register and Records Office with property deeds. Rights-of-way and easements provide a permanent, limited interest in the land that enables the pipeline company to install, operate, test, inspect, alter, repair, maintain, replace, and protect one or more pipelines within the designated easement. These easements can be both permanent and temporary, with temporary easements granting the pipeline company additional space for construction.

Q4: Safety and Failures

- Pigs are robotic devices that are propelled down pipelines to evaluate the interior of the pipe.
- Aerial patrols: Planes are used to ensure that no construction activities are taking place too close to the route of the pipeline, particularly in residential areas.
- Leak detection: Natural gas detecting equipment is periodically used by pipeline personnel on the surface to check for leaks. This is especially important in areas where the natural gas is not odorized.
- Gas sampling: Routine sampling of the natural gas in pipelines ensures its quality and may also indicate corrosion of the interior of the pipeline or the influx of contaminants.
- Preventive maintenance: This involves the testing of valves and the removal of surface impediments to pipeline inspection.
- Emergency response: Most pipeline companies have emergency response teams that train for the possibility of a wide range of potential accidents and emergencies.

Q4: Safety and Failures

- Excavation damage is the #1 cause of pipeline failure for distribution and transmission lines. Other failure causes include: material/weld/equipment failure, incorrect operation, corrosion, natural force damage, and other outside force damage.
- Damage prevention guide for excavators, farmers, homeowners
- Upstream, midstream, downstream

6.6: Summary

In summary, natural gas pipeline development in the United States has increased in recent years as a result of surging production from unconventional gas reservoirs. These pipelines provide a critical link between areas where natural gas is produced and end users. Regulatory oversight of pipeline construction and operation is handled by a variety of state and federal agencies depending on the system. For instance most gas transmission projects are regulated at the federal level while local systems, such as most natural gas gathering and distribution pipelines, are regulated by the states.

Pipelines are constructed in an assembly line fashion with the operator or subcontractor moving across the landscape performing tasks such as clearing the land, digging a trench, stringing pipe sections and welding the sections together. The process is completed when the pipe is placed underground and the site is revegetated and reclaimed.

The easement agreement or pipeline right-of-way contract between the landowner and the pipeline operator details nearly all of the terms and conditions of pipeline construction and operation on the property. With that in mind it is critical for landowners to understand the contract, negotiate for the best terms possible, and have the contract reviewed by an experienced oil and gas attorney prior to signing.

While pipeline incidents are rare, they do occur and can have catastrophic consequences. To ensure the efficient and safe operation of natural gas pipelines, pipeline operators routinely inspect their pipelines for corrosion and defects using a variety of inspection techniques. Inspections are intended to identify areas of corrosion or other conditions within the pipeline prior to failure so that they can be repaired.

7: ENVIRONMENTAL ISSUES--LAND USE PLANNING AND DESIGN

Overview

Any large-scale development has long lasting economic, social, and ecological effects where it occurs. Landscape Architects and Planners are trained to identify and weigh the many considerations and approaches of large scale landscape planning, and then provide valuable input through the entire development process—from providing informed judgments about the potential impacts of well-pad and pipeline placement to opinions as to the best means for eventual management and reclamation of well-pad sites. The inclusion of designers in the land planning and gas development dialogue will help rural areas and small communities manage their resources while preserving the healthy landscape, scenic character and lifestyle of these places for future generations. Marcellus by Design is a Penn State University Department of Landscape Architecture studio initiative to enhance awareness of the roles that landscape planning and design can play in the context of Marcellus Shale natural gas development in the northern tier counties of Pennsylvania. Our goal is to provide stakeholders with information and insights regarding design tools that can help citizens make informed decisions about their land, their livelihoods, and their future.

The main lesson topics include:

- Land Use Planning
- Promise and History
- Design and Planning/Geodesign
- Stories and Voices
- Project and Envision
- Serious Games

Learning Outcomes

This unit mostly describes how land use planning can work at a landscape scale involving complex decisions. By the end of the lesson you should be able to:

- Describe a typical land use planning process
- Define geodesign and a new approach to planning
- Outline the history of landscape scale natural resource extraction in Pennsylvania
- Show how different values influence physical landscape planning
- Show how multiple values can overlap for positive results

[7.1: Promise and History](#)

[7.2: Landscape Ecological Planning and Geodesign](#)

[7.3: Stories and Voices](#)

[7.4: Envision, Project, Evaluate and Illustrate](#)

[7.5: Serious Games](#)

[7.6: Glossary of Land Use Planning and Design Terms](#)

[7.7: Summary](#)

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7.1: Promise and History

Understanding the Context

Extractive industries and northern Pennsylvania are uniquely intertwined. The harvesting of natural resources—oil, timber and coal—have had a tremendous influence in this region. These industries have shaped the landscape and, inevitably, the culture and history of the places where they operated. Therefore, when attempting to understand the potential influence of a new extractive industry, such as the natural gas industry in the Marcellus Shale region, it is important to also understand the context in which it exists. This requires an understanding and appreciation of the culture of the places where extraction is taking place, and an understanding of the impacts of similar industries in the past.

Culture and Place

The Marcellus Shale underlies a large portion of the northeastern United States. This area has many unique places, each with a special history. This historical timeline focuses on the northern portion of Pennsylvania, where the culture and place have had a close connection to extractive industries in the past.

Extractive Industries

The Commonwealth of Pennsylvania has many valuable natural resources, and for this reason it has been the hub of extractive industries in the northeastern United States. This timeline looks at the booms, busts and sustained exploitation of the extractive industries that have had a significant role in the Commonwealth.

When the world first heard about the potential gas reserves held in the Marcellus Shale deposit, the promise of gas development swept through Pennsylvania. A number of potential positive developments were coupled to the opening of this resource, including:

- Lease and royalty payments for landowners
- Jobs in gas industry support and suppliers
- Reduced reliance on farming for income
- New development in an economically challenged area
- Contribution to national energy independence

The promise of gas development was also met with an equal measure of concern, mostly focused on the potential negative environmental and social impacts of gas development, including:

- Water contamination
- Runoff and erosion
- Deforestation
- Habitat destruction

While this is a new resource to Pennsylvania, there is a long history of resource extraction in Pennsylvania, which was met with equal measures of promise and likely concerns when first introduced.

Please review the [Historical Chart](#) on the Marcellus by Design website.

Specific Promise in Pennsylvania:

The Marcellus Gas deposit offered Pennsylvania an incredibly important resource at a particularly challenging economic time in Pennsylvania's history.

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7.2: Landscape Ecological Planning and Geodesign

What is Land-use Planning?

Land is one of our fundamental natural resources and the way it is used or managed directly shapes our quality of life. In light of the landscape changes sweeping rural Pennsylvania since the beginning of the current natural gas boom, citizens increasingly find themselves confronted with the need to think about the future and anticipate the implications of future landscape changes for themselves and their communities.

Land-use planning aims to find solutions to complex land use issues for the good of landowners and communities as a whole. Planning is often misunderstood as a process in which planners tell people what to do with their land. Instead, good planning reveals the many different ways that the future might unfold, and their outcomes and implications for the environment and for communities, thus providing citizens with the help they need to make the best choices for themselves.

Planning is an inherently participatory process involving both citizens and local governments working together to create and implement mutually beneficial plans—for their communities, environments, and natural resources, now and into the future. To this end, planning systematically assesses the potential of land and water, evaluates land use options in the context of economic and social conditions, and communities finally adopt the best of those options to prevent land use conflict and ensure lasting community welfare (Young 1993, APA 2011).

Geodesign?

Geodesign, emerging from landscape ecological planning, offers a new opportunity to blend design and planning with science and community engagement. To learn more about geodesign, please review this [material](#).

Check Your Understanding

Geodesign in the Marcellus Region.

In light of the intensive energy development occurring in Pennsylvania, land use planning has taken on renewed importance. It is important to recognize that the scale of development in relation to land area, physical geography, ownership, and population density in small towns in Pennsylvania results in energy development scenarios that are very different than the energy industry has faced in places like Oklahoma and Texas. In contrast to the wide-open spaces in the western United States, Marcellus gas development for us is occurring in the backyards and forests of rural Pennsylvania. Communities and individuals should plan strategically in order to safeguard their water, woodlands, and way of life while also reaping the benefits of this new resource.

While state law assures citizens of access to clean air and water, land planning and development are guided by decisions made by individuals and local authorities. The rural Pennsylvania landscape of Marcellus gas development is being shaped by an aggregation of individual transactions between landowners and energy companies. The decisions each one makes when negotiating lease agreements regarding the placement of wells, pipelines, water impoundments, and access roads in relation to residential areas, streams, and areas of core forest have widespread impacts to the local and regional landscape.

Landowners who want to have a greater measure of control over natural gas development on their property can negotiate lease details such as road construction, repair or compensation for timber stand damage, effective restoration of impacted farmland, and other site specific factors in a private gas lease (Penn State Cooperative Extension 2008). For example, a landowner may negotiate for:

- Protection of agriculture soils during exploration and well operations, so farmland may be restored to full productivity afterwards.
- Protection of farm infrastructure, such as roadways, drainage features, and fences that may be damaged during operations.
- Road location and construction to be reviewed by the landowner and a qualified engineer or forester in order to

minimize cropland or forest fragmentation.

- The site of the well relative to other property uses, such as housing and farming
- Possible timing of surface operations to allow for livestock pasturing, hunting, or other rural land activities that have restricted seasons (Penn State Cooperative Extension 2008).

Between 2011 and 2016, Penn State faculty and students used a geodesign approach to study land use planning in the Marcellus region. The research was supported by the [National Science Foundation](#). The following video describes this work.

Engaged Geodesign in the Forgotten Quarter of Pennsylvania (8:25)

References:

[American Planning Association](#) (2011). Chicago, IL.

Young, Anthony (1993). Guidelines for Land Use Planning, Food and Agriculture Organization of the United Nations: Rome, Italy.

Exercise

1. Write a brief essay about Geodesign. Define geodesign and explain how it is and/or can be used to plan under complex circumstances.
2. Write a list of five priorities that can be addressed through land use planning and design.
3. Describe a typical land use planning process.

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7.3: Stories and Voices

Introduction

Resources and communities are linked across the landscape. The planning decisions of individual landowners and municipalities matter, especially in the wake of [Pennsylvania Act 13](#). Laws and regulations are just one way communities can be involved in complex decisions like those observed in the Marcellus Region. Landowners and municipalities can frequently regulate oil and gas activities in their communities through zoning ordinances. Examples of such activities include pipe storage yard placement, the location of equipment storage areas, chemical and wastewater storage, water withdrawal facilities, housing for gas workers, etc., as well as gas wells and pipelines. In its original form the Act would have exempted municipalities with such ordinances from receiving impact fee revenue, hence discouraging protective zoning. Such approaches following in a long tradition of land use planning.

Brief History of Land-use Planning in America

Ever since the American Revolution in 1781, the American people have favored individual property rights and the freedom of individuals to plan their land as they please (Corey and Krissoff 2010). As a result, local governments have had limited power to direct city development. In early days, cities and settlements developed often piece-meal, with little attention paid to the interaction of adjacent land uses and the larger picture of land uses as a system (APA 2011).

During the 19th century, cities began to urbanize quickly, becoming very dense and full of disease. As a response to chaotic conditions, planning became a major focus of state governments. As early as the 1840s, it had become increasingly clear that there was a strong relationship between prevalence of disease, land use, and the absence of reliable sewer systems. This realization and the subsequent actions taken to holistically improve the sanitary conditions in infected parts of cities is known as the Sanitary Reform Movement. It is generally considered to be the first attempt at comprehensive land-use planning in America. Landscape architect Frederick Law Olmsted, who designed Central Park in 1857, was a firm believer in the relationship between the environment and sanitation. His parks and open spaces were intended to bring not only recreational benefits to urban communities, but also improve public health (Corey and Krissoff 2010).

In 1898, landscape architect Ebenezer Howard published “Garden Cities of Tomorrow,” which presented the notion of planned communities with different yet harmonious land uses and community services. Around the turn of the 20th century, state governments began to see the need for more local development and growth plans, extending into suburban and rural areas (Corey and Krissoff 2010, Juergensmeyer and Roberts 2003). Planning tools were developed and adopted, most notably, the process of comprehensive planning and zoning.

Comprehensive Planning

Comprehensive planning is a process that determines community goals and aspirations in terms of community development. The outcome of comprehensive planning is a Comprehensive Plan, which dictates public policy in terms of transportation, utilities, land use, recreation, and housing (APA 2011, Young 1993). Comprehensive plans typically encompass large geographical areas, include a broad range of topics, cover a long-term time horizon, and aim to balance the rights of property owners with holistic long-term community planning.

A comprehensive plan is not a permanent document, nor is it legally binding. It can be changed and rewritten over time as community needs change. Local township, borough, and city governments in Pennsylvania are not required by law to engage in comprehensive planning. However, county governments in PA are required to have an officially adopted County Comprehensive Plan and to update it at least every 10 years (Walls 2012, personal communication). The legal provision for comprehensive planning comes from the Standard State Enabling Act written by the US Department of Commerce in the 1920s, which provides a legal framework for local governments choosing to engage in land-use planning (Juergensmeyer and Roberts 2003).

Unfortunately, in Pennsylvania many of those plans are over 10 years old and therefore contain no provisions for managing and planning for Marcellus Shale natural gas development at the local level.

Zoning

Closely tied with the process of comprehensive planning is the practice of land use zoning. The Standard State Zoning Enabling Act gave states the authority to regulate land use at local levels through this practice (Corey and Krissoff 2010). In Pennsylvania, the PA Municipalities Planning Code (PA MPC) is the enabling act authorizing local governments to enact land use control ordinances (Walls 2012, personal communication). As a tool for implementing land-use plans, zoning regulates the types of activities that can be accommodated on a given piece of land, the amount of space devoted to those activities, and the ways that buildings may be placed in relation to other land uses (Bassett 1940). However, the practice remains controversial today due to misconceptions about its purpose. Many municipalities, including most townships in rural Pennsylvania, do not implement zoning ordinances to regulate land use.

Stories and Voices

The key factors in any planning process, whether it involves formal land use plans or legislation like Act 13, are the stories and narratives in communities facing complex decisions.

Stories

Dozens of stories relate to the decisions facing communities in the Marcellus region. Story maps are one way to begin to contextualize important questions facing communities. Please review the following [storymaps on the Marcellus By Design](#) website.

Voices

Individual voices are also critical to listen to when initiating any large scale landscape ecological planning process. Review the [videos on the Marcellus By Design](#) website.

Exercise

Think of and write five story titles related to the complex decisions involving natural gas extraction in Pennsylvania.

7.4: Envision, Project, Evaluate and Illustrate

Introduction

Imagine, Inspire and Implement are common themes when describing the process of land use planning and design. In reality, land use planning is a five step process, which includes:

1. **Envision**—the potential in the existing situation
2. **Project**—where and how change may occur
3. **Evaluate**—the good and bad effects of change
4. **Illustrate**—so that everyone observes the same vision
5. **Monitor**— to ensure change occurs as promised

Building on stories, narratives and voices, landscape architects and planners first investigate the potential in the existing situation, by carefully examining related situations and scenarios. By studying the known, we can carefully envision changes on a broader scale, both temporally and spatially. For example, here's an animation of the changes in unconventional permits in Pennsylvania between 2009 and 2014.

Permit Animation

Studying such patterns allow planners and landscape architects to project where change might occur and when it might happen. These aren't predictions about where changes will occur, but projections designed to begin the community engagement that allows for science based land use planning.

Projections:

Listed below are two examples about how projections can be developed from observations. Please read them.

[Probabilistic Modelling and Complex Energy Landscape Design and Planning: An Experimental Approach](#)

[Pennsylvania Energy Impacts Assessment](#)

Evaluate and Illustrate:

The next step in planning involves framing the original stories and narratives around projects, so that preliminary evaluations can be conducted. The evaluations are then transformed into visualizations so that all involved can understand the scope and scale of potential transformations.

In the following links, the outcomes of these four steps are illustrated through a series of studio based student projects. All of these projects and focused studies were presented to community members. Please review five of the projects found here:

[Studios](#)

[Focused Studies](#)

Exercise

The process of planning involves a thorough analysis of trade offs and consequences. In this activity, you are charged with planning and arranging natural gas production elements on a shared parcel of land to be leased for unconventional gas development, within certain parameters:

- The land is owned and inhabited by an extended family that owns the mineral as well as surface rights. Part of it is forested, part is farmland.
- The father, now retired from farm lives on the forested side of the stream.

- He wants to lease land for gas development, but without fragmenting the woods so much that it ruins the wildlife habitat and hunting grounds that he enjoys.
- The retired farmer's daughter lives on the less forested side of the stream and actively farms it. She also wants to lease the land, but does not want gas operations to compromise the amount of land she can farm.

Design a gas development scenario that accommodates these two perspectives. You must provide an access road and connect your wells via gathering lines to the pipeline and compressor station.

Draw a line down a piece of paper and describe five costs associated with the decisions you need to make and in the other column five benefits.

7.5: Serious Games

The sudden growth of the natural gas industry in Pennsylvania in less than ten years was made possible by combining two technologies: directional (e.g. horizontal) drilling and hydraulic fracturing (commonly “fracking”). Although fracking has been the subject of much media attention, directional drilling may influence the shape of the landscape more—through the location of wells and the roads, water impoundments and pipelines that accompany them. Everyone deserves the benefits of job opportunities, the income to afford education and healthcare for families, but they also deserve an environment free from pollution, flooding, excess traffic and no loss of wildlife, good fishing or fine scenery.

The Marcellus region is comprised of small communities who want to have a say in their future shape—they want to be designers too. However, each location is going to have its own unique needs. There’s a really good chance that we won’t be prepared with the appropriate analysis so we are proposing an approach that will help us understand the things that are important to us, understand how changing some things in the environment affects others, and making sure that we have the right questions ready to ask the landman or DEP official when they come by.

We use stories and games. Stories are the foundations for how we understand places, they reveal our values that then shape our designs. Games are about rules and they can show us how elements in the environment interact, some may “win” others may “lose.”

[Why Games? \(Some Academic Background\)](#)

[Story-telling Reveals and Highlights Values](#)

Please watch this video.

Marcellus cut002 (2:52)

Knowledge Check

Answer these two questions to check your understanding.

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Land Use Planning and Design Terms

Act 13

Act 13 of 2012 amends Title 58 (Oil and Gas Act) of the Pennsylvania Consolidated Statutes, effectively overhauling Pennsylvania's oil and gas legislation. It enacts stronger environmental standards, and authorizes the counties to impose an impact fee, the income from which is directed to local authorities and state agencies. A provision of the Act superseded local regulation of oil and gas operations by enabling the gas industry to proceed with explorations regardless of municipal zoning ordinances regulating oil and gas development but that provision has been reversed by the Pennsylvania Supreme Court. Among the Act's other provisions are increased setback requirements for unconventional gas development; enhanced protection of water supplies; and consistent statewide environmental standards. Source: [Pennsylvania Public Utilities Commission \(PUC\)](#).

Comprehensive Plan

A comprehensive plan is a document that states basic objectives and policies that guide future growth and development for a community. Although it is not a legally binding document, the overall plan represents an agreement decided upon by a governing body, based on input from community constituents, which guides governmental decision-making regarding land use and community planning. It is officially adopted by the governing body of a municipality and is carried out to a large extent by zoning and by subdivision and land development ordinances. Source: Anderson, Larz. (1995) *Guidelines for Preparing Urban Plans*. Chicago: APA Planners Press.

Drilling Unit

A drilling unit is the area from which an actual well would draw its gas. The unit is designated by the company and based on the geology of the area, and is where the gas would be drawn from when a particular well is drilled. Those landowners included in the unit share the royalty money from the gas well on a pro-rated basis based on acreage owned by each in the drilling unit. Source: State of Pennsylvania, House Bill no. 1950, "PA Act 13 of 2012 amending Title 58 (Oil and Gas) of the Pennsylvania Consolidated Statutes" Pennsylvania General Assembly: Harrisburg, PA.

Forest Fragmentation

Forest fragmentation occurs when continuous forest areas are interrupted by gas well pads or bisected by pipelines in a way that leaves relatively small, isolated patches of forest or woodland known as forest fragments. The remnant patches that result may act as islands of habitat in a sea of farmland, subdivisions, or other human land uses. Fragmentation may lead to losses in biodiversity and may result in the conditions that enable the spread of invasive species. Source: [Penn State University Sustainable Forests Partnership](#)

Land-use planning

Land-use planning is an activity of local and regional government that seeks to order and regulate land use in an efficient and ethical way, thus preventing land -use conflicts. Source: Young, Anthony (1993). *Guidelines for Land Use Planning*, Food and Agriculture Organization of the United Nations: Rome, Italy.

Subdivision

A subdivision refers to the creation of lots or to the changing of lot lines. A Subdivision and Land Development Ordinance (SALDO) is a local law passed by either a county or a municipality to regulate the subdividing and developing of land. Source: Clearfield County Planning Commission (2006).

Well Site

A well site is the area occupied by all equipment or facilities necessary for or incidental to drilling, production, or plugging a well. Source: State of Pennsylvania, House Bill no. 1950, “PA Act 13 of 2012 amending Title 58 (Oil and Gas) of the Pennsylvania Consolidated Statutes” Pennsylvania General Assembly: Harrisburg, PA.

Zoning

Zoning is a tool a community may use to regulate the use of land and the location and intensity of development. Source: Bassett, E. M. *Zoning*. New York: Russell Sage Foundation, 1940

Zone of Presumed Liability

The zone of presumed liability is the area in which a gas company is presumed liable for any contamination of a water sources as a suspected result of drilling. Under Act 13, the zone of presumed liability was expanded from 1,000' feet to 2,500 feet. Source: State of Pennsylvania, House Bill no. 1950, “PA Act 13 of 2012 amending Title 58 (Oil and Gas) of the Pennsylvania Consolidated Statutes” Pennsylvania General Assembly: Harrisburg, PA.

7.7: Summary

We have introduced land use planning, along with more recent approaches, including landscape ecological planning and geodesign. Whether it is Marcellus Shale, other resources or other complex community issues, land use planning provides a platform to study, evaluate and envision the stories and voices that can be expressed through landscape.

The planning process is not exclusive, but inclusive and can occur at many levels and many scales. Landowners as well as community members can identify and prioritize community and landscape resources through the planning process. They can also come to appreciate that within complex decisions there are multiple perspectives, voices and stories to understand.

Reference: Orland, B. & Murtha, T. (2015) RESEARCH ARTICLE: Show Me: Engaging Citizens in Planning for Shale Gas Development, *Environmental Practice*, 17(4), 245-255.

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8: ENVIRONMENTAL ISSUES--WATER RESOURCES AND MANAGEMENT

Overview

As society's energy demands grow there has been a significant increase in the development of unconventional shale energy resources in the United States. Development and production of these resources requires relatively large volumes of water in the hydraulic fracturing process, which also generates brine along with the hydrocarbons. In this lesson we will learn about water resources and management for shale energy development including the following main topics:

- Water resource availability
- Drinking water quality
- The water-energy nexus
- Water management practices for shale energy production
- Potential water quality impacts with shale energy

Learning Outcomes

- By the end of this lesson, you should be able to:
- Appreciate the availability of water resources and drinking water quality
- Understand water use for unconventional energy production
- Recognize potential water quality impact pathways with shale energy development and how to prevent them with best management practices
- Discuss water resource issues surrounding shale development with colleagues

8.1: Water Resource Availability

8.2: Water Quality

8.3: The Water-Energy Nexus

8.3.1: Water Management Practices for Shale Energy Production

8.4: Produced Fluids Management

8.5: Protecting Water Resources and the Environment

8.6: Glossary of Water Use Terms

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8.1: Water Resource Availability

Introduction

The information presented here is intended to provide an overview of water resource availability including how water is used to maintain our quality of life, and how it is used for a variety of purposes including energy production, specifically for shale resource development. Water is obviously crucial to life and we rely on it for almost every aspect of our day to day activities, including for drinking, sanitation, industrial uses, irrigation for crops, food production, recreation, and power development. Water also sustains our environment by providing flow to our streams and rivers. The graphic below summarizes how much water is used in Pennsylvania for a variety of these applications.

The combined amount of water used for domestic and public water supply (about 1.57 billion gallons per day) is more than 100 times greater than the amount of water used for hydraulic fracturing (estimated to be 14.8 million gallons per day) on a daily basis in Pennsylvania.

Exercise 1-1

What is the average amount of water used on a daily basis by each person in Pennsylvania assuming a population of 12.8 million people?

Answer available at the end of this section.

The average amount of water used by a family of four in the United States is 400 gallons per day or 100 gallons per day per person (WaterSense). Do Pennsylvanians use more or less water than the national average per person?

Answer available at the end of this section.

This US Geological Survey Publication provides very interesting water use statistics for [Year 2010 for the United States](#)(link is external). Please spend some time (15 minutes, or more if you like) reviewing the report to get a sense of total US water use and for the state you live in.

Exercise 1-2

Find the per capita domestic water use in your state. Is it above, near, or below the national average?

The amount of water contained on earth is finite with about 333 million cubic miles of water, of which only 2.4% is fresh and 97.5% saline; its occurrence is controlled by the hydrologic cycle as shown below.

Schematic of the water cycle

The Water Cycle

Source: [U.S. Geological Survey](#)

Water covers nearly 71% of the Earth's surface: 96.5% of the planet's water is found in oceans, 1.7% in groundwater, 1.7% in glaciers and the ice caps, and 0.1% in clouds or precipitation as illustrated below. Furthermore, of all of the water on earth--about 97.5%--is considered to be unusable; that is, not potable for drinking water purposes. Greater than two thirds of the fresh water on the earth is stored in glaciers and ice caps, with groundwater and surface water representing the other third of fresh water resources. The vast majority of fresh water is frozen in glaciers and ice caps (68.6%) and therefore unavailable for use. The available freshwater comes to us mainly as groundwater (comprising 99% of available fresh water) along with some surface water (1% of fresh water), collectively comprising 30.4% of freshwater resources.

Schematic of distribution of Earth's water

Distribution of Earth's Water

Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993. *Water in Crisis: A Guide to the World's Fresh Water Resources*

Exercise 1-3

How much available fresh water (i.e. groundwater and surface water) is there on a global basis in gallons? (Hint, there are 5280 feet in a mile and 7.48 gallons in a cubic foot). How much water does that make available for each person on the planet (assuming it is evenly distributed!!)?

Answer available at the end of this section.

Answers

Exercise 1-1

Approximately 123 gallons per day per person.

Exercise 1-1

More!

Exercise 1-3

333 million cubic miles of total water times 2.5% of fresh water times 30.4% of fresh water equals 2.53 million cubic miles. Converting to cubic feet and then gallons equals 2,780,000,000,000,000,000 (2.78 quintillion gallons....wow that's a lot!!). Assuming 7.4 billion people live on the planet that means in theory there is 376 million gallons for each of us on the planet, but unfortunately about 10% of the world's population does not have access to fresh water and 85% percent live in the driest half of the Earth ([UN Water](#)).

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8.2: Water Quality

The US Environmental Protection Agency (EPA) regulates drinking water quality via the Safe Drinking Water Act. Drinking water quality standards are known as maximum contaminant levels (MCLs) for contaminants that may affect our health, such as benzene which is a known carcinogen but is also a naturally-occurring hydrocarbon. Secondary MCLs (SMCLs) are drinking water quality standards based on taste and aesthetics of the water, but do not necessarily have significant health impacts. Public water suppliers are required to test for MCLs and SMCLs on a routine basis to ensure the continued delivery of high quality water to their customers. The EPA website lists drinking water MCLs and SMCLs here [EPA Drinking Water Contaminants - Standards and Regulations](#).

The sources of drinking water may include rivers, lakes, streams, ponds, reservoirs, springs and groundwater wells. As water travels over the surface of the land or through the ground, it dissolves naturally-occurring minerals and, in some cases, radioactive material, and can pick up substances resulting from the presence of animals or from human activity. Classes of contaminants that may be present in source water include:

- Microorganisms, such as viruses and bacteria, that may come from sewage treatment plants, septic systems, agricultural livestock operations and wildlife.
- Disinfectants and disinfection by-products that are used to remove or result from removing that microorganisms occur in water
- Inorganic contaminants, such as salts and metals, that can be naturally-occurring or result from urban storm water runoff, industrial or domestic wastewater discharges, oil and gas production, mining and farming.
- Pesticides and herbicides that may come from a variety of sources such as agriculture, urban storm water runoff and residual sources.
- Organic chemical contaminants, including synthetic and volatile organic chemicals that are by-products of industrial processes and petroleum production, and can also come from gas stations, urban storm water runoff and septic systems.
- Radionuclides, which can be naturally-occurring or be the result of oil and gas production and mining activities.

Exercise 2-1

Review the EPA's MCLs and SMCLs on their website and note which contaminants may be in your area's water due to industrial, agricultural, or natural sources. Is your source of drinking water from a surface source, groundwater source, or a combination? If you are on a public water supply, look up your consumer confidence report on the water supplier's website, which states what contaminants have been detected in your drinking water supply. If you have a private water source look up the nearest public source that a family member or friend uses. If there are any contaminants are they related to land use activities in the area, such as agriculture or industry, or are they naturally-occurring

As noted previously, there is an almost incomprehensible amount of water on the planet, though only a small portion of this water is considered fresh so that it can be used for drinking water. Most "fresh" water still requires treatment prior to drinking, typically at least disinfection through use of chlorine or similar disinfectant, but may also involve chemical treatment, filtration, or reverse osmosis to remove natural or man-made constituents. A typical treatment scheme for a drinking water treatment plant would consist of the following steps shown in this figure.

Schematic of a water treatment system
Centralized Water Treatment Cycle

Source: EPA

A good overview of drinking water treatment is found on the [Center for Disease Control](#) website.

Exercise 2-2

Find out what type of treatment system the nearest public water system utilizes so your water meets safe drinking water standards.

Later we will explore drinking water contaminants that can occur in association with oil and gas production and consider how to monitor for them in private and public supplies. First we will consider how water is used to generate energy and power.

8.3: The Water-Energy Nexus

Water is a crucial ingredient to develop and produce energy, a portion of which is then used to generate electricity. Most of the electricity in the United States is produced using steam turbines. A turbine converts the kinetic energy of a moving fluid (liquid or gas) to mechanical energy. In a steam turbine, steam is forced against a series of blades mounted on a shaft. The steam rotates the shaft connected to the generator. The generator, in turn, converts its mechanical energy to electrical energy based on the relationship between magnetism and electricity. In steam turbines powered by fossil fuels (coal, petroleum, and natural gas), the fuel is burned in a furnace to heat water in a boiler to produce steam. Energy sources in the U.S. for power generation are summarized in this graphic.

Sources of U.S. electricity generation, 2015 (coal 33%, natural gas 33%, nuclear 20%, renewable 13%, petroleum 1%)

Sources of U.S. electricity generation, 2015

Credit: U.S. Energy Information Administration, *Electric Power Monthly* (February 2016). Preliminary data for 2015

Note that nearly equal amounts of natural gas and coal are used to generate power and that fossil fuels represent 67% of the sources used. The picture below shows the cooling water coming out of a nuclear power plant in Pennsylvania.

aerial view of beaver vally power station

Aerial photo of Beaver Valley Power Station in Pennsylvania, showing evaporation from the large cooling towers.

Credit: [U.S. Nuclear Regulatory Commission](#)

Electricity is in turn used to pump and treat water from surface or aquifer sources and then to treat the resulting wastewater, thus creating this interdependence known as the water-energy nexus. The US Department of Energy recently completed a study entitled *The Water-Energy Nexus: Challenges and Opportunities*, a summary of which can be read [here](#).

Exercise 3-1

Read [this summary](#) and examine the “Sankey” diagram found in the summary (Figure 6). A link for the Sankey diagram is [here](#). How much water is withdrawn for thermoelectric power generation?

The energy sources contained in oil and gas reservoirs require water to extract and process these hydrocarbons. This is especially true in unconventional reservoirs such as shales or other “tight” (low permeability) reservoirs, where several million gallons may be necessary to hydraulically fracture the shale to allow the hydrocarbons to flow out of the reservoir toward the oil or gas well. While all fuel sources use some volume of water for production, some forms of fuel are clearly more water efficient per million British Thermal Units (MMBTUs) as summarized in the table below

Energy Resource	Gallons of Water Used per MMBTU ¹
Deep Shale Natural Gas	0.84 - 3.70 ²
Coal (no slurry transport)	2 - 8
Nuclear	8 - 14

<u>Conventional Oil</u>	<u>8 - 20³</u>
<u>Synfuel - Coal Gasification</u>	<u>11 - 26</u>
<u>Oil Shale</u>	<u>22 - 56</u>
<u>Tar Sands</u>	<u>27-68</u>
<u>Enhanced Oil Recovery (EOR)</u>	<u>21-2,500</u>
<u>Biofuels</u>	<u>>2,500</u>

1. Source: "Deep Shale Natural Gas: Abundant, Affordable, and Still Water Efficient", GWPC, 2010.
2. The transport of natural gas can add up to two gallons per MMBTU.
3. Includes refining which consumes a major portion (90%) of the water needed (7-18 gal per MMBtu).

Exercise 3-2

What fuel source is most water efficient per MMBTUs of energy produced in the table above?

8.3.1: Water Management Practices for Shale Energy Production

The utilization of the abundant natural gas from shale formations is desirable as a cleaner-burning form of domestically-produced energy, however there are environmental challenges with its development, including water resource management. The graphic below shows the construction of a typical horizontal well illustrating that several strings of steel casing and cement are installed through the upper 1,000 or more feet of the earth to isolate and protect fresh groundwater zones from migrating methane or brine fluids. Once the well bore has reached the target zone in the shale, the horizontal section of the well is advanced several thousand feet in a direction that is favorable to open up fractures based on the Earth's stress field. The approximate volume of water used during the well construction process is 100,000 gallons, primarily for drilling mud and cement.

schematic showing cross-section of a typical horizontal marcellus well
Cross-section of a Typical Horizontal Marcellus Well

Source: PSU Marcellus Center

Once the well drilling is complete, hydraulic fracturing is used to increase the permeability of the otherwise dense, tight shale to allow the hydrocarbons to be released from the shale and flow into the well. The hydraulic fracturing process involves injecting a mixture consisting of mostly water and sand along with a small proportion of other additives under high pressure through perforations in the steel casing that are connected to the surrounding shale to open up fractures. The volume of hydraulic fracturing fluids required for a horizontal well is typically about 4 to 5 million gallons, or about 1 to 1.5 million gallons per thousand feet of the well being fractured. The shale around the horizontal section of the well is fractured in sequential stages, consisting of sections each about 150-300 feet long, starting from the end of the well (known as the toe) and working back toward the bend in the well (known as the heel). A well with a 5,000 foot horizontal section may have 20 or more stages that are separately fractured, with each stage separated by special plugs to avoid loss of pressure into adjacent zones.

The typical chemicals added include a biocide solution to eliminate bacteria in the water, hydrochloric acid to clean up the well and fractures, a friction reducer to minimize fluid pressure losses down the well, a corrosion inhibitor to protect the steel casing, and a scale inhibitor to prevent precipitation in the well and surrounding formation as summarized in the graphic below. In order to keep the fractures open in the shale a proppant is added, typically sand, which can amount to 1-2 pounds of sand for every gallon of fluid used for fracturing operations. Most states experiencing significant shale energy production now require that the chemicals used in fracturing be publicly disclosed.

Schematic of average hydraulic fracturing fluid composition for US shale plays
Average Hydraulic Fracturing Fluid Composition for U.S. Shale Plays

Source: Groundwater Protection Council

Exercise 4-1

Disclosure of additives used in hydraulic fracturing fluids is a regulatory requirement in many states using the FracFocus registry. Go to [FracFocus](https://www.fracfocus.org/) and review the information on the website regarding how hydraulic fracturing works. Look up a well in your state or an area of interest to you. How much water did the well use for fracturing? How many different chemical additives were used to fracture the well? What percentage of the mixture was water, additives, and proppant?

The sources of water used for drilling and hydraulic fracturing are approved by state and/or river basin commission regulators and are withdrawn from surface waters (streams, rivers, ponds, lakes, reservoirs, etc), aquifers, purchased from municipal supplies, or may be sourced from municipal or industrial wastewater discharges. The amount of water that is permitted for withdrawal is typically quite small compared to the streams' or aquifers' available water to ensure that there are sufficient water resources for other uses as well as to sustain natural surface flow or groundwater levels.

Once the water is withdrawn, it is either piped or trucked to the well site for storage in steel tanks or a lined impoundment or

as shown below. Modular above ground water storage facilities are becoming more prevalent as they can be erected in a short period of time (several days), and do not require as much earth-moving thus have a smaller surface footprint.

Once the necessary volume of water is transferred to the well site it is then withdrawn from the tanks or impoundment for use in the hydraulic fracturing process.

Exercise 4-2

A shale gas well has a horizontal section of 5,000 feet and would like to fracture the well in 20 stages, each 250 feet long. They plan to use 5,000,000 gallons of hydraulic fracturing fluid to stimulate gas production. How much water will be used per stage? How much water does this translate into for each foot of the well being fractured? The company plans to use 1.5 pounds of proppant per gallon of fluid. How much proppant will they use to fracture this well? How much proppant per foot will be used?

Once the hydraulic fracturing process is complete, the well can begin to produce hydrocarbons, but also will produce a significant volume of brine from the formation during the life of the well. The next section will address how these fluids are managed to avoid impacts to water quality.

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8.4: Produced Fluids Management

A hydraulic fracturing has taken place on a well a portion of the injected fluids (typically about 5-25%) along with naturally occurring brine in the formation will flow up through the well to the surface, commonly called flowback fluids. During this period, which may last for several days to a week or more, the well is allowed to flow to allow hydrocarbons to begin to be produced efficiently. Once the well has been brought on-line and producing oil or gas, brine will be co-produced along with the hydrocarbons during a well's productive life, and are known as produced fluids. A well will typically produce 5-10 barrels of fluids (or more) for every barrel of oil or for every million cubic feet of gas. The produced fluids typically have high concentrations of total dissolved solids (TDS). TDS may include higher concentrations of salts and metals such as barium and strontium, while containing lower levels of organics and radionuclides such as radium-226. The table below provides a summary of the flowback water quality from Marcellus wells in Pennsylvania.

Summary of the flowback water quality from Marcellus wells in Pennsylvania

Parameter	Drinking Water Standards ¹	Approximate Median Concentration in Typical Pennsylvania Groundwater ²	Approximate Median Concentration in Typical Marcellus Wastewater ³
pH	6.5 to 8.5	7.50	6.60
Total Dissolved Solids	< 500	163.0	67,300
Total Suspended Solids	-	1.0	99.0
Barium	< 2.0	0.070	686
Iron	< 0.30	0.20	39
Manganese	< 0.05	0.01	2.63
Sodium	-	6.87	18,000
Hardness/td>	-	86.1	17,700
Strontium	-	0.26	1,080
Chloride	< 250	5.3	41,850
Sulfate	< 250	18.0	2.4 to 106
Nitrate-Nitrogen	< 10	0.50	0.1 to 1.2
Bromide	-	0.016	445
Dissolved Organic Carbon	-	< 1.0	62.8
Dissolved Methane	-	No data available	No data available
Oil & Grease	-	< 5.0	6.3

Source: Center for Rural Pennsylvania, Boyer et al (2012). ¹ Pennsylvania Department of Environmental Protection, 2006. ² Pennsylvania State University, 2011; Davis et al., 2004; and Thurman, 1985. ³ Hayes, 2009.

TDS levels may be 2 to 3 times the levels found in seawater. Therefore they must be properly managed so they can be reused or treated to meet state regulatory requirements before discharge where allowed. Innovations in recycling of wastewater for reuse in hydraulic fracturing have significantly reduced the volume of flowback and produced fluids that would otherwise be disposed of via surface discharge or disposal wells. Currently it is estimated that the industry is recycling about 80-90% of the produced fluids for hydraulic fracturing in some shale basins such as the Marcellus, while other basins may only see 10-20% of these fluids recycled for hydraulic fracturing. The benefit of recycling the produced fluids for hydraulic fracturing is that less fresh water is necessary to be withdrawn, and less water needs to be treated or disposed. The produced fluids are separated from the oil or gas in the field and stored in tanks and then often trucked to another site for recycling or treatment.

When the fluids are treated for recycling for hydraulic fracturing, they may either be treated in the field or transported to a centralized treatment facility via tanker truck. Typically the produced fluids are treated to the extent that they can be injected back down into the shale without plugging up the formation or otherwise negatively impacting oil or gas production. Often the treatment may be as simple as running the water through a filter to remove sediment, or using chemicals to remove metals via precipitation but leaving the salts in the solution. If higher levels of treatment are required to discharge to a stream or river then a desalination technique such as thermal distillation may be required to remove salts that would otherwise be toxic to fresh water species.

Exercise 5-1

A shale gas well is producing 5 million cubic feet of gas per day and for every million cubic feet of gas generates an average of 8 barrels of produced fluids. How many barrels of produced fluids will this well produce in a day? How many gallons will it generate (hint: there are 42 gallons in a barrel)? Ultimately this well will produce an estimated 5 billion cubic feet of gas. What would be the total amount of brine generated from this one well? Provide your answer in both barrels and gallons.

As mentioned above, not all the produced fluids can be efficiently recycled and therefore at some point will require disposal. If treated to sufficient levels, these fluids could be discharged to a stream or river if the proper permits are in place. However, this is not common in many states. A more typical way to dispose of these fluids is through deep disposal well injection, a process regulated and permitted under the EPA's Safe Drinking Water Act. For more info go [EPA: Class II Oil and Gas Related Injection Wells](#). Wells that are used to inject any fluid into the earth are known as Underground Injection Control (UIC) wells, and are divided into six different classes. Class II wells involve oil and gas operations and include:

- Disposal wells
- Enhanced recovery wells
- Hydrocarbon storage wells

The graphic below shows Class II disposal and recovery wells. It is estimated there are about 180,000 Class II wells in the US, approximately 80% are recovery wells and 20% are disposal wells, collectively accepting 2 billion gallons per day of produced fluids.

Cross-sectional diagram showing UIC class II wells
UIC Class II Wells

Source: [US Environmental Protection Agency \(EPA\)](#)

Class II disposal wells (or Class IID wells) are used to dispose of oil and gas wastes, primarily produced fluids, i.e. saltwater, and are often called saltwater disposal wells. The injection rate and pressure for all injection wells must be carefully monitored to ensure fluids do not migrate into undesirable zones. When geologic faults are close enough to an injection well and the injection pressure is too high it can cause the fault to slip and thus cause an earthquake large enough to be felt at the earth's surface. In the last several years there has been a significant increase in seismicity in some parts of the country, as shown by this USGS

graphic.

Schematic showing central U.S. earthquakes 1973-Jan 2016
Central U.S. Earthquakes 1973 - Jan 2016

Source: USGS

The EPA provides a good overview on the [facts and myths](#) surrounding induced seismicity with injection wells and hydraulic fracturing.

Clearly we need to make sure that oil and gas development is occurring using the best available technologies to reduce the industry's overall environmental footprint, yet meet our society's energy needs. Another lesson will address some of the environmental impacts that oil and gas development can have and the best management practices to prevent them.

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8.5: Protecting Water Resources and the Environment

The development of shale energy resources has created concern about potential impacts to the environment, while also leading to a societal awakening for the protection of our natural resources, especially water resources. There are potential impacts to the environment, for example if a spill occurs or a well is not constructed properly then water resource impacts could occur. On the other hand, shale gas has a lower carbon and water footprint than other forms of fuel. So while not perfect, it can be argued that it is a cleaner source of energy if developed properly. There are multiple waste streams that result from shale energy development. These include solid wastes such as drilling cuttings and sludge from wastewater treatment, and liquid waste streams such as flowback and produced fluids. Therefore proper treatment and disposal are critical. There are also phases during the drilling and fracturing operations that could lead to water contamination. For example the drilling and well construction process has led to methane migration where private wells have increased levels of methane originating from shale wells that were not properly sealed. Methane migration (aka stray gas) has been especially problematic in some of the early Marcellus shale wells drilled in northeastern Pennsylvania. Shallow gas was present in the upper 3000' feet of the Earth, but not sealed off sufficiently, and leaked off into private wells. Through 2015 about 38 shale gas wells had impacted approximately 108 private wells in Pennsylvania, however stronger well construction regulations have decreased these numbers in the last several years. To put this in context, there were approximately 9,600 shale wells drilled through 2015 in Pennsylvania. Therefore 99.6% of the wells drilled had no reported methane migrations issues, but the 0.4% that did needed to be remediated and was surely a major inconvenience to those homeowners involved.

Exercise 6-1

Review the compliance and stray gas sections (p. 19-21) of the [2015 PaDEP annual oil and gas report](#). Do you think the regulations and enforcement are improving with time?

The USEPA has been studying the risks to drinking water from hydraulic fracturing. To date there have been no documented cases of hydraulic fracturing fluids migrating up from the zone in the shale where fracturing occurs and leaking into a drinking water supply. However, there is no shortage of public concern about this occurring. There are other risks that are real and have been documented. Perhaps the biggest risk to impacting water resource quality from shale energy development is surface spills of fracturing or produced fluids. There are large volumes (millions of gallons) of fluids being handled during a fracturing job and a spills can occur, whether via mechanical failure or human error. The USEPA study is attempting to look at these risks and determine if they are a significant threat to drinking water.

Exercise 6-2

Review the [USEPA study's executive summary \(draft version\)](#). Do you feel there are significant risks? Can proper regulation and enforcement make these risks manageable?

While any form of drilling and oil and gas production does have inherent risks, there are many engineering practices that can minimize these potential risks. One of the most important means to ensure oil and gas development does not impact someone's water supply is to collect pre-drilling water samples from their supply to establish baseline conditions. If there is a suspected problem after drilling or fracturing, then additional samples can be collected to determine if there is an issue related to the oil and gas operation. PaDEP has recommended parameters to be analyzed including the following:

PADEP RECOMMENDED OIL & GAS PRE-DRILL PARAMETERS

- | | |
|---------------------------|-------------|
| ■ Alkalinity | ■ Barium |
| ■ Chloride | ■ Calcium |
| ■ Conductivity | ■ Iron |
| ■ Hardness | ■ Magnesium |
| ■ Oil & grease | ■ Manganese |
| ■ pH | ■ Potassium |
| ■ Sulfate | ■ Sodium |
| ■ TDS | ■ Strontium |
| ■ TSS | ■ Methane |
| ■ Total coliform & E.coli | ■ Ethane |

Pre-Drill Water Source Sampling

Pennsylvania Department of Environmental Protection

If high levels of certain parameters occur in your water supply after nearby oil and gas development, there may have been some impact and remedial measures would need to be taken immediately. Again, although this is not common, it is much easier to prevent contamination than to clean it up. Some of the best management practices that the industry are now using to prevent spills and contamination include pre-drilling water supply monitoring, lining well pads to capture spills, and better well construction practices. As a citizen, if there is potential for drilling in your area become engaged in the process by contacting your regulator, attending public meetings, and being aware of drilling operation locations. Allow the oil and gas company contractors to sample your water at their cost and pay attention to the appearance, color, and taste of your water. If there is a change you will be able to detect it early and contact the regulators immediately to have it tested.

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acre-foot (acre-ft)

the volume of water required to cover 1 acre of land (43,560 square feet) to a depth of 1 foot.

animal specialties

water use associated with the production of fish in captivity except fish hatcheries, fur-bearing animals in captivity, horses, rabbits, and pets.

aquifer

a geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

commercial water use

water for motels, hotels, restaurants, office buildings, other commercial facilities, and institutions. The water may be obtained from a public supply or may be self-supplied.

consumptive use

that part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment. Also referred to as water consumed.

conveyance loss

water that is lost in transit from a pipe, canal, conduit, or ditch by leakage or evaporation. Generally, the water is not available for further use; however, leakage from an irrigation ditch, for example, may percolate to a ground-water source and be available for further use.

cooling water

water used for cooling purposes, such as of condensers and nuclear reactors.

delivery/release

the amount of water delivered to the point of use and the amount released after use; the difference between these amounts is usually the same as the consumptive use.

domestic water use

water for household purposes, such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and watering lawns and gardens. Also called residential water use. The water may be obtained from a public supply or may be self-supplied.

evaporation

process by which water is changed from a liquid into a vapor.

evapotranspiration

a collective term that includes water discharged to the atmosphere as a result of evaporation from the soil and surface-water bodies and as a result of plant transpiration.

freshwater

water that contains less than 1,000 milligrams per liter (mg/L) of dissolved solids; generally, more than 500 mg/L of dissolved solids is undesirable for drinking and many industrial uses.

ground water

generally all subsurface water as distinct from surface water; specifically, that part of the subsurface water in the saturated zone (a zone in which all voids are filled with water) where the water is under pressure greater than atmospheric.

hydroelectric power water use

the use of water in the generation of electricity at plants where the turbine generators are driven by falling water.

industrial water use

water used for industrial purposes such as fabrication, processing, washing, and cooling, and includes such industries as steel, chemical and allied products, paper and allied products, mining, and petroleum refining. The water may be obtained from a public supply or may be self supplied.

instream use

water that is used, but not withdrawn, from a ground- or surface-water source for such purposes as hydroelectric power generation, navigation, water-quality improvement, fish propagation, and recreation. Sometimes called nonwithdrawal use or in-channel use.

irrigation district

a cooperative, self-governing public corporation set up as a subdivision of the state government, with definite geographic boundaries, organized and having taxing power to obtain and distribute water for irrigation of lands within the district; created under the authority of a state legislature with the consent of a designated fraction of the landowners or citizens.

irrigation water use

artificial application of water on lands to assist in the growing of crops and pastures or to maintain vegetative growth in recreational lands such as parks and golf courses.

livestock water use

water for livestock watering, feed lots, dairy operations, fish farming, and other on-farm needs. Livestock as used here includes cattle, sheep, goats, hogs, and poultry. Also included are animal specialties.

million gallons per day (Mgal/d)

a rate of flow of water.

mining water use

water use for the extraction of minerals occurring naturally including solids, such as coal and ores; liquids, such as crude petroleum; and gases, such as natural gas. Also includes uses associated with quarrying, well operations (dewatering), milling (crushing, screening, washing, floatation, and so forth), and other preparations customarily done at the mine site or as part of a mining activity. Does not include water used in processing, such as smelting, refining petroleum, or slurry pipeline operations. These uses are included in industrial water use.

offstream use

water withdrawn or diverted from a ground- or surface-water source for public-water supply, industry, irrigation, livestock, thermoelectric power generation, and other uses. Sometimes called off-channel use or withdrawal.

per capita use

the average amount of water used per person during a standard time period, generally per day.

public supply

water withdrawn by public and private water suppliers and delivered to users. Public suppliers provide water for a variety of uses, such as domestic, commercial, thermoelectric power, industrial, and public water use.

public-supply deliveries

water provided to users through a public-supply distribution system.

public water use

water supplied from a public-water supply and used for such purposes as firefighting, street washing, and municipal parks and swimming pool.

reclaimed wastewater

wastewater treatment plant effluent that has been diverted for beneficial use before it reaches a natural waterway or aquifer.

recycled water

water that is used more than one time before it passes back into the natural hydrologic system.

return flow

the water that reaches a ground- or surface-water source after release from the point of use and thus becomes available for further use.

reuse

see recycled water.

saline water

water that contains more than 1,000 milligrams per liter of dissolved solids.

self-supplied water

water withdrawn from a surface- or ground-water source by a user rather than being obtained from a public supply.

surface water

an open body of water, such as a stream or a lake.

thermoelectric power water use

water used in the process of the generation of thermoelectric power. The water may be obtained from a public supply or may be self-supplied.

transpiration

process by which water that is absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface.

wastewater

water that carries wastes from homes, businesses, and industries.

wastewater treatment

the processing of wastewater for the removal or reduction of contained solids or other undesirable constituents.

wastewater-treatment return flow

water returned to the hydrologic system by wastewater-treatment facilities.

water-resources region

designated natural drainage basin or hydrologic area that contains either the drainage area of a major river or the combined drainage areas of two or more rivers; of 21 regions, 18 are in the conterminous United States, and one each are in Alaska, Hawaii, and the Caribbean. (See map on inside of front cover.)

water-resources subregion

the 21 designated water-resources regions of the United States are subdivided into 222 subregions. Each subregion includes that area drained by a river system, a reach of a river and its tributaries in that reach, a closed basin(s), or a group of streams forming a coastal drainage system.

water transfer

artificial conveyance of water from one area to another.

water use

1. In a restrictive sense, the term refers to water that is actually used for a specific purpose, such as for domestic use, irrigation, or industrial processing.
2. More broadly, water use pertains to humans' interaction with and influence on the hydrologic cycle, and includes elements such as water withdrawal, delivery, consumptive use, wastewater release, reclaimed wastewater, return flow, and instream use.

withdrawal

water removed from the ground or diverted from a surface-water source for use.

9: COMMUNITY IMPACTS

Overview

In this lesson, you will learn about the boomtown impact model and consider how the model might be updated to fit the particular conditions of shale gas development. Next, we will assemble a handy “toolbox” of ways to assess information about the social impacts of shale gas development. Assigned readings will give an overview of each topic, which we will review together, then apply to actual data from the Marcellus Shale region.

Main topics include:

- Causation in Social Science
- Community Impacts in the Media
- Boomtown Impact Model
- Risk Perception
- Institutional Trust

9.1: Studying Community Impacts

9.1.1: How do Sociologists Study Community Impacts?

9.1.2: How to Establish Causation in Social Science

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9.1: Studying Community Impacts

Social science is a broad term that covers all the sciences related to studying human beings at multiple scales, such as the individual, family, small group, organization, community, nations, or even whole civilizations. There are many disciplines within this umbrella, including economics, sociology, anthropology, psychology, and political science.

This review will draw largely on sociology. Sociology is a discipline that studies how the organization of societies affects individuals and their behaviors, beliefs and attitudes, their health and well-being, and how they interact with other members of their families, workplaces, volunteer groups, and communities. Sociology also looks at the converse relationship, how societies are shaped by the ways in which individuals interact and form different types of groups (e.g., schools, families, places of work, governments, etc.) that are the building blocks of societies.

In relation to Marcellus Shale development, one important area of research that sociologists examine focuses on ‘community impacts,’ a catch-all term for how individuals and families and local organizations, agencies, governments, and businesses are affected by the exploration, extraction, and production of natural gas from the Marcellus Shale. Some of the impacts researchers study include:

- The economic status of individuals and families (such as gaining or losing jobs, or changes to work hours, income, or work conditions) and how these changes affect the well-being of those families and individuals
- Changes in local populations, in terms of size, composition (age, gender, race/ethnicity), migration rates (in and out of the community), size and type of households, etc.
- Changes in unemployment rates, poverty rates and income inequality which provide insight into a community's social and economic well-being
- Demands on local organizations and agencies that provide services to community residents, such as health care, education, human services, and local government
- Stresses on the physical components of communities that we rely on for daily living, including housing, roads, water/sewer, telecommunications, etc.
- Prevalence of social problems, such as crime, drug and alcohol use, divorce and related family problems, and mental health concerns, and the impacts of these problems on the systems that address them (courts, police agencies, health service providers, social services, etc.)
- Changes in existing and new residents’ feelings of community satisfaction and attachment to their communities measured by perceived quality of life and social and physical well-being

Whether or not you live in an area experiencing shale gas development, you likely hear and see many claims about its social impacts on television news, in the newspaper, or even on your Facebook feed. Many of these headlines and reports contradict each other, and it can be hard, as a consumer of science, to know what to believe.

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Newspaper Headlines Related to Community Impacts of Marcellus Shale

Compiled by Grace Wildermuth

In this section, you will acquire a handy “toolbox” with ways to assess these reports on the social impacts of shale gas development.

In Lesson 1, you learned about causation, correlation, data, and evidence. Here’s a recap:

Causation

One event is the result of the occurrence of the other event. This is also referred to as cause and effect. Beware: just because two things occur together does not mean that one caused the other.

Correlation

A statistical measure that describes the size and direction of a relationship between two or more variables. A correlation between variables, however, does not automatically mean that the change in one variable is the cause of the change in the values of the other variable.

Data

Information, either qualitative or quantitative, that has been collected.

Evidence

Data that has been shown to be valid.

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9.1.1: How do Sociologists Study Community Impacts?

Community impacts research tries to understand how people experience the development in their everyday lives, if/how these experiences form into patterns across communities, and the extent to which these patterns can be causally linked to development of natural gas resources. In other words, we need to conduct the research such that we can say that development of unconventional natural gas (and all that entails) caused the changes that are seen in communities, such as increased crime rates, strains on local government budgets, decreased unemployment rates, increased homelessness, etc.

Here are the critical challenges we have faced as we've researched community impacts of Marcellus Shale development:

Correlation vs causation

Saying that a particular issue (such as a rise in crime rates) is directly caused by Marcellus development is difficult to document. Crime rates can increase for many reasons: 1) Unrelated economic changes can create greater opportunities for crime or can create greater desperation among residents; 2) heightened public awareness can result in more reporting of crimes; 3) changes in laws or enforcement procedures can change how or how likely crimes are reported.

How could Marcellus Shale activity lead to changes in crime rates? Establishing a causal relationship means comparing places with differing levels of Marcellus development and at multiple points in time and statistically controlling for some of these other factors (such as differences in population across places and time). It also means tracing through interviews and administrative data the 'path' by which Marcellus leads to increased criminal activity. Is it simply the out-of-state workers behaving badly? Is it local people working in the industry who have more money and more opportunities to commit crimes? Is it that more people means more opportunities for crime to occur, regardless of who committed the crime? *Simply finding that crime is higher in places with Marcellus development (a correlation) is not enough to establish a causal relationship.*

Data availability

We have come across many instances where data simply do not exist or are not available for the years that we need. For example, the US Census is conducted every 10 years, giving us data in 2000 and 2010. The data from 2000 is a bit too early, in that there are about 6 years between that data point and the beginning of development activity. There are data available through the American Community Survey, but these data are 3- or 5-year averages, depending on the size of the place.

In other cases, data are not released in a timely fashion, such that in some topics the most recent data available is from 2009, which does not provide an adequate time series after the onset of development. For other topics, data simply do not exist. For example, there is no systematic data tracking health impacts, even for workers in the industry, because most health care providers have not collected such information historically. So while we use these data, we have to be very careful in interpreting the results.

Differences across the region

The Marcellus region is quite varied in its ecological, social, political, and economic histories, so it is quite difficult to apply research findings from one area to another. Some research and stories in the media study Bradford County, and simply apply the findings from Bradford County to other counties experiencing Marcellus Shale development. The characteristics of Bradford County (such as low population density, far from population centers, existing government structure and culture, economic history, landholding patterns) make this county more unique than representative of the rest of the state. *It is not appropriate to assume that the impacts felt in Bradford County will be the same across the rest of the region.*

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9.1.2: How to Establish Causation in Social Science

The “gold standard” for making a causal statement is the experiment. Scientists design a test in which one group is given a treatment of some kind, and another group, called the control group, is given no treatment. After measuring the results for each group, scientists decide whether there is a difference between the two groups.

Experimental Research Model

Experimental Research Model

Compiled by Grace Wildermuth

Unfortunately, experiments are difficult to conduct in the social sciences, and may not be possible and/or ethical. For example, if you wanted to investigate whether taking drugs affects school performance in teenagers, an experiment wouldn't be appropriate. It's obviously not ethical to give drugs to teenagers for a treatment group.

So how do you establish causality in the social sciences? Let's go over some common techniques and research design options that help social scientists make causal statements.

Where possible, compare data from multiple points in time: To understand community impacts, it is best to have data from both before and after the start of Marcellus Shale development. This approach is called **longitudinal data analysis**, and allows researchers to compare community characteristics after Marcellus development to what the community was like before the start of development. For example, researchers studying if crime rates are affected by Marcellus development need to understand the rates of felonies and misdemeanors in the years leading up to the start of development. They then can compare these to the rates after Marcellus development began. The example below uses a longitudinal research design to assess the impact of Hurricane Katrina on rates of homelessness in Louisiana.

Longitudinal Research Model

Longitudinal Research Model

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Where possible, compare multiple study locations: Some of this early research examined the changes happening in a single place, such as one county. These are called case studies, and they provide great detail about what's happening in a particular place. They can be helpful to uncover details about how, for example, housing availability is affected by an influx of workers 'on the ground.' However, because the number of cases is limited, it is very difficult to control for all the kinds of changes that might be happening simultaneously and say definitively that the cause is energy development.

Ideally, researchers should study places that are experiencing natural gas development AND places without development but that are similar in other respects (such as population size). As a result, the places being studied only differ in one characteristic – one has natural gas development and the other does not. If the places with natural gas development have different outcomes (such as crime rates or mental health problems) it is appropriate to relate those differences to natural gas development. Comparing different places is the ideal; however, it can be quite challenging to find matching places such that the only difference is natural gas development. The example below uses a **comparative case study** research design to assess the impact of a casino on rural communities.

Comparative Case Study Research Model

Comparative Case Study Research Model

Compiled by Grace Wildermuth

Where possible, control for additional factors: Control for factors that are known to influence the variable you are testing. This ensures that the result that you are measuring hasn't been affected by additional variables not included in your research design. Researchers can do this using statistical models and programming. The example below uses control variables to isolate the effects of contamination on a populations' fertility rate.

Control Variable Research Modeling

Control Variable Research Modeling

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9.1.3: Changes in Crime Related to Marcellus Shale Development

The rapid development of Marcellus Shale in Pennsylvania over the past decade, and the population growth and in-migration of labor associated with it, has raised questions about increases in criminal activity. This study (Brasier & Rhubart 2016) funded by the Center for Rural Pennsylvania examined changes in crime related to Marcellus shale development from 2005-2012. The study is longitudinal (including data from before and after drilling), comparative (including locations with and without drilling activity), and controls for additional variables known to influence arrest rates, such as population density and percent of the population living in poverty. Included in criminal activity are four individual crimes: driving under the influence, drunkenness, drug use violations, and disorderly conduct. The rates of arrest occurrence for these four crimes are measured in areas with no wells, 1-7 wells, 8-85 wells, 86-292 wells, and greater than 292 wells.

Overall, crime generally declined across the region from 2005 to 2012, including in counties with Marcellus Shale development. However, the findings indicated that counties with higher well development experienced slight increases in driving under the influence and disorderly conduct arrests in 2011 and 2012. Although the study did control for additional variables that may have caused this change, it is still not certain how much of the increases are related to Marcellus Shale development.

graph shows number of arrests per 100,000 residents from 2005 - 2012
DUI Arrest rate, 2005-2012, by Cumulative Number of Wells Drilled in County

Source: FBI Uniform Crime Report;; PA DEP

It is important to remember that the data used in this study reflects rates of arrest, and not rates of crime exactly. While arrest rates can provide an indication of crime, they could also be indicators for police activity and areas of enforcement. An increase in police or community attention to certain crimes can lead to an increase in arrests, while the rate of crime remains constant.

Overall, the study showed that different areas of Marcellus Shale development see different effects on arrest rates. You can refer to [“Varied Boomtown Experiences”](#) to consider why this may be.

9.1.4: Traffic Impacts of Marcellus Shale Development

One of the primary concerns associated with Marcellus Shale development is traffic. The use of trucks and large machinery in the development of well sites has lead to complaints about truck traffic and road safety. This study (Brasier & Perchinski 2016) funded by the Center for Rural Pennsylvania examined three indicators of traffic accidents (total crashes, heavy truck crashes, and crashes with one or more fatalities) in relation to Marcellus Shale development. Data on total reportable crashes, heavy truck crashes, and total crashes resulting in one or more fatalities was secured from PennDOT, and analyzed at the county level.

The study is longitudinal (including crash rates from before and during development), comparative (including counties with and without development) and uses control variables, such as daily vehicle miles traveled, which could affect crash counts.

Bradford Wells and Crashes

Annual numbers of vehicle crashes and number of wells drilled in Bradford County, 2005-2015.

Source: Pennsylvania Department of Transportation; Pennsylvania Department of Environmental Protection.

Overall, the study found that counties with Marcellus Shale development had higher total crash rates than those without. Furthermore, the most rural counties with the highest level of development had increased rates of total crashes and heavy truck crashes, with the peak of crash rates occurring during the years of highest activity (2009-2011).

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9.1.5: Community Impacts in the Media

Activity 1

When reading about community impacts of shale gas development, treat each article or story like a scientific research paper. Look for causation, correlation, data, evidence, and the use of experts to evaluate the claims made. Let's look at some newspaper articles related to social impacts of shale gas development and try to figure out whether they suggest causality or correlation, and whether their claims are backed by data and/or evidence.

Reading

Read [Crime Pocono Records "Pa. state police reassigned to gas drilling region as crime rises"](#) (2 minutes).

Exercise 1

After reading, think about how you would answer the questions below. Click for the answer to see how your thoughts compare to the answers provided.

Questions

1.What does the article say is a result of shale gas development?

Answer available at the end of this section.

2. What data/evidence/experts do they use to support this statement?

Answer available at the end of this section.

3. Is this correlation or causation?

Answer available at the end of this section.

4. What are other potential correlations that would lead to the same result?

Answer available at the end of this section.

5. What data/methods would be needed to establish causation?

Answer available at the end of this section.

Reading

Read [Drilling Boom AP](#) (8 minutes).

Exercise 2

This time after reading, type your answers to the questions in the boxes provided. Again, click for the answer to see how your answers compare to the answers provided.

Questions

1. What does the article say is a result of oil and gas activity?

Answer available at the end of this section.

2. What data/evidence/experts do they use to support this statement?

Answer available at the end of this section.

3. Is this correlation or causation?

Answer available at the end of this section.

4. What are other potential correlations that would lead to the same result?

Answer available at the end of this section.

5. What data/methods would be needed to establish causation?

Answer available at the end of this section.

Reading

Find one additional media article pertaining to community impacts of Marcellus Shale development. Again, use the questions above to evaluate the data presented.

Answers

Exercise 1

The article says that shale gas development has led to an increase in crime incidents. Therefore, twenty-five state troopers have been reassigned to the Marcellus Shale region.

Exercise 1

The article quotes two experts: State Police Commissioner Frank Noonan, Lt. Col. George Bivens. However, no data or evidence is provided.

Exercise 1

Without data or evidence, we cannot say if either correlation OR causation exist. IF there has been an increase in crime incidents in the region, we could only say that there is a correlation between shale gas development and an increase in crime.

Exercise 1

An increase in crime could also be caused by population growth, an increase in the population living in poverty, or a spike in unemployment, just to name a few.

Exercise 1

In order to establish causation between shale gas development and an increase in crime, you could conduct longitudinal research (comparing data before and after Marcellus shale development began), use a comparative case study (compare two places with similar characteristics – one that has Marcellus Shale development and one that does not), and/or “control” for other potential causes, such as the ones listed above. Each method strengthens your research, and combining all three would be best!

Exercise 2

The article says that a sharp increase in crime/arrests (drunk driving, bar fights, prostitution, protection-from-abuse orders, and others) has been caused by natural gas workers who have migrated to new areas for work. .

Exercise 2

The article cites law enforcement officials, a District Attorney, and disease control staff as experts on the topic. In many instances, the article notes a “spike” or “rise” in arrests without providing any data. Data is provided, however, in some cases. For Sweetwater County, Wyoming the article cites population increase and arrest numbers taken from “state figures”. Bradford County arrest numbers are cited from a District Attorney, and the Sheriff in Williston, North Dakota provides arrest figures. In addition, data on North Dakota’s rates of sexually transmitted diseases is provided, although the state’s Disease Control Chief notes that three years is not enough data to establish a trend.

Exercise 2

This article has established correlation, but has not provided enough information to establish causation. Although some longitudinal data has been provided, it does not always capture conditions both before and after production began. There is no control group or case study comparison to similar areas without natural gas development, and no evidence that they have controlled for additional factors.

Exercise 2

Population increase alone could be causing changes, or the rates in the areas provided could be on-trend with the state or national averages, and not unique to areas experiencing natural gas development. (There are many other possible answers).

Exercise 2

In order to establish causation between shale gas development and an increase in crime, you could conduct longitudinal research (comparing data before and after Marcellus shale development began), use a comparative case study (compare two places with similar characteristics – one that has Marcellus Shale development and one that does not), and/or “control” for other potential causes, such as the ones listed above. Each method strengthens your research, and combining all three would be best!

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9.2: Boomtown Impact Model

Current research on Marcellus Shale Development draws on important concepts from previous energy development research, including the boomtown impact model. The western United States saw a period of rapid energy development in the 1970s and 1980s. Many coal, oil, and natural gas development projects were located in rural, isolated towns which were unprepared and unaccustomed to the rapid population growth and industrial development taking place. Sociologists, studying these communities, created the boomtown impact model, sometimes called the social disruption hypothesis. The model generally predicts that small communities facing rapid population growth and industrialization will see their services and infrastructure stretched thin, increases in mental health problems, and changes to their quality of life (Jacquet & Kay 2014).

In this section, you will learn about the boom-bust cycle and its impacts, and evaluate whether shale gas development fits within the boomtown impact model.

You will begin with a reading that outlines the perceptions of impacts from community members over time and across space using qualitative data from interviews. As you read the article, complete Activity 2.

Reading

[Brasier et al Boomtown](#) (35 minutes)

Activity 2: (15 minutes)

Divide a piece of paper into three categories: Boom Stage, Bust Stage, and Recovery Stage. As you read the “Background” section (pages 34-38), fill in each section with its corresponding characteristics from the literature.

Answer available at the end of this section.

Answers

Activity 2: (15 minutes)

Check to see if your responses identify or give consideration to the points below for each stage of development. (Some characteristics don't fit neatly within one stage or the other.)

Boom Stage

- Strain on physical infrastructure
- Strain on community services
- Housing shortage, rise in purchase and rental prices
- Bolstering of social and economic cohesion

Bust Stage

- Long-term residents report highest levels of community satisfaction through this stage, as with all stages
- Adaptation begins

Recovery Stage

- Residents create new interpretations of their area and energy development
- Residents form new relationships to their communities
- Indicators of well-being (community satisfaction, trust in other residents, social ties) return to pre-boom levels

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9.2.1: Characteristics of a Boomtown

The term “boomtown” usually refers to a small, rural, isolated community that experiences rapid energy development, and the associated industrialization and population growth that come with it.

Research shows that the attitudes of residents of boomtowns generally progress through four stages:

The Four Attitude Stages of Boomtown Residents

The Four Attitude Stages of Boomtown Resident

Compiled by Grace Wildermuth

Residents may be enthusiastic as they consider the possible positive impacts (jobs, economic growth, etc.) that energy development could bring to their community. As development begins, however, their positive expectations may not be met as they discover unexpected negative side-effects or undesirable changes (environmental impacts, noise or odor, housing shortages, and rent increases). Panic may set in as residents fully realize the negative impacts that energy development has brought to their community. And finally, residents turn towards an attitude of adaptation as they grow accustomed to the new aspects of their community, both positive and negative.

Examples of each state from your reading:

Examples of the Four Attitude Stages of Boomtown Residents

Examples of the Four Attitude Stages of Boomtown Residents

Compiled by Grace Wildermuth

We can also look at boomtowns on the community level. Boomtown communities generally follow a boom-bust-recovery model (refer back to your notes from Activity 2). The figure below illustrates how the boomtown impact model predicts a community will move from the boom stage to the bust stage, and eventually the recovery stage over time.

Graphic of boom stage, bust stage, recovery stage over time.

Boom-Bust-Recovery Model

Compiled by Grace Wildermuth

Boom stage

The ‘boom’ stage is characterized by a rapidly growing demand for a skilled labor force. Initially, rural communities are not able to supply the labor needed, resulting in rapid in-migration of workers and potentially their families and others to provide services to this population (Cortese & Jones, 1977; Albrecht, 1978). With a larger labor force, more money flows into the local economy; however, as demand for goods and services increases, inflation may ensue as well as stratification between those who can afford the goods and those who cannot (Jacquet, 2009).

Bust Stage

When the extracted resource becomes depleted or becomes less profitable, the employment opportunities offered by energy development begin to seep out of the community. Subsequently, outmigration occurs, decreasing revenue for local businesses and leaving an abundance of over produced infrastructure (Jacquet, 2009).

Recovery Stage

Some long-term research on boomtown communities has suggested a 'recovery stage' when community members, local leaders and businesses adapt to the environmental, social, and economic changes happening in their communities due to energy development.

A community's progression from the boom to bust stages of this model are driven by the demand for the resource being developed, fluctuations in the products' market price, changes and/or advancements in the extraction technology, new and evolving extraction processes or methods, and political conditions and/or decisions.

More recently, researchers have begun to modify the traditional boomtown impact model that examines a singular boom followed by a one-time bust. Instead, they believe, communities such as those in the Marcellus Shale region are likely to experience many mini-booms and mini-busts over the course of development. This new boomtown impact model suggests a different experience for communities and residents than the traditional boom-bust cycle (Jacquet & Kay 2014, Stedman et al 2012).

Graph of number of wells by year
The New Boomtown Impact Model: Variations Across Space and Time
Compiled by Grace Wildermuth

Graphs of number of wells by year for 6 counties in PA
The New Boomtown Impact Model: Variations Across Space and Time
Compiled by Grace Wildermuth

A new boomtown impact model is necessary to capture the effects of Marcellus Shale development. The wide geographic footprint and other characteristics of the resource, the industry's strategic development plans, supply and demand of the resource, infrastructure development, and price fluctuation are just some of the factors that lead to a model that shows variation over space and time. Small scale "semi-busts and re-booms" (Jacquet and Kay, 2014) have occurred across Pennsylvania, as illustrated by the data above. Figure 1 displays the temporal differences in the number of wells by county. For example, note that as most counties were experiencing a downward trend or "semi-bust" in 2015, Greene County experienced a sudden increase, or boom, in number of wells. Figure 2 shows the spatial differences in the number of wells by county. Note, for example, that even though Tioga, Bradford, Susquehanna and Lycoming counties are located in close geographic proximity, they show substantial differences in development trends.

Additional Assumptions

Below are some additional assumptions of the traditional boomtown impact model, as well as explanations as to why the model may need to be adjusted to fit Marcellus Shale development:

Rural and isolated communities

The Marcellus Shale formation is expansive, and therefore stretches over many types of communities: rural and urban, isolated and with expansive transportation networks.

Small pockets of natural resources that would be extracted over a short period of time

The Marcellus Shale formation covers a very wide geographic area. Some areas may be more suitable for development under certain conditions or with certain technologies. Therefore, the industry may move around the area as conditions change, perhaps leading to mini-booms and mini-busts for each community.

Differences in land ownership affect ability of community to retain wealth

The majority of mineral rights in the Marcellus region are owned by private landowners, although not necessarily the person who owns the surface rights. Through leasing and royalties, money is transferred from the industry directly to those local residents who own mineral rights. The percentage of local landowners who own their mineral rights varies across the state, with areas having a long history of resource extraction (oil, gas, coal) more likely to have severed surface/subsurface rights. Further, some counties have large private or public (e.g., state forests) landowners. These patterns of surface and mineral rights ownership will affect how much leasing/royalty income is taken in by local residents.

Economic development and corporate behavior

The economic context within which Marcellus Shale Development is taking place is markedly different from that in the 1970s when the traditional boomtown model was put forth. There are different rules, protections, and permitting requirements in place. The initial rapid leasing or “land grab”, foreign investment, and continued production at low prices all lead to a different era of economic development and corporate behavior.

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9.2.2: Varied Boomtown Experiences

Not everyone experiences boomtowns in the same way. Factors such as where you live, the history of your community, the type of development that is occurring, and who you are can lead to different experiences for different individuals.

Where you live

The impacts of energy extraction, and the perceptions of those impacts, vary across regions and communities (Freudenburg and Gramling 1993). Characteristics of places affect how they experience development, meaning that studies need to carefully consider how places differ in terms of their pre-existing economic, social, demographic, and cultural history as well as geography and natural resources. This is especially important when trying to directly apply the original 'boomtown' research to the Northeast US now, which varies greatly from the communities in the intermountain west in terms of geographical context, community size, social and economic history, proximity to urban areas, and natural resources. Further, communities within this region also vary along those same lines. Some key differences we have found to be important include:

- Population size and population density: Places with larger populations are generally able to accommodate population growth easier than places with smaller populations.
- Road networks: Relatedly, places with more extensive road networks are better able to absorb increased traffic associated with development. Additionally, there are more alternative routes. As a result, the traffic is less of a concern in areas with extensive road networks.
- Labor market/housing market: More extensive road networks and proximity to urban areas also mean that the population of an area is more spread out. The housing market is larger, offering more options for different types of housing, and is less likely to be acutely stressed by population growth.
- Local history and culture: The social, economic, cultural, and political history of places matters, particularly in relation to the familiarity and acceptance of a specific industry. For example, some of our research suggests there is less concern about the potential risks of Marcellus development in those parts of the state with a history of oil and gas extraction. This history creates familiarity with the type of process and economic ties to a related industry.

Types of Development

Development is a broad term that encompasses multiple stages of the exploration, extraction, and production of natural gas. These stages have differing types and levels of community impacts because they require differing types of workers and technology in a region. Consequently it is important to understand the characteristics of development and how it unfolds in a particular place to identify the types of impacts it will have:

- Stages of production: The development stage – when the most workers are needed to initially tap into the resource and build the infrastructure needed to extract the resource – tends to have the greatest impacts on communities. As the development stage gives way to the production stage, when fewer workers are needed to extract the resource and take it to market, fewer workers are needed overall.
- Geology/infrastructure/leaseholding: The combination of geological resources (where are the most promising or proven resources?), existing infrastructure (especially pipelines), and lease-holding patterns have created 'hotspots' of development. These hotspots have the fastest pace and largest scale of development, resulting in the most workers, business activity, trucks and traffic, and materials needed.
- Organization of the industry: The energy industry is organized with several large national or multinational energy production corporations that subcontract for many of the services that are needed to produce natural gas, from clearing a well pad to hydraulic fracturing to building pipelines. The production companies have been setting up headquarters, several located in Canonsburg, PA, as well as regional headquarters in some of the major cities such as Williamsport. They also have built field offices located around the region. The service companies also set up offices in this kind of regional pattern. This makes a difference in terms of the number and types of employees located in each office, which influences housing needs and other potential community impacts.

Who you are

At the individual level, how a person experiences development will vary based on who they are and their social position. The main influence is the ability to directly benefit from development, including the ability to gain economically through a new job or increased work hours or through direct leasing and royalty income. Those who are unable to receive these benefits – such as the disabled, elderly, renters, etc. – experience the inconveniences and potential problems created by the activity (such as traffic, safety issues, population change, etc.,) but do not receive any benefits to off-set those problems. In addition, certain segments of the local population may be affected uniquely. For example, Freudenburg (1986) found that school-age youth were unable to insulate themselves from the newcomers to the community who brought different cultural and ethnic backgrounds. These students reported more negative attitudes about energy development and lower levels of community satisfaction than adults.

Activity 3: (5 minutes)

Take a minute to think about how you would experience a boomtown given the information above. Now, pick a friend who doesn't live in your community, and consider how they might experience a boomtown differently?

Answer available at the end of this section.

Answers

Activity 3: (5 minutes)

Your answers should touch on ideas such as:

- *Population size and density*
- *Infrastructure*
- *Jobs and housing available*
- *Local history and culture*

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9.2.3: Risk Perception and Institutional Trust

Reading

[Freudenburg & Pastor](#) (45 minutes)

As is stated in the article you have just read, academic discourses on risk perception have traditionally focused on the ignorance or irrationality of the public, assuming that the public's concerns stem from insufficient or inaccurate information, and that this can be reversed by education. Sociological studies have been among a group of research that suggests otherwise. Studies have shown that in many cases, an individual's perception of risk may increase as they gather more information on a specific topic. Moreover, technical information is just one factor in a long list that together build an individual's perception of risk.

An individual's perception of risk is not a scientific calculation, but a human decision that takes into account factors such as previous experiences, emotions, values, culture, and worldviews. Risk perception is affected by the content and level of information received, sociodemographic attributes such as gender and age, as well as personal values. Familiarity with the action or technology being considered, how it is portrayed in the media, and visions of what could go wrong all play a role in an individual's perception of risk (Freudenburg 1993).

The figure presented below shows data collected from a 2009-2010 6,000-household survey administered by mail to households in New York and Pennsylvania (Willits et al 2010). As the graph illustrates, more than half of respondents in a recent survey on community satisfaction and change in the Marcellus Shale region felt that potential negative impacts could be prevented, and just slightly less than half (48%) were concerned that benefits would accrue to only a few individuals. Respondents were nearly evenly split in their level of worry about a catastrophic accident, while about a third felt that we did not know enough to move forward with Marcellus Shale development.

Perceptions of risk related to Marcellus
Perceptions of Risk Related to Marcellus

Source: Community Satisfaction and Change: A Study of Communities in the Marcellus Shale Region

When applying risk perception to the topic of shale gas development, it's important to consider the role of institutions in an individual's perception of risks. Institutional failures and their associated consequences – caused by technological failings, human error, or institutional self-interest – can lead to an individual's distrust in various institutions, such as government agencies, regulatory bodies, or industry. Level of trust, in the ability of institutions to manage risks, or in their willingness to fulfill their responsibilities, factors into the weighing of risks done by individuals.

The figure below illustrates the level of trust that respondents have in a series of organizations and agencies that have been involved with Marcellus Shale issues. Respondents had relatively high trust in scientists and extension, followed by environmental groups and state regulatory agencies. Respondents were somewhat split about trusting the natural gas industry, with about half trusting and 40% distrusting.

Institutional Trust
Institutional Trust

Source: Community Satisfaction and Change: A Study of Communities in the Marcellus Shale Region

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9.3: Resources

Acknowledgements

Research included in this lesson was sponsored by a grant from the Center for Rural Pennsylvania, a legislative agency of the Pennsylvania General Assembly. The Center for Rural Pennsylvania is a bipartisan, bicameral legislative agency that serves as a resource for rural policy within the Pennsylvania General Assembly. It was created in 1987 under Act 16, the Rural Revitalization Act, to promote and sustain the vitality of Pennsylvania's rural and small communities. Information contained in this report does not necessarily reflect the views of individual board members of the Center for Rural Pennsylvania. For more information, contact the Center for Rural Pennsylvania, 625 Forster St., Room 902. Harrisburg, PA 17120, telephone (717) 787-9555; email: info@rural.palegislature.us, www.rural.palegislature.us.

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9.4: Summary

Although we have models, such as the boomtown impact model, that suggest what community impacts we might see from Marcellus shale development, research has revealed a range of social impacts, and inconsistencies across and within communities. Every person experiences Marcellus Shale development differently, based on factors such as their geographic location, the history of their community, and their own unique characteristics and circumstances.

When assessing information about community impacts of Marcellus Shale development, it's important to look for signs of causation. Look for research techniques used to establish causation including:

- Measuring at several points in time – ideally before, during, and after development
- Comparing places with and without Marcellus Shale development activity
- Controlling for additional variables that could be affecting the outcome

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10: ECONOMIC IMPACTS

Overview

Energy development is big business. Oil and gas companies, electric utilities and wind and solar power developers have been pouring many billions of dollars into energy infrastructure. States often act like they are competing with one another to lure energy-related companies to operate within their boundaries versus going to another state. Politicians of all stripes point towards the economic benefits of harvesting energy resources, whether those resources come from below the earth's surface (oil and gas) or from the sun and sky.

Virtually all energy development, whether fossil or renewable, involves heavy industry. There will be economic benefits and economic costs to any particular project. In this portion of the course we'll discuss some of these benefits and costs, and discuss in particular where claims of "job creation" come from, how to decode some of those claims, and some of the great myths of the economic development potential in the energy sector.

In addition to the material presented here, there are several studies of the economic impacts of energy development that are accessible to the public.

- The [Pennsylvania Green Jobs Report\(link is external\)](#) focuses on employment in renewable energy sectors in Pennsylvania.
- [Economic Impacts of the Atlantic Sunrise Pipeline Project\(link is external\)](#) is one example of how "input output analysis" has been applied to major energy development in Pennsylvania.
- [Pennsylvania Marcellus Shale Workforce Needs Assessment\(link is external\)](#) is another example of a study of economic impacts in the natural gas industry, but it is more focused on one segment of the natural gas supply chain.

Learning Outcomes

By the end of this lesson, you should be able to:

- Identify the three types of workforce impacts associated with energy development, and describe the differences between each
- Interpret the "multiplier" for economic impacts
- Explain input-output modeling and identify some advantageous and disadvantageous aspects of this tool for calculating economic impacts

[10.1: Jobs, Jobs, Who's Got the Jobs?](#)

[10.2: Direct, Indirect and Induced Economic Impacts](#)

[10.3: The Ins and Outs of Workforce Impact Modeling](#)

[10.4: Check Your Understanding](#)

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10.1: Jobs, Jobs, Who's Got the Jobs?

Debates and discussions over the economic impacts of energy project development often seem confusing, conflicting and dominated by spin. In many cases, these discussions equate “economic impacts” with something called “job creation.” While employment is certainly high on everyone’s mind (and many large energy development projects happen in rural areas that have tended to have high unemployment), it is certainly not the only economic impact that energy projects can have.

Some economic impacts are certainly positive, such as lower energy costs. Others are certainly negative, including impacts on existing infrastructure (like roads, bridges and public utilities), crime and housing costs. But none of these have gotten the attention (or analysis) as has the issue of employment.

It is easy to see how confusion can arise from competing “jobs” numbers. As a case in point, read this article from the Washington Post ([Will Keystone XL pipeline create 42,000 'new' jobs?](#)) about the proposed Keystone XL pipeline project that would have transported oil from Canada to refineries along the U.S. Gulf Coast. One U.S. Senator supportive of the project cited a study claiming that Keystone XL would have created more than 40,000 new jobs. Another Senator opposed to the project, however, claimed that Keystone XL would have created ten times fewer jobs. The two numbers seem irreconcilable.

What is going on here? Companies in the U.S. have built hundreds of thousands of miles of pipelines – don’t we know by now how many people it takes to build a pipeline? The reason for the confusion comes down to just a few key facts about measuring (and reporting) the workforce implications for energy project development.

1. The total size of the workforce needed to sustain a given level of energy development extends far beyond the people that actually drill wells, lay pipeline or erect wind farms. Part of the disagreement over the Keystone XL and other big energy projects comes down to using different definitions of what constitutes the ‘workforce’ and which jobs in which industries are counted.
2. The number of people required to build a large energy project like a gas well or a pipeline is very different than the number of people required to run the project once it is complete. There thus may be very different short term versus long term workforce implications. Some jobs may be temporary contract employment while others are more like permanent positions.
3. Creating a job is not the same thing as reducing unemployment, since workers may shift from one job to another. While we often talk casually about the number of jobs that a given energy project will create, it is more correct to refer to the size of the workforce needed to develop and sustain a given energy project.

The Washington Post article contains a nice summary of why it is so difficult to pin down the exact economic or workforce impacts, and would be relevant for any large energy or infrastructure project, not just the Keystone XL pipeline. In the material that follows we’ll go into some more depth as to where the numbers for economic impacts come from, and understanding the advantages and shortcomings of the methods used to generate these numbers.

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10.2: Direct, Indirect and Induced Economic Impacts

Recently, the Tesla Company announced that it would build a giant new factory in the Nevada desert, where it would manufacture batteries on an enormous scale. Because the factory is so large, it's a good example to use to differentiate between three types of workforce that are commonly used in analyses of economic impacts, like in the Washington Post article or in the other studied referenced earlier in this lesson.

Direct Workforce

Construction workers will be needed to build the Tesla facility, and once it's built it will need to be staffed with factory workers, administrative assistants, a cleaning crew and so forth. These are all examples of the *direct workforce* needed to sustain Tesla's factory.

Indirect Workforce

The contractors hired to build the factory will need, in turn, to contract with land management companies, law firms and other professionals. These companies will then purchase goods and services from other businesses. When the factory is up and running, the maintenance company hired by Tesla will need to purchase goods and services from other businesses, such as cleaning and plumbing supplies. These are all examples of the *indirect workforce* that contribute to sustaining Tesla's factory. A key difference between the direct and indirect workforce is that those in the direct workforce would essentially be working for Tesla full-time. Those in the indirect workforce, such as the owners of hardware or plumbing supply stores, would sell goods and services to those in the direct workforce.

Induced Workforce

When Tesla hires people to work at its factory, those people earn wages that are then spent on other things like entertainment, health care and so forth. To the extent that the dollars earned by Tesla workers are re-circulated into the Nevada economy, these dollars help to support other jobs. In cases of very rapid build-up of industrial activity (as has happened with unconventional natural gas drilling in Pennsylvania, for example), entirely new businesses can sometimes spring up to serve new workers. These are all examples of the *induced workforce* that might be associated with Tesla's factory.

Going back to the Washington Post article about the Keystone XL pipeline, it is easy to see how two people talking about "jobs" can mean different things. The Senator in support of the pipeline, who cited a figure of 42,000 jobs, was talking about the workforce inclusive of the direct, indirect and induced workforce. The Senator in opposition to the pipeline who questioned whether a figure of 42,000 jobs was realistic, was most probably talking about just the direct workforce associated with the pipeline.

Measuring the indirect and induced workforce can be tricky as we'll see, but there is no doubt that these impacts are real. For example, bringing a single natural gas well on-line requires hundreds of people across dozens of occupations, as shown in the summary of direct and indirect workforce needs for natural gas wells in Figure 1. Only around one of out of every five of these workers are actually at the drill site (and would thus be considered part of the "direct" workforce).

Pie graph shows natural gas workforce occupations by category

Figure 1: Breakdown of occupations (direct and indirect workforce requirements) for a single natural gas well.

Source: Marcellus Shale Education and Training Center

Some of the induced impacts can be very apparent as well, and are often concentrated in service sectors. Figure 2 shows the growth of tax collections by the hotel industry in three Pennsylvania counties that have been the locus for unconventional gas drilling. The growth in tax collections, at least through the peak in drilling activity through 2013, tracks with growth in the number of wells being drilled and coming on-line in those three counties.

bar graph shows hotel tax collections in three PA counties 2008-2013

Figure 2: Hotel tax collections in three Pennsylvania counties

Source: Marcellus Center for Outreach and Research

Sometimes the spillover effects from energy project development actually outweigh the size of the direct workforce, meaning that there is a type of multiplier effect to energy development. Economists, in fact, use just this term to describe the size of these spillover effects. The *employment multiplier* (or just “multiplier” for short) is defined as the ratio of the size of the indirect and induced workforce to the direct workforce. A multiplier equal to one means that the spillover effect is just as large as the size of the direct workforce, and a multiplier greater than one means that the spillover effect is larger than the size of the direct workforce. Multipliers have been calculated for many different studies of the oil and gas industry and tend to range between 1.4 and 1.7 (depending on the location and type of activity). Multipliers above 2.0 are very uncommon.

10.3: The Ins and Outs of Workforce Impact Modeling

So, where do all these numbers come from? Most studies of workforce impacts utilize a method known as “input-output modeling.” They use data from the U.S. government to identify how much money flows between different economic sectors in a given year. For example, drilling a natural gas well requires spending a certain amount of money on concrete, electricians and so forth. The U.S. government collects this data from companies that develop natural gas wells and assembles it into gigantic databases. Calculating the workforce impacts amounts to using these databases to see how a dollar invested in one industry trickles through other industries. This process is described in Figure 3, using the Pennsylvania Marcellus Shale as a visual backdrop.

Map shows investment dollars enter the PA economy from within and outside PA.
Map shows some of these dollars are recycled within the PA economy through spending and hiring
Map shows some dollars leave the PA economy for other states and counties.

Figure 3. The process of input-output modeling

Source: Marcellus Center for Outreach and Research

Input-output models can be used to estimate both direct, indirect and induced workforce impacts because the databases collected by the government include data on consumer spending and saving. For example, suppose that the natural gas industry spends ten million dollars within Pennsylvania on a new well. The input-output tables might tell us that for every ten million dollars spent within the natural gas industry, one million of those dollars are spent on construction workers. Those workers represent a direct economic impact. Then, those same input-output tables are used to see how the construction industry spends one million dollars. They might tell us that for every million dollars spent by the construction industry, one hundred thousand dollars are spent on cement. This expenditure on cement would represent an indirect economic impact.

Input-output models are the best tools that economists currently have for estimating workforce impacts associated with any industrial activity, not just in the energy industry. Calculating the direct workforce associated with a specific energy project can be done without input-output modeling (the study referenced above by the Marcellus Shale Education and Training Center is one good example of how this is done) but getting a handle on the size of spillover effects to other sectors of the economy usually requires something like an input-output model.

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10.4: Check Your Understanding

Check Your Understanding

1. Describe the difference between the direct and indirect workforce.

Answer available at the end of this section.

2. Define induced workforce.

Answer available at the end of this section.

3. True or False: The *employment multiplier* (or just “multiplier” for short) is defined as the ratio of the size of the indirect and induced workforce to the direct workforce.

Answer available at the end of this section.

4. True or False: Input-output models can be used to estimate both direct, indirect and induced workforce impacts because the databases collected by the government include data on consumer spending and saving.

Answer available at the end of this section.

5. Which of the following economic impacts is difficult to capture in an input-output model (select all that apply):

- a. Technology improvements in drilling natural gas wells will reduce the number of workers needed on the drill site within the next five years.
- b. Because of natural gas drilling, companies that operate fleets of trucks need to hire more workers and buy more trucking equipment.
- c. Marcellus Shale development in Bradford County, Pennsylvania, will lead to a major decline in unemployment in that County.
- d. If a planned ethane cracking plant is built in Pennsylvania, the availability of low-cost petrochemicals will lead to new industry coming into the state.

Answer available at the end of this section.

Answers

Check Your Understanding

1. *Direct workforce: Construction workers are needed to build a new factory. Once the new factory is built it needs to be staffed with factory workers, administrative assistants, a cleaning crew and so forth. These are all examples of the direct workforce needed to sustain the factory.*
2. *Indirect workforce: The contractors hired to build the factory will need, in turn, to contract with land management companies, law firms and other professionals. These companies will then purchase goods and services from other businesses. When the factory is up and running, the maintenance company hired by the Tesla (in the example) will need to purchase goods and services from other businesses, such as cleaning and plumbing supplies. These are all examples of the indirect workforce that contribute to sustaining Tesla's factory.*
3. *A key difference between the direct and indirect workforce is that those in the direct workforce would essentially be working for Tesla full-time. Those in the indirect workforce, such as the owners of hardware or plumbing supply stores, would sell goods and services to those in the direct workforce.*

Check Your Understanding

In the example given, when Tesla hires people to work at its factory, those people earn wages that are then spent on other things like entertainment, health care and so forth. To the extent that the dollars earned by Tesla workers are re-circulated into the economy, these dollars help to support other jobs. In cases of very rapid build-up of industrial activity (as has happened with unconventional natural gas drilling in Pennsylvania, for example), entirely new businesses can sometimes spring up to serve new workers. These are all examples of the induced workforce.

Check Your Understanding

True

Check Your Understanding

True

Check Your Understanding

The correct answer is (a), (c), and (d). Explanation:

- a. *Economic input-output models are “static” – they describe economic flows at a moment in time. Because industries tend to get more efficient and productive over time, it can be hard for input-output models to make projections about economic impacts in the future.*
- b. *Input-output models capture economic flows between sectors of the economy. If natural gas drillers demand more truck transport because they are drilling more wells, this impact will be captured by the input-output model.*
- c. *Input-output models cannot tell where workers will come from, only that they will be needed in specific economic sectors. These models thus cannot themselves predict changes in employment levels.*
- d. *Because input-output models are static, they are not usually good tools for forecasting growth or contraction in industries other than the one being directly studied. An input-output model would assume that, despite the new ethane cracking plant, industry in Pennsylvania would demand the same amount of petrochemicals as they had historically.*

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10.5: Summary

Energy development is big business. Oil and gas companies, electric utilities and wind and solar power developers have been pouring many billions of dollars into energy infrastructure. Virtually all energy development, whether fossil or renewable, involves heavy industry. There will be economic benefits and economic costs to any particular project. Some economic impacts of Marcellus Shale development are certainly positive, such as lower energy costs. Others are certainly negative, including impacts on existing infrastructure (like roads, bridges and public utilities) and housing costs. We discussed some of these benefits and costs, and in particular the confusing process of determining “job creation” in the energy sector. The article [Will Keystone XL pipeline create 42,000 'new' jobs?](#), provided an example of two very different numbers for new job claims that would be created by Keystone XL. The reason for the confusion comes down to just a few key facts about measuring (and reporting) the workforce implications for energy project development.

1. The total size of the workforce needed to sustain a given level of energy development extends far beyond the people that actually drill wells, lay pipeline or erect wind farms. Part of the disagreement over the Keystone XL and other big energy projects comes down to using different definitions (direct, indirect, induced) of what constitutes the ‘workforce’ and which jobs in which industries are counted.
2. The number of people required to build a large energy project like a gas well or a pipeline is very different than the number of people required to run the project once it is complete. Some jobs may be temporary contract employment while others are more like permanent positions.
3. Creating a job is not the same thing as reducing unemployment, since workers may shift from one job to another. While we often talk casually about the number of jobs that a given energy project will create, it is more correct to refer to the size of the workforce needed to develop and sustain a given energy project.

Input-output models can be used to estimate both direct, indirect and induced workforce impacts because the databases collected by the government include data on consumer spending and saving. Currently, input-output models are the best tools that economists have for estimating workforce impacts associated with any industrial activity, not just in the energy industry. However, there are caveats to keep in mind regarding the input-output model:

1. Input-output models capture the flow of dollars through the economy at a snapshot in time.
2. Input-output modeling can’t differentiate between short-term and long-term workforce needs.
3. Input-output models themselves cannot capture where workers or money come from, only that they exist.
4. Rapid expansion of natural gas drilling in an area may induce new growth in industries with high demand for natural gas. But if these industries did not exist in a region prior to natural gas drilling, or were not very large, then input-output models cannot capture the growth and scale-up that might occur. On the other hand, it is true that if the growth of natural gas drilling caused other industries to shrink or disappear altogether, then this economic contraction would not be reflected in an input-output model.

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11: USING WHAT YOU HAVE LEARNED/OPPORTUNITIES

Overview

This last lesson is designed to provide food for thought on ways to incorporate what you have learned in your day-to-day lives. You now have a grasp of the complexities of the scientific process. With more of a scientific world view, we hope that you will notice and consider opportunities, events, change, and information within a new light. This lesson is comprised of examples, exercises, and encouragement for you to identify and engage in meaningful dialogue with friends, family and community.

[11.1: Orphaned and Abandoned Wells](#)

[11.2: Affinity Groups](#)

[11.3: Summary and Final Tasks](#)

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11.1: Orphaned and Abandoned Wells

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11.3: Summary and Final Tasks

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