MITOCW | 16. Shale: Opportunities & Challenges

RICHARD SCHMALENSEE: For those of you who don't read *The Times* back to front every day, there was a terrific section that relates to today's lecture. It didn't give me nice cases as Don's did, but the headline captures a lot of what goes on in the section, and a lot of what we'll talk about today. The headline is, "Fuel to burn-- now what?"

So I'm going to talk about shale and its implications, and what it's done to the energy universe in the last couple of years. But first, I've got some unfinished business from last time, a couple of questions I didn't answer. Prosper asked whether anybody was still making coal gas in the old-fashioned, manufactured gas, town gas, heat it and use the results style.

And I couldn't find anybody. I looked around. I did the usual kind of web crawling.

But what I did find is a lot of people that have made and are making gas from wood. This is a reactor being sold by a company in South Africa that's sold it to a number of locations-- wood pellets to make gas, sometimes for a vehicle, sometimes for use in gas mains. And this one, this is from Wikipedia, but I couldn't resist it-- this is a North Korean wood-powered truck.

But if you browse around, there are a lot of examples during World War II where these reactors were put on cars that were then converted to run on wood because you couldn't get gasoline in continental Europe in World War II. So it's not a novel technology. It's not your first-choice technology for vehicles, but in places that have a lot of wood and not much else, it apparently is an interesting and used technology.

There are plenty of vendors. There plenty of examples. So wood gasification-- but I couldn't find anybody who's doing coal commercially. So that's unfinished item one.

Unfinished item two was CO2 emissions. [? Siddhartha ?] asked about how fossil fuels compare, and I kind of mumbled, you will recall. It turns out if you think about it a little bit beyond the mumble stage, it's not a simple question.

You can do emissions per BTU. You burn the stuff. What do you get per BTU?

And that's the carbon-hydrogen mix in the fuel, which varies slightly. So you see coal has about 75% more emissions per BTU than natural gas. And petroleum-based fuels are somewhere in between.

But of course, you don't buy fuels for BTUs. You buy fuels for some purpose, some energy service. You will recall, we don't actually, most of us, live for BTUs alone.

So home heating-- that would be a good comparison, but suppose you want to do electricity. Well, then you have to think about how efficiently you can use them in electricity. You'll note that a gas combined cycle plant is more efficient than a traditional coal/steam turbine plant.

So that means in terms of per kilowatt hour, the advantage to gas over coal grows. And you think about gas-powered automobiles versus gasoline-powered automobiles-- again, there's a difference in engine efficiency. But even that, you've got to think about the emissions in producing it if you want to do this kind of comparison.

And I haven't really seen a good study that lets you get to that third level-- so good question. Easy answer here, somewhat easier answer, somewhat harder answer here. Can't answer that. Any questions or comments on either of these first two topics?

OK, let me go to shale. So the new technology that really has changed-- but it isn't a new technology. So let me be a little bit clear about that. But this is horizontal drilling and hydraulic cracking, called fracking.

So there are sort of two pieces to it. One is the ability to drill deep into shale. This little example shows shale 7,000 feet deep, in this case, the Marcellus. I think this is from the PennEnvironment thing.

And to do horizontal drilling-- horizontal drilling is not that new, but it's relatively new-- and then to put down fluid, which I'll talk about in a bit, under pressure to make cracks in the shale, which permits gas and/or oil to come back into the pipe. Fracking, if you just drill down and crack horizontally, has been done for a long time. Horizontal drilling has been done for a relatively long time.

Putting the two pieces together has had a revolutionary impact. I caution you, "The Times" repeats what the president said in his State of the Union message, which is, DOE started all of this in the '80s. This drives people in the industry crazy.

They say, DOE invested a few dollars in the '80s, and then a whole bunch of little US companies have invested a lot since then to actually make this work. So big firms like Exxon did not have this technology. They're busy buying small firms. Does this sound like a familiar story from Don's discussion? I mean, little guys experimented and experimented and got it to work.

So most of this fluid-- and we'll come back to this-- is water and sand, but there's other stuff. And what other stuff varies from producer to producer, and is the source of a good deal of controversy. But it's mostly water and sand.

And what this does is it makes it economical to extract gas and oil from 7,000, 10,000-foot underground shale deposits. Now, it's not just that it's possible-- it's cheap. And cheap is the story.

Now, there's shale around the world. This is what one installation looks like. This would be called the "pad."

And what normally happens is you drill multiple wells from a single pad. So they might go underground this direction, and this direction, and whatever. So you cover an area with multiple wells from a pad.

When you pump the water down under pressure, it comes back-- there's a shock. And it comes back not only with the stuff you put down, but with stuff it picks up-- various underground minerals, and chemicals, and occasionally something's radioactive or something's toxic. It is then typically, I assume, piped-- although I don't see pipes.

It's piped to a holding pond, and from there it's interesting-- in this picture, it's being trucked away. Sorry, the water is stored in a pit or a pond, and then taken to a treatment plant. What's often done with it instead is it's injected underground in a deep well.

So the water either gets treated out of this pond or it gets, either here or someplace else, dumped back into something that'll hold it underground, some formation where you might otherwise store CO2, for instance. But those are the two possibilities. So questions about the basic story here, the basic process? Yeah.

AUDIENCE: It [? prevents ?] the ground after you start to [INAUDIBLE].

RICHARD SCHMALENSEE: Well, the gas has come up with it, so you're basically taking the gas off, and then you take the water. Yeah, no, this is not full of commercially recoverable gas. Yeah, Jacob.

AUDIENCE: What kind chemicals and fluids do you typically pump?

RICHARD SCHMALENSEE: Well, usually a surfactant of some sort to reduce surface tension, to make it more easily penetrate. In some cases, people have put benzene and various petroleum products down. This causes a lot of distress, as you could imagine, but usually-- usually-- some surfactant and other stuff.

For the little guys, this has been sort of a secret sauce. It's mostly water and sand. And I'm not going to tell you what the rest is, haha. Well, what's missing here is this might be an aquifer, so there might be groundwater issues.

And we're going to talk about this-- usually not coming up from 7,000 feet down. The aquifers are higher. But if the well's integrity is breached, stuff can come out from the well. And that happens.

OK, anything else? All right, so that's the picture. So this process now makes it economical to extract oil and natural gas from shale.

Where is the shale? The key thing is this gray bar. The height is the amount of shale gas recoverable. The black is coalbed methane, which is also doable.

But the new thing is the gray bar. And you will notice we have a lot of it. There's not that much in the Middle East, some, presumably, in Africa, but little exploration, some in Latin America, a lot of it over here in Asia-Pacific, which is mostly China. So China appears to have a lot of shale.

We got really lucky. We have enormous amounts of shale from which this stuff is recoverable. Australia often refers to itself as "The Lucky Country." In this one we got lucky. Europe-- this, I believe, is OECD Europe, and that is mostly Poland, which is starting to work on it.

So where is it in the US? Well, the good news and the bad news is, a lot of it is near where demand is, as opposed to, say, wind or solar that tend to be in the desert or in the high plains. A big play here is the Marcellus, and that's New York, and Pennsylvania, and Ohio, and in this Eastern region. That's enormous. That's just an enormous amount of recoverable gas.

The other play that people talk about, other plays that people talk about, are the Bakken up here, mostly in North Dakota. The Bakken has a lot of oil that is being recovered using this same technique, as well as gas. There are not a lot of pipelines out of North Dakota, and as we will see, that's a problem, but oil you can move. Oil's valuable enough. You can find a way to move it.

The other places are the Barnett, the Barnett shale, a lot of which is-- oh, yeah, there are a lot of people up here in the Marcellus. Some of this is rural. Some of it's near urban areas.

You read that PennEnvironment document. They talk a lot about schools, libraries, and stuff. Down here in Texas, a lot of it's not near anything, which is all good. And in the Bakken, a lot of it's not near anything.

I think the Eagle Ford supposedly has a lot of oil. But people have been doing various kinds of fracking in Texas, not necessarily horizontal, but vertical and experimental, for a long time. Nobody's drilled for anything in the East since the first Pennsylvania oil field went dry in the 19th century.

Well, I'll say a little more. As you see, there are plays elsewhere, in Arkansas, for instance, there's some action. But this is the Marcellus, is what people talk about a lot. The Bakken there's a lot of action, and then down in Texas, with a little bit elsewhere, little bit in California.

Colorado-- again, people have been doing this in Colorado for a while. The reserves are smaller. And I don't know much about most of the others. Comments or reactions about this?

OK, so what's all this done? Well, it's created a boom. This is a map of wells in Pennsylvania through the end of 2010. You see their trajectory-- 27 wells drilled in 2010, then 161, then 785, then 1445, and 3,000 wells in the ground producing by April of 2011, with rapid permitting going on, concentrated in a few areas.

Similar story elsewhere-- the Pennsylvania folks just happened to have provided a convenient map. So you have a drilling boom to get at this resource. What's it done? Well, it's depressed gas prices.

You may recall last time, this is a Henry Hub price. Last time, this graph cut off about here. This is the result. This is the rest of it.

We're down in the neighborhood of $2 per million BTUs, where the normal price was tending to be around 10, eight, 10, was what people thought was sort of normal. And again, if you go back to the Pennsylvania figure, the drilling, this is all since-- it just began in 2007. There is no pre-2007 drilling in Pennsylvania, and there are more than 3,000 wells, probably 4,000 by now, producing. So this has come on very fast, very big, and in parts of the country where people live.

And it's depressed the natural gas price. To go to a question that we discussed last time, this is arguably old business, but just to do an oil-- oh, yeah, people in the business say what happened, the reason we're at $2, is a lot of people got very excited. This happens in businesses like this-- everybody drills a well.

All of a sudden, oh, my god, we've drilled too many wells. It's not profitable, most people say, to get at this gas at $2 a million cubic BTU, but at $4 it is, and at $6 it is. Somewhere in the four to six range is where people look for a long-run equilibrium.

Drilling will slow down for gas alone. Demand will pull the price up, blah, blah, blah. So they look at the four to six range, as opposed to the eight to 10 to higher range, as a place where gas will settle down.

And there is a lot of it. There's controversy about how much there is. So one thing it did was to depress the gas price.

It drove an interesting wedge between gas and oil. So this is another one of these comparisons. If you just look at dollars per BTU, which I caution is kind of a crude measure, because not all BTUs are created equal. Gasoline is better for automobiles because you can have a higher energy density and a longer range, and so forth, and it's easier to transport per BTU.

So oil has a variety of advantages, but if you just look at BTUs, then the conversion factor is apparently 5.825, which references tend to agree on. So that means if gas is $2 a million BTUs, that translates into $11.65 a barrel of oil. But when gas hit $2 recently over here, oil was over $100. So that says in BTU terms, the difference right now is enormous.

If you can find a way to use the gas BTUs and not oil BTUs, it makes a big difference. And it makes a difference in a lot of settings. I have a colleague-- I haven't seen the paper, but he says it's straightforward that a natural gas car dominates an electric car. An all electric car, you've got to have an expensive battery, it has limited range, dadada, you've got to plug it.

And natural gas, you need a tank. Engine is trivial to modify. It doesn't cost much more, and the range is also limited, but it's about the same.

So why would you buy an electric car when you can buy a gas car? Well, we'll see. They're not subsidized yet. We'll see.

But anyway, this is a big deal. Again, historically, there are gaps between oil and gas. They don't track precisely because as I mentioned last time, you don't really have electric utilities substituting every five minutes between oil and gas.

But this is pretty much unheard of. That difference in price per BTU is unheard of. And it's opened in the last couple of years. So that has implications. And again, "The Times" talks about this without the picture.

The other thing it does is look at this. This is the Energy Information Administration's Annual Energy Outlook Early Release, which came out either January or February. It says this is their projection for future production of natural gas.

This brown thing on the top is shale. I mean, look at it-- there's nothing going on here until about 2006, 2007, and then it explodes. And by 2035, it accounts for almost half of total US production.

Previous work sort of focused on these, just plain old gas, gas that you get with oil, coalbed methane-- steady decline, increase in demand, lots of imports. Tight gas, which is related, is going up, but shale gas is projected to explode. I happened to look because I was updating last year's lecture, and I had a graph like this last year.

The graph last year showed-- this was, again, circa last March or April-- it showed the US being a net importer of natural gas through 2035. Again, this was a year ago. It projected big increases in shale, but not enough to offset demand, and said we would be an importer through 2035.

The current projection a year later is we'll be a net exporter of liquefied gas by 2016. We'll be a net exporter overall-- pipeline and liquefied-- by 2021. That's in a year.

That's unheard of, just to be clear. That's a dramatic, dramatic change. I think when I taught this two years ago, I'm not sure we mentioned shale.

Anyway, the other thing is it has had an impact also on oil. If you look at oil, US production of oil, as we discussed early in the semester, has been in long-term decline. in large part because of shale and related developments, they now project a pretty steady increase in US production. And this is not, oh, my god, we've authorized deepwater drilling or oh, my god, we're drilling the National Wildlife Refuge on the North Slope. This is under current policy. This is under current policy we will produce lots more oil.

OK, what's good about this? What are the benefits? We'll come to cost in a minute, but is this a good thing? Why is this a good thing? Maxwell.

AUDIENCE: [INAUDIBLE]

RICHARD SCHMALENSEE: It'll get us energy. It'll move us toward energy independence if we use the natural gas in transportation, energy security, rather. It'll affect our balance of payments regardless. But since most of our gas imports are from Canada-- I know they're shaky up there-- but to the extent we use it in transportation, you really get some energy security benefits.

And let me just expand on that a little bit, because I know other people want to talk. One of the interesting things in here that I hadn't focused on-- in "The Times," rather-- they talk about the garbage truck market. Garbage trucks are perfect for this.

They're centrally fueled. They're in use for a few hours a day. It's perfect. And given the price difference, the fuel price difference, they said something like half of garbage trucks sold now are natural gas compatible. A third of buses sold now are natural gas compatible.

So you do expect a reasonable amount of use in transportation. That'll reduce our imports, improve the trade balance, and improve energy security. Anything else? Yeah.

AUDIENCE: Reduction in emissions.

RICHARD SCHMALENSEE: Reduction in emissions, we'll get. I want to come back to that later because that's an issue. You expect it to reduce CO_2 emissions as we move from coal to natural gas. There's some controversy there and I want to come back to that. Jessica.

AUDIENCE: [INAUDIBLE] resource, but you have mostly infrastructure layout [INAUDIBLE] so you're taking [INAUDIBLE] or it's easier, there's less of a barrier to entrance [INAUDIBLE].

RICHARD SCHMALENSEE: You don't have too much of a chicken/egg problem because you do have the pipeline infrastructure in place-- not everywhere, and we'll see that in a second. You do have to put in, if you're going to do it in transportation, you have to put in refueling stations. "The Times" argues that to do it effectively and trucking-- forgetting about garbage trucks and so forth that you can pretty much do now-- to do it for interstate trucking you need, they said, 2,800 fueling stations on the major truck routes. And people are building them. David.

AUDIENCE: [INAUDIBLE].

RICHARD SCHMALENSEE: You expect the US industry to be more competitive because costs have come down. There's the other interesting thing that we tend to forget, because we think of natural gas, particularly in this class, as mostly an energy source. But it's a feedstock for a variety of chemical processes.

And so a bunch of the industries that use that as a feedstock-- plastics, importantly, but others-- are moving back to the US because it's so much cheaper here than elsewhere. So you're getting natural gas based manufacturing moving back, not only because energy costs are down but because feedstock costs are down. Anything else? Ryan.

AUDIENCE: [INAUDIBLE] American jobs.

RICHARD SCHMALENSEE: Jobs-- I've got a great graphic on that, that I'll show you in a minute. But that's normally the first thing-- in Congress it's the first thing they say-- this is jobs. OK, I think we have most of the benefits, but not all. Anything else anybody can think of? Oh, sorry, yes, Kirsten.

AUDIENCE: [INAUDIBLE] continue to explore [INAUDIBLE] increases, so in the future [INAUDIBLE] prices to be less volatile [INAUDIBLE] in the ground?

RICHARD SCHMALENSEE: It might be less volatile. I think so. But you still have this short-run inelastic demand, inelastic supply issue. And a really cold winter or really warm winter can have an impact.

They do store gas, not just in the big tanks you see when you drive south along the waterfront. But it's stored in underground caverns and has been for a long time. So you would hope that the volatility will go down because we're a little bit out of the world market. Yeah, didn't have that. Anything else? Yeah.

AUDIENCE: Would that mean money for the government in terms of royalties?

RICHARD SCHMALENSEE: It might if it comes from federal lands. Suppose it comes from private lands. I have friends who inherited an otherwise useless ranch in Texas and were told there's natural gas under your land. We'd like to drill.

They like that, because they weren't going to live there. In fact, nobody was living there. And they're happy to cash that check when it comes in every month. So it's money for the government in revenues, depending on the royalties. It could be money from landowners.

And that's everything except something that we haven't talked about and you might not pick up until we've talked about electricity. And that is one of the issues of bringing in wind and solar is they vary and they vary unpredictably. So you need resources that can respond to that.

I mean, storage would be swell. Storage is the Holy Grail. We don't have storage economically.

So what you tend to use is you tend to use gas turbines. And gas turbines, if you recall from-- not combined cycle, but old gas turbines-- and on an earlier slide I had the efficiency of those. And it's not high, but they're quick. Well, this reduces the running cost of the devices you will use to use more wind and solar, and thus makes it easier to integrate wind and solar into the system. Jacob, you had a point?

AUDIENCE: Yeah, I was just going to say I hope you're going down the path of it provides baseload power for [INAUDIBLE]

RICHARD SCHMALENSEE: It can provide baseload. It provides, as we were saying, lower emissions baseload power, particularly the combined cycle stuff.

AUDIENCE: [INAUDIBLE] used to turn on and off really quickly when the power demand spikes.

RICHARD SCHMALENSEE: And you use the combined cycle stuff for baseload. You may or may not remember the brief discussion of combined cycle. We'll probably come back to it.

But when we talked about Hexion, I mentioned there were two sorts of technologies. And the combined cycle technology is a generating technology, not unrelated to what was going on in Hexion, but it's generating technology. You use natural gas or oil or whatever, but typically natural gas, to run a gas turbine.

The exhaust from the gas turbine is hot. You use the exhaust from the gas turbine to heat water to make steam and you run a steam turbine-- hence combined cycle. You can get a lot of efficiency because you're not putting out a high temperature exhaust.

You're not wasting that heat. You use it. And you can use it effectively in a steam turbine. So that's effective.

So the other thing we didn't talk about and that's because you don't own homes, but if you own a home, you'll have lower heating costs. That bill that comes around in the winter will be lower. This is a good thing.

I just managed to persuade my condo to convert to gas from oil. And electricity will be cheaper. So for those of us who pay these bills, that's a good thing. We'll reduce gas and probably oil imports. It will reduce it because there's more production but also because you'll be substituting gas for oil.

US manufacturing-- people get very excited about a rebirth of US manufacturing, some of which is driven by energy, some of which is driven by feedstock prices. Easier to integrate wind and solar, money for people in rural Texas for ranches they had no intention of living on. We're going to talk about-- I didn't underline "some," but I probably should have underlined "some." Fewer neighbors in rural Texas than, say, in urban Pennsylvania-- that's an issue. And of course, jobs.

These are pictures of North Dakota. And this is oil production in North Dakota. North Dakota is now the number four oil-producing state in the country from pretty far down the league table.

And for the last three years, I don't know what the early 2012 numbers are, but for the last three years, it's had the lowest unemployment rate in the country. So if you're from North Dakota, this is fabulous stuff. All of a sudden the land is worth something. All of a sudden there are a lot of jobs. And if you're running a restaurant, all of a sudden there are people who come in.

This is oil production. This is gas production. And this is an interesting graph for a number of reasons.

You see what you would expect, which is natural gas production goes way up. But there aren't pipelines. And this is the percentage flared.

So "not marketed" means "flared." They're burning it. So they're burning, depending on the month, up to 40%, typically above 30% of the gas produced.

The money is in the oil. They don't have enough pipeline capacity to get the gas out so they burn it, which is a shame. Somebody will build a pipeline. That's money being burned. OK, comments?

But there are issues. You can find, and I was going to try to do it but my earlier attempts to link YouTube videos didn't work well. But you can go to go to YouTube, and most videos on fracking look like this. Somebody pours water, lights a match, foomp.

And earthquakes-- there was some recent press coverage of fracking-related earthquakes. So this is not a completely benign technology. I mean, neither were railroads. Neither were coal-fired power plants. Neither are automobiles, but it has issues.

Some of the issues-- they mostly come from these features. Some of the fluids contain toxics, some of the stuff that's pumped down-- and again, it varies from player to player-- is toxic. The water that comes up is at least as bad as the stuff that went down, often quite a bit worse. It's got whatever junk it picked up traveling through thousands of feet of rock.

The wells go through aquifers often. You drill down. You're drilling down through an aquifer. That's somebody's groundwater. That's the well water that's burning.

Methane has its own toxicities. It is flammable, per that picture. And it is a greenhouse gas. So the question that Philip raised of lower emissions gets to be a little complicated, because methane leaks.

So these are the main issues. Let me just walk through some of the environmental problems. First is groundwater contamination-- not that big a deal in Texas, big deal in Pennsylvania. They actually have water in Pennsylvania. The best evidence I know says that the problem comes from the well bore, from going down-- that it's very hard for the gas to leak up through 7,000 feet of rock into the groundwater.

But in any case, there are plenty of examples where groundwater has been contaminated. There's also this issue of wastewater, the stuff that's coming back. It's got all kinds of junk in it. If you don't inject it safely, if the holding pond leaks, if the treatment isn't adequate, you can have that as a source of contamination.

There is nearby pollution. There's all this junk. You're running an industrial operation-- again, not necessarily so terrible in Texas. Do I have a picture? No, I don't?

Not so terrible in some places, but the methane will be out. That's not nice stuff. Various other toxic things come out-- volatiles in the groundwater.

You get dust, and noise, and a lot of traffic, a lot of vehicle traffic. You truck the gas out typically, and find a pipeline. You don't build a pipeline to every well site.

So it's noisy, and messy, and dirty. Does that matter? Well, in Pennsylvania and New York, there tend to be a lot of people around. In North Dakota and Texas, not so many.

So whether these things are important or not depends on A, what the well does, and B, what damages it inflicts. I mean, my friends' ranch, there's nobody for miles. So yeah, there's dust, and dirt, and traffic, and junk, but it's polluting the sagebrush. In that PennEnvironment thing, there are schools, hospitals nearby.

Methane leakage-- let me talk about methane leakage. There was just a piece in "Nature" about methane leakage from one field that folks managed to measure well. And it was like-- not to make up a number-- like 6% of total production leaked.

Well, methane is a greenhouse gas. We talked about that earlier. It has a relatively short half life, order of magnitude 10 years-- quicker than carbon dioxide to come out of the atmosphere, but while it's in the atmosphere, it's potent, more potent than carbon dioxide per unit of mass, or maybe per mole, one way or the other.

In any case, this is sort of a serious issue. If you're going to produce this stuff at scale for a while, and dump a lot of methane in the atmosphere, you're going to have climate implications. There was a study that said producing and using natural gas via fracking is worse for the climate than coal on a lifecycle basis.

That study was pretty badly flawed because it assumed very inefficient coal plants, but if the methane leakage is high enough, that could be right. And if you use the right measure of climate damage, which I think he used the wrong measure of climate damage as well. But that's a serious issue.

Earthquakes-- "Another Fracking Earthquake," from that t-shirt-- great t-shirt. Again this year there were discussions of earthquakes in northeastern Ohio, thought to be associated with basically dumping all that water deep underground, kind of lubricating the formations. An Ohio regulatory authority, with a lot of consultation with geologists, has verified, they think, that in fact, the fracking was the cause of small earthquakes. But small earthquakes are earthquakes-- magnitude 3 kind of earthquake, for those who follow that sort of thing.

In Ohio, they've responded by saying it doesn't always do this. It does it when it's injected in certain ways into certain formations. And they have a set of regulations for Ohio that they think will deal with this. But it's an issue-- earthquakes, not everybody's favorite.

How many people have been through an earthquake? Oh, yeah, from California? Where? All over.

AUDIENCE: Last summer here.

RICHARD SCHMALENSEE: Yeah, there was a little one here. OK, that's true, that's true. That doesn't count. If it's not magnitude 5 at least, it doesn't count.

It's a weird feeling. And in Ohio it doesn't happen, but it does now. It does now.

And this one is actually very interesting if, as I hope you did you looked at the Jacoby et al. article. Their argument is if you look down the road, and you're serious about climate, you will recall from our difficult negotiations the world's going to need big reductions. And you can't get the big reductions unless you can figure out some magical way to do transportation.

But you're not going to get the big reductions unless you get the carbon emissions from the electric power sector way down. Natural gas doesn't do that for you. It gets it down, but not way down.

But if natural gas is cheap, then you don't build a nuclear plant, and you don't fool around with nuclear technology because it's so noncompetitive. And wind and solar require bigger subsidies to compete. And so the argument is it's quite possible that cheap shale gas will slow the development of very low-carbon technologies, and thus be a bridge to nowhere.

We will easily lower the carbon content of the electric power system, and heating, and other things. But after a while, we won't be able to go any farther, because we won't have the technologies we need, because they will have been non-competitive all along, and been very expensive in subsidy terms. And so this could easily be a bridge to nowhere that stops progress on climate after a while.

That's why it's a complicated question. Short term, yeah, unless you get a lot of leakage, but the long-term question's really hard. What's it mean for wind, solar, nuclear, or other carbon-free technologies?

The European Union, I learned on Monday, has a formal plan to have zero carbon dioxide emissions from its electric power sector by 2050-- zero. And as the presenter said, we in Europe do a lot of talking. But if you do a projection of what it takes to get 80% of reduction in greenhouse gas emissions, boy, you better be pretty low carbon. And natural gas won't get you there no matter how cheap it is.

What's the policy [INAUDIBLE]? Questions on any of this? Yeah, Max.

AUDIENCE: [INAUDIBLE] wind, solar, nuclear are fairly not competitive right now, [INAUDIBLE] still develop the technology. So why would we keep developing [INAUDIBLE]

RICHARD SCHMALENSEE: Well, wind and solar are being driven by subsidies, and those subsidies get to be more expensive as the alternative gets to be cheaper. So the argument is yeah, you could, but if you were starting a wind turbine business, you'd have to be really sure of the subsidies or pretty sure that you can get the cost down so you won't need them.

The lower the cost of gas is, the harder that second is to be sure of. And the lower the cost of gas is, in a way, the first gets shaky because it becomes hard politically to justify subsidizing wind and solar when we're moving into gas and emissions are going down and we're all swell. Nuclear, I think, is going to be hit the hardest.

Well, we may talk about nuclear. And we'll hear about nuclear from some of your papers. So I'm looking forward to learning.

But I think what people do tend to say is with gas at these prices, even forget $2 but $4, boy, is a nuclear plant out of the money. And if you don't build them, it's hard to really prove out the technology. There's all these fabulous designs for intrinsically safe, small-scale nuclear plants, but unless we build them, we're not going to know.

And building them gets to be a more expensive proposition. So it's hard to do that nuclear stuff, because you really need to do it at scale. That means somebody's got to bear the commercial risk, and the commercial risk gets bigger with cheap gas.

So I think that's the basic issue. I mean, the government could say, look, I think this is so important we're going to keep doing it. The Europeans might. I worry about us, and we'll see about the Europeans. We'll see about the Europeans. Anything else? Yeah.

AUDIENCE: Does it matter also, though, if, in a few years, we'll have some sort of carbon tax or something like that? Because then you would start arguing that whatever emits carbon will become less competitive.

RICHARD SCHMALENSEE: Yeah. I mean, with a serious carbon tax-- again, cheap shale, cheap gas, the advantage of renewables over gas-fired power goes down with the price of gas, given any carbon tax. You're right, the carbon tax widens the gap. Cheap gas narrows it, so you need a bigger carbon tax to have the same differential.

I mean, we all say, of course, we're going to have a carbon tax at some point. We have to have a carbon tax at some point. I know people who have been saying that for 20 years.

So I would love to be young enough to have the feeling that of course it'll happen soon. But I've watched it not happen for so long. And I've watched the Republican Party harden against climate so firmly that we'll see.

It may take-- those of us in the area speculate from time to time that it's going to take something like an ozone hole. You recall or you may not recall. What led to the Montreal Protocol wasn't all the brilliant chemical work done, a lot of it here at MIT that won a Nobel Prize. It was the opening of the ozone hole over the Antarctic, such an image.

There's a hole in the ozone? Most of us didn't know there was ozone to have a hole in. But there's a hole in the ozone, and it's letting in all these harmful rays, and it's getting bigger. That was pretty dramatic.

Having the Arctic be ice-free maybe-- maybe that'll be dramatic, but we don't see that. Ozone hole, you go out, and you get a suntan, and your risk of skin cancer goes up. Well, that kind of comes home.

There aren't any more polar bears? Well, that's too bad, but I can go to the zoo. So I don't know what on the climate side-- I love polar bears.

Please don't quote me. They're "charismatic megafauna," as the phrase goes. It may well take something like that. Anyway, anything else before I go to the policy arena? Yeah.

AUDIENCE: Are the big players large companies or small [INAUDIBLE]?

RICHARD SCHMALENSEE: In terms of this industry?

AUDIENCE: Yeah, like Chevron [INAUDIBLE]

RICHARD SCHMALENSEE: The big companies have bought small companies to get the technology. So the people who were big gas producers are big gas producers. Again, there are still small players. There are still small players.

AUDIENCE: [INAUDIBLE] direct a little R&D money that way.

RICHARD SCHMALENSEE: I don't know. I don't have the sense-- I could be wrong, but I don't have the-- and we do sort of see these folks when they come to the Energy Initiative to fund research. So we get some sense of what at least some of them are interested in. I hear a lot more interest in finding technologies than extraction technologies, 3D seismic underground mapping, improvements there, rather than better drilling.

It's a young technology, but it seems surprisingly mature. Nobody says, "If only we could do this." The one issue that people talk about, and "The Times" mentions it a little bit, is the technology was aimed at gas and it's not yet tuned for oil. And there are places where there's oil, but they're getting a ton of oil out of North Dakota, so it's not too badly tuned.

So this particular technology doesn't seem to be a huge R&D target. At least that's my sense. It's very deep shale. The stuff that would help you figure out where the gas is seems to be higher on their wish list than techniques to get it out. If they can find it, they can go down 10,000 feet, drill sideways, break the shale, and get the gas out, which is pretty amazing.

The policy arena-- so the PennEnvironment report is pretty good on this. It's a bit of an advocacy piece, but it's pretty good. You would normally think that the air stuff would be EPA, the air pollution issues I talked about.

There is a Safe Drinking Water Act that you would think would cover stuff that would affect the aquifer. And indeed, it does in a lot of areas. But there are exemptions to a lot of federal legislation, put in place quietly in the middle of the night, that means there's relatively little EPA can do.

It can set some standards for local air emissions. And it's doing that for methane emissions. It will probably have regs on methane leakage.

But the water side is pretty limited by law. I mean, it covers a lot of stuff that pollutes aquifers. It can't get at this.

And even if it set the standards, the enforcement would be at the state level. And if you think about it, this is not easy enforcement. I showed you 2,400 wells in Pennsylvania-- lots more coming. How many inspectors do you think the State of Pennsylvania has to inspect natural gas wells?

Well, they haven't had any natural gas drilling in Pennsylvania or drilling for anything in Pennsylvania. So they probably started out with, let's say zero. And maybe they have a few if their budget's been generous.

So enforcement is a state issue. The rules about the fluids are state issues. EPA can't control that. Rules for that well, the bore, how well it's sealed, how thick the concrete is, what, kind of concrete all of the stuff that gets you down below the aquifer and that has to be inspected-- that's the state.

The experience and attitudes vary enormously among states. New York, as I'll mention in more detail, has a moratorium. You cannot do this in the State of New York-- full stop, done. Pennsylvania is letting people drill. Does Pennsylvania have expertise?

Does Pennsylvania have an adequate budget? Does Pennsylvania have adequate laws? The PennEnvironment report suggests not. Others may disagree. I don't know enough to have a view.

Texas does oil and gas. They've been drilling and fracking in Texas for a long time-- not at this scale. And Texas also has a lot of rural areas, where it's dusty, and it's dirty, and it's I don't care.

Nobody lives here. It's a job. There are jobs. That's fabulous.

Some states are revving up. There's a lot of industry interest. Texas is now requiring fluid disclosure. I think others are.

There's an interesting industry split. The small guys oppose regulation. The small guys say, I don't want to tell you what my fluid is.

I don't want to be inspected. I'm doing a good job. Leave me alone. I'm just a little guy.

You talk to people from Exxon, and people from Exxon, and Chevron, and those guys say, we need regulation. This is anti-stereotype, and it's worth thinking about because we'll come to public policy in a little while. They want regulation.

Why do they want regulation? They don't want to see a lot of those videos of drinking water burning. They don't want a lot of states to do what New York has done and say, you can't drill here.

So the big guys think, OK, it adds $1 or $2 per million cubic feet, to control methane emissions, to inspect the wellbore, to limit the fracking fluids, to disclose everything. $1 is nothing to the big guys. $1 might be something to the little guys.

The big guys are afraid of a backlash. The big guys are afraid, and you hear them say this after about two drinks. This industry could go to the way of nuclear power.

The public could be so fed up with earthquakes, and groundwater pollution, and burning water coming out of faucets, that we get shut down. And the country that could have all this abundant, relatively clean energy won't get it. So the big guys are in favor of sensible regulation.

There's a lot of industry best-practice activity. There's a lot of work by the big guys with the states to avoid a backlash. Please impose reasonable costs on this industry we will still be cheap. Don't shut it down.

An awful lot in the environment community think state regulation can't work. Pennsylvania's going to regulate natural gas drilling? They haven't seen a well for 100 years. What?

So they say it's hard to enforce. You're going to inspect every well as it's being drilled. You've got to monitor the quality of concrete.

This is a serious enforcement problem. They're all over the landscape. You can't do it.

Yes, in principle, regulation might make this safe, and so forth, and clean, but you can't do it. So you should just kill it. Just kill it. Again, if you Google fracking on-- if you look at Google Images and call for fracking, you will get posters and rallies galore-- ban it, ban it, ban it.

Stop fracking in Ohio. Where else do you see a lot of-- it's banned in New York. It's banned in France. It's banned in at least one German state. And there are debates in lots of other places that say basically, it's a moratorium. If you can prove it's clean and safe, we'll let it go on.

In North Dakota, it's jobs. In Texas, it's we know this and nobody lives out there on those ranches anyway. In New York, this is New York. People live here. Pennsylvania, people live here. Yeah, Jessica.

AUDIENCE: How long could they go using the natural gas reserves? [INAUDIBLE]

RICHARD SCHMALENSEE: The ones we have now, the shale gas?

AUDIENCE: Mm-hmm.

RICHARD SCHMALENSEE: Hard to know-- what we're getting are estimates of probably recoverable reserves. Proved reserves are much lower, but estimates are hundreds of years. It's just a lot of gas at low cost. So what that thought leads to, and the fact that it's cheap leads to, it may be impossible to kill because the economic benefits are so large that politically it may be hard to kill.

But suppose everybody in Pennsylvania has their water burn when it comes out of the. Tap will New York drop its moratorium? Probably not. Will Ohio impose a moratorium? Probably.

So if you can't make it safe-- what's a little burning water? I mean it's things. But anyway, think about the stuff we breathe every day. But that's dramatic. That's a YouTube video.

The PennEnvironment report has sort of a balanced proposal. It talks about there's another part of the environmental community. It clearly couldn't be killed in Pennsylvania. It's 3,000 producing wells and 10 a day being permitted.

What, are you kidding? We're going to kill this? I don't think so, not now. So they say what you need to do is eliminate these federal exemptions so EPA can play a role for groundwater.

And they have a number of very specific suggestions, which I don't want to go in, for tightening regulation in Pennsylvania, like not letting this stuff happen near a school or near a hospital just because there is increased local pollution, no matter what you do, and giving the agency some money to enforce. It's easy to write rules. Enforcement takes people.

And then finally, that lovely interview with Fred Krupp from the Environmental Defense Fund. As we'll talk about later, the Environmental Defense Fund has played a very interesting role historically in making environmental policy in this country, to the extent possible, economically sensible. And Krupp argues you can't do anything in Washington, so to say the EPA should play a role-- of course, it should, but you can't get that passed.

You can't get sensible legislation passed in Washington. You can't get those loopholes closed, at least not now . And you probably shouldn't kill it because the benefits are so large.

I think underlying that is a realist saying, you probably can't kill it because the economic benefits are so large for so many people. So there really isn't any choice but to work with the states. Encourage the states to talk to each other. Encourage the big producers to work with industry.

So that's sort of the policy environment, I think. Reactions? Comments? Anything? OK, let me throw the floor open. Suppose we were lucky enough or unfortunate enough to have shale in Massachusetts.

You're an MIT students. You can march on the State House. You can get TV time. You can make noise. What do you do?

Drill, baby, drill-- we need the jobs. We need the benefits. Let's be real. Let's make it hard.

It's not under Boston. That would be too easy. They're never going to drill under Paris. But suppose the shale is in the western part of the state, which has been chronically depressed.

Suppose that's where the shale is, the western part, not the Berkshires, kind of central Massachusetts. Pittsfield, has anybody been to Pittsfield? You've been to Pittsfield, all right. Are you from Pittsfield?

AUDIENCE: It's near Tanglewood.

RICHARD SCHMALENSEE: It is near Tanglewood. Tanglewood is nice. Pittsfield, well, MASS MoCA, but otherwise been depressed for a long time. We've got shale in Pittsfield, in the central part of Massachusetts where there are no jobs, and you're going to march on the State House. Alex, was that your hand I saw?

AUDIENCE: I was going to say, I think if there is a way to do it safely, if they can figure out how to do it so your faucet isn't burning, then I think it would be [INAUDIBLE]. But otherwise, I don't think it's worth it if you're causing more problems to all the people who live there. Because there are a lot of people in [INAUDIBLE].

RICHARD SCHMALENSEE: Even in Pittsfield. So would you advocate a moratorium until we know for sure how to do it safely?

AUDIENCE: I'd advocate for regulations.

RICHARD SCHMALENSEE: Are we sure we know how to regulate?

AUDIENCE: No.

RICHARD SCHMALENSEE: No. OK, but you would say at the very least, the state ought to acquire some expertise. We ought to have a legal framework. I mean, nobody's drilled for anything but water in Massachusetts ever, so we don't have anybody who knows about deep wells or groundwater conta-- well, we know about groundwater contamination. OK, anybody else? Arianna.

AUDIENCE: My parents have a house in upstate [INAUDIBLE] New York. And a couple of years ago, actually, our town exploded the anti-fracking [INAUDIBLE]. We were on literally everyone's yard.

And I think that even though there are a lot of large-scale benefits, in the end, I think it's great to do in Texas and places where people don't really live. But there is a large segment of not in my backyard. And we like our house, and primary residence in New York City. Part of it, I know, is that it's nicer and clean. The air is clean, and getting to spend some time with nature, I guess.

RICHARD SCHMALENSEE: I hope you have some nature up there. Yeah

AUDIENCE: Lots of trees. But the idea it's great if energy prices fall, but I don't want it at my expense.

RICHARD SCHMALENSEE: So you'd advocate, if we can translate to western Massachusetts, which isn't that dissimilar, you'd say, no. No, thank you. They're doing it in Texas, they're doing it in North Dakota. The people in Pennsylvania may or may not have made a mistake, but we're not going to do it, full stop. OK.

AUDIENCE: I would also say, why would-- if you're [INAUDIBLE] or whoever has a significant population and has no experience with it, why be in a hurry to go ahead and drill everything and not just wait to see some sort of regulations? I mean, to have a clear framework of what you should regulate, and how you should do it, and what are the consequences, and all that. So like North Dakota and Texas have a smaller, lower population density. Figure out the hard stuff, and then figure out if you want to do it or not in a few years when you know what the consequences are.

RICHARD SCHMALENSEE: Of course, we may not be happy with a regime that would make them unhappy in North Dakota. Because they're desperate for jobs and we're not that desperate. So they might be willing to deal with that to accept environmental harms that we wouldn't like. So you wouldn't just want to follow them, necessarily. Julian.

AUDIENCE: So I'm going to agree with Alex for the most part, in that regulation is needed to some extent. It is needed to keep things safe. But realistically, you're going to have to work very, very hard to keep people's hands off of money sitting underground. I'm from Santa Barbara, and--

RICHARD SCHMALENSEE: You can see the oil out there, can you?

AUDIENCE: You can see 13 oil rigs from my house. And there is a very, very, very strong environmental movement. It's California, blue Democrat as hard as you can go, pretty much.

RICHARD SCHMALENSEE: You do have some Republicans in Santa Barbara.

AUDIENCE: We do, but it is quite blue. It is quite, quite blue. And still people drill for oil. You can see the oil rigs out there. There are even pumps on land and whatnot.

And it's kind of a tough argument to go against it economically. I mean, when you can say that OK, these people might have some bad health effects from fracking and whatnot, but if they can't afford health care anyway, then what's the difference, really?

RICHARD SCHMALENSEE: Well, we have universal health care in Massachusetts, to a pretty good approximation. So we're OK here. So we may as well just drill because everybody can get health care?

AUDIENCE: Well-- like if someone can't afford something, the economic benefits-- I mean, not necessarily in Massachusetts exclusively, but let's say in another state which doesn't have universal health care.

RICHARD SCHMALENSEE: Let's say.

AUDIENCE: That argument could be--

RICHARD SCHMALENSEE: Connecticut or western Connecticut, Rhode Island, yeah.

AUDIENCE: I mean, there are economic benefits, which can in turn have other benefits. And yes, there should definitely be regulation, but the argument to say, no, we should absolutely not touch this stuff that's under the ground is going to be extremely, extremely hard, especially when you go against probably all the lobbyists from X different firms which are for this measure.

RICHARD SCHMALENSEE: And all the mayors of depressed towns who say, we need jobs. We need jobs. [INAUDIBLE], you're going to agree or disagree?

AUDIENCE: Disagree, actually. Because when we had the climate negotiations, we were talking about how urgent it is to start taking action to reduce the CO2 emissions [INAUDIBLE]. So if you start using this method, and many studies shows that it might have very bad effects on the environment, and in 10 years we will see what are the bad effects that this method had, it's going to be like 2022 and then we start discussing again how to reduce greenhouse emissions. I think it's going to be too late by then.

RICHARD SCHMALENSEE: So you'd say no.

AUDIENCE: We don't have room for any more mistakes anywhere.

RICHARD SCHMALENSEE: Or let them make the mistakes in North Dakota and not nationwide.

[INTERPOSING VOICES]

AUDIENCE: --everyone.

RICHARD SCHMALENSEE: Nobody in here is from North Dakota, as I recall. I can insult North Dakota. Get out of town. David.

AUDIENCE: I think from an environmental perspective, even if you didn't know it's 100% clean and no methane, no water caught on fire, it's still a terrible thing for carbon emissions. Because your actions for decreasing your heating bill or insulating your house so it's more efficient and so you don't need as much heat, or using cheap natural gas but then to continue having a really inefficient house and leaking heat everywhere.

RICHARD SCHMALENSEE: So you're troubled by the bridge to nowhere argument. And you'd say, unless we actually can fit this into a climate policy-- which it could be if it were part of a carbon tax, use this for a while, get off it-- would you be comfortable with that? Or you just say no.

AUDIENCE: I say environmentally that's-- yeah. Or you could use-- if the costs are so low, you can have a very high carbon tax, and use that money to perhaps support solar or nuclear or whatever. But I think economically, you can't make that argument. You have to give people jobs and environmental arguments are going to get legislation passed.

RICHARD SCHMALENSEE: So you're saying you'd march on the State House, and you'd say, "Only with a carbon tax," and you'd count on losing.

AUDIENCE: Yeah.

RICHARD SCHMALENSEE: OK. No, no, I mean, hey-- you fight the good fight.

AUDIENCE: Jobs are not going to part of the environment.

RICHARD SCHMALENSEE: Yeah, you've actually been patient.

AUDIENCE: So I would say that this is an opportunity for Massachusetts to help take the lead a relatively new industry. And I don't think that people will pass that up.

RICHARD SCHMALENSEE: So you think no matter what we say in here, and what you guys do when you march on the capitol, we're going to drill.

AUDIENCE: Yeah.

RICHARD SCHMALENSEE: But New York didn't, maybe because of all those signs in Arianna's town. Maybe Arianna's town shut down New York. And there are a lot of people in upstate New York who need jobs. There are a lot of depressed towns up there. There are a lot of landowners up there who would love to lease for drilling. But they managed to shut it down. We're going to talk about that. But you want to go one.

AUDIENCE: Well, yeah, I was just saying I'm from South Dakota, so I'm kind of jealous. [INAUDIBLE] if you look at that map, basically, took a huge loop right around South Dakota.

RICHARD SCHMALENSEE: Yeah. Well, my guess is there are people from some South Dakota towns who are now living in North Dakota. North Dakota was going to change the name of its state to "Dakota" to avoid the "North" for a while, but Matthew.

AUDIENCE: I just think the economic benefit is too big to pass up. And if it was a serious environmental concern, it'll become more apparent. It'll be accelerated to regulation if we allow it to happen more here.

RICHARD SCHMALENSEE: So you think it's going to happen. We're going to see environmental concerns. What the big guys are worried about is weak regulation, leads to environmental disasters, leads to a nationwide moratorium.

Whatever happened in New York could happen nationwide, maybe. Maybe not in North Dakota, but that's their concern. And you're saying we should run that.

AUDIENCE: Yeah. I mean, I think if they realize the economic benefit in the beginning, they're not going to solve it immediate-- like, altogether, they're going to provide some regulation.

RICHARD SCHMALENSEE: Well, there's a lot of work doing regulation. Again, it varies state to state, but OK. Yeah.

AUDIENCE: I think there's a two-part argument for doing it, but doing it on a limited scale, versus like you said, there's kind of an oversupply of gas at the moment. And the technology being relatively new, it's relatively expensive, so you're buying high and selling low. But it is important to start getting some kind of understanding of the drilling process. Because from what I understand, the effects are different from place to place because what's in the shale is different. So what works--

RICHARD SCHMALENSEE: And what's on the way down, and the differences.

AUDIENCE: --in the Dakotas is different from what maybe works in Massachusetts, but it's different compositions. So I would argue for doing a limited roll-out. You don't do it five miles from town, you do it 40 miles from town. And you don't authorize 3,000 wells, you authorize 30 and see what happens.

Hopefully, if there is an earthquake. You can figure out what's going on before people freak out and shut down the whole state.

RICHARD SCHMALENSEE: So that's interesting. And I hadn't heard that proposal before, which is what makes it interesting. So you'd say, we're Massachusetts. We haven't done this before.

We're going to hire some people with expertise, but the ones in Texas who know what they're doing are mostly staying in Texas. So we can't effectively regulate 300 wells. Let's authorize 30, and let's watch them closely, and see what we can learn.

AUDIENCE: Yeah. And once the market stabilizes, then you can start pumping more. And then you'll have a nice boom, hopefully using cheaper technology that's more developed and at a higher price.

RICHARD SCHMALENSEE: Interesting. Yeah, I hadn't heard that. OK. Marie, you had a--

AUDIENCE: Yeah, I just wanted to mention that I think there has been some somewhat successful regulation on this, as in Lebanon, Texas, is going to make [INAUDIBLE] long time, a lot of regulation around this area. And the Barnett Shale is actually right over the Dallas/Fort Worth Metroplex, so it is really in an urban location, and they're drilling all around that. And it's just a place where it has been well regulated, and [INAUDIBLE] follow their example.

RICHARD SCHMALENSEE: Yeah, I mean, Texas, for instance, in the Bipartisan Policy Center thing, seems to have been the first state to basically require disclosure of fracking fluids, which is sort of a first natural step, I think. And then you limit things that can go down. So maybe we can copy Texas, but they have been drilling in the Barnett for a while with different technologies. OK, and we will all wear hats. That'll be great. Sam.

AUDIENCE: First, as far as Massachusetts, I think if you're trying to sell that proposal, you might have a hard time selling it to Massachusettsians copying Texas, just from like association, people of Massachusetts aren't huge fans of Texas. I think--

RICHARD SCHMALENSEE: You didn't like Rick Perry's campaign? Never mind.

AUDIENCE: But I did think politically it would be hard to sell. Just in Massachusetts, people are pretty environmentally conscious. And I think all it would take is, like, one anecdote of oh, my cousin in Ohio, he had an earthquake or his water is on fire--

RICHARD SCHMALENSEE: So you think.

AUDIENCE: We like to overreact.

RICHARD SCHMALENSEE: The political system overreacts. So your view is, even though Arianna's community managed to shut down the State of New York-- it's a pretty blue state, but probably less environmentally conscious than this one-- it would be tough to do here. So what would you advocate instead, when you march on the State Capitol?

AUDIENCE: Take the money and invest in green technology instead. I think the path to nowhere argument is pretty good, as well.

RICHARD SCHMALENSEE: It's pretty interesting. Yeah. What about the "go slow" approach?

AUDIENCE: I think once you start down that, it's going to be pretty hard to stop. I mean, once you start putting in a few, it is going to produce cheap energy, but it doesn't really--

[INTERPOSING VOICES]

RICHARD SCHMALENSEE: And jobs, and jobs. We'll put them in Pittsfield or someplace like Pittsfield. Yeah, Max.

AUDIENCE: I think the biggest [INAUDIBLE] of this is [INAUDIBLE] take a lot of transparency in the industry, the argument that the chemicals are proprietary, so [INAUDIBLE] nobody really has a good way of measuring how much methane exactly is being released in the environment.

And so we know the economic benefits, but we don't know the environmental [? measurements ?] of it. And that's the biggest problem with regulating. Even if you did a few small wells before you moved into the large scale, [INAUDIBLE] regulating them, just because of those loopholes and the fact that there's no real metric for how much damage it's actually doing.

RICHARD SCHMALENSEE: There are techniques-- not great techniques, but there are techniques-- that can measure methane emissions, methane leakage. It isn't trivial. That piece in "Nature" talked about how they managed to measure methane emissions from one area, methane leakage. But it's naturally tricky, because it comes from lots of different places and is dispersed.

You can, however, talk about ceiling requirements and how joints are done. You could put in things. It may be hard to measure what happens, but you could put in place regulation that will reduce it, whether it'll reduce it enough, blah, blah, blah. So you're saying-- so where would you go when you march?

AUDIENCE: I would advocate for it because [INAUDIBLE] there, but demand transparency from the firms that are doing it to kind of [INAUDIBLE] and having them [INAUDIBLE] or at least come up with some sort of metric to [INAUDIBLE] how much damage they're actually doing.

RICHARD SCHMALENSEE: Yeah, so you might work on the development of measurement methods for methane, for instance, and require them to implement them, and so on, and so forth. Yeah.

AUDIENCE: Given how afraid some of the companies are of backlash, especially if you invite the bigger ones, perhaps it isn't as slippery a slope [INAUDIBLE]. And if you build 30 and they do well, and regulation starts loosening, almost immediately if anything does go wrong, that's the whole thing gets shut down. The companies are quite incentivized, in a similar way to nuclear companies, to keep a completely white sheet.

RICHARD SCHMALENSEE: The big guys are.

AUDIENCE: Precisely, and so--

RICHARD SCHMALENSEE: The little guys are the potential trouble spots.

AUDIENCE: And so if you have 30, given that you have some data from the big guys in other states, it would make sense if you have 30 test cases, and then for the future cases to be from those people that have at least some prior history.

RICHARD SCHMALENSEE: Oh, that's interesting. So you'd look at their regulatory history elsewhere, and you would try, in Massachusetts, not to let people who have bad records drill.

AUDIENCE: And then you have the comparative issues between what they do in Massachusetts versus North Dakota [INAUDIBLE].

AUDIENCE: Just from an environmental perspective, isn't it better to drill in Massachusetts, in the sense that it's going to be happening [INAUDIBLE], so you could argue that it happened in Massachusetts, and the type of population that you have and the quality of engineers, you're going to set industry best practices in Massachusetts, which are going to be copied in North Dakota, then.

RICHARD SCHMALENSEE: Maybe. The counter-argument is that because of our population density, the potential for damage is higher, potential for environmental damage.

AUDIENCE: [INAUDIBLE]

RICHARD SCHMALENSEE: Yeah, no. So you're saying you'd do it here, but you would allocate state resources, and of course you'd beg for federal resources, to improve best practices, to improve measurement methods. One of the things that the Secretary of Energy Advisory Board, the SEAB report that's cited in a couple of places, stressed-- they said the government is lousy at this.

The big guys in the industry are able to develop and improve best practices. They need to be encouraged to do it. The problem is once you come up with a best practice, it becomes a compulsory practice, and so forth.

But that's another issue. OK, I think we're out of time. Have a great long weekend. We will do electricity next week.