Title
A Pipeline in Paradise, Part 1: Learning the relevant science

Authors[1]
Shannon Conley, Kathryn de Ridder-Vignone, Mary Handley, Paul B. Goodall, and Michael L. Deaton

For what courses might this case study be appropriate?
This case study is the first part of larger 3-part interrupted case. This part requires about 1 week of class time (3 hours) plus about 4-6 hours of outside class work. The materials and activities herein are appropriate for use in introductory courses of up to 30 students involving the study of human-environment interactions. Sections of more than 30 students should be divided and run as separate case study groups. Examples include courses covering any subset of the topics below

- Political or human geography
- Introduction to environmental science
- Science, Technology, and Society
- Earth Science

For what level of student is this case appropriate?
This case study can be used with upper division high school through all levels of undergraduate college, with appropriate scaffolding for students, depending on their level and background. The case, as documented here, was designed for sophomore-level undergraduates in an introductory course in Science, Technology, and Society within an integrated science and technology bachelors of science degree program.

Socio-Environmental Synthesis (SES) Learning Goals addressed
1. ***Understand the structure and behavior of socio-environmental systems.***
   (Explicitly addressed). By immersing themselves in a real-life case that involves hydrology, mining technology, geology, regulatory considerations, and social dynamics, students will learn how each of these knowledge domains are manifested in this case (at an introductory level) and explore the interrelationships among those domains. The domains that students will explore are:
   - *Technology and natural science behind hydraulic fracturing*
   - *Environmental issues (the relevant environmental concerns and science associated with hydraulic fracturing)*
   - *Governance (the regulatory environment governing the decision about a pipeline)*
   - *National Energy Security (the role of hydraulic fracturing in the geopolitics of U.S. energy policies)*
   - *Society (the social, political, and economic issues associated with gas pipeline expansions in local communities)*
2. ***Consider the importance of scale and context in addressing socio-environmental problems.***
   Students will explore how the decision about whether to admit a pipeline through the region is affected by governance at a variety of scales: from the decisions of private citizens regarding their own land to state and national regulations affecting the decision. Students will also see how

[1] Faculty in the Department of Integrated Science and Technology, James Madison University, in Harrisonburg, VA (www.isat.jmu.edu)

the benefits and risks associated with hydraulic fracturing and a pipeline can vary greatly, depending on the geographic scale of the analysis. Finally, students will distinguish between the issues associated with hydraulic fracturing and the decision to permit a pipeline, while also delving into the interconnectedness of the two domains.

3. ***Co-develop research questions and conceptual models in inter- or trans-disciplinary teams.***
   During the case study, each student will participate on a "knowledge domain team" that will explore one of the aforementioned knowledge domains. Student teams will synthesize and summarize their findings within each knowledge domain and present their analysis to the rest of the class. All students will develop concept maps showing the main principles within each knowledge domain and how those principles interact across domains.
4. ***Find, analyze, and synthesize existing data, ideas (e.g. frameworks or models), or methods.***
   In order to learn about their assigned knowledge domains, students will acquire, analyze, and interpret data on the history of hydraulic fracturing in the context of national energy security. Students will evaluate data and information on the environmental and social risks associated with hydraulic fracturing and the proposed pipeline. They will also review and evaluate the arguments for or against these technologies from the perspective of the various knowledge domains.

Case Learning Objectives and SES Learning Goals

Case Study Learning Objectives Students will....	SES Learning Goals			
	Understand structure & behavior of S-E systems	Consider importance of scale & context in S-E problems	Develop res. questions & models in inter- or trans-disciplinary teams	Find, analyze, and synthesize existing data and ideas
Identify the five knowledge domains in the case study that are relevant to the Madison County, VA Board of Supervisors' decision to either permit or prohibit the routing of a natural gas pipeline through the area.	Directly related			
Use concept diagrams to describe the relevant principles and findings within each domain and their interrelationships across domains	Directly related			
Use appropriate terminology and graphical representations to accurately explain how hydraulic fracturing works to extract oil and natural gas from Marcellus shale fields.	Indirectly related		Indirectly related	Directly related
Explain the relationships between the gas, water, and the land (i.e the geoscience behind the Marcellus shale gas fields), and how those relationships are potentially affected by hydraulic fracturing.	Directly related			Indirectly related
Identify and describe the governance structures and regulatory environment at the local, state, and national levels that impact the policy-making actions of the Madison County Board of Governors with respect to the proposed pipeline.		Directly related		
Describe at both the local and regional scale the potential environmental benefits and risks associated with hydraulic fracturing and the proposed pipeline through Madison County, VA.		Directly related		
Find and analyze relevant data to understand the debate around hydraulic fracturing, as well as the benefits and risks of allowing a pipeline to run through Madison County, VA.				Directly related

Introduction to the Case Study

This case study focuses on the people and landscape of Madison County, VA, through which Spectra Energy wishes to route a natural gas pipeline that runs from the marcellus shale hydraulic fracturing wells in Pennsylvania to Duke Power's generating plans in North Carolina. The case provides a rich context for students to explore the natural science, political context, and social dynamics associated with hydraulic fracturing and with that community's decision and power to permit (or not permit) the pipeline.

The "hook" is a story about a real-life centenarian landowner named Culton Goodall, who owns a beautiful farm on the proposed pipeline route. Mr. Goodall's family has owned this farm for generations. Their care and love for the land is evident by their progressive and sustainable land use practices. The story opens when Mr. Goodall is visited by a Spectra Energy representative who requests permission to survey the farm and evaluate the feasibility of the pipeline. Students are are introduced to Mr. Goodall, his land, and the beautiful landscape around Madison county via a recorded 8 minute video created by Mr. Goodall's son, Paul (a faculty member in JMU's Department of Integrated Science and Technology). The video ends by posing the question: "What should Mr. Goodall do?" The video can be found here.[2]

This case study is the first part of a larger 3-part case study in which each step guides students through three different types of analyses of this problem. This current case (Part 1) requires students to integrate information across the following five "knowledge domains" to develop a baseline understanding of the problem: (1) technology and natural science, (2) environmental issues, (3) governance, (4) national energy security, and (5) society. Students gain a more complex understanding of the problem by learning how to interpret knowledge from different disciplines, make connections across domains, and evaluate sometimes conflicting perspectives.

Parts 2 and 3 of the larger case study will be submitted separately under the SESYNC website. ***Part 2: Understanding Stakeholder Perspectives*** requires students to look at the pipeline decision through the lenses of several different stakeholders. In ***Part 3: Making Recommendations*** students are assigned roles as either a knowledge domain expert, a stakeholder, or a member of the Madison County Board of Supervisors. All these roles come together in a meeting of the Board of Supervisors, where a recommendation will be made regarding the proposed pipeline through Madison County. In Figure 1 below we have created a graphical representation of the relationship of each of these three parts to one another. Part 1 on knowledge domains is more fully detailed.

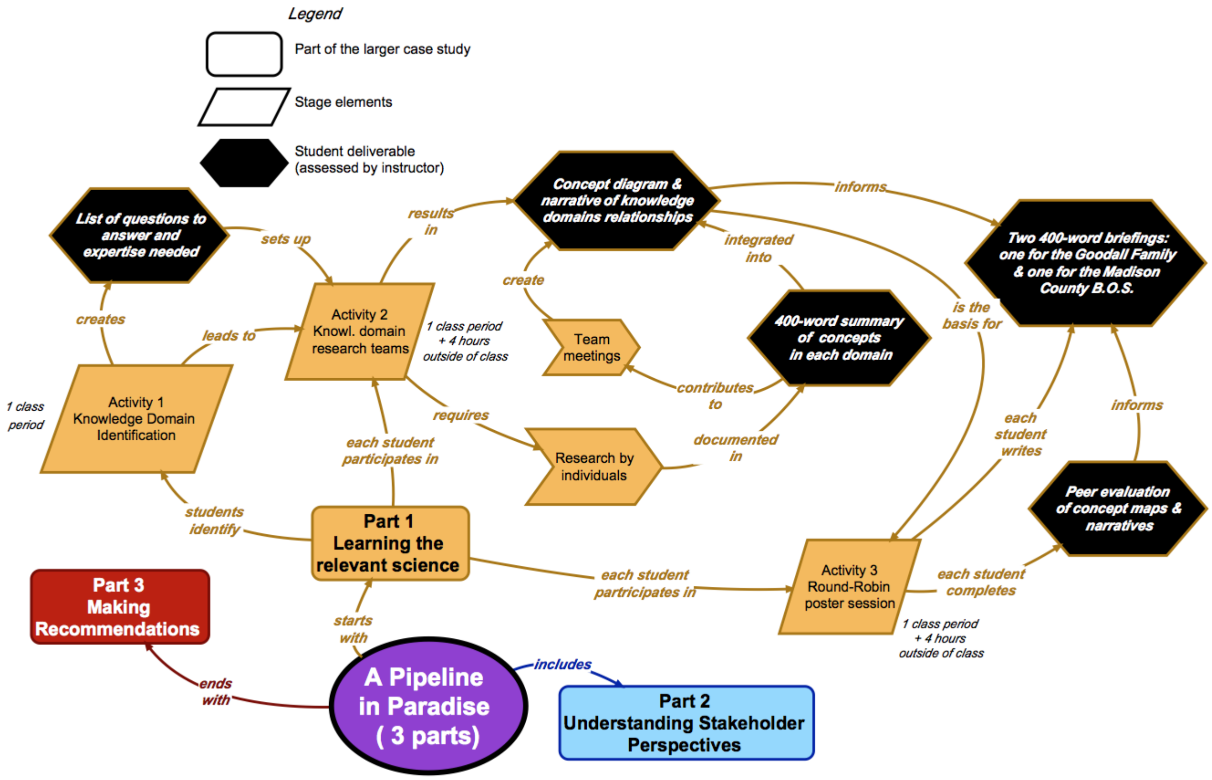
The main purpose of this case study is to help students grasp the interdisciplinary nature of S-E problems and to gain experience in building and integrating a baseline of knowledge that is relevant to a particular problem. By completing this case study, students will also gain experience in the use of brainstorming, concept maps, and team management practices that are useful for tackling S-E problems. Students demonstrate their competency in the learning objectives for this case through a series of deliverables. These are:

- From each student: Participation in a brainstorming session to identify questions and areas of expertise that should be addressed in the pipeline decision
- From each student: A 400-word summary of their findings with respect to a single knowledge domain to which they were assigned. This demonstrates their ability to acquire, digest, synthesize data from a variety of sources, and use those data to communicate useful information and insights that are relevant to the case.
- From each knowledge domain team: A concept map integrating the analysis across five relevant knowledge domains, plus a 600-word written narrative that "tells the story" represented in the concept map.
- From each student: An evaluation of the concept maps and narratives from each of the other teams in class. The evaluation is based on a rubric provided by the instructor (and included in the student materials), and it provides students with an opportunity to evaluate their own work and compare it to the work of others, all the while applying criteria provided by the instructor.

[2] http://jmutube.cit.jmu.edu/users/goodalpb/presentations/It_s_Complicated_PBG_10_16_14_20141016_111046_12.zip.content/

- From each student: Two 400-word briefing papers; one written to the Goodall family, and one written to the Madison County Board of Supervisors. Each paper provides the arguments for and against the pipeline decision, as it relates to the audience for the paper. These arguments will be based on what the relevant science has to say about the decision and will identify outstanding questions or issues that may yet need to be addressed.

Figure 1: The Three-Part Case Study, with Details for Part 1: Learning the Relevant Science



Classroom Management - The three activities comprising this case study

1. **Activity 1: Knowledge Domain Identification**
   a. Length: Approximately 50 minutes of class time
   b. Purpose
      i. To introduce the story and decision dilemma posed in the case study.
      ii. To help students recognize the wide range of disciplines and knowledge domains that can help inform the decision about the pipeline by the Goodall Family and the Madison County Board of Supervisors.
      iii. To “set up” the idea of knowledge domains and the knowledge domain research teams that are used in Activity 2.
   c. General description
   This is a brainstorming exercise in which students identify questions that should be considered in the pipeline decision, followed by the development of themes or knowledge domains that are represented by the questions.
   d. Relevant handouts (all found in the ***Student Handouts*** document)
      i. ***Introduction - A Pipeline in Paradise***. This introduces the problem and directs students to the 8-minute video introducing the Goodall farm and the pipeline dilemma.

ii. ***Activity 1: Brainstorming Exercise - What kind of knowledge is needed?*** Directions for the brainstorming activity

e. Student deliverables from Activity 1: None

f. Logistics: Running the activity (50 minutes)

   i. Before this exercise: Determine which of the five knowledge domains will be assigned to each student. Also divide the students into 5-student teams, where each team will have one student from each knowledge domain. Don't reveal any of this to the students yet. Save it for the end of the class period.

   ii. Make sure you have a classroom with lots of empty wall space. *While teams can work at their own tables, you will need about 3 ft x 5 ft of wall space for all the teams to display their post-it notes on a common wall. The key is to provide a common wall space for them to see each other's ideas (on post-it notes) and to consolidate those ideas into natural themes that run across all teams.*

   iii. (5 minutes) Pass out the document entitled ***Introduction - A Pipeline in Paradise***. Give students 5 minutes to read the document

   iv. (8 minutes) Show the video giving an introduction to the Goodall farm and the decision that must be made

   v. (25 minutes) Brainstorming exercise

      1. Split the students up into tables of 3-4 students each (groups of more than 4 can be counterproductive, as some students may not feel as much need to contribute).
      2. Give each group a stack of 30-40 small post-it notes. Pass out the ***Brainstorming Exercise*** handout let the teams work.
      3. Circulate among the teams to answer questions, clarify directions, etc. You might need to "seed" their thinking to help them think more broadly than, short-term concerns. You can do this by asking questions that can prompt student thinking about areas they've not considered.
      4. Monitor the process and watch for emerging themes of post-its. As themes emerge, make sure students draw a circle around them and name them, like "Environmental expert" or "Farming expert" or "Lawyer" Encourage students to use the themes already placed on the board by other teams, but also to create new ones, if needed. After about 10 minutes of work on the front board, have everyone sit down. *NOTE: This activity can be too chaotic with classes bigger than 30 or so students. If you have are using this case study in a much larger section, we suggest splitting the section into two separate groups for this activity and placing each group in a separate room. You can then combine the groups back together for the final wrap-up.*
      5. Explain to the class that the themes on the board represent different kinds of "knowledge domains" that are needed to make a good decision about the pipeline. Explain that most real-life problems in which humans are making decisions about how to use their natural resources involve a wide range of questions and areas of knowledge. The same is true for this problem. In the next activity we will now work in teams to begin answering some of these (and other questions).

   vi. (10 minutes) Debrief

      1. After the above exercise, the students should have created several "expert groups" of questions, where the questions within a group would require a common kind of expertise, but different than the expertise required for another group.
      2. Write the five knowledge domains on the board (technology and natural science; environmental issues; governance; national energy security; society) and briefly explain what each domain stands for.
      3. Ask the students to compare this list of knowledge domains with the various areas of expertise identified by them in the brainstorming exercise. Ask them (in their teams) to place each of their brainstorming "expert categories" under one (or more?) of the knowledge domains. Let the groups report out and clarify misunderstandings.

4. Pass out the directions for Activity 2 (document entitled ***Activity 2: Knowledge Domains - Learning the Relevant Science***). Go over and answer questions.
5. Let the students know their knowledge domain and team assignments.
6. Dismiss class.

2. **<u>Activity 2: Knowledge Domains - Learning the Relevant Science</u>**
   a. Length: 50 minutes of class time + 2-4 hours individual research time + 2 hours team meetings
   b. Purpose
      i. To develop a baseline of knowledge across five knowledge domains that are relevant to the case study
      ii. To integrate that knowledge into a "big picture" description of how the relevant physical, engineering, social, and political science can inform the decision about a pipeline for both Mr. Goodall and for the Board of Supervisors
      iii. To give students practice in working on an "interdisciplinary team"
   c. General description
   This is a "crowd-sourced" research activity, where each student conducts research in an assigned knowledge domain, develops answers to a set of questions, and then summarizes their findings for the other members on their team (each team having at least one student assigned to each of the five knowledge domains). Each student will turn in a 400-word summary of their findings in their assigned domain. The team will jointly develop and turn in a concept map and accompanying narrative that describes the relevant science and how that science informs the decision about a pipeline.
   d. Relevant handouts
      i. ***Activity 2: Knowledge Domains - Learning the Relevant Science*** (NOTE: The Evaluation Rubrics for the 400-Word Summaries created by each student and the concept map and narrative created by each team are included in that document.)
   e. Student deliverables from Activity 2
      i. From each student: A 1-page summary of their findings in their assigned knowledge domain (ASSESSED BY: ***Evaluation Rubric: 400-Word Summary of Your Assigned Knowledge Domain***, found in the above ***Activity 2*** handout)
      ii. From each team: A concept map integrating the information across the knowledge domains, coupled with a 600-word narrative (ASSESSED BY: ***Evaluation Rubric: Integrated Concept Map of Knowledge Domains***, found in the above ***Activity 2*** handout)
   f. Logistics - Running the Activity
      i. CLASS MEETING #0 - PRE-PREPARATION (10 min): To be done at the end of the class period in which Activity 1 was done.
         1. Pass out the document entitled ***Activity 2: Knowledge Domains - Learning the Relevant Science***. Go over and answer questions.
         2. Assign each student to one of the knowledge domain teams.
         3. Arrange the students into teams of at least five students each, where each team includes at least one student assigned to each knowledge domain.
      ii. OUT-OF-CLASS INDIVIDUAL WORK (approx. 2-4 hours): Each student will conduct research on their assigned knowledge domain (based on assigned readings + 1 additional and credible reading that they find). Based on this research, each student will prepare a 1-page summary of their findings in their assigned domain. The instructions for preparing this summary are found in the document ***Activity 2: Knowledge Domains - Learning the Relevant Science***.
      iii. NEXT CLASS MEETING: TEAM MEETING (50 minutes). Students will come to class and meet in their Knowledge Domain teams.
         1. Each student will spend 4-6 minutes summarizing for their team members their findings from their research. If more than one person was assigned to a given knowledge domain, those students must individually summarize their analyses.

2. Each team will appoint a SCRIBE to take notes on the board or a chart pad visible to the rest of the group. The purpose of the scribe is to highlight the main ideas that emerge from the summaries. This will be used by the team as they work on their concept map.
3. The instructor can circulate among the teams to monitor progress and answer questions or provide (minimal) direction. In the last 20 minutes of class (approximately), the teams can begin formulating their concept map.
4. Before leaving, each team must identify a time and place for their next meeting (prior to the next class session) and provide that information to the instructor. The purpose of the out-of-class meeting is to finalize their concept map and the “story” that it tells.

iv. OUT-OF-CLASS TEAMWORK (approx 2-4 hours): Each team must meet at least once before the next class meeting to create a concept map that integrates the findings across all the knowledge domains. A large, neat poster-sized version of the concept map must be prepared and brought to the next class, along with 6 copies of a 1-2 page narrative that tells the story represented in the concept map. These will be used in the last activity (Round Robin Poster Session). After the Round Robin Poster Session, the concept map 1-2 page written narrative will be turned in for a grade.

3. ***Activity 3: Round Robin Poster Session***
   a. Length: 50 minutes of class time
   b. Purpose
      i. To gain practice in evaluating concept diagrams (and accompanying narrative) for clarity, correctness, and demonstration of interactions among domains
      ii. To prepare students to each write their own 1-page summary and reflections on the entire case study experience.
   c. General Description
      This as structured poster session in which each of the Knowledge Domain teams will have an opportunity to review and evaluate all the teams’ efforts to understand and integrate the science associated with the pipeline decision (including their own team’s work). Each team will hang up a poster-sized copy of their concept maps and provide multiple copies of the 600-word narrative for interpreting the map. During each fixed-length time window, each student will review one other team’s concept map and read their narrative. The student will evaluate each team’s work using the ***Round Robin Rubric: Integrated Concept Map and Narrative (***found in the Student Handouts***).*** These will be turned into the instructor. During successive time windows, students will circulate to the next team’s station and repeat the process...continuing in this way until all stations have been visited by all students. Each student will evaluate their own team’s work last. This gives them a better perspective on what excellent or poor work looks like when they evaluate their work.
   d. Relevant Handouts
      i. Round Robin Rubric: Integrated Concept Map and Narrative
      ii. Wrap-up: Final Briefing Papers (includes an evaluation rubric for this assignment)
   e. Student deliverables from Activity 3
      i. Each student will complete evaluation rubric for all of teams in class (including their own) and present it to the instructor. After checking for completeness and hiding the names of the evaluating student, instructor will give the evaluations out to the teams (ASSESSMENT: A student’s score is based on the extent and quality of involvement. (0 = student did not participate; 1 = unacceptable; participated but either did not complete all evaluations or provided superficial feedback; 2; 3 = acceptable; completed all evaluations, with some effort at meaningful feedback; 4; 5 = Outstanding; completed all evaluations; consistently substantive feedback))

Evaluation Rubric: Student participation in the Round Robin Poster Session

Level of participation	Score
None; Student was absent or, if present, did not actively participate	0
Unacceptable: Student either did not complete evaluations or provided only superficial feedback	1
	2
Acceptable: Student completed all evaluations, with some evidence of substantial feedback in a few cases	3
	4
Outstanding: Student provides substantive feedback to all teams	5

ii. Following the Round Robin Poster Sessions, each student will prepare a two separate 1-page briefing papers. One will be addressed to the Goodall family, and the other to the Madison County Board of Supervisors. The briefings will explain to each audience those items that must be addressed in order for a good decision about the pipeline to be made. j (ASSESSMENT: ***Evaluation Rubric: Final Briefing Papers for Goodall Family and Board of Supervisors***, found in the handout entitled ***Wrap-up: Final Briefing Papers***).

f. Logistics: Running the activity

i. Before class make multiple copies of the ***Round Robin Rubric: Integrated Concept Map and Narrative***. This is the same rubric that the students have access to in the Activity 2 handout, but is adapted to provide spaces for students to give their name and the names of the team members they are evaluating. The number of copies needed is #students in class * #teams. SUGGESTION: In order to identify which team's work is being evaluated on each complete rubric, try using a different color for each team. Then place a stack of the same color by each team's station.

ii. Make sure you have sufficient wall space for all teams to hang their concept maps.

iii. Each team should bring at least as many collated and stapled copies of their 1-2 page narrative as there are teams in the class.

iv. Arrange the room so that each team has a small table or chair by their poster where they can place copies of the narrative that explains their concept map.

v. Based on the total number of teams in the class, define the time interval for each round of reviews. Assume you will lose 10 minutes (at least) for set-up and break down of the class before and after the exercise. So, for a 50-minute class, you have about 40 minutes for the poster session. If you have 5 teams, then you will need 5 time windows (one for reviewing each team). Hence, you should use eight-minute time windows.

vi. Make sure the teams split up so that a given team does not travel as a group around to the other teams.

vii. Also make sure that each team evaluates their own poster and narrative last. This gives them some basis for comparing the quality of their work to the work done by other teams (hopefully leading to more realistic self-assessment).

viii. During each time window, each student will go to one of the stations, examine the concept map, and read the accompanying narrative. They will evaluate the work at that station by filling out the rubric (color coded) left at that station. Each student should hold onto their color-coded completed rubrics until the end of class, when they turn them into the instructor (with their name on each).

ix. At the end of the class period, collect all of the completed rubrics.

Blocks of Analysis

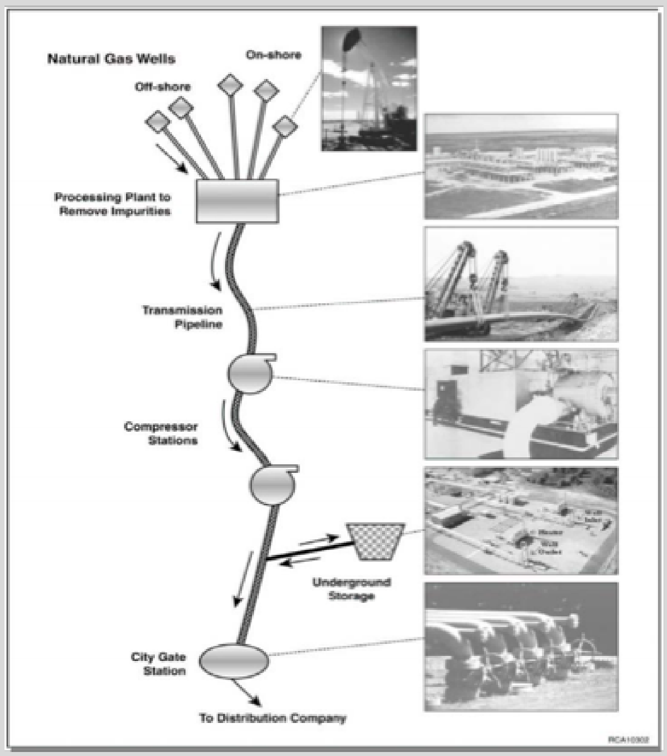
- The core science related concepts in this case study are covered in the assigned readings under each of the knowledge domains research assignments. These readings are found in Table 1 of the document entitled ***Activity 2: Knowledge Domains - Learning the Relevant Science***.
- A summary of the main ideas and concepts under each of the five knowledge domains are given below.

Domain 1a. Technology and Science Domain - Pipeline Technology

Questions the students are asked to explore in this knowledge domain

- *What is hydraulic fracturing? How does it work?*
- *My is there so much gas in the marcellus shale?*
- *How would a pipeline be built in the county? Where would it go? What effect would it have on land and animals?*
- *One additional question that you identify from this knowledge domain.*

Once it leaves the producing area, a pipeline system directs flow either to a natural gas processing plant or directly to the mainline transmission grid. The natural gas mainline (transmission line or trunkline) is a wide-diameter, often-times long-distance, portion of a natural gas pipeline system located between the gathering system (production area), natural gas processing plant, other receipt points, and the principal customer service area(s).



Schematic of Natural Gas Production, Processing, Transmission, and Storage (Source: Cirillo et al. 2003)

Pipeline materials and construction

Pipelines are made of high-strength steel pipe, and operate at pressures up to 1400 pounds per square inch. They range in size from 6 to 48 inches in diameter; long distance transport pipes are usually 30-36 inches in diameter. Pipe sections are factory-coated to protect the pipe from corrosion and rusting. The coatings are often fusion-bond epoxy or polyethylene. Cathodic protection is also used.

The individual sections are welded as the pipeline is assembled. Every weld is tested with X-ray and/or ultrasonic inspection; epoxy or polyethylene coatings are applied to each welded joint after inspection. The entire pipeline is then inspected for defects in the coating before being lowered into the trench. Before lowering, the ends of the pipes are capped and the bottom of the trench is inspected. In steep, rocky, or otherwise difficult terrain the trench and/or the pipe are protected with shields, foam, wraps, or padding to protect the pipeline. After lowering, the trench is backfilled and topsoil replaced. Hydrostatic testing is performed after the pipeline is installed to ensure that the pipeline can withstand the operating pressure. Once the line passes this test the final tie-ins are made, the pipeline is cleaned and dried with pressurized dry air and all operating systems are tested. Finally, air is purged from the pipeline and natural gas is loaded.

Additional Components of a pipeline system

- **Compressor Stations:** Compressor stations are placed at 40 – 100 mile intervals along the pipeline to boost pressure that is lost to friction and thereby maintain the movement of natural gas along the pipeline. These stations also filter out any water or other liquids that have condensed out of the gas.
- **Safety Cutoff Valves and Meters:** To address the potential for pipeline rupture, safety cutoff valves are placed every 5 to 20 miles along the pipeline. They close automatically for emergency shutdown and are manually closed for pipeline maintenance.
- **SCADA systems:** Supervisory Control and Data Acquisition (SCADA) systems continuously monitor flow rate, status, temperature, and pressure along the pipeline.

Installing a pipeline

Pipelines are normally installed with 30 – 36 inches between the top of the pipe and the soil surface, deeper at road/water crossings, shallower in rock. The right of way (i.e. the the pathway through which the pipeline is routed through a given section of land, and that must remain accessible to the pipeline company to maintain the line) is usually 75 – 100 feet wide during construction but may be wider for road or stream crossings. The permanent right of way is usually about 50 feet wide.

After a company has received authorization from FERC as well as all necessary permits, and has an easement on a property, construction would proceed as follows:

1. The civil survey and any uncompleted environmental surveys are completed and the construction right-of-way would is marked for the clearing crew.
2. The clearing crew removes any trees or brush within the right of way that would interfere with construction.
3. Temporary erosion control devices are installed as required.
4. The right-of-way is graded.
5. Topsoil is separated from subsoil in agricultural/residential areas (or in other areas requested during the easement negotiations.)
6. Heavy equipment digs the trench. In areas where bedrock is near the surface, blasting may be required.
7. The pipe is delivered to the right-of-way in segments (called joints)
8. The pipe is bent to fit the trench and welded together. All welds are tested prior to placing the pipe in the trench.
9. The trench is backfilled and topsoil returned.
10. Construction debris is removed.
11. The right-of-way is regraded, seeded, and erosion control devices are installed.
12. Prior to gas flowing, the pipeline is pressure tested (normally with water) to be sure it does not leak.
13. Any water or debris in the pipeline is removed, and the pipeline is dried completely. Air is purged from the system and natural gas is loaded.

Domain 1b. Technology and Science Domain - Hydraulic Fracturing

(NOTE: Unless otherwise indicated these notes summarize and quote directly from from USGS, 2009, ***Water Resources and Natural Gas Production from the Marcellus Shale****)*

What is shale gas?

Shale gas is natural gas produced in shale formations that arose from sediment deposition and consolidation over time. The clay-sized particles in the sediment compact into a thinly-layered sheet that also contains remains of organisms and organic debris. This debris decomposes anaerobically over time to produce natural gas. The low permeability of the shale prevents the gas from escaping, resulting in a reservoir of high quality natural gas. Large shale gas formations are present in many locations in the US. The principal hydrocarbons normally contained in the natural gas mixture are methane, ethane, propane, butane, and pentane. Typical non-hydrocarbon gases that may be present in reservoir natural gas are water vapor, carbon dioxide, helium, hydrogen sulfide, and nitrogen.

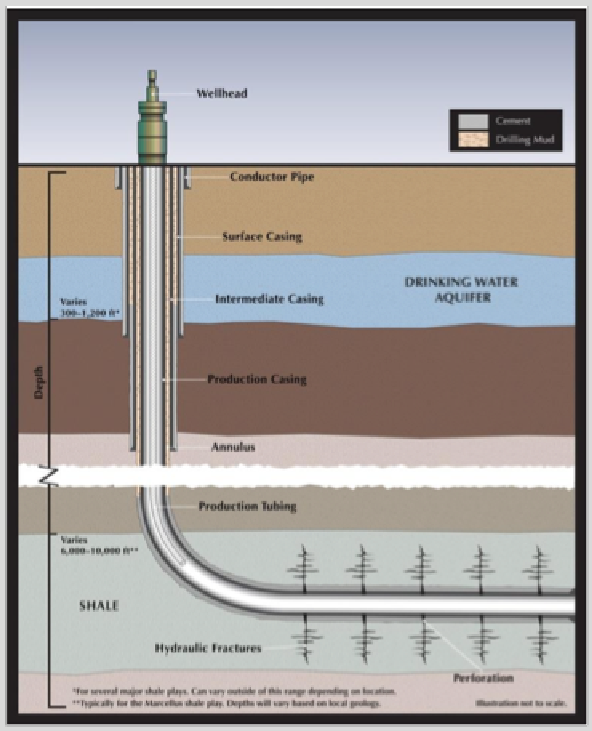
The Marcellus Shale basin (or play), also referred to as the Marcellus Formation, is a Middle Devonian-age black, low density, carbonaceous (organic rich) shale that occurs in the subsurface beneath much of Ohio, West Virginia, Pennsylvania, and New York and small portions of Maryland, Kentucky, Tennessee, and Virginia. It is the largest shale gas formation in the US with an estimated area of 95,000 square miles.

How is shale gas extracted?
(summarized from H. King, ***Marcellus Shale - Appalachian Basin Natural Gas Play,*** *http://geology.com/articles/marcellus-shale.shtml)*

Natural gas occurs within the Marcellus Shale in three ways: 1) within the pore spaces of the shale; 2) within vertical fractures (joints) that break through the shale; and, 3) adsorbed on mineral grains and organic material. Most of the recoverable gas is contained in the pore spaces. However, the gas has difficulty escaping through the pore spaces because they are very tiny and poorly connected. Producing natural gas from a shale bed includes the following steps: road and well pad construction, drilling, casing, perforating, hydraulic fracturing, completion, production, abandonment, and reclamation.

<u>*Drilling and casing*</u>
(summarized from ***Modern Shale Gas Development in the United States: A Primer****, U.S. DOE. 2009)*

Drilling and casing of gas wells includes both vertical and horizontal drilling, with casing and cement installed to protect aquifers. Vertical wells are drilled until the borehole gets close to the shale formation. Then a directional drill is used to curve the borehole which becomes horizontal as it reaches the shale. The horizontal drilling continues for a mile or more. Horizontal drilling provides more exposure to a gas formation, and since multiple horizontal wells can be drilled from the same well pad, the number of surface installations is reduced.



Typical Configuration for a Horizontally Drilled, Hydraulically Fractured Shale Gas Well
http://www.afdc.energy.gov/uploads/publication/anl_hydraulic_fracturing.pdf

Drilling fluid (often called mud) is pumped into the borehole during drilling to help cool and lubricate the drill bit, maintain pressure, prevent cave-ins, and bring rock cuttings to the surface. The mud contains water and a complex mix of additives to adjust weight, viscosity, and lubrication. Drilling muds return to the surface, where the solids (rock cuttings) are separated and the liquids can be reused.

As drilling progresses, steel casing pipe is installed into the well and cement is pumped into the space between the casing and the surrounding rock. The entire length of the well is cased and cemented in order to protect aquifers from contamination and to prevent leakage of natural gas.

Vertical vs. horizontal wells

Most historic wells in the Marcellus produced gas at a very slow rate because of the low permeability mentioned above. This is typical for shale. The most successful historic wells in the Marcellus are found in areas where the shale has numerous fractures. Fractures allow the gas to flow through the rock unit and into the well. The fractures intersecting the well also intersect other fractures and those fractures intersect still more fractures. Thus, an extensive fracture network allows one well to drain gas from a very large volume of shale. A single well can recover gas from many acres of surrounding land. The fractures (also known as "joints") in the Marcellus Shale are vertical. So, a vertical borehole would be expected to intersect very few of them. However, a horizontal well, drilled perpendicular to the most common fracture orientation should intersect a maximum number of fractures. Horizontal drilling has made it more economically feasible to drill in shale formations.

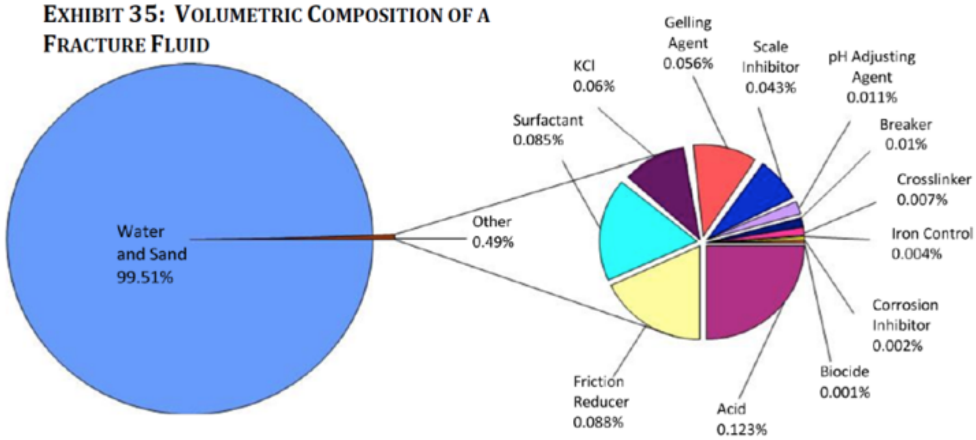
Hydraulic Fracturing (Fracking) (Unless otherwise indicated, this material is summarized and quoted from Clark, et al, 2013)

Creating and expanding fractures in the shale allows even more gas to flow to the well. To do this, large volumes of hydraulic fracking fluid are pumped into horizontal wells under high pressure. Fracking fluid is a water based fluid that contains additives that help the fluid penetrate into fractures in the shale beds, biocides to inhibit microorganism growth and sand proppants to hold the fractures open so gas can move into the well. Between 2 million and 4 million gallons of fluid will be injected into each well. If gas production from a well slows down it may be fracked again to extend production.

To prepare a well for fracking, small pores are created in the horizontal portion of the well casing, and then fracking fluid is injected under very high pressure forcing it out through the pores and into the surrounding rock. The high pressure fractures the rock and pushes the fractures open. When the fracturing occurs millions of sand grains (proppants) are forced into the fractures, keeping them partially open when the pressure is reduced. This provides an improved permeability for the flow of gas to the well.

Fracking requires several million gallons of fracking fluid for each well. This fluid flows back out of the well when the pressure is released. Flowback water contains fracking chemicals as well as chemicals from the environment that leach into the liquid. Flowback water may be reused in subsequent fracking operations. Past disposal methods have included direct dumping and wastewater treatment; today disposal is usually at injection wells to prevent the fluids from contaminating surface water or other drinking water sources.

EXHIBIT 35: VOLUMETRIC COMPOSITION OF A FRACTURE FLUID



Source: ALL Consulting based on data from a fracture operation in the Fayetteville Shale, 2008

http://energy.gov/sites/prod/files/2013/03/f0/ShaleGasPrimer_Online_4-2009.pdf

Collecting and Purifying the gas

Gas enters the well and is sent to a series of small collector pipelines that connect to larger pipelines. Most natural gas is processed to remove water and other impurities before being sent to transmission pipelines.

Domain 2: Environmental Issues of Natural Gas Drilling and Pipeline Transmission

Questions the students are asked to explore in this knowledge domain

- *What are the possible environmental risks associated with fracking and a pipeline?*
- *What is the evidence that those risks are real? How strong is that evidence?*
- *What questions are still unanswered about the risks from fracking or the pipeline?*
- *One additional question that you identify from this knowledge domain.*

The environmental impacts of natural gas drilling and pipeline construction and operations are hotly debated by the various stakeholders involved in the process. This overview presents a compromise between the doom and gloom of the opponents and the rosy picture of the industry proponents. It provides a brief review of the possible impacts with a limited discussion of the strength of the evidence and unanswered questions.

Direct Impacts primarily attributed to well drilling and fracking

(Unless otherwise indicated, this material is summarized and quoted from Clark, et al, 2013)

1. *Climate change*
   Methane is a potent greenhouse gas, with a global warming potential 25 to 75 times greater than that of CO_2, depending on the time horizon being considered. Combustion of methane produces less carbon dioxide than coal or petroleum, but the biggest risk is the release of methane through leakage and venting. Significant amounts of methane escape during hydrofracking as the flowback water is removed from the well. There are control measures that can reduce these emissions but data on their implementation and effectiveness is extremely limited. Other emissions come from leaks and venting. Estimates of the lifetime emissions are between 3% and 8% of total production. Combining methane emissions with direct and indirect emissions of CO_2, the GHG footprint of shale gas is significantly larger than that for coal or oil on a 20 year horizon and similar to the footprint of these other fossil fuels on the 100 year horizon.

2. *Air quality*
   In addition to methane, other air pollutant compounds are released during shale gas production. These include many different hydrocarbons, including hazardous air pollutants such as benzene. Nitrogen oxides and particulates are released by the equipment used in the operations. Ozone levels may also be higher as these primary pollutants react in the atmosphere. The sand proppants used in fracking fluid generate silica dust during mining, transporting, and mixing with fluid. Silica dust is considered a hazardous air pollutant that can lead to lung cancer and silicosis. This is a serious worker health issue and may also impact local communities.

3. *Water quality and availability*
   Hydraulic fracturing involves injecting large amounts of water mixed with chemicals and sand into the shale layer to open and enlarge pores and fractures so the natural gas can flow into the wellbore. Table 1 lists several chemical additives that are commonly used in fracking fluid. Drilling and fracturing just one well requires between 2 and 7 million gallons of water. Much of this fracking fluid flows back out of the wellhead, carrying with it the original chemicals and any other substances that have dissolved into it. Wells also continue to produce water throughout

the operating life of *the* well. The water contains methane, fracking fluid additives, high levels of dissolved solids, and naturally occurring radioactive materials (NORM) such as radon gas. These chemicals pose a hazard to waterways and groundwater if released. Because of the high concentrations of dissolved solids (a single well can produce more than 200 tons of salt during flowback) the water cannot be treated at conventional wastewater treatment plants. Two disposal options are injection into deep wells or treatment for reuse in another well. (Vidic et. al.) A newer option is to frack with nitrogen gas, which eliminates many of the water quality issues. This is a relatively new technology and may not be appropriate for the Marcellus shales because of their depth. (Kothare, 2012)

Table 1: Common chemical additives for hydraulic fracturing. (Vidic et. al., 2013)

Additive type	Example compounds	Purpose
Acid	Hydrochloric acid	Clean out the wellbore, dissolve minerals, and initiate cracks in rock
Friction reducer	Polyacrylamide, petroleum distillate	Minimize friction between the fluid and the pipe
Corrosion inhibitor	Isopropanol, acetaldehyde	Prevent corrosion of pipe by diluted acid
Iron control	Citric acid, thioglycolic acid	Prevent precipitation of metal oxides
Biocide	Glutaraldehyde, 2,2-dibromo-3-nitrilopropionamide (DBNPA)	Bacterial control
Gelling agent	Guar/xantham gum or hydroxyethyl cellulose	Thicken water to suspend the sand
Crosslinker	Borate salts	Maximize fluid viscosity at high temperatures
Breaker	Ammonium persulfate, magnesium peroxide	Promote breakdown of gel polymers
Oxygen scavenger	Ammonium bisulfite	Remove oxygen from fluid to reduce pipe corrosion
pH adjustment	Potassium or sodium hydroxide or carbonate	Maintain effectiveness of other compounds (such as crosslinker)
Proppant	Silica quartz sand	Keep fractures open
Scale inhibitor	Ethylene glycol	Reduce deposition on pipes
Surfactant	Ethanol, isopropyl alcohol, 2-butoxyethanol	Decrease surface tension to allow water recovery

The large volumes of water required for fracking have the potential to affect local water supplies, particularly in drought periods or in areas with low rainfall. This water often has to be trucked to the well site, causing damage to local roads, noise and traffic problems, and air pollution. Road damage may lead to erosion and sediment deposition in local watersheds. Major land use changes in agricultural or forested lands will accompany large-scale development of the Marcellus shale play. Fragmentation and urbanization will change watersheds throughout the region. Downstream impacts should be considered as wells are developed.

4. *Earthquakes*
   Deep well injection of waste water has been linked to an increased number of small seismic events.

Impacts primarily attributed to pipeline construction and operation

Several of the impacts associated with drilling and well operation also extend to pipelines, especially the risk of explosion and emission of GHG from leaks or damage to pipelines. Other risks are more specific. These include land disturbance and land use change due to easements and right of way vegetation alterations, particularly across sensitive ecological areas such as wetlands and riparian zones. Ecological impacts include loss of habitat and habitat fragmentation. In addition to ecological impacts, agricultural production and tourism are also impacted.

Land disturbance and clearing can increase stormwater runoff and erosion potential which can affect aquatic communities due to sedimentation, and also impact drinking water supplies downstream from the pipeline. Additional concerns include the integrity of water transport infrastructure (pipelines from reservoirs to cities) and other subsurface infrastructure that might be disturbed by pipeline installation.

Indirect impacts

While not often considered in a list of environmental problems, health and safety issues for workers and community members are part of the environmental impact. Natural gas extraction and related industries are historically dangerous occupations. Exposure to the toxins in fracking fluid, silica dust from sand mining and mixing, and air pollutants can all be hazardous to workers and community members living near a gas well. Blowouts, fires, and explosion hazards are also present.

Development of a new resource like the Marcellus shale play or installation of a new pipeline will affect the community. Noise and light pollution, odors, dust, damage to roads and other infrastructure, increased traffic congestion, housing shortages as population increases with an influx of workers, increased need for schools, public safety and fire/emergency response, health care shortages—all are possible community health problems associated with rapid community change. The boom and bust cycles associated with extractive industry development are difficult for small communities to manage. (Korfmacher, 2013)

Tradeoffs

Many studies fail to account for the impacts avoided by substitution of gas for coal. This is especially true for climate change impacts and provides some rationale for the development of shale gas production. In addition, it is projected that by 2030 the U.S. will be some a net energy exporter, largely because of shale gas production.

Domain 3: Governance

Questions the students are asked to explore in this knowledge domain

- *What are the "legal ground rules" that dictate where a pipeline might go?*
- *What decisions about the pipeline can be made at the individual level (i.e. by individual landowners), the county level (by the Board of Supervisors), the state level, and the national level? Which decisions "trump" the others?*
- *One additional question that you identify from this knowledge domain.*

Governance at the LOCAL LEVEL

What role do local communities play in the governance of fracking?

The role of local governments in the regulation of fracking activity has received little attention in legal scholarship (Minor 2014, 64). However, local government entities, such as city councils and county boards of supervisors, play an important role in zoning residential and industrial uses of land. In 1926, the US Supreme Court recognized and affirmed this power in Vill. of Euclid, Ohio v. Ambler Realty Co. (Minor 2014, 63). As a case in Longmont Colorado has illustrated, tensions can arise between local and state governments regarding the regulation of oil and gas extraction activity. The city of Longmont passed an ordinance regulating industrial and residential uses of land, but because the ordinance was regulating fracking activity, the state sued (Minor 2014). Municipal governments are prohibited from regulating the oil and gas industry if there already exists legislation on the state level.

A municipal gas ordinance in Pennsylvania, for example, was overturned by the Pennsylvania Supreme Court. The court determined that the town's regulations regarding drilling, site restoration, bond requirements, and wellhead and capping rules, were superseded by the state's Oil and Gas Act (Negro 2012, 5).

Minor (2014, 87) highlights that a fracking boom in a specific region can change or impact a local community's character. The local social geography can be augmented with the influx of workers, who live in makeshift "man camps," comprised of RVs and other temporary dwelling units, or move into hotels. Since the majority of workers are male, the issues that result are often gendered in nature, such as an increase in sex workers and an increase in sexual assault (Minor 2014, 82). A fracking boom can also result in increased stress on local infrastructure, with one example being traffic issues. Local residents and local governments fear that a fracking boom will lead to a disrupted community character, as large numbers of outsiders move into the community. Tensions also arise between community members, because while some might benefit financially from selling mineral rights, the rest of the population "must face the boom's impact while enjoying few of its benefits" (Minor 2014, 87).

Minor (2014, 87) notes that the disparities in who benefits from fracking activity do not only occur within local communities, but disparities also occur at different levels of government. Although local governments have to foot the bill for increased infrastructure (ranging from social services and increased law enforcement to building roads), the primary financial beneficiaries of fracking are the state and federal governments, who benefit from tax revenues from mineral leasing and severance taxes (Minor 2014, 88).

What issues might <u>landowners</u> face?

When negotiating the right of way with pipeline companies, landowners must consider a number of complexities. One issue is that because pipes are typically constructed with the "shortest distance between" two points in mind, the pipe might inconveniently cut across land, disrupting wildlife, the natural ecosystem, animal grazing and other farm activities. While the landowner's ability to access the area is restricted during the time of construction, the area is resurfaced after the pipe is built, and landowners are then able to access the easement area once again (Chambers, et al. 227).

<u>Who is involved</u> in local pipeline governance dynamics of fracking and pipelines at the local level?

In order to accommodate the expanding onshore gas industry facilitated by fracking, companies such as Spectra Energy and Dominion have proposed natural gas pipelines. Parts of Virginia have proven to be key pipeline terrain as industry seeks to move the supply from the Marcellus Shale to the east coast for processing. As a result, dynamics in local communities have shifted in response to the proposals. After sending letters to landowners regarding the proposed pipelines, Dominion and Spectra made "house calls" to survey potential pipeline routes. Conservation groups and landowners began raising concerns in response to the pipeline proposals, with local anti-pipeline groups forming (Brashear 2014).

A number of local actors have been involved in pipeline conversations throughout the country. Involved parties include landowners, environmental groups, such as the Piedmont Environmental Council, local government officials, and residents concerned about the environmental impacts of a pipeline and also the impact of a pipeline on property values. There has been a significant level of activity on the local level regarding pipeline governance. In Madison County, for example, a petition was created by Rural Madison, Inc. asking the Board of Supervisors to hold a public hearing on the pipeline issue (Rural Madison 2014). The Madison County Board of Supervisors held a public meeting on the pipeline issue in July 2014. At this meeting the County Administrator and the County Attorney reported out, and residents, landowners, and environmental advocates spoke during the public comment period (Madison News Staff 2014).

Governance at the STATE LEVEL

What is the <u>role of states</u>?

States are the primary regulators of onshore gas and oil extraction activity (Biswas 2013). Regulation of the oil and gas industry has traditionally been left up to the states, although the EPA is reevaluating its role in the regulatory terrain (Negro 2012, 2). In Virginia, the Department of Environmental Quality and the Department of Mines, Minerals, and Energy (DMME) are reviewing the environmental impacts for oil/gas drilling in the Coastal Plain. DMME currently has primary regulatory authority over natural gas and oil wells (Virginia Department of Mines, Minerals, and Energy n.d.). DMEE has also held public meetings with an advisory panel to discuss current and future regulations. The State Corporation Commission (SCC) regulates interstate pipelines and gas storage fields.

Governance at the FEDERAL LEVEL

Who regulates fracking?

While the Supremacy Clause of the Constitution establishes that federal regulations would take precedence over state or local regulatory activity, there is little federal regulation for fracking. Hammersley and Redman (2014, 37) note that fracking was made exempt to the Energy Policy Act of 2005. It is exempt from major laws and regulatory statutes, such as the Clean Air Act, the Safe Drinking Water Act, the Solid Waste Disposal Act, and the Emergency Planning and Community Right-to-Know Act. In 2012, under the Toxic Substances Control Act (TSCA), the EPA began a rulemaking procedure that requires companies to disclose the substances that are in the underground injection mixture (Biswas 2013). The EPA is currently conducting a review that looks at the "EPA's and states' ability to manage potential threats to water resources from hydraulic fracturing" (Hicks 2014).

Who regulates pipelines?

Interstate natural gas pipelines, on the other hand, are regulated by the Federal Energy Regulatory Commission (FERC). FERC conducts environmental surveys, holds public meetings, and collects public comments as part of its assessments. FERC's analysis is then published, and is available for public review and comment. The materials, including public feedback, then go to the commission, which is made up of five members who have been appointed by the President. The members of the commission decide whether to approve the proposal, reject it, or hold a hearing on some part of the proposal. It typically takes FERC up to 18 months to vote on a proposal (Levulis 2014).

What is the role of eminent domain in pipeline projects?

Federal law states that land can be seized for infrastructure projects under eminent domain, which is (under the Fifth Amendment of the US Constitution) the power of the government to seize private property for public use as long as the owner is justly compensated (Chambers et al. 229). However, questions arise when that land is used for conservation. The proposed Dominion and Spectra pipelines run through protected land such as the George Washington National Forest, conservation easements held by the Department of the Interior, and Montpelier, James Madison's estate (Brashear 2014). In Madison County, for example, the Board of Supervisors advised landowners that they still had the right to refuse access to their land, however eminent domain is a concern that could arise in the future if a proposed pipeline were to be approved by FERC. Once a pipeline is approved by FERC, if a landowner receives a certified letter requesting access to the land, they would no longer be able to prohibit access to the land (Madison News Staff 2014).

Domain 4: National Energy Security

Questions the students are asked to explore in this knowledge domain

- *What role does natural gas production from hydraulic fracturing play in our nation's energy strategy? In it's foreign policy? In our nation's environmental stewardship?*
- *What are the long-term prospects for our nation's energy needs as a result of gas production from marcellus shale?*
- *What role does the pipeline play in helping our nation achieve more energy security while reducing the impact on the environment?*

- *One additional question that you identify from this knowledge domain.*

In July 2012 Jaffe and O'Sullivan of Harvard university completed their analysis of four scenarios with respect to geopolitical outcomes of a natural gas boom on natural gas security and use. The following is a reduction of two sources which summarize the geopolitical implications of expansion of infrastructure for natural gas extraction.

- Nadis, Steve. "Harvard Kennedy School - Shale Gas Unbound: The Global Implications of Fracking." *Impact*, 2013. http://www.hks.harvard.edu/news-events/publications/impact-newsletter/archives/autumn-2013/shale-gas-unbound-the-global-implications-of-fracking.
- Jaffe, Amy Myers, and Meghan L. O'Sullivan. *The Geopolitics of Natural Gas: Report of Scenarios Workshop of Harvard University's Belfer Center and Rice University's Baker Institute Energy Forum*. Cambridge, MA: Harvard University, July 2012. http://belfercenter.ksg.harvard.edu/files/The%20Geopolitics%20of%20Natural%20Gas.pdf.

What happens to natural gas production in the future?

Meyers and O'Sullivan argue:

Some of the most dramatic energy developments of recent years have been in the realm of natural gas. Huge quantities of unconventional US shale gas are now commercially viable, changing the strategic picture for the United States by making it self-sufficient in natural gas for the foreseeable future. This development alone has reverberated around the globe, causing shifts in patterns of trade and leading other countries in Europe and Asia to explore their own shale gas potential**.** Such developments are putting pressure on longstanding arrangements, such as oil-linked gas contracts and the separate nature of North American, European, and Asian gas markets**,** and may lead to strategic shifts, such as the weakening of Russia's dominance in the European gas market**.**

Experts in the geopolitics of energy transitions have recently updated their models and forecasting scenarios to include shale gas reserves, to illustrate the interplay between global politics and natural gas markets, depending on variations in market responses. According to their prediction scenarios, shale gas production worldwide more than quadruples over the next two decades**.**
The United States becomes an exporter, rather than an importer, of liquefied natural gas. Russia and other former Soviet countries remain the biggest suppliers of natural gas, with North America close behind. Europe, having many sources to choose from, is suddenly awash in natural gas, and demand soars in China and India. By 2040, global consumption doubles, with natural gas replacing coal as the largest primary energy source.

How will geopolitics affect future natural gas projects?

Geopolitics are affected by the trajectory of gas markets as much it shapes that trajectory. Geopolitics play a significant role in whether a number of gas projects are realized and come online and where pipelines are built . Individual country decisions about natural gas resources can have dramatic impacts on responses in international discourse.

What role do the largest producers (Russia, former Soviet block countries, and the United States) play in spurring natural gas markets?

Developments in global gas markets are either spurred by the actions of great powers or trigger changes to their relative positions. The relative fortunes of United States, Russia, and China – and their ability to exert influence in the world – are tied in no small measure to global gas developments and vice versa.

What is the role of critical events in natural gas production?

Critical events such as natural disasters, political change, accidents, or new scientific information serve as potential triggers of energy policy change. If associated with natural gas specifically, such events could lead to more stringent environmental and safety regulations, to a shale gas moratorium, or to new uses for natural gas.

What role do unstable governments play in oil and gas markets?

The collapse of political regimes in major energy producing and consuming countries (such as Russia, Saudi Arabia, and Venezuela) could significantly alter the landscape of gas and oil markets world-wide. With the collapse of the regimes of producer countries potential effects include short to medium term supply shortages or significant changes in demand growth in response to price changes. On the consumer side, an economic and political collapse of China would seriously reduce global demand for gas.

What role do transportations and power systems play in natural gas transitions?

The power and transportation sectors are critical determinants of total natural gas demand. While the gasification of the power sector is well underway, it remains unclear whether natural gas will be adopted widely in the transportation sector. Geopolitical or environmental drivers are likely to play a critical role in the pace of gas substitution in power and transportation if a transformation is to occur.

How does renewable energy policy affect natural gas as a bridge fuel?

Renewable energy policy will critically shape the future of natural gas and vice versa. Climate policies or energy security considerations could play a major role in influencing the competition among fuels. Geopolitics and renewable energy policy could greatly influence the window for natural gas as a potential bridge fuel. Alternatively, frustrations over developing gas resources could combine with other factors in leading to a renaissance for coal, with all its attendant problems.

How does access to gas reserves relate to current political perspectives like NIMBY?

Access to shale gas reserves cannot be taken for granted. While France already has a moratorium in place, it is in the realm of the possible that some US states might also enact a moratorium — for instance, in case of an accident or a general “not - in - my - backyard” (NIMBY) sentiment. Alternatively, litigation over acreage and ownership might significantly delay shale gas development.

***************For further analysis***

The above summary was partially quoted from the following: Jaffe, Amy Myers, and Meghan L. O’Sullivan. *The Geopolitics of Natural Gas: Report of Scenarios Workshop of Harvard University’s Belfer Center and Rice University’s Baker Institute Energy Forum*. Cambridge, MA: Harvard University, July 2012. http://belfercenter.ksg.harvard.edu/files/The%20Geopolitics%20of%20Natural%20Gas.pdf.

Review the above document for a more detailed analysis of the table below. The geopolitical effects of four different scenarios of “unconventional gas” transition are outlined. In this table, “success” means that gas markets spread and expand. “Liberalization” refers to a the relaxation of government restrictions in the market, particularly across nation-states.

It’s important to remember that these geopolitical outcomes are heavily shaped by both expansion of unconventional gas which includes both more drilling and more pipelines. Pipelines, given their construction requirements, are in many ways MORE necessary to geopolitical market factors than drilling alone.

Success of Unconventional Gas

Liberalization		High	Low
	High	Scenario 1	Scenario 3
	Low	Scenario 4	Scenario 2

Domain 5: Society

Questions the students are asked to explore in this knowledge domain

- *What possible effects (positive or negative) might the pipeline have on the well-being of the land and citizens of Madison County? What evidence is there that these effects are real?*
- *What are the possible effects (positive or negative) of the pipeline or hydraulic fracturing on the the well-being of communities beyond the Goodall family, or Madison County?*
- *One additional question that you identify from this knowledge domain.*

In the Fall 2014 Issue of *Issues in Science and Technology* Rosenberg et al. outline the problem space the public must navigate to understand the role unconventional natural gas and pipeline expansion in their communities. They argue:

> *"The public needs access to reliable information about the effects of unconventional oil and gas development in order for it to trust the local communities' concerns won't be ignored in favor of national and global interests."*

Local communities greatly fear being ignored for longer term national and global interests. The Oil and gas industry has secured many exceptions to regulation at the federal level while the expansion of drilling and distribution capacity has been swift. This swift expansion has left the jurisdiction of expansion to the states, which are often not equipped to manage the complexities of the issues (see Kinchy and Perry 2011). Although discussions about the risks of unconventional gas and oil expansion have occurred in the media, academic literature, at federal agencies, and among special interest and advocacy groups, these conversations have occurred largely outside of formal and overarching policy frameworks. These frameworks have not kept up with the rapid pace of expansion (Rosenberg et al 2014).

In response to this lack of regulatory framework, city governments have begun testing their powers to zone fracking and pipelines into the courts. Most recently the town of Dryden successfully won their case in the New York Supreme Court (see "NY Communities Triumph Over Fracking Industry In Precedent-Setting Case | Earthjustice." Accessed October 31, 2014. http://earthjustice.org/news/press/2014/ny-communities-triumph-over-fracking-industry-in-precedent-setting-case.) This win in the Supreme Court has now led to the town of Denton, TX to put a ballot initiative to a vote in November of 2014. For more information see: Buchele, Mose. "North Texas Town Could Become First In The State To Ban Fracking." *NPR.org*. Accessed October 31, 2014. http://www.npr.org/2014/10/27/359403518/north-texas-town-could-become-first-in-the-state-to-ban-fracking.

Finally, other scholars have argued that only through local dispatchment of citizens to collect data on water quality can the long-term environmental and health implications of unconventional oil and gas drilling be sufficiently managed. See Kinchy, Abby J., and Simona L. Perry (2011). "Can Volunteers Pick up the Slack-Efforts to Remedy Knowledge Gaps about the Watershed Impacts of Marcellus Shale Gas Development." *Duke Envtl. L. & Pol'y F. 22*.

Whether talking about lack of regulatory frameworks or health and environmental risks public trust and the lack thereof plays a huge role in a community's abilities to interpret and participate in unconventional oil and gas expansion. A push to make the governance, regulatory structures, city-planning and processes more accessible and less opaque will encourage more democratic decision making and go a long way to achieve more equitable outcomes for all parties involved. To do so, Rosenberg argues that the federal government must enact comprehensive baseline and analysis studies focused on water and air quality, public health, and climate change and make the outcomes of these studies freely accessible to citizens. See Rosenberg, Andrew A., Pallavi Phartiyal, Gretchen Goldman, and Lewis M. Branscomb (2014). Exposing Fracking to Sunlight. *Issues in Science & Technology 31(1)*.

Suggested Modifications

This case study includes three different activities that cover about 1 week of work and three 50-minute classroom sessions. The activities are:

- Activity 1: Identifying Knowledge Domains
- Activity 2: Knowledge Domain Research Teams
- Activity 3: Round-Robin Poster Session

If time is an issue, some options are available for using only a subset of these activities.

1. Only Activity 1 (one 50-minute class period). You can use this activity "as is."
2. Only Activity 2 (one 50-minute class periods + approximately 2-4 hours of individual outside work + 2-4 hours of student team meetings)

References

- Interactive map showing U.S. energy resources, infrastructure, etc. You can turn layers on/off to see things specific to shale gas production and distribution. http://www.eia.gov/state/maps.cfm?v=Natural%20Gas U.S. Energy Information Administration (EIA)
- See the references list under "blocks of analysis" and under Table 1 of the document entitled ***Activity 2: Knowledge Domains - Learning the Relevant Science.***
- Other references (not provided to students)
    - Biswas, Asit. "Shale Gas: Black Hole for Water." *The Huffington Post*. TheHuffingtonPost.com, 29 Mar. 2013. Web. 29 Oct. 2014.
    - Brashear, Graelyn. "With Central Virginia Poised to Become a Gas Pipeline Cut-through, Conservationists Urge Caution." *C-ville.com*. N.p., 02 July 2014. Web. <http%3A%2F%2Fwww.c-ville.com%2Fwith-central-virginia-poised-to-become-a-gas-pipeline-cut-through-conservationists-urge-caution%2F%23.VFKfj76przl>.
    - Chambers, Valerie, Brian Elzweig, and Anita Reid. "Eminent Domain in Oil and Gas: Tax Treatment When a Pipeline Devalues Surrounding Property." *Southern Law Journal* 23 (2013): n. pag. Web.
    - Cirillo, R., et al., 2003, *Planning for Natural Gas Disruptions — Chicago Metropolitan Area Critical Infrastructure Protection Program — Critical Infrastructure Assurance Guidelines for Municipal Governments*, ANL/DIS/RP-109839, prepared by Argonne National Laboratory for the U.S. Department of Energy. Available at http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=811290. Accessed February 7, 2007
    - Clark, C, A Burnham, C Harto, R Horner, 2012, Hydraulic fracturing and shale gas production: Technology, Impacts, and Policy, Argonne National Labs, US Department of Energy, http://www.afdc.energy.gov/uploads/publication/anl_hydraulic_fracturing.pdf
    - Hammersley, Ross A., and Kate E. Redman. "Local Government Regulation of Large-Scale Hydraulic Fracturing Activities and Uses." *Michigan Bar Journal* June 2014 (2014): n. pag. Web. <http://www.michbar.org/journal/pdf/pdf4article2392.pdf>.
    - Hicks, Josh. "Is EPA's Inspector General Overstepping with Review of Fracking Regs?" *Washington Post*. The Washington Post, 21 Oct. 2014. Web. 29 Oct. 2014.
    - Jaffe, Amy Myers, and Meghan L. O'Sullivan. *The Geopolitics of Natural Gas: Report of Scenarios Workshop of Harvard University's Belfer Center and Rice University's Baker Institute Energy Forum*. Cambridge, MA: Harvard University, July 2012. http://belfercenter.ksg.harvard.edu/files/The%20Geopolitics%20of%20Natural%20Gas.pdf.
    - Kinchy, Abby J., and Simona L. Perry (2011). "Can Volunteers Pick up the Slack-Efforts to Remedy Knowledge Gaps about the Watershed Impacts of Marcellus Shale Gas Development." *Duke Envtl. L. & Pol'y F. 22*

- King, H. *Marcellus Shale - Appalachian Basin Natural Gas Play*, Geology.com, http://geology.com/articles/marcellus-shale.shtml
- Korfmacher, KS, WA Jones, SL Malone, LF Vinci, 2013, Public health and high volume hydraulic fracturing, ***New Solutions, vol. 23(1)*** 13-31, http://www.ncbi.nlm.nih.gov/pubmed/23552646
- Kothare, Simone (2012). Economics and applicability of nitrogen for fracking, *Air Products and Chemicals, Inc.*, http://www.airproducts.com/industries/energy/oilgas-production/oilfield-services/product-list/~/media/F3F68760EB7D49E1A9C8512623254459.pdf
- Levulis, J. "Federal Energy Regulatory Commission Holding Pipeline Meetings." *WAMC: Northeast Public Radio*. N.p., 29 Oct. 2014. Web. 29 Oct. 2014.
- Madison News Staff. "Supervisors Discuss Proposed Gas Pipeline." *Madison Eagle*. N.p., 4 Aug. 2014. Web. <http%3A%2F%2Fwww.dailyprogress.com%2Fmadisonnews%2Fnews%2Fsupervisors-discuss-proposed-gas-pipeline%2Farticle_5656f4b2-2c94-11e4-b5db-0017a43b2370.html>.
- Minor, Joel. "Local Government Fracking Regulation: A Colorado Case Study." *Stanford Environmental Law Journal* 33.61 (2014): n. pag. Web.
- Nadis, Steve. "Harvard Kennedy School - Shale Gas Unbound: The Global Implications of Fracking." *Impact*, 2013. http://www.hks.harvard.edu/news-events/publications/impact-newsletter/archives/autumn-2013/shale-gas-unbound-the-global-implications-of-fracking.
- Negro, Sorell E. "Fracking Wars: Federal, State and Local Conflicts over the Regulation of Natural Gas Activities." *Zoning and Planning Law Report* 35.2 (2012): n. pag. Web.
- Rosenberg, Andrew A., Pallavi Phartiyal, Gretchen Goldman, and Lewis M. Branscomb (2014). Exposing Fracking to Sunlight. *Issues in Science & Technology 31(1)*.
- Rural Madison. "Madison Board of Supervisors: Convene a Public Hearing on the Proposed Pipeline Project!" *Gopetition.com*. N.p., 19 July 2014. Web. http%3A%2F%2Fwww.gopetition.com%2Fpetitions%2Fmadison-board-of-supervisors-convene-a-public-hearing-now-on-spectras-pipeline-project.html.
- U.S. Department of Energy (2009). *Modern Shale Gas Development in the United States: A Primer*; DE-FG26-04NT15455; U.S. DOE: Washington, DC. http://energy.gov/sites/prod/files/2013/03/f0/ShaleGasPrimer_Online_4-2009.pdf
- Vidic, RD, SL Brantley, JM Vandenbossche, Y Yoxtheimer, JD Abad (2013). Impact of shale gas development on regional water quality, *Science 340, 1235009 (2013)*. DOI: 10.1126/science.1235009
- "Virginia Department of Mines, Minerals and Energy." *Virginia Department of Mines, Minerals and Energy*. N.p., n.d. Web. 29 Oct. 2014.: http://www.dmme.virginia.gov/dgo/HydraulicFracturing.shtml
- U.S. Department of Energy. *U.S. Energy Mapping System*. http://www.eia.gov/state/maps.cfm. This is an interactive map for viewing all types of energy resources (oil/gas fields), resource distribution networks (pipelines and pumping stations), and production facilities (oil/gas wells and power generation plants). You can turn layers on and off to explore all of these features.

Answer Key:

See the Blocks of Analysis for background information on the Knowledge domains addressed in this case study. Because the deliverables are concept maps and briefs written by the students, there is not an "answer key," per se. These deliverables will be evaluated using the rubrics provided with the case study.

Assessment

Assessment is provided for each of the student deliverables. These deliverables and the assessment tools are listed below.

Student Deliverable	Associated Activity	Assessment criteria
Each student: Results from a brainstorming session to identify areas of expertise relevant to the pipeline decision	Activity 1: Brainstorming Exercise - What kind of Expertise is Needed?	This is a credit/no credit assignment. Students are given full credit if they are present and engaged during the activity.
Each student: 400-word summary findings in their assigned knowledge domain	Activity 2: Knowledge Domains - Learning the Relevant Science	***Evaluation Rubric: 400-Word Summary of Your Assigned Knowledge Domain.*** Found in the student handout *Activity 2: Knowledge Domains - Learning the Relevant Science.*
Each knowledge domain team: Concept map and 600-word narrative	Activity 2: Knowledge Domains - Learning the Relevant Science	***Evaluation Rubric: Integrated Concept Map and Narrative.*** Found in the student handout *Activity 2: Knowledge Domains - Learning the Relevant Science*
Each student: Peer evaluation of concept maps and narratives from all Knowledge Domain Teams	Activity 3: Round Robin Poster Session	***Evaluation Rubric: Student Participation in the Round Robin Poster Session***. Found in these *Teaching Notes* under the description for Activity 3.
Each student: Two 400-word briefing papers; one addressed to Madison Board of Supervisors; one addressed to the Goodall family	Following Activity 3: Round Robin Poster Session	***Evaluation Rubric: Final briefing papers.*** Found in the Student Handout ***Activity 3 Follow-up: Final Briefing Papers for the Goodall Family and Madison County Board of Supervisors*** *.*

Acknowledgements

This work was supported by the National Socio-Environmental Synthesis Center (SESYNC) under funding received from the National Science Foundation DBI-1052875.