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SELECT COMMITTEE REGARDING THE RISKS AND BENEFITS OF HYDRAULIC FRACTURING

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Tuesday, May 27, 2014 — 8:30 a.m.

Chair: Patti McLeod

SELECT COMMITTEE
REGARDING THE RISKS AND BENEFITS OF HYDRAULIC FRACTURING

Chair:	Patti McLeod
Vice-Chair:	Lois Moorcroft
Members:	Hon. Currie Dixon Darius Elias Sandy Silver Jim Tredger
Clerk to the Committee:	Allison Lloyd
Witnesses:	Mark Jaccard, Professor, School of Resource and Environmental Management, Simon Fraser University Lalita Bharadwaj, Associate Professor, Toxicologist, School of Public Health, University of Saskatchewan

EVIDENCE
Whitehorse, Yukon
Tuesday, May 27, 2014 — 8:30 a.m.

Chair: Good morning, everyone. I would like to call these proceedings of the Yukon Legislative Assembly's Select Committee Regarding the Risks and Benefits of Hydraulic Fracturing to order now.

Please allow me to introduce the members of the Committee. I'm Patti McLeod, the chair of the Committee and Member of the Legislative Assembly for Watson Lake. To my left is Lois Moorcroft, who is the Committee's vice-chair and Member for Copperbelt South. To Ms. Moorcroft's left is Sandy Silver, the Member for Klondike. Behind me is Darius Elias, the Member for Vuntut Gwitchin. To Mr. Elias' left is Jim Tredger, the Member for Mayo-Tatchun, and to Mr. Tredger's left is the Hon. Currie Dixon, the Member for Copperbelt North, Minister of Environment, Minister of Economic Development and the minister responsible for the Public Service Commission.

On May 6, 2013, the Yukon Legislative Assembly adopted Motion No. 433, thereby establishing the Select Committee Regarding the Risks and Benefits of Hydraulic Fracturing. The Committee's purpose, or mandate, is set out in the motion and it specifies that the Committee is to develop a science-based understanding of hydraulic fracturing and also allow for an informed public dialogue. To this end, we shall hear several presentations over the next two days concerning both the potential risks and benefits of hydraulic fracturing.

I would like to welcome the visitors to the public gallery and our first presenter, Dr. Mark Jaccard. Dr. Jaccard is a professor with the School of Resource and Environmental Management at Simon Fraser University. His principal research focus is the design and application of energy economy models that assess the effectiveness of sustainable energy and climate policies.

Following Dr. Jaccard's presentation, we are going to take a short recess before proceeding with questions. If visitors in the public gallery would like to submit questions, forms and pencils are available at the entrance to the gallery. A page will collect the written question forms before the end of Dr. Jaccard's presentation. After asking a few questions each, members of our Committee will randomly select written questions from those that have been submitted by visitors in the gallery. Time, of course, will not guarantee all public questions will be asked and answered, but we will do our very best with the time that we have. I would ask that questions and answers be kept brief and to the point so that we may deal with as many as possible. Please note that these proceedings are being recorded and transcribed. If your question is selected, the information you fill out on the form may be read into the public record.

I would like to remind all Committee members and Dr. Jaccard to wait until they are recognized by the Chair before speaking. This will keep the discussion more orderly and allow for those listening on the radio or over the Internet to know who is speaking.

I would also ask that the visitors in the gallery respect the rules of the Legislative Assembly. Visitors are not allowed to disrupt or interfere in the proceedings. Please refrain from making noise, including comments and applause, and mute any electronic devices.

We are now going to proceed with Dr. Jaccard's presentation.

Mr. Jaccard: Thank you, Chair McLeod and members of the Committee. Good morning to everyone. It's a great pleasure for me to be back here in the Yukon.

As you might see from my CV, I have been here several times. In fact, my first time as a professor coming here was in 1991. That might even predate when some of you moved here. I just looked back in the files. It was interesting to see the different kinds of issues that I have been asked to come here and interact with you on.

Back in 1991 and on other occasions, it was the issue of how to deal with risk on an isolated grid. For me, it was a fascinating problem in learning from Yukoners about an isolated grid. I don't even know if you're connected at this point to anywhere. You're still an isolated grid. I actually used the lessons I learned from that experience in my teaching for years afterward — not to say that we treat people like you on an experimental basis for an interesting problem.

I also chaired the British Columbia Utilities Commission from 1992 to 1997 — sometimes I start speaking quickly, so just slow me down when you need to — and came up here to help with issues about electricity sector regulation. I have also been up here to work and help with doing an energy plan or planning or decisions that related to climate change and greenhouse gas emissions and evolution of your energy system in a direction that would reduce emissions, and now here with shale gas.

One of things I have learned is to dutifully try to answer your questions, but also to be very careful as an outsider coming in. I feel I know a fair bit about the Yukon, but when time passes the situations change. I will try to help you with the knowledge that I have gained in various parts of the world and through my experience but sometimes it may just not apply here in the Yukon. It is a very special and wonderful place and I want to recognize that up front.

So now I will get into my remarks — or my slides — and I also want to apologize to the Committee that I did not get my slides to you in advance. One reason is that I had a very full schedule at the end of the teaching semester and I also knew that I would be where I had been invited — and I was there last Thursday, Friday, Saturday and Sunday — at Oxford in England for a think-tank with some world-leading experts on what they called the "shale energy revolution". It was very pertinent and that will come through, I think, in some of my remarks; plus I then took the time that you had already seen on this Committee. The comment that I would make up front is that you have heard a lot on local concerns

about fracking and shale gas, which I think is quite appropriate.

I have not as much expertise on that — on the technical side or health side or environmental safety — as some of the many speakers you had, so I thought I could bring the most value added to you as a Committee by dealing with other aspects of risk related to energy markets and even the situation of government in the face of those risks. That will be the main focus of my remarks, but, of course, in questioning afterward, I will be very happy to range widely as you see fit.

My next slide is simply my background. I'll skip past that. The bottom point mentions the times that I have been here in the Yukon before, including doing an energy plan and so on.

The overview of my talk is: Is the shale energy revolution a surprise? Are the local risks of fracking acceptable? I'll spend virtually no time on that. I will focus on the final three points.

Is it a surprise? I was trained as an energy economist doing my PhD in the mid-1980s at an energy institute in France. It was an economics and policy institute but it had also had an engineering school, so I was trained in various aspects of engineering as well — although I have forgotten it all. We were told at that time that the earth's crust was chock-a-block full of fossil fuels — of hydrocarbons. That was made very clear to us. It was also made very clear that human beings will continue to innovate for how to get to those fossil fuels. That is why people with my kind of training never understood concepts like peak oil or peak gas or peak coal. These were concepts that might reflect a shortage at any given time, but not a generic shortage of fossil fuels. Therefore, the real challenge to human beings isn't going to be running out of fossil fuels — it's what to do with so much of fossil fuels if they are a really high quality form of energy but dangerous to handle in various ways.

I say all that, not to say that I had great predictive ability. If I could have taken the 10 leading energy economist experts in the world in 1975 or 1985 or 1995, every one of them would have all agreed on this point: we might have temporary shortages but, in general, the kinds of things that people talked about with peak oil, where price would go high and stay high for fossil fuels, without any innovation correcting and finding more of that plentiful resource, didn't make a lot of sense.

On long-term scarcity and human ability to innovate, some of those leading thinkers, like Peter Odell — so you can look back and find out — Morrie Adelman from MIT, talking about oil, coal and gas in the 1980s. There was a world energy assessment in the year 2000 and I was a participant in the global energy assessment from 2007 to 2012 — so there are major assessments, where we brought together all of the world's experts, and also individual studies. I just thought I would show here that even in the book I published 10 years ago called *Sustainable Fossil Fuels*, I simply pointed out what was well-known, that we have huge quantities of fossil fuels. Therefore, the challenge was, what do we do? Not use them? Or if we use them, how do we use them in a way that doesn't soil our nest, the earth on which we live?

The global energy assessment is the latest version of this and, as I said, came out in 2012. I could have taken the table from my book, but that's 10 years old. It was based on the earlier world energy assessment. I'll take the global energy assessment because that's a newer table and that's my next slide.

There is a lot on here and I hope you can see it back here. It shows the different forms of fossil fuels. It also has uranium in the left column and what I want to focus on is natural gas. What you see there are the estimates of what the production was of conventional and unconventional natural gas — unconventional, for example, shale gas, so very little back in 2009. Those units are exajoules. The global energy system at that time, or today, is about 450 exajoules, depending on how you measure biomass and so on — natural gas being about a quarter of that system, mostly conventional and unconventional. Look at the estimates here. A reserve is something you know more firmly. A resource is a broader estimate. Reserves, you tend to already know that you can bring to market economically.

Let's just look at the unconventional reserves of natural gas — reserves, not resources, so the next column after production. You see a number like 20,000 to 67,000. Take the annual production of natural gas, both the 112 conventional and the 12 unconventional and divide that into that number, and you see just how much natural gas is out there.

If you swing over to the far right-hand side, you see the number 1,000,000. Remember the human energy system — 400 exajoules per year, a million exajoules. That number actually doesn't even include as much shale gas as we've now started to correct our numbers for, but it does include some estimate of gas hydrates, which is natural gas on the ocean floor or embedded in water crystals in the permafrost as well, but it is a very conservative estimate. Basic story: Earth's crust chock-a-block full of fossil fuels.

Now on to this question of local risks of fracking and, as I said, I am going to disappoint there. I will make one comment and it is just a judgment comment. As a former regulator, the general sense from what I have seen is that effective regulation should be able to reduce most local technical risks of shale fracking to acceptable levels. Some environmentalist friends of mine are not going to want to hear that, but that is my reading of the evidence. I talk to experts all the time. I just happened to be at Oxford a few days ago with Jeremy Boak — he is a professor at the Colorado School of Mines — and with Susan LeGros, who heads an association in Pennsylvania. She is based in Pittsburgh and works with industry to improve practices voluntarily for safety. This is the kind of thing, depending on where you go in the Yukon — there are so many people with really good experiences now. There are many things that were done wrong — no doubt about it, and one can point to those — but I keep getting the sense from the independent experts whom I would tend to trust that this kind of thing can be done with very minimal

environmental harm. That is just an opinion and, as I say, I would not put too much weight on my view. I am mostly based as an economic regulator. I am not asking anyone to take my comment — it is more me interacting with experts in the field.

I am going to move to the third, fourth and fifth points, and those are what I will be focusing on. Advocates often will emphasize single-use comparisons and I saw that in, I think, some of the slides that you had, where someone will say, "Look, natural gas has got to be a good thing for our climate concern, because when you burn natural gas, say to make electricity, you might, per kilowatt hour generated, produce only 50 percent of the carbon dioxide, the main greenhouse gas." Or they might say, "Let's use natural gas in vehicles because it might produce only 75 percent, so 25-percent less of the CO_2 per kilometre travelled in a vehicle." But the researchers who work on this — and there is huge literature on this, and there is a lot of uncertainty in this literature — emphasize how complicated it gets. I am just going to give you a few bullets under here to give a sense of that, once you look at the full cycle.

First of all, we know that CO_2 is a greenhouse gas. We also know that methane is a greenhouse and on a molecular weight basis it is way more powerful as a greenhouse gas than CO_2. So you are going to be interested in methane and CO_2 emissions in the fuel-production phase. Then you are also going to want to look at that in terms of fuel transport, so think of major transport pipelines. They require combustion for energy, for running compressors and other activities. There is also leakage of what we call "fugitive emissions", both in the production and along the pipeline path, and there is a lot of research on that. Then, and this is interesting just in terms of using natural gas in our society, if we have natural gas pipes under the cities — again in our recent sessions at Oxford, I was looking at a map of Boston — I don't know, some people have seen this — which was some kind of satellite type of photo, but it was able to just pick up methane just rising up from leaks in the regular distribution pipeline and it was quite significant. People are working on trying to get this into the full-cycle estimates. Then finally, we get to that simple unit that people compare, which were the emissions at the point of combustion, so it is way more complicated. I would be happy to talk further about that if people have questions.

From that, one needs to broaden the analysis also. That's where my own expertise comes in — trying to think of the entire energy system. How do we use energy so the different sectors of energy — industrial, transportation, of course, buildings for commercial or residential — and then all of the different supply side options that we have. Once you start to get into that, then it gets trickier. Just to give you a few examples, in electricity generation, you might have that natural gas versus coal — NG verses coal — but you also have nuclear or diesel and, as you know here, of course, wind. I don't know if there is still anything on Haeckel Hill, but there was back in the day. Biomass — we used to talk in the Yukon about using a lot of the old burn of wood that was out there. There is solar, large hydro, small hydro — both factors here — and geothermal certainly. You have to look at — well, wait a minute, how do any of these compare? You know, you're going to compare them on an emissions basis perhaps, but also on cost and that is very different from one jurisdiction to another and one locality to another, which is why I made that point about me wanting to be careful always when you come into another jurisdiction and start talking about what is preferred. It is the same with transportation, of course, with space heating and then with industry. I'm not going to dwell on these; I just wanted to get the point that analysis broadens out. Then I'm going to say it broadens out one step further with this slide to region differences and global market effects.

You're going to see in my later slides I'm going to talk about that even a little bit more. Each region has different costs for its energy options and these change as one is pursued or the other. Of course, when the Yukon pursues one or the other, it's not going to have the same effect on prices as when China or the United States makes decisions, because they actually affect the global market price for at least a commodity like oil. But that's where you get into the game that I'm involved in, which is working with global energy economy modellers and their models.

I have an example here, just thinking about China. In British Columbia, our Premier has said, "Let's rapidly expand shale gas and export it to China with LNG, because then that means the Chinese will burn natural gas instead of coal, and that means that their greenhouse gas emissions will decline, or at least won't grow as fast, given how many plants they're building." That's the logic there. So that says to replace some future coal with gas for generating electricity, then greenhouse gas emissions would go down, but a global energy modeller says to hold on because there's a whole bunch of other things I have to take account of. Will that natural gas also be replacing some of the renewables and nuclear that China was developing, which would mean the net effect is greenhouse gases going up in that particular aspect of the decision? Also, might it mean that electricity prices won't rise as fast as they would have in China, and lower electricity prices means lower electricity use, which still — electricity in China has a lot of greenhouse gases embodied in it, so the greenhouse gases are going up.

What about heavy transport? We might say, "Well, let's replace diesel with natural gas for our trucks." At the point of consumption we would say greenhouse gases go down. What if the effect — demand for oil, and diesel being a refined petroleum product, part of what oil provides — might be that oil prices don't rise as much or even fall compared to what they would have been, which means you will have more consumption of oil somewhere else, possibly as diesel, possibly as heating oil — who knows what — and greenhouse gases rise.

Then also, in the production of energy — if you're doing the expansion that we're talking about in British Columbia — the production of shale energy produces more greenhouse gases at the incremental point of expansion than does

conventional gas greenhouse gases going up. You see how complicated it is.

That's why there are some questions I can answer quite definitively. For example, if people ask me: "So we don't allow temperatures to rise more than two degrees Celsius, can we still expand the oil sands and do that?" I can talk to the 10 leading modellers in the world and they will unequivocally say, "No, you shouldn't be doing that."

When I ask them about natural gas, the answer is all over the map because some critical assumptions about cost of coal, carbon capture and storage with coal, renewables, storage for renewables, shale gas emissions, net emissions and so on can lead to different outcomes.

That's why we end up with this question: Is shale gas a climate bridge or a detour? I just talked about the global models. In all of their scenarios, emissions from electricity generation must fall dramatically globally by the middle of the century, which is only 36 years away, and transport must literally fall in half.

Some scenarios accept increased gas production for a few decades, but not much more, and some show that if we are expanding gas infrastructure — whether it is pipelines, liquefying natural gas terminals — this actually increases the cost of staying within two degrees Celsius because it delays innovation in energy efficiency in renewables, possibly in nuclear, and possibly with carbon capture and storage when using fossil fuels. This is a big debate right now among experts.

Politicians — present company excluded — might come to very quick slogan-type points on this, as at least our Premier has in British Columbia, but it is a complicated question and that is why I really commend you for examining this as carefully as you are.

That is the point that led to the book I wrote — that we have plenty of fossil fuels and human ingenuity. We have free access to use the atmosphere as a dumping ground and we do not have effective global governance for what is a global tragedy of the commons — a global common property resource, our atmosphere that is being abused. Humans have a really good ability, where they might make money, to rationalize harmful acts — to say, "Let's do this because it is going to help us and we are going to make some money expanding oil sands, expanding shale gas, and by the way, we are going to make the planet better off," or "We are going to make oil supplies more secure for our neighbours in the United States," and so on.

When you combine together all of those factors, the odds are not good, which is why I devote much of my life to trying to help all of us wrestle with this very difficult challenge.

On to the final two points here — and here's where I want to bring in a bit about shale gas and what the markets might look like. That's where I'm thinking I can provide some help to you as a committee, and that will lead me to sort of a final slide about advice or suggestions for what a government should do in the face of that.

We had this revolution in horizontal drilling and fracking in the Barnett shale in Texas, leading to this U.S. revolution and this rapid increase in U.S. oil and gas production so that production cost of shale gas now might be $4 per million cubic feet — there are a whole bunch of different units here and I get confused myself — and tight oil — so that's oil or shale oil, for example — from North Dakota with production cost of $45 to $55 a barrel, whereas the global price is above $100 a barrel right now.

Oil prices are set in global markets. My next bullet shows the U.S. gas price has fallen from where it was at about $10 to $13 per million cubic feet in 2008 to $3 to $4, fluctuating today, and gas production in the U.S. — total gas production — has increased 25 percent in just the last three years, which is quite phenomenal. Total U.S. oil production has grown 60 percent in the last five years, so the U.S. was producing at about five million barrels a day, now up to about eight million barrels a day.

At our meeting in Oxford, there were people asked to speculate on what that might mean for the global price of oil. At least the experts who really work in that area — and I don't have any way of verifying — said that they felt that the international price of oil would be $10 to $20 a barrel higher right now were it not for this dramatic expansion of tight oil, or shale oil, production in the United States.

Of course, as we know, the potential to expand production in the U.S. and Canada alone is huge. Some of you may have seen this slide. I'm not going to spend time on it. It just shows the shale plays, but what I wanted to focus on was the effect on prices. We now have this enormous gas price — what we economists call "disequilibrium" or gap between the price in Asia or parts of Asia and the price in North America. The slide is a bit hazy so I'm going to describe it for you. On the left is the year 1995, so these are years along the bottom. 2012 is on the right — the latest data done to produce this slide by the Energy Information Administration in the United States. Looking on the right-hand side — so the top orange line — is the Japanese price for LNG. That is above $15. The units on the right at the top are $18. They're going in $3 units — 18, 15, 12, nine, six, three and down to zero.

Look at this amazing gap. The red line at the bottom is the U.S. in Texas — what is called "Henry Hub". In 2012, you see an enormous gap. The middle ones are the United Kingdom and Germany buying gas from North Sea and from the Russians.

What does a price gap like that do, especially with plentiful potential to produce in North America? It creates a gold rush mentality. I'm saying that here in the Yukon where you know what I mean by that. What has that meant?

First, I want to talk about what it means in terms of markets. It has reduced the power of OPEC and Russia in setting gas prices because OPEC is a major exporter of gas, and this is on the oil side.

The U.S. is poised to become oil self-sufficient and an LNG exporter to Europe and east Asia. China has huge shale resources, which I will show in graph in a minute, but there is

uncertainty about its ability to quickly ramp up production. Europe has shale resources, but faces public resistance in many countries over local environmental impacts. They may go ahead in the United Kingdom, but Germany and France have seen very strong resistance. As I just said, this gas price disequilibrium has triggered a race, therefore, among producers in the U.S., Canada, Australia, Russia and others to supply gas to east Asia and Europe.

So what are the specific risks for shale gas investors in western Canada, and I have about five minutes left to speak so hopefully I am doing fine in terms of the time limits. I have 21 slides. Some uncertainties can be controlled in advance. I am going to work through the uncertainties facing a shale gas investor today in western Canada.

What can they try to control in advance? They can try to require governments to set the tax and royalty rates in advance. They are dealing with their own government. This is what is going on in British Columbia today. You are probably aware of this. In the last provincial election in British Columbia, Christy Clark, our Premier — well, it was an election campaign. She simply took that price difference that we saw, added on a little bit of cost of production to get LNG over to Europe, and then sort of assumed that it would stay fairly constant over time, which economists would not normally do for reasons I have already mentioned, but will mention some more, and then said, "Oh my goodness, this is wonderful. We are going to rapidly expand LNG and here's the date by which we're going to get rid of our government debt. Here's how we're going to start building up resources and so on."

That's not normally what one would expect to happen.

So right now, industry is saying that actually we're not sure if there will be any large income taxes or royalties to speak of, so please be very careful how you set any of these regimes because, if you do that, if you set them in a way that is substantial, we may well have to back away from our investments. One can say, "Oh well, they're saying this in a threatening way." That is part of the give-and-take of government debating royalty rates and income tax rates with industry — the mining industry, everyone's familiar with that and certainly the Yukon would be — but actually I have some sympathy for the position of the investors for reasons that I'll show you. That surplus value could be very ephemeral.

Of course, they're trying to lock in long-term fixed prices and quantities with their customers, which is obviously very important, before they can even get approval to do things like build an LNG plant or a pipeline. Again, that's difficult, because what is long term? When I chaired the British Columbia Utilities Commission, I got to look at various kinds of contracts, and there are avenues in any kind of contract for people to, at some point in the future, whether it's five years, 10 years, 15 years down the road, to revisit those if market conditions have changed. It's pretty hard not to have that in there. In fact, after I ended as head of the Utilities Commission, I once, just for the fun of it, sat as an arbitrator on a gas contract dispute between suppliers and customers.

It was a very interesting process. Clauses that you thought were firm in the contract protecting price weren't so firm as things played out. You would try to lock in contract construction costs because you're worried about high costs of construction happening if everybody is part of a gold rush to hit the high prices in Asia and be first in line.

What are the difficult-to-control uncertainties? On the very thing of construction costs you can get inflation when everybody is trying to build at the same time — costs for drilling, pipeline construction, materials, skilled labour, equipment, siting, even costs of government — and of course we've seen all of that, especially during the oil sands periods in Alberta of rapid expansion. There is also a lack of social licence. The process that you're trying to go through right now, if that's not seen, whether from First Nations or anyone who has some kind of legal claim, then that can delay things.

In British Columbia right now, oil sands pipelines such as the Kinder Morgan — you've got the City of Vancouver seriously challenging the National Energy Board and its terms of reference. It's not just First Nations. That whole process might end up in court.

What I'm going to focus on in this next slide or two is the natural gas price and demand in east Asia — that price gap that I showed you. First of all, the Energy Information Administration in the United States has just put out another crude estimate of shale resources around the planet, and it is very crude. You see two numbers for the U.S., which is the fourth row there, simply because ARI is a private entity that also did estimates.

The American estimate is 665 trillion cubic feet, but I wanted to draw your attention to the estimate for China: 1,115 trillion cubic feet. Now, some of what they call "play" — some of the locations for shale gas in China — might not be as economic as the ones in the United States. So again, quantity does not necessarily mean what is going to show up in the market at what price, but you cannot ignore that either, so that is why I bring that to your attention.

If you look globally — this is also from the U.S. Energy Information Administration — when I was at the meeting in Oxford, Jeremy Boak, a professor at the Colorado School of Mines at the University of Colorado and someone you might want to talk to at some point, pointed out just one thing. He said, "Oh, by the way, they have not even done an estimate for much of African or for what he called the 'stans'" — Kazakhstan, Uzbekistan, Kurdistan and Tajikistan. They are all close to China and, of course, would love to perhaps do large pipeline projects to supply China.

Two slides now on the future of the East Asian gas price. Gas demand in China, we do believe, will rise strongly. It will rise because energy demand is rising in that country, whether to generate electricity or for industrial uses and so on — possibly transportation — and also because, increasingly, the Chinese are very concerned with coal. Now with coal, for air quality, they are also investing in desulphurization and electrostatic precipitators that will catch particulates and moving some of the coal plants further from ur

They're already doing things within the ambit of continuing to use coal to reduce the air quality impacts in major urban areas and regions, but I think there is a good argument that their gas demand will grow dramatically so that would be good news for an investor.

Some of that gap that you saw was because the Chinese shut down most of their nuclear industry — or all of it — for a while after Fukushima and burned a lot of natural gas to generate electricity. There's a lot of betting on this. It's really hard to say, but I think there is a chance that the Japanese are waiting awhile and slowly will reactivate some of the nuclear power. In fact, they have already been starting to do some of that. I wouldn't depend greatly on natural gas demand in Japan.

As I said, that price has been $13 to $15 per million cubic feet, but what are China's gas options in future? One is pipeline gas from Russia. You may have read about that last week in the news and I will have more to say on that. Russia obviously wants to diversify who it supplies gas to because of conflict with sales to Europe because of the Ukraine and other issues.

China can develop those huge shale gas resources. It can get pipeline gas from other central Asian suppliers as I mentioned, or even a longer distance from Arab countries — OPEC. There are multiple LNG suppliers so that instead of pipeline, this is by ship, of course — but from the U.S., Australia, Canada, Qatar — an OPEC member in the Gulf — Indonesia and other sources as well. It's going to be and already is now a very competitive market out there.

So what does it cost? I have British Columbia here — let's say British Columbia or the Yukon — it's probably going to cost $8.50 to $10 — these are the estimates I'm hearing — including a production cost to get shale gas of $3.25 to maybe $4.75 or $5.00, and then another $5.00 or so to transport, including making the LNG. So you kind of need a price these days close to $10 to make a go.

That Russia-China deal, the meeting in Oxford was Chatham House Rule, which means I couldn't reveal who said what, but there were some very good sources, including Russian energy experts, at the meeting. The general sense I got was that it's confidential, we don't really know for sure, there's a speculative, but the price is just above $10 of the deal that the Russians just signed with the Chinese, after you factor in a whole bunch of complicated things. The Chinese gave them $25 billion up front. When people work through all these different numbers, they come up with something like that, so you don't see a huge margin there.

Then there are all those other prospective LNG suppliers that may well have lower production costs than estimated for western Canada. I'm also involved in a process with the Energy Modelling Forum at Stanford University, so I get a glimpse — again, in confidence — at production costs for others that may be competing with us. Certainly some of them seem below $10.

Then China is trying to bring in co-investors to develop its shale gas. I don't think that will go as fast, but certainly eventually those costs will be well below $10. What we also heard was that China, Japan and Korea are exploring options to form a buyers negotiating group. So the general point here is a lot of uncertainty for an investor, in terms of what kind of return. You are looking into the risks, and I am talking now more on the financial side of that.

My final slide is to talk about what implications — on a very simple level — that I would draw from that in terms of government risk-management options. First, I would establish top environmental regulations from the start. Now you have the benefit of — I mean, I am not questioning what is going on in British Columbia; that may be the model to follow. Again, I do not have enough expertise to say that. I got the impression, though, that there have been some very good developments in the United States as well. There have been some bad examples there, and there seems to be some good learning going on. This is a good time to be doing that and even though industry might complain and say that is going to make it more costly, then it might be better that that industry just not get started at this time and at these prices, rather than get started and make a mess that you really regret, both as a society and, of course, politically as a government.

I would also have considerable confidence that the east Asian-North American price gap that I showed will diminish over the next five to 10 years. I do not know by how much. I think there will always be a gap there. Unlike international oil prices, we have always seen that natural gas prices can be segmented. Liquefied natural gas — the ability to move it around — brings prices more into line, but it will not make them perfectly into line. There will be — just like there is with electricity — regional pricing arrangements in natural gas compared to oil. But there is going to be some real cut-throat competition there as prices are renegotiated, so be prepared for the few- or no-LNG-plant scenario.

I would be very careful about major public infrastructure investments. If industry is trying to tell you how lucrative this is going to be, say, "Thank you, that's wonderful to know. If it's going to be so lucrative, then we're happy to let you cover those costs of infrastructure and so on." That's interesting. This brings me back to my very earliest work in the Yukon where much of the discussion was about a high-voltage transmission line that had been built to — now I've forgotten the name of the mine — and the issue was what to do now when the mine had closed after government had invested some of the money into that infrastructure — how much of it.

Also be prepared for LNG happening, and so fracking happening and an LNG outport at Kitimat or wherever — or even from the Yukon possibly. But be prepared for an LNG boom-and-bust scenario, and thus cases where tax and royalty revenue could sometimes fall to zero and, as an economist, I would argue, as they should when industry is on its knees. In other words — and these are debates they had in Alberta. I'm quite familiar with energy economists there, who are good friends of mine, reviewing royalty and tax structures. If an industry is not producing anything and taxing it would drive it out of business, that's a reality, but it does mean that, as a

government, you have to be very careful about what parts of your budget are dependent on that revenue stream or you may get trapped and caught in the boom and bust itself.

Finally, in looking at the slides, be careful of rationales for local production or distribution of LNG. I'm not saying that that should not happen, but just be careful about it. Again, if some corporate company is arguing that this is the cheapest way to provide for trucking in your region or electricity backup and so on, then remember what your environmental goals are, whether its greenhouse gases or others and targets, and ask yourself how this will occur within that ambit, and put the onus again back on that company to show how it can make an economic case for doing that, rather than luring in government funds for that basis.

That concludes my remarks and I'm very happy to take questions, but I think your process involves a break right now. I'll leave that with the Chair. Thank you very much for your attention.

Chair: Thank you, Dr. Jaccard. At this time, we will take a short recess and reconvene at 9:30. All written questions from the public gallery should now be submitted to the page.

Recess

Chair: Order please. We're going to reconvene and we're going to proceed with questions for Dr. Jaccard. As mentioned previously, please wait until you're recognized by the Chair and your microphone is turned on.

I'm going to start with a question from Ms. Moorcroft.

Ms. Moorcroft: Good morning, and thank you for coming, Dr. Jaccard. I wanted to begin on your page 7. When you asked if local risks of fracking are acceptable, you made a comment that you have little to add to the evidence of local technical risks witnesses. I just wanted to point out that witnesses have not really presented local evidence, but they've identified the absence of local knowledge and baseline data on water, air and on the Earth.

I also know that there are certainly people in the gallery and in the public who would not put weight on the view of an economic regulator, so it was good of you to inject some humour on that.

I want to turn to a question about the net greenhouse gas effect of shale gas and how it's calculated in comparison to other fossil fuels. You pointed out that you have to take in the full fuel cycle and include many factors, including estimated methane leaks — and that's one of the concerns. You recommended broadening the analysis of emissions to include all key energy uses and supply options and, beyond that, to reflect regional differences and global market effects.

Do you think there is an additional challenge posed by the lack of available data reflecting the real conditions of unconventional natural gas development on the ground generally, and also particularly here in the Yukon? I'm hoping that I will have time for a follow-up question in our four-minute exchange here, but I'll just leave it at that for now.

Mr. Jaccard: Yes, I would agree that there is a lack of data and, in making decisions about everything in life, we have to do without complete information, so that would not be a reason to make a decision. It would be a reason to be very careful but it would not be a reason to make a decision.

Ms. Moorcroft: You said that the gas price uncertainty has triggered a race among U.S., Canada, Australia, Russia and OPEC to supply gas to east Asia and Europe. You said that some uncertainties can be controlled in advance and others cannot — for example, price and demand. Yukon faces a number of significant challenges as a northern and more isolated territory, and we also have a small population in our jurisdiction.

Are there particular risks for Yukon associated with trying to participate in a market that is so unpredictable and filled with much larger players, even within Canada?

Mr. Jaccard: When you say "Yukon", I make a distinction in my mind between the Yukon government and companies working within the Yukon that want to work within the Yukon, and that is why I made the distinction in my slides. What I said is that the Yukon government should be very careful about what it commits to on behalf of taxpayers, but that does not mean that if a private enterprise wants to take some risks and you feel that they are safe enough from some other perspective, such as environmental or social or whatever, I do not know why a government would say no to that.

Ms. Moorcroft: Well, certainly the issue of infrastructure investment is one that comes into play regardless of your statement that government should be asking industry to make those investments themselves. The fact is that the pressures are put on government to make those investments.

You made statements that may be somewhat contradictory. You asserted that regulation can result in very minimal environmental effects and then, later in your presentation, you said it is better that industry not get started rather than make a mess. Can you point to examples in other parts of the world where shale gas development has occurred and there have been strong stringent environmental regulations that have prevented damage and reduced risk?

Mr. Jaccard: No. I was making a general point that strong regulation usually should be able to prevent that and that's the impression I have from a very large literature, but I won't be able to point to specific areas. I see no inconsistency here. The point is that if there are going to be impacts, you should be using regulation to prevent them from happening.

Mr. Silver: Thank you, Madam Chair, and thank you again for your time today. Thank you for doing your research into what we have already heard in these presentations.

I only have a few questions here. As a regulator, could you direct the Committee to what is, in your opinion, some of the more formidable research when studying fugitive emissions in pipelines?

Mr. Jaccard: Yes. Richard Howarth is, I think, actually at Cornell and he finds high rates of methane emissions.

The general impression among experts is that he is somewhat isolated in those findings and someone who has done a pretty good job of summarizing the work is Adam Brandt, who is at Stanford, I believe.

Mr. Silver: The reason I ask is that this is one of the deficits we seem to be coming across — in our research, anyway.

Mr. Jaccard: Adam Brandt has summarized a lot of work and I have seen it but I have not read his work in detail. I know this by second-hand knowledge from the experts whom I talk to, which was also the basis of my answer to Ms. Moorcroft.

Mr. Silver: In your opinion, would you say that there is a deficiency in the amount of research in fugitive emissions in pipelines, or is it just something that is not necessarily in your expertise?

Mr. Jaccard: We don't have perfect knowledge about almost every aspect of the energy systems so it's easy for me to agree that it would be nice to have far better data on, for example, fugitive emissions.

Mr. Silver: I have just one further question. When you say that we are to benefit the Yukon in terms of a select committee, what, in your opinion, were the mistakes — or maybe the shortfalls — that the government in B.C. had to endure in terms of the regulatory process? In your slide, you did mention taxes and royalty rates and a lock in the long-term fixed prices, but where do you see regulations having to catch up with the industry in British Columbia?

Mr. Jaccard: In terms of immediate local environmental impacts of developing shale and fracking, I do not have enough expertise to answer that question — I am sorry.

Hon. Mr. Dixon: In following up on some of the questions that have been asked, my first question is on fugitive emissions again and the regulation and potential regulation of them. Do you think that it is possible to effectively regulate for fugitive emissions, given the fact that production, transportation, distribution and the actual combustion could all potentially occur in different jurisdictions? Are you aware of any state, organization or group that is doing this effectively?

Mr. Jaccard: Speaking in British Columbia, yes, I think one could regulate for fugitive emissions. The form of regulation is one that I have recommended in various venues to government and even in the report that I did, which is on the Pacific Institute for Climate Solutions website. At that time — this is three years ago or so and again I am saying all this saying that this is not my total area of expertise, but as a former regulator, there are ways to require that industry do monitoring and set up the monitoring necessary to calculate what their fugitive emissions are.

There are ways to then have spot checks on them, which industry would have to pay for, but which are done by an independent entity. Now exactly what the B.C. Oil and Gas Commission and its regulatory process are doing, I do not have detailed knowledge on that, and I do not want to pretend that I do. I am answering this in a generic sense. I have never bought into the argument that one could not get at fugitive emissions. In my case it was, for example, the levying of a carbon tax. That was really me helping government talk about how to make the carbon tax in British Columbia more inclusive of all emissions. So it is in the context of those discussions, I do believe that you can get at those.

Hon. Mr. Dixon: I will move on. On your slide you talked about the debate around natural gas — should it be viewed as a bridge or a detour? You gave us some good both sides of that argument. Where do you land on that?

Mr. Jaccard: In the case of oil sands, oil sands are definitely a detour. In the case of shale gas, globally and regionally, I think it is important to say that we are not entirely sure and be honest about that. So this is on greenhouse gas emissions. What I can say — and this is literature I do know very well — is that when people talk about natural gas as a bridge, it turns out, by most of the major modelling teams in the world, it has to be a pretty short bridge. It has to be a two- or three-decade bridge, and then you should actually see even global natural gas demand either declining or carbon capture and storage growing dramatically and being lumped on to natural gas use anywhere.

My answer to your question is that, as I interpret the leading research, you would really have to wonder about building a lot of infrastructure, either on the production side or the consumption side, for natural gas. So I tend to be somewhat skeptical of the argument to rapidly expand natural gas of all kinds because it'll be a nice bridge to this ultra-low-emission future. You need to have natural gas demand starting to fall pretty rapidly after 2050.

Hon. Mr. Dixon: My last question was about one of your assumptions moving forward. You talked about the diminishing price gap between North America and Asia with regard to the price of gas. Which way do you see that diminishing? The gap — should we expect to be seeing the price in North America decrease or would you see the Asian price increase, or some combination of those two?

Mr. Jaccard: The price in North America I don't expect to go any lower and, if anything, to go a bit higher. It is even below production cost sometimes, because you're awash with all this rapid production. Some of that's even driven by the way in which licences have been awarded for mineral rights in the United States. There is, like, a five-year limit in some of the contracting, so the production has really grown rapidly and kind of flooded the market, hence the low prices in North America.

The general thinking — and I concur with that thinking — is that the price in North America would rise a little bit. But the key driver — and those are the slides that I have there that you can refer back to — is what would happen in China. None of us were shocked with the Russians came through with this contract to supply China. They have huge amounts

of conventional gas and they are going to want to see even more of that go to market. That contract that was signed with China — people should understand that that wasn't just a reaction to what is going on in the Ukraine and pressure being put on Russia. That contract was about three years in the negotiation phase and was close already. Maybe the Ukraine crisis sped it up.

Then you have the Chinese doing their own shale gas. Now the United States would go much faster, just because of all the independent producers and the way in which mineral rights work, but I can see where China could follow a different model and we're perhaps going to see this in other countries as well — there is talk about Poland and so on — where it could be a state company, but it could be larger independent oil companies and apparently they're in discussions with the Chinese right now. That could happen over a five- to 10-year period and be quite significant.

Finally, there are all the other people wanting to build LNG terminals to export, whether it's Australians or whether it's in the U.S. Gulf to send U.S. natural gas to China and Europe, Indonesian and Qatar and other places as well. So there are a lot of things to push the price down in China.

Mr. Tredger: Welcome, Dr. Jaccard. I just wanted to talk a little about the international energy report and it was repeated somewhat in the Intergovernmental Panel on Climate Change. No more than one-third of proven reserves of fossil fuels can be consumed prior to 2050 if the world is to achieve the two-degree-Celsius goal. I know you referred to that. Essentially, two-thirds of our proven reserves cannot be burned before 2050.

You mentioned some scenarios where natural gas may be used for the next couple of decades, but not much more. Does it make sense to develop a natural gas industry in some of the more extreme areas of the world like the Yukon where there is no infrastructure, with the understanding that there may be price pressures on that in the near future and that it may become a stranded asset? Have you looked into that from an economic point of view? What are the chances of that happening?

Mr. Jaccard: Again, I will say the thing that I know with more confidence: I wouldn't be expanding oil infrastructure. I wouldn't be expanding coal ports as we're dealing with in British Columbia right now — efforts to expand coal ports. Those are easy answers to give.

You have asked me to focus in on a jurisdiction like the Yukon. The Yukon is a special place and I'm always nervous to give advice to people in the Yukon because there is so much ignorance that I have. But if you cornered me on this, I would be very reluctant to be expanding natural gas for consumption, let alone production, in the Yukon. I would be really exploring my renewable options or my zero-emission options for your energy system. You are a fairly small population in a very large resource base.

From my earlier work in the Yukon, I just know there's a lot of renewable energy potential out there. I do work in California, and there are 35 million people there, and yet they're doing quite well developing all sorts of renewables. It's not just solar; it's wind, biomass, geothermal, even some hydro and so on. I just see that the Yukon should have enormous possibilities that don't involve expanding the hydrocarbon base, given where we need to go as a planet.

Mr. Tredger: Thank you for that answer. We talked a little bit about greenhouse gas and methane emissions. We seem to have limited data and limited access to it and an uncertainty about it, not just from the Committee, but almost universally. I know the Council of Canadians referred to that. Is there a jurisdiction — because just a small increase in the percentage of natural gas or methane that escapes as fugitive emissions can have significant greenhouse gas effect, has there been any effective or credible or economic — and sometimes economics factor into that — way of measuring fugitive emissions? Given that B.C. and Alberta have been aware of this, with their state-of-the-art regulatory systems, have they developed a way through their practices and regulations to explain the fugitive emissions and share them with the public?

Where that is a crunch for us is, right now, we're looking at the life cycle of diesel versus natural gas for our power production. It is very difficult to come up with an understanding of just how much methane is produced in the production and in the byplay of natural gas. How do we make a scientific-based comparison?

Mr. Jaccard: Again, I need to be careful what I say because I do not have great expertise in this area. Here is what I have some confidence in: first of all, any fugitive emissions in a pipeline system — you should be able to find those because you are measuring both the gas that goes into the pipe and you are measuring it when it comes out the other end. So everything I have heard — and again this is me talking to other energy experts in the regulator domain; it is not me doing my own studies and examining the research — tells me that you can measure all the fugitive emissions in the pipeline system. Actually, this comes from my work on carbon taxing. When it comes to the production side, then the answer is the one that I have already tried to give, but I will just give it again — succinctly, I hope. That is simply that one says to industry, "I am sorry, but you are going to have to set up ways of estimating and measuring this and if you can't do that, you cannot get a licence to operate. When you do set up that system, we are also going to set up a monitoring entity, as any regulator should to do spot checks or somehow ensure that in fact you have a good system for counting those emissions." Will it catch everything? I doubt it, but I bet you could catch a lot of it.

Mr. Elias: Thank you, Dr. Jaccard, for your presentation. I only have a couple of questions here. When we are looking at the development of — I do not even like these words — unconventional or conventional or shale gas — I think it is all oil and gas development, because it is so rapidly expanding that I do not even like those words.

I will pick on northeast British Columbia with the thousands of shale gas wells that have been drilled there and

are in production. Is there someplace where I can look to look at — from an economic standpoint, from the tax base to government royalties to benefits to the service industry to small communities? Because we are the third-largest producer of gas in the world — in Canada — is there some type of concrete data out there that I could look at — because we have to look at the risks and the benefits of this issue here — that says, this is what is happening? I will just pick on northeastern B.C. because the Liard and Horne and Cordova shale plays do come into the Yukon right around the Liard area and Watson Lake. Is there something that I can look at that looks at the localities of this issue in terms of the economic benefits?

Mr. Jaccard: First of all, just to react to your comment about conventional and unconventional, I want to agree strongly with what you were pointing out. In fact, in the book *Sustainable Fossil Fuels*, I point out that the definition of what is conventional or unconventional oil changes through the decades. Enhanced oil recovery used to be seen as unconventional and now it is seen as conventional. Deep offshore and even offshore — you can go right through the list. I think it is an important thing to remember.

You've asked me where you can get more information and then you kind of listed several things. I thought you were talking about revenues, benefits from oil and gas development. British Columbia has an oil and gas regulator, and I used to look at their website fairly regularly but I think they were already here as a witness before you in any case, so that's where I would look. If you're talking about the financial implications, I think they record that, but I would also go to the British Columbia Ministry of Finance.

Finally, when you're talking about how to assess local effects — how much money does government spend on infrastructure in an area and how much has industry provided — it would have to be in academic literature, and that is something that I could undertake to come back to the Committee with in terms of giving you some suggestions. I was just asked to review a study recently — but I can't say who or what yet because it's still under review — that was done by some academics in British Columbia on getting at some of the questions that you're talking about.

I don't mean to be dodging around but, other than the standard sources, I don't have anything. When it comes to even drilling down to the level of details that you're talking about, then, as an academic, I would scan through and see if there are independent entities that have looked into that.

The Pacific Institute for Climate Solutions, which is based at the University of Victoria and which funds British Columbia-focused research by people like me and others on energy climate and other climate-related questions, may have sponsored some studies on that. I will take a look and perhaps get back to the Committee on that.

Ms. McLeod: Thank you. We're going to proceed now with questions from the public gallery. We have a number of questions. We're just going to draw randomly and go around the Committee. I'm going to start.

This is a question from J.P. Pinard. Can you give us your assessment of the Howarth et al 2011 study that warns of fugitive methane at the well site?

Mr. Jaccard: In some cases in our academic world, there are big differences of views and it can be balanced — you know, sort of half of the experts are thinking one thing and half are thinking another. In other cases, everybody is quite close together. If I'm to give my sense as an academic following the literature, Howarth has been finding very high fugitive emissions and leaks that suggest that the full-cycle emissions of natural gas are so high that they may even exceed the full-cycle emissions of coal, for example — producing natural gas, transporting it and then burning it in an electricity thermal plant, mining coal, bringing it and burning it. The general sense of the literature that I have as a reviewer of journals and other experts I know is that Howarth is in a minority, and a fairly small minority, in seeing the emissions being that big.

That's why, in response to an earlier question, I mentioned Adam Brandt at Stanford. My own feeling is that he has a more balanced sense of what the researchers are finding. That's my take on it.

Ms. Moorcroft: Dr. Jaccard, the first question that I drew — I think that one of my colleagues asked it, but I'm just going to read it and then move on to a related one. Are you for or against fracking, as the odds are not good?

The next question is: Do you know that, in Texas, the cost to repair roads is higher than the royalties? What is the gold rush you are talking about?

Mr. Jaccard: As a researcher, I'm sorry, but I can't take on face value evidence that people provide me without looking at it. My entire career has been one of revealing how often people have told me facts and then, when I investigated them, I found that that was not true. I'm not saying that the person who wrote that question isn't sincerely believing that, and I'm not saying I disbelieve it — I just don't know, so I can't respond to that question.

Mr. Silver: This question comes from Sandy Johnston. You forget to mention free access to the oceans. Why didn't you talk about the imminent deterioration of the oceans — for example, acidification — in your presentation?

Mr. Jaccard: I take that question as a friendly amendment to my presentation. If you read my literature, or my blogs, I think I mention ocean acidification almost all the time. I believe that is a huge issue. The City of Vancouver just made a submission to the National Energy Board to ask to be recognized to address greenhouse gas issues before the National Energy Board hearing for the Trans Mountain Pipeline expansion. They used evidence from me as their key evidence, and in there I mention ocean acidification much of the time.

Hon. Mr. Dixon: This question is from Don Roberts. We know for a fact that, in unconventional drilling, billions of litres of fresh water are used. How can you state that regulations will safely protect our water when used in fracking and is polluted forever?

Mr. Jaccard: My understanding is that, if industry were regulated, it would not have to use much fresh water in the fracking process. It would be using saline water that it recycled and reprocessed. The threat as I understand it — and again, I want to be careful; this is not my area of expertise — is really up near the surface where the casings of the drilling have not been done well enough to have long-term integrity. That is where the water might be at risk.

Again though, my understanding — just talking from other experts who are independent like me — and that's the best way I have to judge an area and the same reason I believe that we're acidifying the oceans and causing climate change. It isn't my research, it's me talking to experts I trust — climate scientists. In this case, the particular independent experts I have talked to give me a strong sense that one could regulate so that that threat to the water, and even the levels of water used, can be dramatically reduced — and that there are apparently already cases of that. I'm presenting this almost as hearsay and I'm not comfortable with that.

Mr. Tredger: Thank you. You sort of touched on this question earlier but I'll ask it again. With no infrastructure in place and with B.C. far ahead, does it make economic sense to move toward exporting LNG in the Yukon?

Mr. Jaccard: My answer is yes, this is a similar question and my answer is that, as always in markets, that is a difficult decision for me or even government to make. I think what government needs to do is make sure that, if somebody believes they can make money on that, that you regulate them properly and that, if you think it's very risky financially, you don't pull community money and resources into that situation — and that's the basis for all of the recommendations I made on those last few slides.

Mr. Elias: This question is from Sandy Johnston from Mary Lake. You stated effective regulations should be able to reduce most local technical risks. Please give us examples of those risks that are less likely to be covered adequately by regulations.

Mr. Jaccard: Again, my apologies, but this is not my area of expertise. My understanding of the literature — second-hand, not as a primary researcher — is that induced seismicity may be important in certain areas, less stable structures — again, it is not my expertise. The second one would be what I already mentioned, and that is the importance of drill casing integrity for fresh water. There is even work now — I just learned that — but again, this is jargon. The experts I was meeting with in Oxford talked about green chemicals, but that sounds like jargon, but these were independent people who I really trust, and they are very rigorous — but I can't elaborate on that because I am ignorant.

Chair: This is a question from Sandy Johnston. What do you think the North American price of natural gas and LNG will do once LNG starts being exported from North America?

Mr. Jaccard: You can look up a group at MIT. It's called the MIT Joint Program on the Science and Policy of Global Change — something like that — but maybe if you Google MIT and natural gas study. This was done a couple of years ago and I was involved — before the U.S. — it was the National Academy of Sciences — I forget.

But that study was trying to predict — if you rapidly developed the shale gas in the United States — which they are doing — and continued to do that for a significant period of time, what might happen to the price of natural gas in North America. That study concluded that the price would not go up very much over the next couple of decades at least. We're talking about an enormous supply with very low production costs.

In the study, as I recall, they also looked at sort of the most stringent kind of regulations that you could have — like total water recycling, protection of the surface, chemical choices, and so on. They found that didn't increase the cost of production by more than a small percent. I hazard to give a number because it's just off my memory, but let's say 15 percent — 10-percent increase in the cost of production — so these are not things that would drive the price of gas up to $8 or $10. You cannot predict anything in energy markets so it's just a probabilistic statement, but there are some strong probabilities that the gas price would stay quite low for some time in North America, even with significant export.

Ms. Moorcroft: I have a question from J.P. Pinard in Whitehorse. Wind with hydro, demand-side storage and smart grid can meet both space heating and transportation needs in Yukon. Should we pursue this or natural gas?

Mr. Jaccard: I'm an economist and I work on sustainable energy systems. My bet is that if I had a talented team with me, we could design probably 10 different variants in the Yukon of zero greenhouse gas emission, near zero air emission, such that it would have no impact, minimal risk to other things like water, ecosystems, and communities. There are probably at least 10 variants that we could design of renewable energy systems for the Yukon, but the key factor will be their cost, the ability to technically manage those systems and a whole bunch of other questions as well.

The answer of "do this versus do natural gas," in my view as an academic, would be extremely irresponsible for me to say yes this, not that. I could explain to you the kind of process that I would do to do that. When I chaired the British Columbia Utilities Commission, I required BC Hydro to do an integrated resource planning process that involved looking at all of the various options for an electricity system that did not start building coal plants or natural gas-burning plants — possible to store carbon. We required them to do that and we went through an integrated resource planning process. Those documents are available to anyone. That is still roughly what B.C. Hydro does to this day in planning its electricity system.

The final point I'll make is that Mark Jacobson at Stanford University is continually creating studies about different options for combining renewables to provide 100 percent of the energy system to the United States over a multi-decade transformation period. We also have scenarios like that in the global energy assessment as well. These things are all

possible. It's usually a question of cost, which can relate to various aspects, the size of a jurisdiction and so on.

Mr. Silver: This question comes from Peter Becker from Whitehorse.

Would you have written your book, *Sustainable Fossil Fuels*, today?

Mr. Jaccard: I wouldn't change a word. I feel very vindicated by how things have unfolded.

Hon. Mr. Dixon: This question is from Anne from Tagish.

Water pollution emissions, processing, linear development, habitat fragmentation, and wildlife populations endangered are all realities in B.C.'s Horn River basin. Do you think the B.C. Oil and Gas Commission has regulated and enforced properly in northeast B.C.? Why or why not? And how do you think the LNG export situation will affect water, air, wildlife and communities in the northern half of British Columbia and south Yukon?

Mr. Jaccard: Apologies, but again, I don't feel I have enough knowledge to provide the assessment that they've done enough or not. It would irresponsible to answer that.

What I would like to say is that human energy systems affect the Earth. That is a point I make in *Sustainable Fossil Fuels*. We humans are not benign. We occupy land. I remember doing a plan for the Yukon and finding out just how much you affect the land here, how spread out you are. I measured your greenhouse gas emissions on a per capita basis and compared them to Vancouver and so on. You have impacts on the land.

What becomes important, though, whether we are analyzing small hydro in British Columba, which I was very involved in, or other renewable options or fossil fuel options is not if you are going to affect the land in some short time period. Yes, you are going to have a footprint on the land. The more important question will be, What happens over time? Do you develop this in a way where you go underground, you get some chemical-stored solar energy — that is what fossil fuels are — from out of the ground, you use them, and can you rehabilitate that land? Can the land in the northeast of British Columbia be rehabilitated or will it be rehabilitated under the regulatory process that they have there right now? I cannot say, but it ought to be — that is certainly what I would argue.

Mr. Tredger: This question is from Sally Wright of Kluane Lake.

Yukon Energy Corporation's liquefied natural gas project economics is dependent on a $4.25 MCF to continue for the next five years. Is this possible, and what is the 30-year forecast?

Mr. Jaccard: Right. There are different forecasts out there but, as I was explaining earlier, the general thinking among market experts right now is that a combination of factors will keep natural gas prices in North America fairly low over the next while. It relates a little to — somebody asked about gold rush — the gold rush way in which natural gas, shale gas, is being developed in the U.S. right now. You have a lot of land owners, and even communities, who are very happy to be rapidly expanding shale gas. I learned more about that in the last few days at Oxford.

I think that price for five years is a fairly safe bet. Going into the future, I've already kind of answered that. I think the North America natural gas price could stay low for awhile, but one can never be certain.

Chair: This will be our last question.

Mr. Elias: There's no name attached to this question, but the question is — and I'm assuming they're talking about peak water use here: Do you have a concept of peak water if all the fossil fuel you want to extract?

Mr. Jaccard: If I can interpret liberally, it sounds like the questioner is linking water use to fossil fuel extraction and asks about a peak in water use that will go beyond that.

The fossil fuel industry uses a fair bit of water in different processes because regulators have not required them not to. Wherever I have been involved in estimating — sometimes in confidence with industry and this is back 12 to 15 years ago related to oil sands — the impact of regulations that dramatically constrained the use of things like water in the production process — you did not find it leading to a dramatically higher cost of production. In other words, the implicit lesson from that is that we should not automatically assume that extracting fossil fuels from underneath the earth has to have a whole bunch of other things, like great amounts of water use or permanent land alienation. It is kind of a choice that people are making as regulators, and they could make that same choice whether they were developing renewables or anything else. They could do run of river hydro in ways that were very harmful to the land, or they could regulate themselves and do it differently.

That is the way that I would answer a question about water use. It t is my understanding that it does not need to be a dramatic increase in water use. Again, I would have to look at each individual kind of process as we go along. That is a general statement based on my knowledge of the research.

Chair: Thank you very much. The time for questions has elapsed. I want to thank Dr. Jaccard, and I want to thank all the visitors in the gallery who submitted questions. The Committee is going to review the remaining questions and we will do our best to follow up and ensure that we get an answer.

Now we are going to recess until 10:30 with our next presentation.

Recess

Chair: This is the Yukon Legislative Assembly Select Committee Regarding the Risks and Benefits of Hydraulic Fracturing.

For those joining us for this presentation, allow me to introduce the members of the Committee. I am Patti McLeod, the chair of the Committee and the Member of the Legislative Assembly for Watson Lake. To my left is Lois Moorcroft who is the Committee's vice-chair and the Member for Copperbelt South. To Ms. Moorcroft's left is Sandy Silver, the Member

for Klondike. Behind me is Darius Elias, the Member for Vuntut Gwitchin. To Mr. Elias' left is Jim Tredger, the Member for Mayo-Tatchun, and to Mr. Tredger's left is the Hon. Currie Dixon, the Member for Copperbelt North and Minister of Environment, Minister of Economic Development and the minister responsible for the Public Service Commission.

This Committee's mandate is set out in Motion No. 433, which specifies that the Committee is to develop a science-based understanding of hydraulic fracturing and also allow for an informed public dialogue. To this end, we shall hear several presentations over the next two days concerning both the potential risks and benefits of hydraulic fracturing.

I would like welcome the visitors in the public gallery and introduce our next presenter, Dr. Bharadwaj.

Dr. Bharadwaj is a toxicologist with expertise in human and environmental health risk assessment and research involving indigenous communities. She is a member of the Council of Canadian Academies Expert Panel on Harnessing Science and Technology to Understand the Environmental Impacts of Shale Gas Extraction.

Following the presentation we will take a short recess before proceeding with questions. If visitors in the public gallery would like to submit questions, forms and pencils are available at the entrance to the gallery. The page will collect the written question forms before the end of the presentation.

After asking a few questions each, the members of our Committee will randomly select written questions from those that have been submitted by visitors in the gallery. Time will not permit all public questions to be asked and answered but we will do our very best with the time that we have. I would ask that questions and answers be kept brief and to the point so that we may deal with as many as possible.

Please note that these proceedings are being recorded and transcribed. If your question is selected, the information you fill out on the form may be read on to the public record.

I would like to remind all Committee members and the presenters to wait until they are recognized by the Chair before speaking in order that we can ensure the microphones are turned on.

I would also ask that visitors in the gallery respect the rules of the Legislative Assembly. Visitors are not allowed to disrupt or interfere in the proceedings. Please refrain from making noise, including comments and applause and mute any electronic devices.

We are now going to proceed to Dr. Bharadwaj's presentation.

Ms. Bharadwaj: First of all, I would just like to again reiterate that I was a part of the panel for the Council of Canadian Academies that conducted a review of the environmental and human health impacts regarding the shale gas industry.

What I would like to do today is share with you some of our key findings around the potential risks of shale gas development in Canada. So just briefly, the outline of my presentation will really focus on public understanding and provide information to inform public understanding basically of what natural gas is, where is it found, what is the difference between conventional and unconventional and shale gas and hydraulic fracturing.

I think it is extremely important when working with industry, government as well as the public to really understand the terms that are utilized by industry and also have a common understanding of those terms that are utilized to really gain an understanding of what people are actually talking about when they talk about shale gas.

So I think terminology is really important when considering risks or benefits of shale gas development. I'll also discuss some of the potential sources of contamination. I'll review some principles of toxicology and, for this reason, I do this to sort of inform our understanding of risks to human health and then identify some knowledge gaps.

Our growing population is increasing our energy supply demands. This particular graph illustrates the U.S. Institute for Energy Research predictions of what potential world energy consumption will be. You'll notice from the pie charts that natural gas and petroleum gas are going significant energy sources even in the year 2040. The reason I present this information here is because there are concerns that renewable energy resources will not be significant through the years from 2011 to 2040, and this might be a result of the new technologies that are utilized now to extract natural gas in shale formations. So the concern here in relation to shale gas is that shale gas may replace some renewables and may not lend to the development of renewable energy. Natural gas is a fossil fuel, and I won't explain the process.

It is simply a hydrocarbon. It is considered a clean, safe energy source. However, in comparison to coal, it might be considered a clean, safe energy source. However, in situations where there is natural gas that is extracted from the earth's crust that are rich with carbon dioxide, for example, in the Horn River shale play, this may actually offset the emissions of CO_2 and lend to an increase in greenhouse gas emissions. Also, we heard about well completions and leakages in terms of shale gas development and extraction. There are benefits for using natural gas, but there are also risks as a result of potential methane emissions from improper well completions and as a result of leakages of wells and because of impurities of CO_2 present in the methane. There are both risks and benefits as a result of utilization of natural gas.

Natural gas is primarily methane. It's a hydrocarbon; however, there are other hydrocarbons present in methane that is extracted from underneath the Earth's crust. These include other hydrocarbons, such as ethane, propane and butane.

I also want to mention that from a toxicological perspective, methane is physiologically inert, meaning it has no direct effect on the human body. Methane, however, will displace oxygen in air and is considered a simple asphyxiant.

For example, if it's released in confined spaces — such as propane, for example, which is a gas we use to barbecue our food — it will displace oxygen in the air and can lead to asphyxiation. There are some impurities, as I mentioned

before, in natural gas, and these include water, oil, sulphur and CO_2.

Just briefly, the natural gas geological formations in which natural gas is found are conventional sandstone, unconventional tight sandstone, coal — so you'll also hear coalbed methane, for example, as an energy source — and shale. Gas hydrates are present in the ocean sediments and deep lake sediments and are also sources of methane, or natural gas. These are considered unconventional sources. They're harder and more expensive to extract and they use different technologies. That's really what differentiates conventional versus unconventional.

Conventional and unconventional natural gas resources utilize some of the same infrastructure. However, the difference between shale gas as an unconventional resource is the intensity and scale of the development. For example, the pad in which the well is placed is much greater in size as compared to a conventional well pad. For example, in a conventional well pad, you are going to utilize about one hectare of land, whereas in a shale gas pad development, you will use approximately three hectares.

Also there is an increase in truck and diesel traffic as a result of shale gas development, as compared to conventional. This will include greater infrastructure in terms of roadways, greater use of gravel and sand to create those roadways, et cetera. There will be a lot of road traffic, for example. This can also lead to diesel emissions as a result of increased road traffic. It is estimated that there could be — as a result of the hauling of sand, the hauling of water and hydrofracturing chemicals — up to and greater than 2,000 trucks utilized in this particular industry.

There are also various holding tanks or other infrastructure to hold water, hydrofracturing chemicals, et cetera, and this could lead to accidental spills in this particular industry.

The main difference between conventional and unconventional natural gas is the combination of the horizontal drilling with multi-stage hydrofracking.

It is really important to understand that horizontal and hydrofracking — or multi-perforation hydrofracking — is a stage within the shale gas development. There are seven steps within shale gas development, and each could pose a potential risk to the environment as a result of the activity associated with that. I will talk about that in a second.

Another difference is that there are water storage pits that are utilized in the shale gas industry. Flowback water is a term that is utilized in this industry and it can be stored in ponds. These are typically lined ponds. However, there are incidences of leakages as a result of the construction of these particular ponds.

The industry is moving toward storing flowback water into storage tanks, but then this needs to be transported and needs to be treated and then disposed of. I just wanted to present a picture here — and this is a picture from our report, the Council of Canadian Academies report, *Environmental Impacts of Shale Gas Extraction in Canada*. This just particularly gives a diagram of the shale gas infrastructure in northeastern British Columbia. You can see the well pads and the distribution of those well pads in the northern part of British Columbia. You'll see that there is a significant infrastructure that needs to be developed here and what could result in the development of this infrastructure. Although it's planned for the shale gas industry, this could potentially lead to increased activity and use of these roads for other services — for example, for hunting, trapping and other sorts of activities. This could increase the human traffic within this area, thus causing maybe a cumulative impact on the particular wildlife, the water resources, et cetera, in this particular region. So there might be some benefits and risks associated with this infrastructure development here.

What I would like to talk about now is shale gas and define it here. Shale gas can be biogenic, meaning that biogenic shale gas, or methane, is produced by the bacterial decomposition of natural materials that are found in sediment.

These are located in shallow depths — a few hundred metres below the surface. Thermogenic is methane that is primarily produced by pressure and heat. This is primarily shale gas. Shale gas is also referred to as sweet, and this is shale gas or methane gas that is absent of sulfur content. It can be dry, meaning that it's pure methane, or wet, meaning that it can contain other hydrocarbon constituents such as butane and ethane, et cetera.

What I would like to do right now is just identify the shale gas plays in Canada — the Horn River in northeastern B.C. — which extends into the Yukon area with the Liard and Cordova — and the Montney, for example. The reason I am going through the locations of these particular shale plays is to really indicate that there are regional differences, obviously, within the location of those shale plays, so there is going to be regional regulatory differences between how shale gas development is regulated, and there are going to be differences in populations, the type of land in which the shale development will occur and also the impacts because of the location and geology of these particular shales. This is the Colorado in Alberta and touching in Saskatchewan. Again, this is occurring in the southwest corner in Alberta and this could have impacts in agriculture areas, for example, as opposed to forested areas in British Columbia. The risks and benefits will be different depending on in which regions the development occurs.

The Utica Shale, which is present in Quebec, is primarily deposited in agricultural and in urban and semi-urban areas. There is potential development to occur in populated regions. This could, again, have an impact on the risks of this development. The Horton Bluff and the Frederick Brook are located in New Brunswick and Nova Scotia, and this area is particularly significant in terms of groundwater. The population in New Brunswick is highly dependent on groundwater for drinking and there are concerns around potential groundwater contamination as a result of shale gas development.

As I mentioned before, shale gas development involves seven stages: seismic exploration, which is basically geological characterization of the shale site; site preparation — so this involves the land clearing, the preparation of the pad and the bringing of sand and gravel, et cetera, so you're going to have some traffic related to this particular aspect of development. Then there's borehole drilling, so there is going

to be drilling mud brought to the surface. This could potentially bring naturally occurring constituents within the mud up into the surface. These could include naturally occurring radioactive materials — some heavy metals, for example — and minerals.

Well completion is the fourth stage of shale gas development, and this is the installment of the casing and cementing of the casing. This particular aspect and stage of development is extremely important because, as the council report concludes, well integrity was one of the main concerns as a result of shale gas development in this production.

Then we have the production stage, and this involves the hydraulic fracturing, so the insertion of the vertical well, the bending into a horizontal plane and then the multi-stage hydraulic fracturing process. This involves water — the consumption of high volumes of water — hydrofracturing fluid injected into the ground under high pressure, and then we have restimulation. Another aspect of this development that is different from convention development is that refracturing could occur over a longer period of time, so some of the impacts that could occur five, 10 or 20 years from now, as opposed to immediate or acute impacts, as a result of the development. Then there is abandonment, which is restoration of the site and the insertion of cement plugs into the well and restoration of the area.

Hydraulic fracturing is definitely a public concern. I think the social media has really sparked debate around this particular process or technology. Basically what it involves is high-pressure, high-fluid injection.

What is unique about the shale gas industry and this hydraulic fracturing technology is that the hydraulic fracturing fluid that is utilized in the process will differ, depending on the geochemistry and geomechanics of the shale play. This also poses some challenge to understanding the risks, because the hydraulic fracturing fluid will be different based on where it will occur because of the differences in the geology and geomechanics of the shale plays. This will be different across the regions of Canada. It makes it quite difficult to assess or put a one-mandate approach to the use of hydrofracturing chemicals and the fluids that are utilized.

This is a picture of drilling rig in the Marcellus Shale in Pennsylvania. Dr. Jaccard did mention that the mineral rights are different in the United States as opposed to Canada. Mineral rights are owned by the private landowner in the United States. You will notice here in this particular picture — and again, this comes from our report — that the drilling rig is basically inserted in a rural area between two to four homes. This particular placement produces extreme risk and as a toxicologist and a risk assessor, I would be mortified to see this in Canada and I don't think this is going to happen here, thank goodness, because of the physical risks of explosion — not only exposure to chemical contaminants — but the physical risks here.

Who are the individuals living in that home? Who are the vulnerable people to that particular site here? So, what is important in this particular slide is really land use planning and making informed decisions as to the placement of these particular well sites. This is another example from the United States, where the fracking rig is basically placed in the back yard of this particular individual. Again, this is important, because there could be children in the home who are more vulnerable. There could be individuals with respiratory disease, who might be more vulnerable to airborne contaminants and so on. Perhaps this individual did not realize that the multi-stage fracturing period could last for weeks, so noise disturbance et cetera can pose some lifestyle issues for individuals.

This is a picture of a well pad completion and restoration and here you will notice that there are approximately 18 to 20 wellheads on this particular area and this is just depicting what a restoration and completion would potentially look like. But, again, you can see that there are roadways placed in the area and, depending on how those roadways are utilized in the future, could lead to more cumulative or additive impacts over time and not just present or acutely at the industry development.

What I would like to do now is talk a little bit about the potential sources of contamination throughout the pathways of development.

First of all, as I mentioned before, water is a resource that is utilized in the hydrofracturing process, and this will involve the transport of this water into the site, which would result in diesel truck exhaust and diesel exhaust emissions as a result of over 1,000 trucks bringing water to the site. So there are potential surface impacts, or surface sources of contaminants, but then there are also sources of contamination at the subsurface, or below the ground. This really refers to the potential leakage of methane gas as a result of poor well integrity, but it also could result from the leakage of flowback water, which could contain naturally occurring radioactive materials and metals. So there are generally surface-level contamination events, but also subsurface contamination events.

Again flowback water, which is the injected water and it flows back up the wellhead, needs to be stored, so this is waste water. It needs to be stored. Some are stored in ponds, for example, some are taken off-site and treated. Industry has moved on to treating the flowback water and then recycling it, or taking it off-site for treatment. Again, this could result in potential accidental spills that could potentially contaminate surface or groundwater sources.

We have mainly two areas of concern in terms of the sources of contamination: we have surface sources and subsurface sources. Potential sources of contamination as it relates to the well — I'm not going to go through all the

pathways, but essentially there could be migration pathways through the cement holding the casing in place as well as through the casing itself as a result of fractures. This has two or three potential impacts. This could lead to greenhouse gas emissions. Methane is a significant greenhouse gas as opposed to carbon dioxide. It could potentially result in migration of methane into the groundwater aquifer, so there are potential impacts in terms of climate and groundwater.

The fracturing fluid composition is mainly water. Approximately 90 percent of fracturing fluid is made up of water and a proponent, which is sand. Other industries are using silica now, which can pose an occupational health risk to individuals who are exposed to silica. In fact, the U.S. Occupational Safety and Health Administration has now reduced the occupational exposure level of silica for shale gas workers. It has reduced that threshold limit value.

For example, the amount of water that is utilized in a fracturing stage — one fracturing stage along the horizontal pipe — is approximately 2,000 cubic metres. This is equivalent to approximately 20 backyard pools — that's the amount of water. The water supply is another issue in terms of potential impacts related to this industry.

Literature has debated on how much water is used per well. As I mentioned before, there could be up to 20 wells placed on a particular well site. The water that is utilized per well is approximately 20,000 cubic metres, and this could be equal to approximately 200 backyard pools.

You'll notice in this pie diagram, which is also from our report, that the percentage of chemicals that are utilized in the fracturing fluid is small. However, if you look at the total volume of fluid that is utilized in this particular process, the concentration of that particular chemical is actually quite high.

For example, in a 20,000 cubic metre total fracturing fluid stage, there would be 1 million kilograms of sand — if you can picture 1 million kilograms of sugar in your pantry; I don't know if you can do that — and 80 cubic metres of acid — which is approximately a backyard pool — and 900 kilograms of friction reducer — which would be equivalent to a smart car with a 100-kilogram man in it — but the concentrations are what is important here. It's not necessarily the percentage; it's the concentrations.

The purpose of these particular chemicals within the industry is to basically create the slick water — to create better performance, basically, of the hydraulic fracturing process. I looked at this particular picture or table, and it really illustrates that, yes, the compounds that are utilized within the hydrofracturing fluid are common things that we are exposed to day to day, like our table salt. They are common constituents within cosmetics and in household products. However, again, it is the concentration of these particular agents that are utilized in the total volume of the fracturing fluid that is significant.

Flowback water, for example, has the constituents of the fracturing fluid. I want to also mention here that the potential risks related to the flowback water are that, when you go below the surface, the temperature and pressure increases. With an increase in temperature and pressure, it's going to favour chemical reactions. We don't have a clear understanding. We know what's going into the ground, but we don't really know what's actually coming out of the ground. We know that there are naturally occurring radioactive materials and natural elements below surface, but with the introduction of these chemicals underground at high temperature and high pressure, there could be potential for mixing a new contaminant formation, and we don't have a good understanding of what those are at present.

Another significant or potential source of airborne emissions are substances such as nitrogen oxide, sulphur oxides and volatile organic compounds, and these are primarily going to be emitted from the diesel engines, the natural gas compressors and fluid, as well as a result of fluid evaporation in potentially stored flowback water.

There is also a potential for development of ground-level ozone. Ground-level ozone is significant in terms of health because it is a significant respiratory irritant and can lead to exacerbations of asthma and respiratory diseases in individuals who already have a compromised respiratory system.

Benzene, toluene, ethylbenzene and xylene are also potential volatile organic compounds that could be emitted as a result of this particular industry. These sources could be as a result of venting fugitive emissions, flaring and, again, fluid evaporation. These have an impact potentially on air quality.

Benzene, toluene, ethylbenzene and xylene are not specific to the shale gas industry. Neither are nitrogen oxides and sulphur oxides and other volatile organic compounds. We are exposed to these every day. For example, benzene is a common volatile organic compound that is emitted from polyurethane foams, from our paints and so on. However, it could be that, because of the intensity or the scale of development, these air emissions could be greater than what would be expected in other types of industries.

Particulate matter, for example, is another, just as a result of the diesel engines' methane and carbon dioxide, and these have implications for greenhouse gas emissions and climate change.

The Canadian air quality management system has been developed and it was recently developed in 2011. This initiative was developed through the Canadian Council of Ministers of the Environment and the system is to gain more information to improve air quality in Canada. The objectives and goals of this particular management system is to establish Canadian ambient air quality standards and to address emissions from mobile sources, such as reduce emissions with technologies for vehicles, for example, reducing that diesel emission for increased maintenance and to reduce emissions from the use of diesel engines by creating greener fleets.

The air quality management system is also set up as a goal to develop base-level industrial emission requirements. These emission requirements would be proposed for new developments, but also for existing major industrial sectors.

There is a movement toward improving air quality in our country, which is a good thing.

I just wanted to mention that in June 2000, ambient air quality standards for fine particulate matter and ozone had been developed. Just utilizing ozone as an example, that 50 parts per billion of ozone in ambient air — so that means 50 parts of ozone per one billion parts of air — is an acceptable target level for ozone, so it's considered safe for human exposure. However, as monitoring suggests that the ozone level is increasing, there are actions that should be taken at particular increments over this particular threshold. For example, at 56 parts per billion, there should be a management mitigation action. Above that, there would be immediate action or retribution.

In summary, chemicals of concern in terms of the shale gas industry are hydraulic fracturing chemicals, potential air pollutants, hydrocarbons and gases present in shale, natural constituents of flowback water and also mixtures of chemicals that are unknown to this date because, as I mentioned before, with increases in temperature and pressure, new chemicals will be formed as a result of the natural chemistry of chemicals because they will react. The frequency and intensity of development will impact or influence the health or environmental impacts — also ambient environmental conditions.

So what other sorts of industrial or other activities are taking place in areas where shale gas is developed? This could lead to cumulative effects as a result of a combination or of additive impacts as a result of additive emissions as a result of industrial activity. The geology of the shale will also dictate what chemicals will be utilized and will also influence potentially what could be brought up to the surface and what could be taken to the surface for the development.

My great colleague Dr. Bernard Goldstein — he's from the School of Public Health in Pennsylvania; he's retired now — was on our panel and he conducted a short survey at a board meeting in Washington — it was a public meeting — and asked, basically, "What are some of the reasons why you're not in favour of unconventional gas development?" And you can see just by the table here that environmental concern was definitely one; also negative effects on water — and I think those have been brought up — and air, et cetera, and also concerns about lack of regulation of the industry. Can it be regulated appropriately and to an extent that will mitigate risks?

In terms of human health and shale gas development, human health is determined by a number of factors: by our physical environments, by our social environments, by our own behaviours or lifestyles, and also our economic environment. If we take this into the context of shale gas development, the geographical location and the political regulatory framework will have an impact on these determinants of health.

What are the potential health risks? There could be direct physical risks, and there could also be indirect. Again, this will depend on the nature, magnitude, frequency and intensity of development. There have been some studies that have looked at impacts as a result of the development in Fort McMurray and we can see some social impacts as a result of that particular development.

As a toxicologist, I think about chemicals and chemical exposures. How can we improve our understanding of potential risks as it relates to potential exposures to contaminants within this industry? First of all, chemicals that are released into the environment will be distributed and transported and potentially transformed. We need to understand how these chemicals are released, when they're released and how they move in the environment and react in the environment. I think that's highly important.

What are the environmental levels? We need to do some more monitoring. We need to understand, once they are distributed into the different components within the environment, such as the air, water soil and sediments — what are the levels? Are humans and animals potentially exposed to those levels and what is the frequency and duration of that particular exposure? So we need to understand exposure as well as receptor uptake. Who and what is potentially the receptor to these chemicals? Also the concentration — what are the concentrations within environmental media?

Physical and chemical properties of a chemical will dictate what it does in the environment and what it does to human beings or animals. For example, if we look at oxygen as a typical, the molecule oxygen is made out of two oxygen atoms combined. We know we need this to survive. It's not going to harm us. However, if we add another oxygen and create ozone, it is a very active chemical and because of its chemical and physical properties, it will have deleterious and adverse effects on the respiratory system when inhaled. We need to really understand the chemical and physical properties of the chemicals related to the shale gas industry and how they behave. It's very important.

Also the human exposure pathways — and we can talk about animals, but I'm more in the human risk assessment, so I'm going to talk about human exposures. What are the potential exposure routes? We need to get an understanding. Are they inhaled? Can we be exposed through ingestion and dermal exposure? We need to understand these exposure routes more clearly.

The Centers for Disease Control is doing some biomonitoring around exposure of persistent organic pollutants or contaminants within our environment. This includes metals, pesticides and also chemicals that were related to the oil and gas industry. There is evidence that we are exposed. What I want to mention here is that the United States has been doing some biomonitoring — collecting blood-in-urine samples from individuals across the United States and getting an understanding of the levels of contaminants in humans across regions of the United States. Why is this important? Biomonitoring will inform us whether or not there is going to be a certain spike or a presence of a particular contaminant in a certain region of the United States, for example, and why that might occur — for example, if lead

is all of a sudden occurring in a particular region in the United States as compared to other regions, we can go and investigate the source, what's happening, why these people are exposed.

Just briefly, what is a toxic agent? The father of toxicology says that all substances are poisons, there is none which is not a poison, and the right dose differentiates a poison and a remedy. So the dose makes the poison. You might be exposed to a particular contaminant in the environment, but what is absorbed and uptaken into the body, what is circulating and reaches a receptor in which that toxicant can act — then a toxicity will occur, but until an appropriate concentration reaches a particular target within the body, there will be no toxicity. The dose does make the poison.

I use this as an example. We know that a particular concentration of lead within the body, in the blood, will produce toxicity, and we have a good understanding of exposure, concentrations of lead and the dose that will cause an adverse health effect. For example, 150 micrograms of lead per decilitre of blood will produce death, and levels of 10 micrograms per decilitre of lead per blood will result in developmental toxicity in children. There is a large range there, but we know the dose and we know the exposure. Children with elevated blood as a result of mitigation risk management measures — they have been reduced as a result of taking lead out of our paints and lead out of our gasoline.

Duration and frequency of exposure is extremely important in assessing risk to health. This basically represents the industry in the centre, so who is the population. We need to characterize who the population is — who are the receptors? What are their demographic characteristics? What are their health characteristics — to understand the potential risk. We also have to understand, again, the distribution of that particular airborne, waterborne or soil contaminants. What are the levels and what are the levels of exposure outside the particular area?

I wanted to mention again that the dose makes the poison. Exposure and frequency is very important when assessing risk. I want to bring this example to highlight those principles because in 2007 a woman died. She entered a radio contest, "Hold Your Wee to Win a Wii". What happened is that her consumption of water — the frequency and duration of the consumption of water — resulted in water intoxication and she died. So the frequency and exposure to a particular agent can result in adverse health effects. That is very important to understand.

What are our knowledge gaps? We have a poor understanding of baseline information in terms of our air, water and soil. In regions where development might occur, we do not have an understanding of potential chemical mixtures, additive risks — there are unanticipated chemical constituents as I mentioned — the fate and transport, the magnitude, frequency and duration of exposure in humans or in animals, and dose response assessments.

The significance of any human health impact associated with this industry will be reflected by population density and proximity of that industry to the population. The baseline demographic characteristics, the baseline health status, the ambient environmental conditions, the other industries that are happening in that area, geology of the shale, the legal regulatory framework, the frequency and intensity of development.

What are our challenges to date to assessing the risk as a result of this industry? Through our panel deliberations over a two-year period, there is limited evidence, there is limited access to it and there is uncertainty about it. Evolving research is conflicting in the literature — the rapid evolving technology but minimal independent assessment of performance to understand the efficacy of that technology. The regional variation as well as some impacts may take decades to become evident.

Thank you.

Chair: Thank you very much, Dr. Bharadwaj.

At this time we are going to take a short recess and reconvene at 11:30. All written questions from the public gallery should be submitted to the page at this time.

Recess

Chair: Order. We're going to proceed now with questions and, as mentioned earlier, please wait until you're recognized and the microphone is on. We're going to start with the first Committee question with Mr. Silver please.

Mr. Silver: Thank you, Dr. Bharadwaj, for your time here today — we really appreciate it. I would like to thank you, also, for your participation on the ground-breaking research and review from the Council of Canadian Academies' environmental impacts of shale gas extraction in Canada report.

I have a question on the report, not necessarily on your presentation — I hope that's fine. According to the CCA report, long-term exposure to airborne particulates has been documented to be associated with mortality in Canada. The report goes go on to state that health effects from the airborne emissions from coal-fired power plants cost the United States $62 billion per year.

Can you elaborate on the nature of non-disclosure agreements and difficulties in the shale gas extraction industry to document contamination, and perhaps maybe include a regional comparison between the United States and Canada?

Ms. Bharadwaj: In terms of the health risks of particulate matter, there is a host of literature — from diesel exhaust to coal fire related to particulate matter. Again, it depends on the size of the particulate. In terms of monitoring in Canada, we look at particulate matter of 10 micrometres and 2.5. What's important is the respirable size, so 10 and 2.5 will generally get trapped in the upper respiratory tract. It's important to measure below 2.5 microns of particulate matter to get a real clear understanding of what's actually getting into the lung, because a lot of the larger sizes of particulate matter will be cleared, so they won't get into the body or absorbed. That is one thing.

Non-disclosure agreements — I think it's really important in determining and making judgments around risks to have the correct information. It's important to have industry disclose what materials they are using and what emissions are being emitted into the air.

There is a challenge in the United States as compared to Canada. I think Canada is moving to more disclosure. For example, in British Columbia and Alberta, industry needs to present the chemicals used in fracking fluid within 30 days of the fracturing job. I'm not exactly sure, but in the United States, things go through the legal system, so the legal system stops or puts a cork into the disclosure process. It's a little different in Canada than it is in the United States. I think we are moving to disclosure, but legally, it's different — that legal structure. I hope that answers your question.

Hon. Mr. Dixon: Thank you, Madam Chair. I guess to build on that, I was going to ask you to comment a little bit further. Given your comments about the need to understand not only the chemical but the concentration of the chemical, can you comment on the systems that have been employed to date to do that sort of reporting? I mean, we're probably most familiar with sort of the FracFocus or that type of thing here in western Canada, but I know there are others throughout the world. Can you comment on the success, or lack thereof, of those sorts of systems in the reporting of chemicals and their concentrations?

Ms. Bharadwaj: For one, I think we do a poor job in collecting baseline information before industry activities. We don't have a clear indication of the ambient conditions prior to — so we don't have comparative data, which really hampers the assessment of risk because we have nothing to compare it to.

We do have monitoring stations. For example, in Wood Buffalo National Park in Alberta there are air monitoring stations. However, public perception of those air monitoring stations is poor because it is government-run. I think independent air monitoring, along with industry and government, would be helpful because I think it would improve public trust of the information and I think it would improve transparency. I think we just do a poor job of that right now.

Hon. Mr. Dixon: Thank you for that answer. In advance of any activity going on — hydraulic fracturing — what sort of process would you recommend to be undertaken to ensure that these sorts of health impacts are considered prior to development occurring?

Ms. Bharadwaj: There are seven steps in the process of shale gas development. I think impact assessment could be staged within those different steps. For example, for exploration, there should be a staged screening assessment or impact assessment conducted, as well as the baseline information on social and health, as well as cultural impact assessment — could be done in stages throughout the process. But, again, baseline information has to be collected and I think that you could probably conduct at least one, two or three years of baseline information to get an indication of what the conditions are.

The reason I choose about three years is because you are could fall into situations where there is going to be an adverse weather event or something like that. You want to get seasonal information as well because ambient conditions will change with seasonal or climatic conditions, so I think that would be a step forward.

Hon. Mr. Dixon: So in a situation where you had a sufficient amount of baseline data, do you think that effective regulation could mitigate the negative impacts of hydraulic fracturing and the associated activities on human health?

Ms. Bharadwaj: If I understand "effective regulation" — my definition of effective regulation means that there is enforcement and oversight. For example, if we were to effectively regulate the construction of wells for the oil and gas industry, I think you have to look at how the wells are implemented by different companies.

Each well is — what I am trying to say is that in the shale gas industry, it is fragmented. So the well is owned by the well operator and the fracturing job is conducted by a fracturing company. I think there needs to be a concerted, overarching regulatory framework over the different fragmented players and stakeholders within that process and there needs to be adequate oversight and enforcement.

I guess it depends how you define what effective regulations are. There needs to be enough funding in human resources to effectively regulate and enforce with proper oversight. If you look, at for example, my own work in water monitoring, it's fragmented and regulation over water depends on the size of your system — municipal versus First Nation water supply, for example, which is federally looked after. In a fragmented system, there needs to be some stringent oversight over all players in the development.

Mr. Tredger: Welcome, Dr. Bharadwaj. When I was in southern Alberta, I talked to a number of landowners and residents who described a number of health effects: hair falling out, skin and respiratory problems and possible cancers. They also noticed an effect on their livestock in terms of fertility and health. They were particularly concerned about air emissions and air quality and the effects of volatile organic chemicals coming from ongoing flaring, as well as from incineration during the completion process, which can last several days to several weeks, as you mentioned.

In trying to research that — and there seems to be a consistent theme — there seems to be a lack of independent monitoring and gathering of meaningful data.

Have you had access? Have you seen any studies that are transparent, effective and economical ways to measure and monitor? The Council of Canadian Academies talked about there being no established examples of what such a monitoring program would look like.

You just mentioned enforcement and oversight. What are the challenges? Are there any established practices now of what a credible monitoring program would look like, where the research is openly discussed and debated, and what we

could look to as a jurisdiction — where it is being done as you have suggested?

Ms. Bharadwaj: That's a really good question. I honestly can say that, through our assessment over the 24 months, we could not find in our research an effective, comprehensive and transparent, public-informed monitoring system. It's something that needs to be developed — and not only for the shale gas industry, but for industries that could develop in the future. It is something that should have been, in my opinion at least, developed prior to industry. Like I said, we don't have baseline information so it's really hard to judge.

In terms of sentinel species, such as farm animals and things, there have been some studies that have looked at farm animals as sentinel species to look at exposures. For example, even in tobacco smoke, people have utilized dogs — companion animals — to look at exposures to tobacco smoke and damage to lungs. There have been some studies that look at farm animals, for example.

What that system is and what that monitoring system would be — I think, really, a concerted effort with government, the public and industry needs to take place. I am a strong believer in collaboration and consultation. I think a community-based approach to monitoring development could serve everyone.

Mr. Tredger: Have there been any studies done on the labour force or people who are working within the industry to assess the long-term effects of exposure to the chemicals, to the combination of chemicals, to the lifestyle and other various aspects of the industry and the health of the labour force working within it, because that may give us, in some ways, the health of labour force, but also indicators of what residents or wildlife may be exposed to over a long period of time?

Ms. Bharadwaj: We could turn to the chemical industry for examples — occupational health and safety. The United States, for example, has a survey looking at individuals who work with industrial chemicals. They conduct cohort studies where they follow employees in chemical industries over time to look at mortality rates, cancer rates and so on. I think that is a good start. In the oil and gas industry, I am not aware of what studies have been done in terms of the employees, but I think it is a good idea to look at exposure. To my knowledge, I don't believe there are any studies that have looked at oil and gas workers over time as a cohort, to look at exposures.

In terms of some of the social impacts on communities, there has been some work done in the Fort McMurray area looking at some of the correlations between the industry and sexually transmitted diseases, for example, or alcohol abuse, crime rates and things like that. There has been some work done in that area.

Mr. Elias: Thank you for your presentation. There has been a lot of new information I've heard here today. I want to ask a couple of questions, but I'll ask a quick question. In the president's message from the Council of Canadian Academies, there was mention that building consensus on some of the information that was either presented or gathered by the panel was difficult to reach. The validity of some academic studies or the conclusions they make, and the conflicting scientific conclusions that we've had to come across, as a committee or that I recognize — how did the panel work through those challenges? I'll put it that way.

Ms. Bharadwaj: We agreed to disagree — just kidding. There were some definite challenges. Like anyone, when you read something, you interpret it one way, and if I read something, I interpret it another way. We agreed to disagree, basically, on some things, and agreed to agree on other things.

We tried to present information in a very objective way, looking at both the benefits and the risks to the shale gas industry. It is a challenge to communicate and work with a number of academics, but it was a good experience for me personally. I think that is what we need to do — to start understanding peoples' perspectives and views, so that, as a collective, we can move forward. Once we understand — industry understands the public's view, for example, or a government's view, et cetera — I think we can move forward.

Maybe that is my pie-in-the-sky thinking, but I found it very useful in my academic work, working with First Nation communities and government, as well as industry, on water supply issues in communities in Canada.

Mr. Elias: I have one more question and it is, in my opinion, the most important issue when we talk about fracture stimulation, whether it be foam or propane or water or whatever substance. It is with water and it is with regard to the proper regulation surrounding water. I am a big wellbore-integrity guy. Here in the Yukon, we have constitutionally protected First Nation final agreements. Under those agreements we have a Water Board, which is quasi-judicial, that issues permits and they have their own framework with regard to issuing those permits. We have the *Yukon Environmental and Socio-Economic Assessment Act*, which is another federal piece of legislation that is derived from the land claims process. We have the federal *Fisheries Act*, sections 34 to 36, and our own territorial *Waters Act* and we have all of these safeguards that haven't been tested with regard to fracture stimulation in the territory around the protection of waters. You kind of touched on it in your presentation and I realize regulations are not going to protect the waters themselves, it's going to be people and the enforcement and the oversight.

I haven't had a clear answer over the multitude of presentations that we have. In the jurisdiction that we're in, where our safeguards have not been tested to hydraulic fracture stimulation, has the Canadian Council of Academies discussed a jurisdiction where this hasn't happened — whether or not their regulation framework is good enough? That's what I'm trying to get at.

Ms. Bharadwaj: I think I understand your question. The regulation you have in place here, right now — is it enough to satisfy water use for shale gas development?

Now, it would depend on the other water users in the area. If shale gas comes in as a single entity into the region, I

think perhaps, the regulatory frameworks could be enough to protect the water supply and resources in the region.

However, a strategic assessment of water use in the area, I think, needs to be conducted. That doesn't just necessarily apply to industry; it applies to the public. So what are the public's uses and supply of that water — because if you look at water in some sectors of society, it's a commodity, but in other sectors it is sacred and it has meaning. I think in perhaps the regulatory — and I'm not familiar with your regulatory framework — but I think what needs to be done is consideration of all stakeholders in terms of that water supply and its use. There is always competition when it comes to water supply and use. In fact, we are doing a study right now in an area of Saskatchewan, Lake Diefenbaker, which supplies over 50 percent of the Saskatchewan population with their drinking water. There are regulations on that water supply in terms of licensing and withdrawals and so on, but there is competition and conflict between industries and also between the public and industry around that supply. I think there needs to be an understanding of how water will be utilized, who uses it, the value of it, et cetera.

Ms. Moorcroft: Thank you, Dr. Bharadwaj, for presenting to us and as well for your work with the Council of Canadian Academies. In their recent report, they commented that most Canadian shale gas development to date has taken place in remote areas with small populations.

We thought that was us, but there are certainly much larger areas. The Council of Canadian Academies report says little research on health impacts has been conducted in Canada. That's where we're starting.

You talked about a number of health risks associated with fracking and shale gas extraction in your presentation and highlighted a number of challenges to understanding and assessing the full health risks. You noted there is limited evidence and further problems in accessing it and minimal independent assessments of efforts to reduce impacts and a lack of local development evidence. You noted that some impacts may take decades to become evident.

The first question I have for you is to ask: What problems have you encountered in accessing evidence that you need to carry out health risk assessments in areas where hydraulic fracturing has occurred?

Ms. Bharadwaj: The main problem in terms of assessing the risk is the baseline information. What are the ambient conditions of the air, the soil and the water prior to the development? Another is: What are the baseline conditions of the potential exposed population? What are the ages? What are the existing health conditions? What are the social structures? What is the built environment like?

I'm a strong believer in human impact assessments. Human impact assessments need to be included in the environmental impact assessment strategy. Although human impact assessment is part of the EIA process, it is not always implemented.

Ms. Moorcroft: You also spoke about how we need to understand how chemicals are released into an environment and how they move and react. You commented that the chemicals that are introduced underground are at a high temperature and high pressure. We have heard different reports that have suggested that between 20 to 50 percent of frack fluid is recovered. Other studies will say that 20 to 80 percent is recovered. That leaves an awful lot of material and chemicals underground and we don't really, I believe, have a full understanding of where that goes and what it does and what impacts it has. That is something that I would like to ask you to elaborate on. Also, in case I don't have time to come back for a further question, I would like to hear more about the work you have done to ascertain potential health risks in communities and all of the both direct and indirect potential health risks that you referred to in an earlier slide.

Ms. Bharadwaj: Yes, there is conflicting information around how much flowback water is recovered. I think in terms of a regulatory oversight, that type of data is very important to gather to make informed decisions of how to manage that water and how to treat that water. I think a chemical characterization of flowback water is important. I think you can utilize some indicator chemicals. For example, you could measure benzene. If benzene is present, likely toluene, ethylbenzene and xylene might be present, for example.

There are developing methods to characterize the flowback water, but I do think that is important because without knowing the constituents of the flowback water, it is very hard to determine how to dispose of it.

Of health risk assessment — there have been some studies, mainly on the social aspects and social impacts of the oil and gas industry and again this work has been primarily done — at least in Canada — in the Fort McMurray area.

Ms. McLeod: Thank you. We are going to start with some questions from the public gallery. We are going to start with Mr. Silver.

Mr. Silver: This question comes from Sally Wright from Kluane Lake. Would you drink flowback water?

Ms. Bharadwaj: That is a very easy question. No, I would not.

Hon. Mr. Dixon: There are three questions here, so I will just listen and you can choose to respond to them as you would like.

What would you do, as a remote hospital worker, if 10 workers from a gas field are victims of an accidental spill? Do you know that FracFocus will not permit you to know the cocktail of chemicals within 30 days? How will you protect staff and treat the unknown contamination?

Those are the three questions.

Ms. Bharadwaj: That is a really good question.

This is where transparency is very important, because I do believe that the chemicals within the fracked fluid and the concentrations that are utilized within that fluid need to be known, because in a situation where you know the concentrations and you know what the individual was exposed to, you can make decisions around their treatment.

If you don't know, it's hard to act as a health professional to treat — plus inform — the patient to begin with. Because you don't know, you could potentially create fear in the individual. So I think it's really important.

In terms of the disclosure of information within 30 days, at least in British Columbia — and it's starting in Alberta — there is some regulatory requirement that the company needs to provide the FracFocus group with the chemical constituents of the frack fluid that is utilized within that frack job within 30 days. That's what we found through our investigation as a panel member.

However, there is a clause, of course, where if it is — I can't remember the term they utilized — not a proprietary, but if it's a proprietary chemical or information, there's a process that industry can go through. However, certain health professionals do have access to that information. I'm not exactly sure of the process.

Mr. Tredger: This if from Jacqueline. Do you know Dr. Theo Colborn's toxicology reports and what do you think of her warning to ban fracking for proven health harm?

Ms. Bharadwaj: Yes, I am aware of Dr. Colborn's assessment. It was a categorization of the number of chemicals and the different types of chemicals that could be utilized in the fracking fluid. Some of those chemicals have been identified as endocrine disrupters and cancer-causing agents, et cetera. There was a list of over 700 or 900 chemicals that were utilized. I am aware of that information. There is a list of chemicals that have been catalogued in this particular article that could potentially be used in the fracking process.

Mr. Elias: This question is from Don Roberts. How do you restore the billions of litres of fresh water that are used and taken out of the hydrology forever?

Ms. Bharadwaj: I'm not a hydrologist or a water specialist; however, I do work in the water area. How do you restore it? I don't even think I can answer that question because I really don't know. Some of it will be lost underground forever, so it will be taken out of the hydrogeological cycle. Some will definitely be lost, but I don't know what percentage. I don't think we know that, but it's something that we can also ask industry or regulators to determine or monitor.

Chair: This is a question from Jacqueline. Do you think radioactive water can be completely recycled anywhere in Yukon or on Earth?

Ms. Bharadwaj: There are methods and, again, I'm not technically aware of these methods because I'm not an engineer, but I know there are methods that can contain radioactive materials through waste-disposal environmental technology. What those technologies are I'm not aware of, but they have been put in place in instances. I'm sorry, I can't answer that question.

Ms. Moorcroft: I have a question from Werner Rhein. How would a regulator mitigate fugitive methane through naturally occurring fractures and fissures in the geology because of the dramatic increase in pressure underground? This is happening in Australia and in the U.S. There is no information yet from the Horn Basin. Again, how would a regulator mitigate fugitive methane through naturally occurring fractures and fissures in the geology?

Ms. Bharadwaj: I do think we're lacking information around fugitive emissions below the surface of the Earth. There are methods to detect and differentiate biogenic methane and thermogenic methane.

This is through isotopic analysis. It is something that could be implemented and monitored to determine experimentally — set up a field experiment, place a well and conduct those types of experiments to determine fugitive emissions. There are technologies that can be utilized and it's called isotopic measurement.

Mr. Silver: This question is from Sandy Johnston. Can you please explain why you state that natural gas is clean when one considers the life-cycle greenhouse gas emissions of the gas extraction, transportation and use? Can you explain why you perpetuate the myth that natural gas is clean from a life-cycle perspective?

Ms. Bharadwaj: I did say that natural gas is a clean and safe energy. That was one of my statements in my slide. However, I did indicate that, although some believe that natural gas is clean, because of the potential of CO_2 to be present in that methane that is taken underground, it could lend to CO_2 emission. Also, as a result of well integrity — so there could be a leakage of methane into the air — it could also lend to methane getting into the atmosphere and contributing to greenhouse gas.

On one side, it's considered clean as compared to coal burning because you have particulate matter and other chemicals — volatile organic compounds — released as a result of that, and petroleum hydrocarbons, as a result of that burning coal, especially if it's not pure and clean. But on the other hand, there are situations within the shale gas development that could lend to higher emissions of greenhouse gas.

Hon. Mr. Dixon: This question is from Sandy Johnston. Your view of risk and unacceptable placement of rigs seems only to apply to humans. Why such a limited scope? Can you comment on the health risks, say, to caribou, fish, birds, et cetera? There are several reports of mortality to non-humans.

Ms. Bharadwaj: Thank you for that question. My area is human health risk assessment, although I have done some environmental risk assessment, so my focus was on human health. However, in the picture that I presented with the pad development in northern B.C., I do believe that the introduction of roadways, et cetera, can influence animal behaviour and impact the ecosystem and the habitat for animals. This is something that needs to be considered when placing shale gas infrastructure into those areas.

Mr. Tredger: This is from Kevin Alexandrovich. Is there any known research on the full extent of fractural patterns, where and how far the post-fracked fractures go?

Ms. Bharadwaj: That is a very good question. To date there is very limited understanding of the natural fissures in shale gas. I should not say little understanding, but I can say that there is little understanding how the hydraulic fracturing process lends to additional fissure development. There are natural fissures in the shale gas that basically hold the methane. That is where the methane is trapped. However, there has been very little scientific experimentation or discovery as to how that fracking process will create new fissures in the shale. That is something that needs to be assessed.

Ms. McLeod: I think we have time for one more question. Mr. Elias, please.

Mr. Elias: This question is from Sally Wright from Kluane Lake. Do the fracking chemicals poison the water forever? And the second question is: Can you take the chemicals out of the water once it is put in?

Ms. Bharadwaj: That is a good question. What we know is there is a potential for fracturing chemicals to get into perhaps surface water and groundwater. What we do not know is the fate of those chemicals and the behaviour in the environment, whether they settle in sediment, for example, or they're dissolved in the water and where they end up. That's something that we don't know. That's a gap in our knowledge.

Chair: We have time for one more question for sure. This is from Jacqueline. Do you think there are enough unknowns to ban fracking?

Ms. Bharadwaj: That's a good question. Right now, in certain regions in Canada, there is a moratorium on shale gas development and based on that — based on the lack of evidence and the unknowns related to that industry. I think my colleague, Dr. Goldstein — he says you can start shale gas development in 2020 or you can start it in 2025. So why not have enough information — the appropriate information — to inform decisions as to whether or not you should go forward today — I guess in 2020 — or 2025. I think we need to gather information to make those decisions.

Chair: Thank you very much. The time for questions has elapsed. I want to thank Dr. Bharadwaj and thanks to all the visitors in the gallery who submitted questions. The Committee will review the remaining questions and we will do our best to follow up and ensure they are answered.

Just a reminder that the Committee will hear more presentations tomorrow, starting at 8:30 a.m., and these proceedings are now adjourned. Thank you very much, everyone.

The Committee adjourned at 12:15 p.m.