Shale Gas Exploration and Production:
Overview
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UKRAINE
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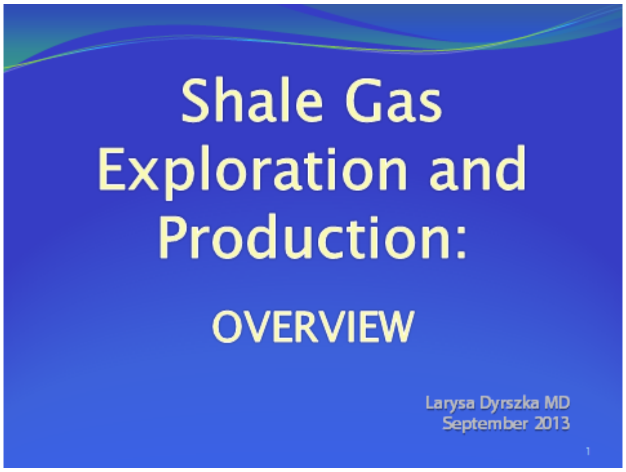
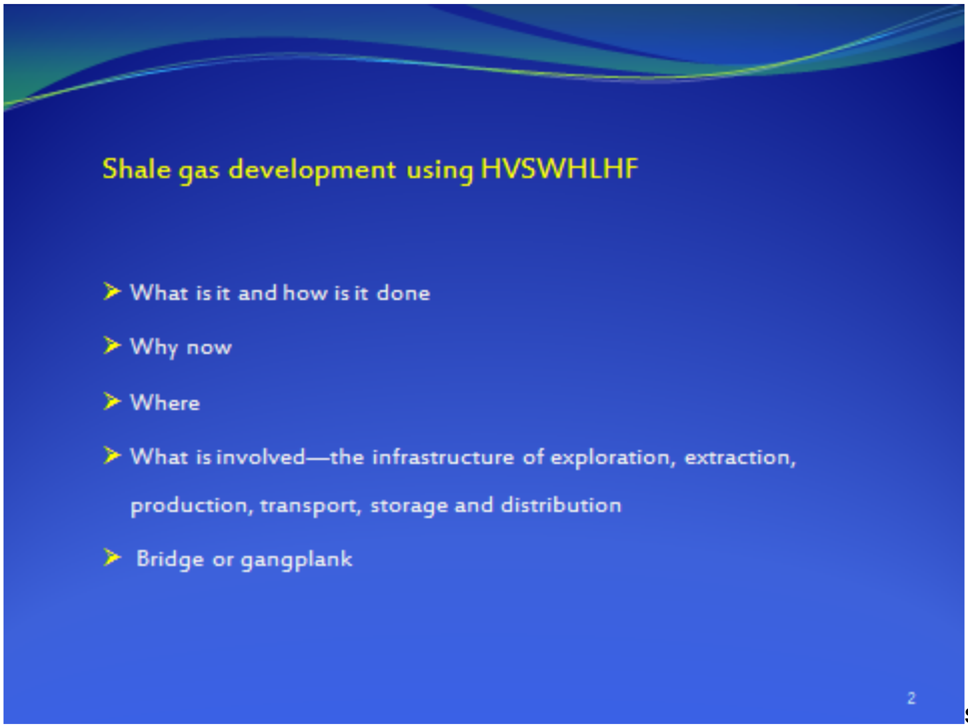


It is an honor to be here with you in my ancestral home. Although I was born in America, my first language was Ukrainian. Both my parents, the Melnyks and the Hunczaks, came from western Ukraine.

My name is Larysa Melnyk Dyrszka and I am a pediatrician by profession. Five years ago, when I realized that my home in New York was sitting on top of the Marcellus shale and that land around me was being leased for gas drilling, I tried to research the health effects since this was my area of expertise.

At first, there was no health information available, and almost no discussion of adverse environmental impacts. But we knew that people were ill where there was drilling. So my colleagues and I set out to find out as much as possible about the process of gas development. Now we know a lot—about the process, which I will discuss in this presentation—and now also about the health impacts, and that will be in the next presentation.



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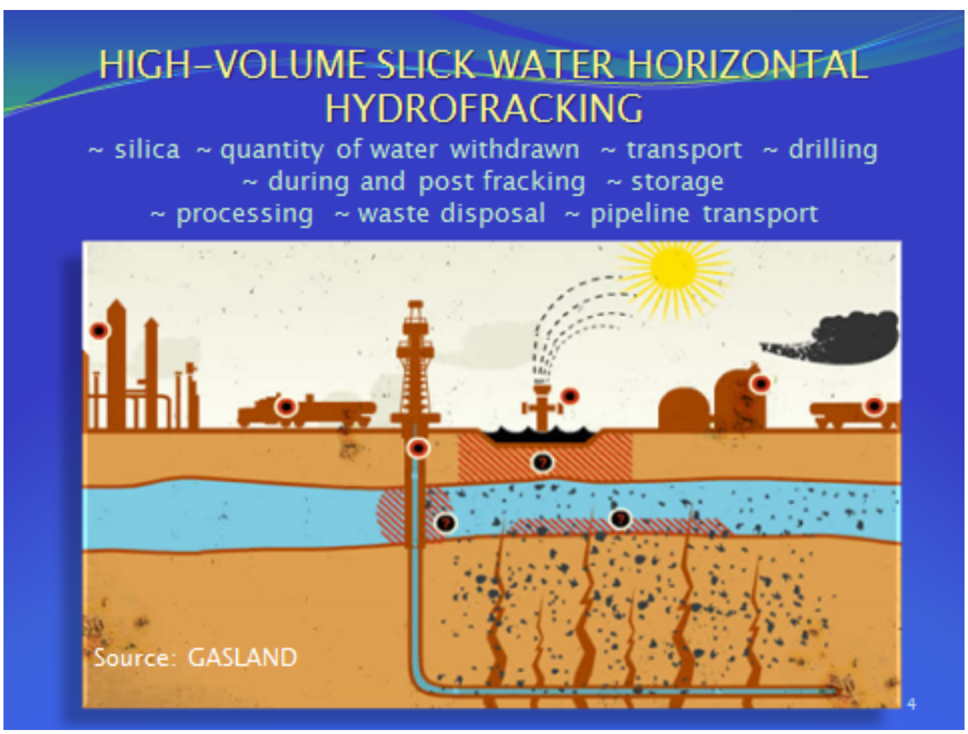
What I will cover here is the process of shale gas development using hydraulic fracturing with high volumes, slick water, and horizontal legs (HVSWHLHF)—what is it, how is it done, where, why and the infrastructure that comes with it. And is it all that it is promised to be…



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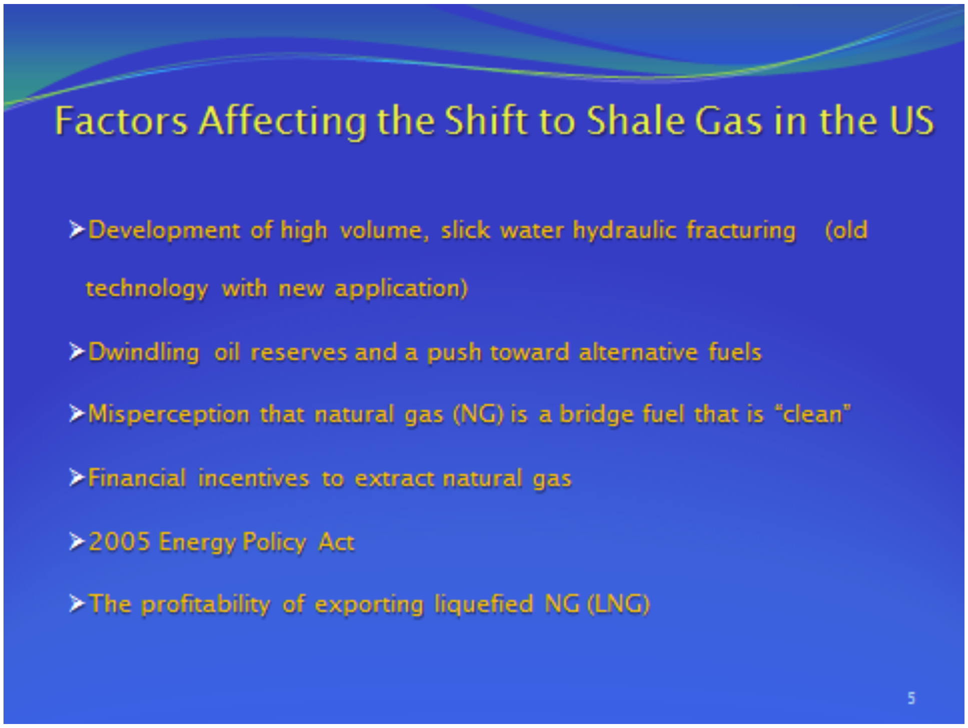
High volume horizontal hydraulic fracturing is a new application of an old technology. That's why you hear that fracking has been done for 60 years. That was the old type of fracking, not this new one which was only developed in the late 1990s. About ten times more water, silica and chemicals are used in the new unconventional well compared to the older conventional type.

The fracturing is done from a wellbore drilled into rock formations to increase the recovery of natural gas. The process uses 2-9 million gallons of water per frack, silica sand and chemicals blasted at high pressures. This enables the recovery of natural gas from low-porosity tight shale formations.

Fracking is just one part of the process of gas exploration and development and usually takes only a short time compared to the drilling and production phases.

In this presentation, I'll be speaking about the entire process of gas extraction and production, from beginning to the end, because environmental problems have been encountered, and negative health impacts have been observed during all the steps.

For example,
--exposure during the mining of silica sand can cause lung diseases
--water withdrawal can cause the depletion of the water supply because exceptionally large amounts of water are used
--in transport there can be spills of chemicals and traffic accidents
--during drilling aquifers can become contaminated with methane due to casing failure
--there could be exposure to radionuclides, which are carcinogenic
--air pollution with ozone production from diesel transport vehicles, and then during drilling, venting, flaring and processing, and also at compressor stations occurs
--disposal of waste is a problem as there are few treatment facilities able to handle it
--noise and light pollution occur
--there are health issues from climate change
--and people can experience psychological stress during the entire process due to concerns about the potential loss of home value and loss of water, and health impacts.



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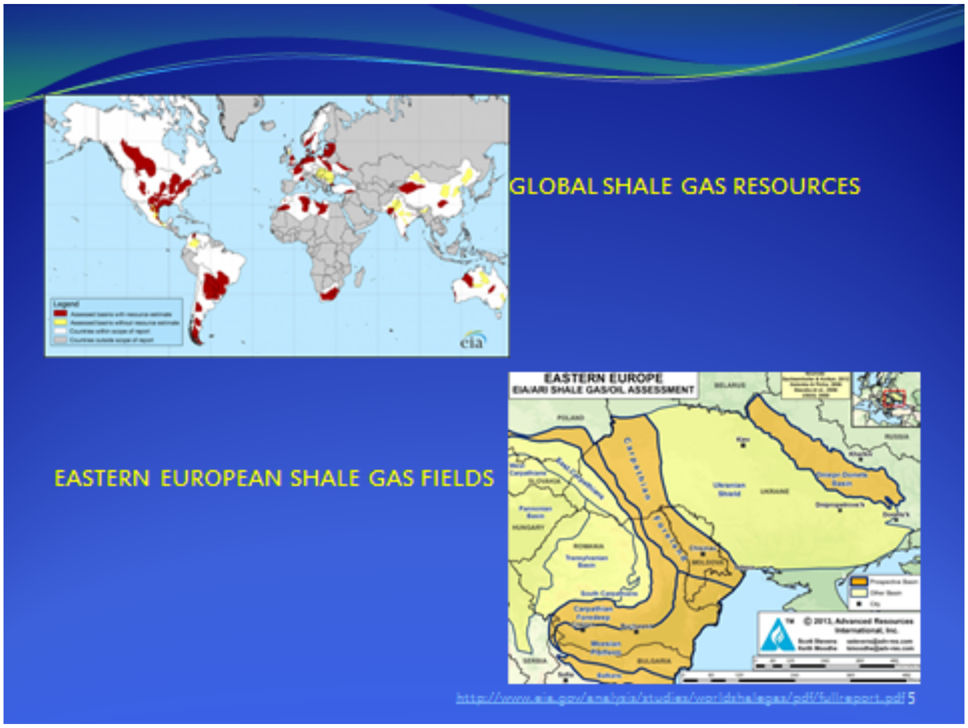
Why is fracking taking off now?
-- fracking technology has been modernized so industry can now get at the shale more easily;
--globally there is less oil and there is concern about climate change, so there is a push toward alternative fuels—coal and oil are considered dirty, but there is a misperception that natural gas is a bridge fuel that is "clean";
--oil and gas industry receive tax incentives which makes it more profitable for them;
--the loophole in the 2005 Energy law allowed the industry to drill without oversight; less regulation means industry has to spend less to put safeguards in place
--there is profitability in exporting liquefied gas (LNG) because the demand is there.



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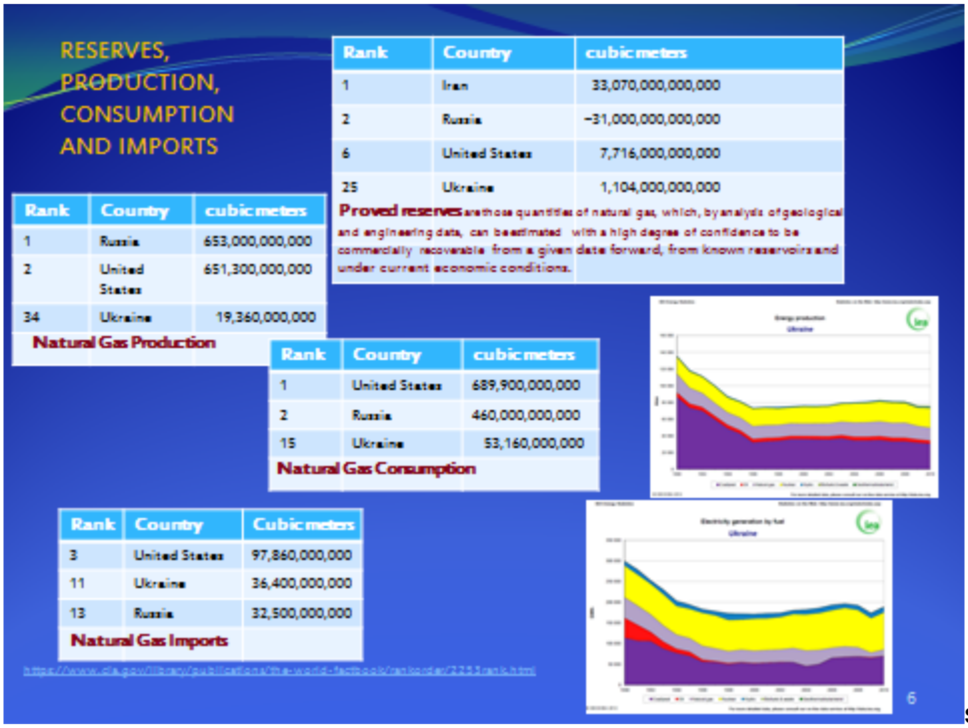
Shale gas is being extracted in over 30 states in America.

The US Energy Information Administration (EIA) has identified 95 shale basins and 137 shale formations around the world.

Ukraine is said to have Europe's third-largest shale gas reserves according to the U.S. Energy Information Administration.
It is estimated that with 1.18 trillion cubic meters technically recoverable this resource could cover domestic gas consumption for 22 years.

As we have learned in the United States, it is important to have an understanding of shale reserves, whether they are recoverable, and what the impacts of the recovery might be, as well as the cost of such recovery, in order to determine if they will be an asset or a net drain.



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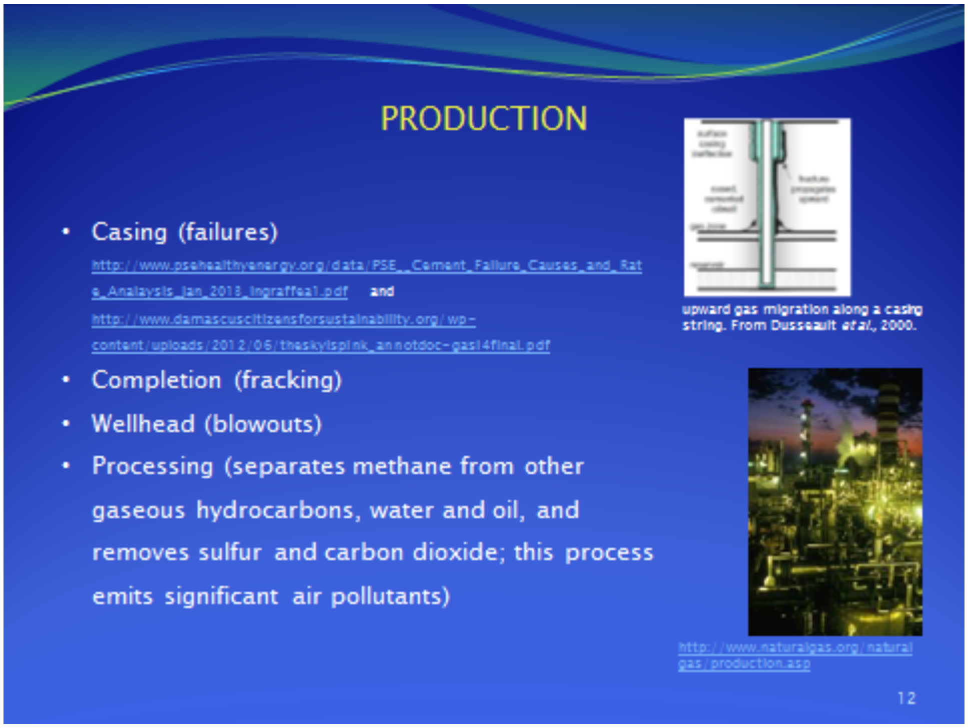
Proved reserves are those that are technically and economically recoverable, and it is important to distinguish between the two types. Technically recoverable resources represent the volumes of oil and natural gas that could be produced with current technology, regardless of oil and gas prices. Economically recoverable resources are those that can be profitably produced under current market conditions.
The economic recoverability of oil and gas resources depends on three factors: the costs of drilling and completing wells, the amount of oil or natural gas produced from an average well over its lifetime, and the prices received for oil and gas production.

In the former Soviet republics, the proved reserves were equated with technically rather than economically recoverable, and so they were revised down in 2012, and that put Iran at the top in a Central Intelligence Agency report, with the largest proved gas reserves of 33.6 trillion cubic meters (tcm).
Proved gas reserves in the US at the end of 2012 were about 8 tcm, around 3% lower than a revised figure for the previous year as the drop in gas prices due to the shale gas production boom made some resources uneconomic to develop.

The US consumes 690 billion cubic meters (bcm) of gas annually; next is Russia; Ukraine consumes 53bcm a year.

The additional graph on the right, shows sources of Ukrainian energy production currently, and the majority is still from coal and nuclear, as well as gas.



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Once the bore hole has been made, and before fracking occurs, the hole is cased in cement. Because it is man-made, and also due to unique underground geological features, plus erosion from chemicals and high pressure, the cement fails in significant numbers.

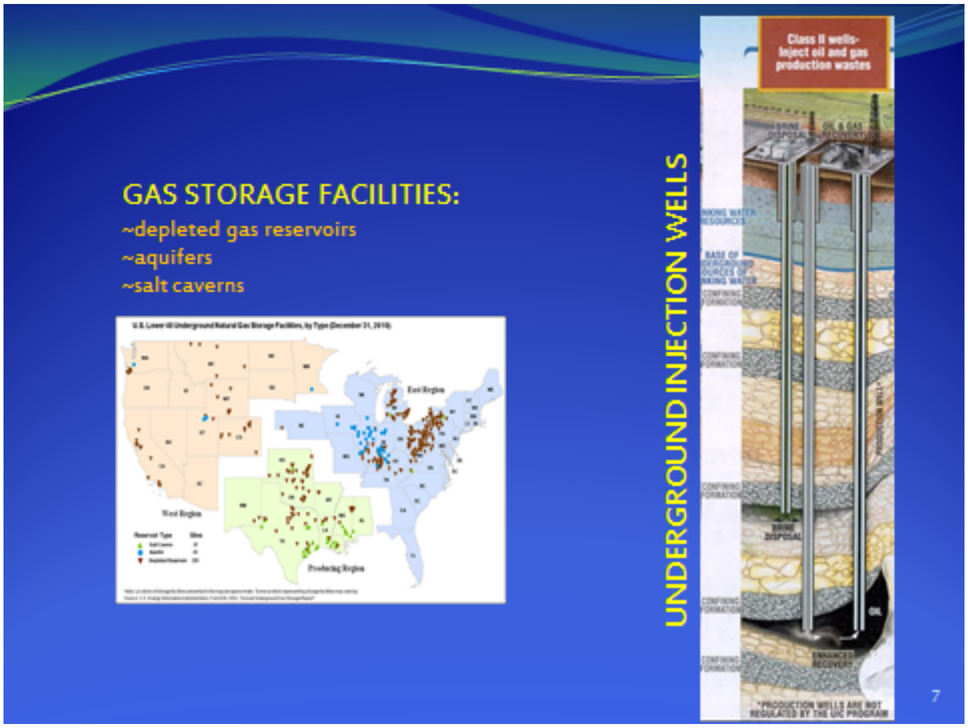
When the cement fails, it opens a pathway for gas and other toxins involved in the drilling and fracking process to migrate into groundwater and to the surface.

6-9% of all well casings fail immediately, and the failure rate is 60 percent over a 30-year span.

Blowouts occur occasionally, and an offshore example is the BP oil disaster.

Natural gas processing consists of separating all of the various hydrocarbons and fluids from the pure natural gas, to produce what is known as 'pipeline quality' dry natural gas.

A major problem with processing plants is that they are highly polluting because of the by-products they produce, like volatile organic carbons (VOCs), hazardous air pollutants (HAPs), nitrogen oxides, sulfur dioxide, etc., and these have adverse health impacts and all contribute to an increase in greenhouse gases.



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If it's produced but not immediately needed, shale gas or its products may be stored.

There are three main types of underground natural gas storage facilities: depleted gas reservoirs or wells, aquifers, and salt caverns.

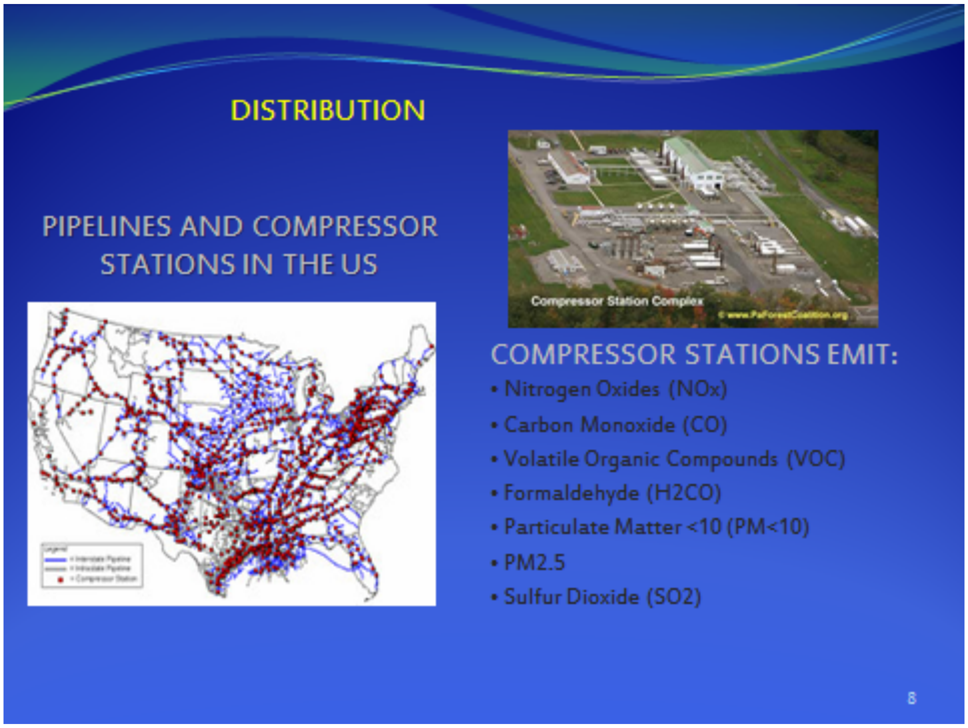
Depleted gas reservoirs are formations that have already been tapped of all their recoverable gas, and this is the most common and desirable storage.

Aquifers are the least desirable and most expensive type of natural gas storage for a number of reasons, such as unknown geology and uncertain capacity.

Underground salt formations offer another option for storage. Although the walls of salt caverns are usually strong, they are susceptible to degradation, especially in the presence of hydrocarbons, high pressure and seismic activity, and accidents.

On the right is a schematic for an underground injection well to dispose of waste, and is the preferred method for waste disposal currently in the US.

A complication--earthquakes have been documented to occur at increased frequency at or near injection wells.



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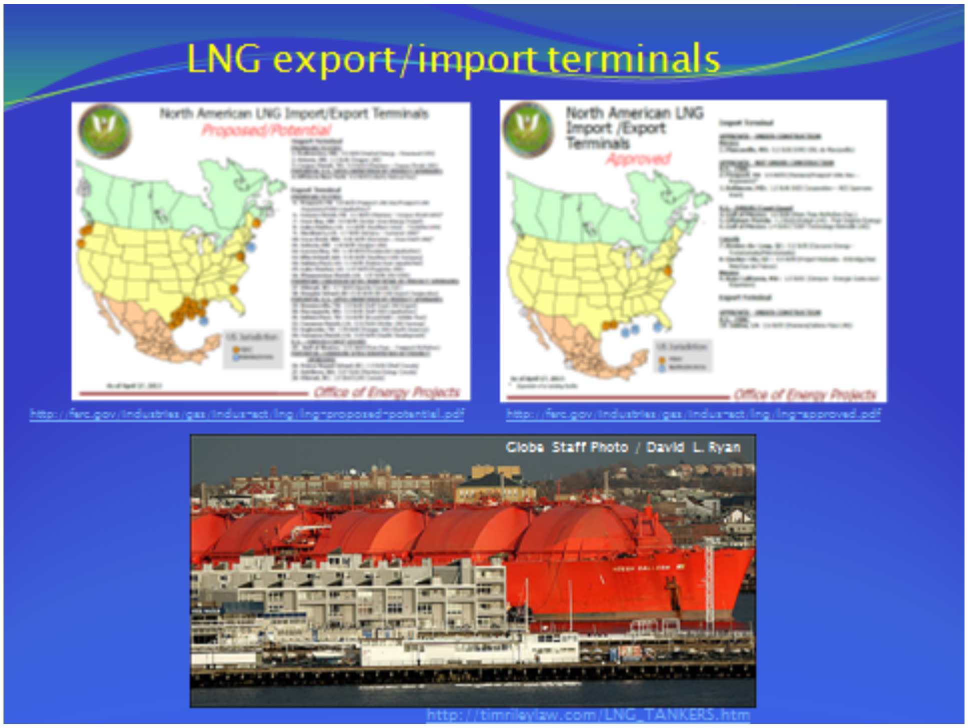
To transport and distribute the gas, compressor stations and pipelines are required.

On the left are the existing pipelines in the US; the red dots are compressor stations.

What do compressor stations emit?

Nitrogen oxides (NOx) which are associated with respiratory disease. Ozone is formed when NOx and Volatile Organic Compounds (VOCs) react in the presence of heat and sunlight.
Volatile organic carbons (VOCs) are neurotoxins and have significant cognitive and behavioral effects. They are known hepatotoxins, reproductive toxins and fetotoxins, and have been associated with teratogenesis and fetal wastage. All are dermatotoxins.
Formaldehyde is a carcinogen.
Sulfur dioxide (SO2) is also associated with respiratory illness, increased visits to the hospital, and death.
Particulate matter is of small size and large surface area, and they carry toxic pollutants deep into the lungs when inhaled, and elsewhere in the body as they enter the bloodstream.



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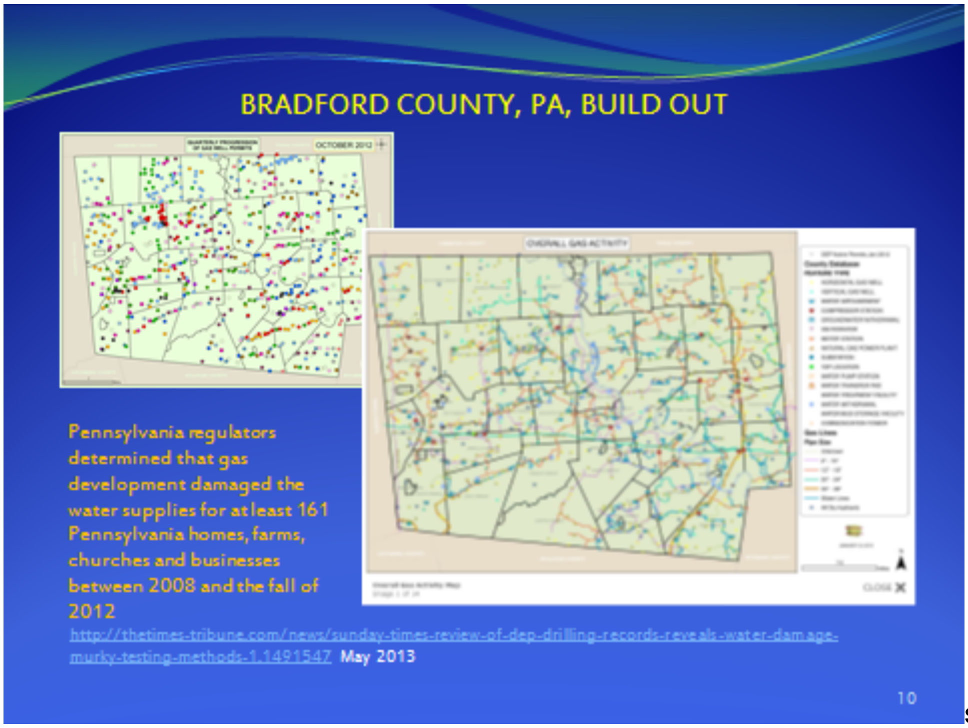
In the past year there have been numerous applications made to the federal agency in charge (FERC) for export terminals, largely due to the projections of Marcellus gas volume, and also because gas can bring a lot more money from the international market.

The bottom picture is a representation of an LNG tanker (the orange structure is one big ship) pulling out of a harbor past 4 story townhomes.



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This is the infrastructure for the gas drilling activities in Bradford County, one of 62 counties in Pennsylvania. Every mark on the map includes something that was not there before gas exploitation.

- The dots on the left map are gas wells -- today there are 1125 gas wells in Bradford County

In an investigative report in May 2013, Pennsylvania State environmental regulators determined that oil and gas development damaged the water supplies for at least 161 Pennsylvania homes, farms, churches and businesses between 2008 and 2012.

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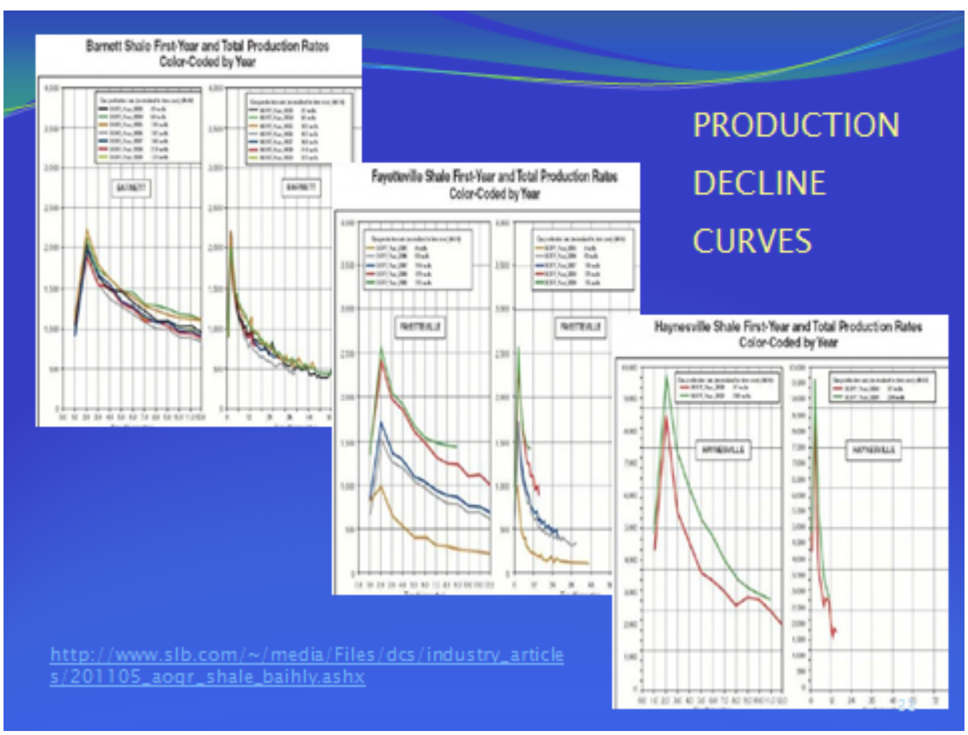
The landscape of the US, above and below ground, has already been profoundly impacted by drilling for oil and gas.

This is Wyoming—these are federal lands—and you can see the development from 1986 to 2006.



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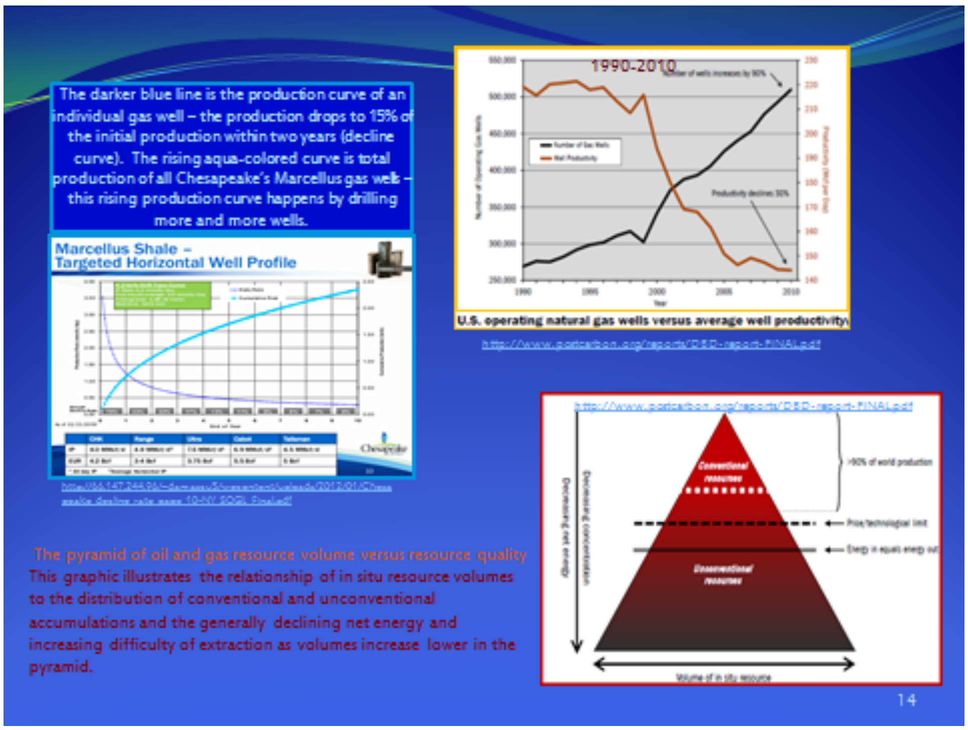
So all this gas will be extracted, the infrastructure built, with resulting environmental and health impacts which I will describe in the following presentation…and then how long will this gas last?

Not very long, as presented by industry engineers.

For this article published in 2011, the authors were reporting on new techniques to see if there were improvements in production per year. A total of 1900 wells were observed in these three areas.

What is consistent, in every shale formation, is the steep decline in production after two years.



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The graph on the left is from CHESAPEAKE's 2010 STOCKHOLDERS REPORT filed with the federal government Securities and Exchange Commission (SEC), where it is necessary to be accurate. Giving false information to stockholders of a publicly traded company in the US carries severe penalties, and the law is firm in this. The desired result is improved transparency in business.

The darker blue line in the graph is the production curve of an individual gas well.
The decline rate is 70% the first year. 85% of the gas is gone in two years and the well is unproductive in another year or so more.   The rising lighter colored curve is total production of all of Chesapeake's gas wells – this rising production curve happens by drilling more and more wells because the wells decline so fast.

On the top right is another reference for the production decline.

It is also called the law of diminishing returns for US natural gas production, as you can see in this figure from David Hughes' Post Carbon Institute paper. More and more wells must be drilled and operated to maintain production as the average productivity per well is declining. Since 1990, the number of operating gas wells in the United States has increased by 90 percent while the average productivity per well has declined by 38 percent.

Will there be as much gas as the projections estimated by the US Energy Information Agency?

The EIA's forecast for United States natural gas supply through 2035 is very aggressive. Dr Hughes and others believe that this is an unattainable amount of shale to recover, because problems with environmental impacts and its economic viability. Dr Hughes writes that "Given the realities of geology, the mature nature of the exploration and development of U.S. oil and gas resources and projected prices, it is unlikely that the EIA projections of production can be met. Nonetheless these projections are widely used as a credible assessment of future U.S. energy prospects."

While there is little doubt that in situ resources of unconventional hydrocarbons are quite large, the proportion that can be recovered economically is much smaller. More realistic are estimates for the US that range from 20 to 60 years, and not 100 years.

Another way of looking at oil and gas resources is illustrated by the resource pyramid, the figure on the bottom. The highest quality resources in the most concentrated accumulations which can be recovered at the lowest cost are at the top of the pyramid. These are supergiant and giant conventional oil and gas fields.

As one moves lower in the pyramid, resource volumes increase, resource quality decreases, hydrocarbons become more dispersed, and the energy required to extract them increases. The dashed line represents the transition from high quality, low cost, conventional resources and lower quality, higher cost, unconventional resources. The hydrocarbon resources at the base of the pyramid are very plentiful, but totally inaccessible.

The price/technology line reflects the fact that as prices go higher, the higher cost (but lower quality) resources become accessible through technological innovations, such as multi-stage hydraulic fracturing. The ultimate barrier is the second line, which is the point when the amount of energy in the resources that are recovered is less than or equal to the energy that must be invested to recover them.

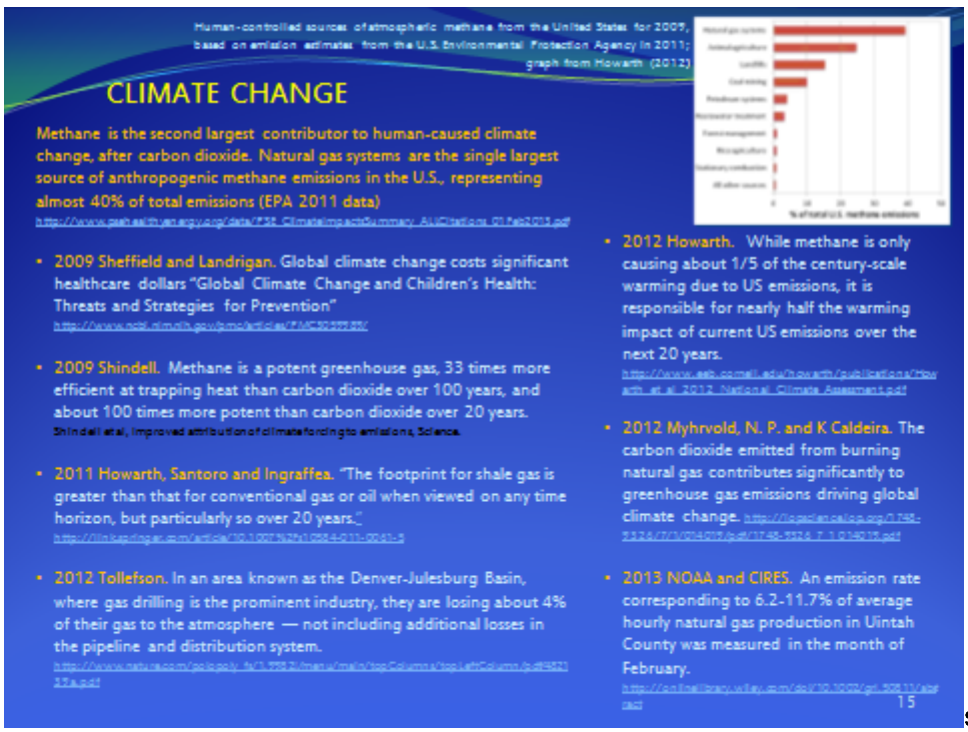
All resources below this line represent an energy drain, not an energy source.

Politicians often do not see the importance of these differences in resource quality which ultimately impact the rate at which hydrocarbons can be produced and the net energy they will provide. They instead look only at purported resource volumes and declare "one hundred years of natural gas" or "energy independence."

The higher costs of energy production from gas include the costs of health and environmental impacts:

--methane and chemical contamination of groundwater,
--waste disposal and fracking which induce earthquakes,
--the huge industrial footprint,
--air toxicity,
-- high water consumption that is not returned to hydrological cycle,
--and one must consider the full cycle greenhouse gas emissions which are worse than coal.

These issues are very real and will certainly impact the ability of shale gas drillers to access locations, and this will further impact future shale gas production. Yet, they have not been realistically factored into the economic equation of the cost of gas development. The collateral environmental impact of shale gas drilling will increase going forward as industry attempts to compensate for the steep declines in existing gas fields.



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I will cover the health and environmental impacts in more detail in the next presentation. However, because this topic is related to energy use as well as energy security which are part of this presentation, I have included climate change here.

Howarth tells us that methane contributes substantially to the greenhouse gas footprint on shorter time scales, dominating it on a 20-year time horizon. Methane is 33 times more efficient at trapping heat than carbon dioxide over 100 years, and about 100 times more potent than carbon dioxide over 20 years. The footprint for shale gas is greater than that for conventional gas when viewed on any time horizon, but particularly so over 20 years.

Since the time the first Howarth paper was published, other studies have demonstrated the urgent need to consider methane emissions at the shorter time scales. Both a report from the

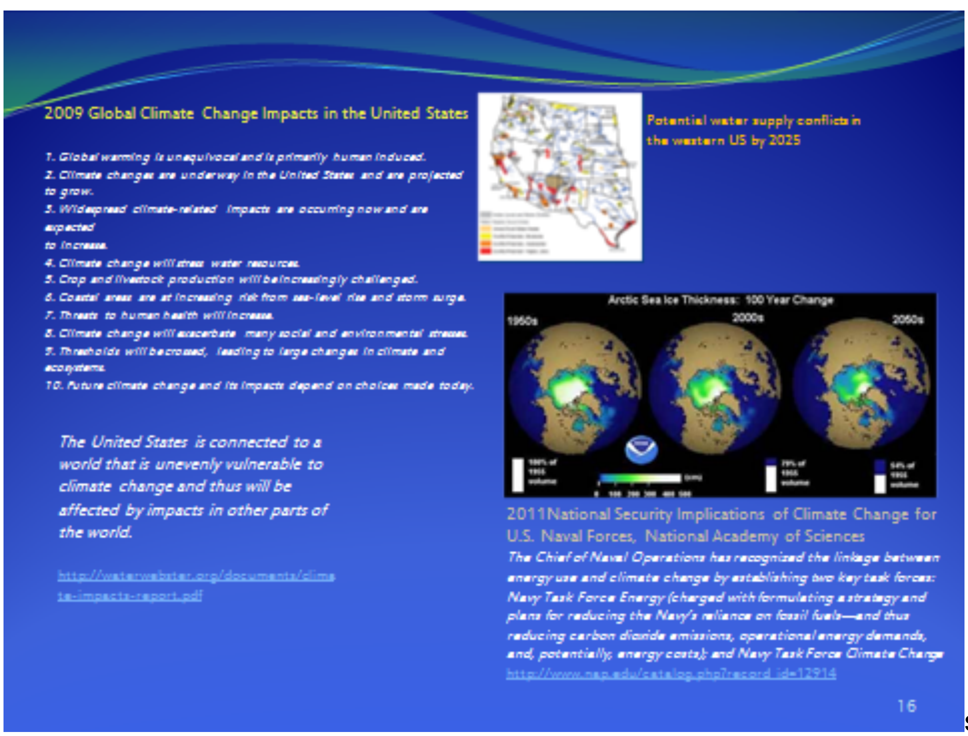
United Nations and a paper by Shindell show that controlling CO2 alone is not sufficient to avoid warming the planet to dangerous temperatures in the coming years. The only way to avoid that is to reduce methane emissions, beginning immediately.

What evidence is there that the natural gas industry is the #1 source of methane emissions in the US? In an area near Denver Colorado, where gas drilling is the prominent industry, they are losing about 4% of their gas to the atmosphere — and that does not include additional losses in the pipeline and distribution system.

And just a few months ago, a federal agency, the National Oceanic and Atmospheric Agency (NOAA), wrote that the rate of methane emissions from natural gas production was 6.2-11.7% of average hourly natural gas production. And this will offset the climate benefits of natural gas over other fossil fuels.

This research tells us that methane emissions from high volume hydrofracking and related operations have been significantly underestimated by both the gas industry and the US Environmental Protection Agency. Methane leaks have to be kept below 2 % for natural gas to be better than coal for slowing climate change. Given the magnitude of these documented gas emissions and proof of their harm to our atmosphere, dependence on natural gas, and on high volume fracking, precludes any chance of keeping greenhouse gases in the atmosphere at levels where we might avoid climate catastrophe.

Development of natural gas is not part of the climate solution, and it is not the bridge fuel that will help us make the transition from coal and oil to renewables.



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Who else is concerned about climate change? In an important 2009 paper on climate change impacts in the US, these were the key findings:
-that global warming is real,
-climate changes are increasing
-and they are already evident;
-water resources will be stressed
-and crop and livestock affected;
-coastal areas are at risk from sea-level rise;
-there already are threats to human health and
-there will be social and environmental stresses
-there will be large changes in ecosystems;
-future climate change and its impacts depend on choices made today.

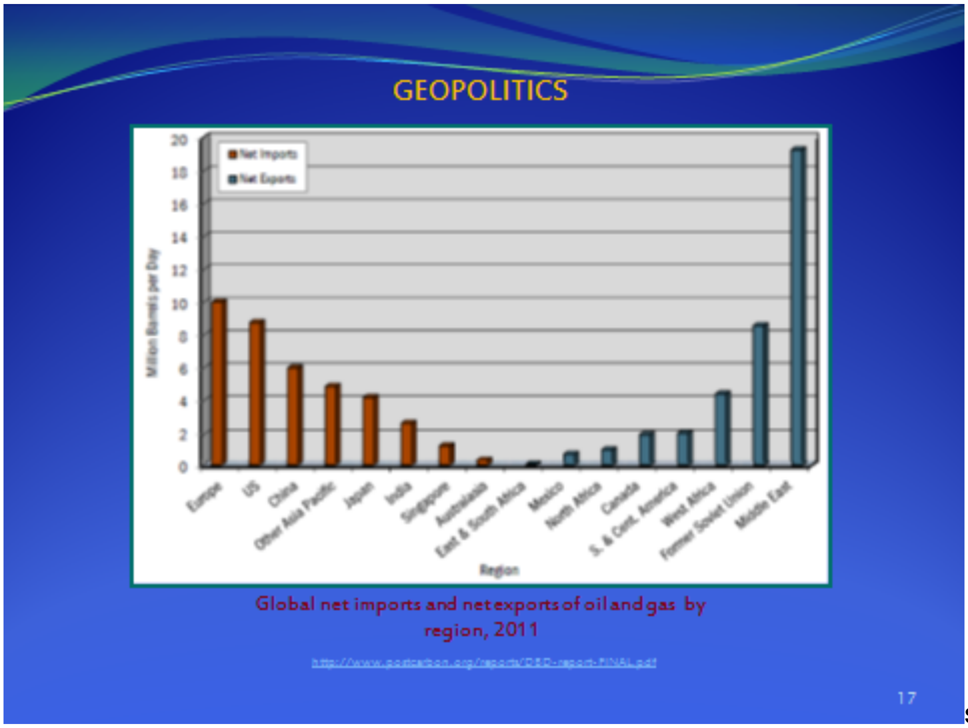
In many places, water systems are already taxed because of aging infrastructure, population increases, and competition among water needs for farming, municipalities, hydropower, nuclear power, recreation, and ecosystems. Climate change will add another factor to existing water management challenges, making water systems more vulnerable. A US Bureau has identified many areas in the West that are already at risk for serious conflict over water, even in the absence of climate change.

The US Navy had concerns, and a special committee was appointed to study the national security implications of climate change for U.S. naval forces. In conducting this study, the committee found that even the most moderate current trends in climate, if continued, will present new national security challenges for the US Navy.

Some areas of concern in the National Academy of Sciences report written for the Navy include:

- The effects on water—with prolonged droughts, more intense storms and floods, melting ice, and changing ocean conditions, including ocean acidification;
- Melting sea ice in the Arctic that will impact geopolitics, and there may be a demand for humanitarian relief;
- Vulnerabilities due to anticipated sea-level rise and increased storm surges;
- There will be implications of climate change for allies of the US.

The point of mentioning these diverse reports is that they are saying the same things—that climate change is real and that it will have serious consequences globally.



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Geopolitical risks concerning energy supply arise from both the inequitable consumption rates of developed versus developing countries and the concentration of supply, particularly of oil, in politically unstable regions. In terms of consumption, developed countries such as the US consume many times more energy than developing counties: four times more than China and 17 times more than India. And, rapidly growing economies will require increasing amounts of energy.

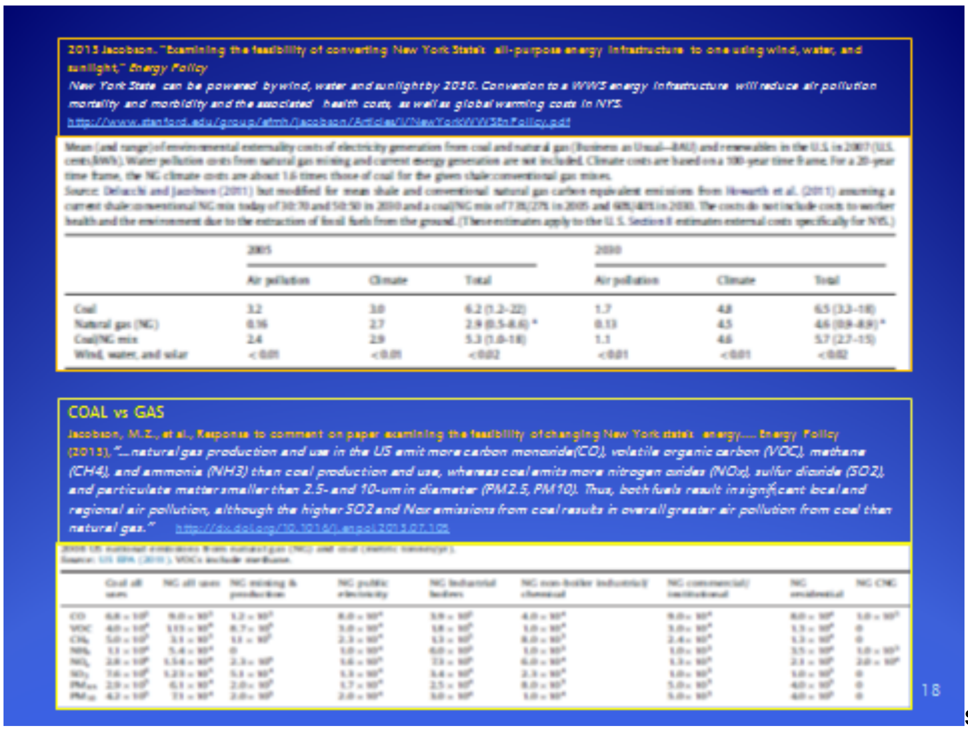
In terms of energy supply, oil remains the most vulnerable to geopolitical risks; natural gas is an issue in Europe and Asia, due to both pipeline supplies out of Russia and LNG imports.

According to David Hughes, the vulnerability of oil supplies to geopolitical disruptions is illustrated in this graph by the disparate concentration of export capacity and import requirements. Half of the global net exports in 2011were provided by the Middle East, with 12 percent of the balance provided by West Africa. These regions are political hotspots. The former Soviet Union controlled an additional 22 percent of net exports in 2011, particularly to Europe and Ukraine.

Disruption of production in a major oil producer through war or sanctions could easily remove all surplus capacity from the system. Disruption of shipping channels would precipitate a crisis of supply if it lasted long enough to consume global stocks of crude oil storage.

There are many other risks to geopolitical stability emerging besides energy. Access to water, food, minerals and a host of other resources as well as the impacts of climate change will be additional major challenges. The ever-increasing energy consumption is not only likely to be very difficult or impossible to achieve over the long term, but it exacerbates these other geopolitical risk factors.

We need to rethink our approach to energy because the rates of energy enjoyed for the past century are not sustainable. By rethinking the way we expend energy we will ensure a much less disruptive transition to a world with less energy. This will not be a world without hydrocarbons, at least not for the foreseeable future, but it will be a world where energy is more sustainable, environmental and health impacts are minimized, and climate change can be mitigated.



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Our conversation in the US is not just about the risks of shale gas extraction, but also how do we move forward in a proactive way. It includes an evaluation of whether renewable energy sources can replace all fossil fuels. In their peer-reviewed paper, researchers from Stanford and Cornell Universities projected that New York State can be off of fossil fuels, and nuclear, by 2030.

Their study examined the technical and economic feasibility of converting New York State's energy infrastructure into a clean and sustainable one powered by wind, water, and sunlight (WWS). Such a conversion will improve the health of NYS residents, and is expected to create jobs to manufacture, install, and manage the infrastructure.

The study found that complete conversion to WWS in NYS will reduce end-use power demand by 37%, due mostly to the efficiency of electricity versus combustion, but also due partly to energy efficiency measures.

The 2030 NYS power demand could be met by onshore and offshore wind turbines, concentrated solar plants, solar-PV power plants, residential and commercial/government rooftop PV systems, geothermal plants, wave devices, tidal turbines, and hydroelectric power plants.

The authors explain that "the main argument for increasing the use of natural gas has been that it is a 'bridge fuel' between coal and renewable energy because of the belief that natural gas causes less global warming per unit electric power generated than coal. Although natural gas emits less carbon dioxide per unit electric power than coal, two factors cause natural gas to increase global warming relative to coal: higher methane emissions and less sulfur dioxide emissions per unit energy than coal."

On the question of COAL vs GAS…these authors, in a "Response to comment on paper examining the feasibility of changing New York state's energy....in press in Energy Policy (2013), write*"…natural gas production and use in the US emit more carbon monoxide(CO), volatile organic carbon (VOC), methane (CH4), and ammonia (NH3) than coal production and use, whereas coal emits more nitrogen oxides (NOx), sulfur dioxide (SO2), and particulate matter smaller than 2.5- and 10-microns in diameter . Thus, both fuels result in significant local and regional air pollution, although the higher SO2 and NOx emissions from coal results in overall greater air pollution from coal than natural gas."*

(only for reference—in their original paper, they continue on the question of coal versus gas: When sulfur dioxide emissions from coal are considered, the greater air-pollution health effects of coal become apparent, but so do the global warming impacts of natural gas, indicating that both fuels are problematic. Coal combustion emits significant sulfur dioxide and nitrogen oxides, most of which convert to sulfate and nitrate aerosol particles. Natural gas also emits nitrogen oxides, but not much sulfur dioxide. Sulfate and nitrate aerosol particles cause direct air pollution health damage, but they are 'cooling particles' with respect to climate because they reflect sunlight and increase cloud reflectivity. Thus, although the increase in sulfate aerosol from coal increases coal's air-pollution mortality relative to natural gas, it also decreases coal's warming relative to natural gas because sulfate offsets a significant portion of coal's CO2-based global warming over a 100-year time frame. And in their response to Gilbraith et al. who claim that a WWS system will cause short term warming to the extent that it reduces the use of coal because of the reduction in cooling aerosols related to coal use, Jacobson et al reply that in the short term (<5 years) WWS displacing coal will cause much less warming than natural gas displacing coal, since natural gas emits more than 60 times the CO2-equivalent emissions per unit energy than wind. In the medium term (5–50 years), WWS will reduce warming relative to coal, whereas natural gas will increase it. In the long term (>50 years), WWS will ultimately eliminate warming; whereas natural gas will allow warming to persist. In all cases, WWS will eliminate air pollution mortality almost immediately, whereas neither coal nor gas will.)

Conversion to a wind, water and solar (WWS) energy infrastructure will reduce air pollution mortality and morbidity, the associated health costs, and global warming costs in NYS.

Every country will be impacted by climate change, and this is a good time to take stock of what our resources are, conserve them, develop an energy efficiency plan, de-centralize energy sources, so rather than large power plants, we develop smaller solar and wind installations, and geothermal and hydropower facilities. A plan similar to the one proposed by Stanford University could be developed for any region, but to implement it will take education, political will and a supportive population.

There may be advantages in using domestically produced gas, but one must consider all the impacts, not just positive but also the negative ones, such as impacts on health, climate change, the economy and sustainability.

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