JOHN M. SHAW

Name: John M. Shaw, BSc Chem Eng, PhD was educated at the University of British Columbia in Vancouver, Canada where he obtained a bachelor degree in Chemical Engineering (1981) and a PhD in Metallurgy and Material Science (1985). He was a professor in the Department of Chemical Engineering and Applied Chemistry at the University of Toronto (1985-2001), where he also held visiting appointments at the Technical University of Delft, Netherlands (1991-1992); Syncrude Canada Ltd., Edmonton Canada (1997); and the French Petroleum Institute, Reuil-Malmaison (1998-1999). Since joining the University of Alberta in 2001, he has held a visiting appointment at ITESM Guadalajara, Mexico (2003), and a joint visiting appointment at the University of Pau and the Total Research Centre, Pau, France (2011-2012). He is currently an Associate Editor of Energy and Fuels, a member of the Network Coordinating Council for the Canadian Oilsands Network for Research and Development (until its dissolution), and a theme leader and member of the management committee for Carbon Management Canada. He is also President of Chemical and Materials Research Consultants Ltd.

Date and place of birth (if available): August 30th, 1959 in St. John's, Newfoundland

Date and place of interview: 9:30 am, June 24th, 2013 in Dr. Shaw's Edmonton home.

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Consent form signed: Yes

Transcript reviewed by subject: Yes

Interview Duration: 1 hour and 6 minutes

Initials of Interviewer: AD

Last name of subject: Shaw

AD: It's Tuesday the 25th of June at 9:35 a.m. and I'm interviewing John Shaw for the Petroleum History Society Oil Sands Oral History Project. John, thanks so much for agreeing to be interviewed.

SHAW: You're more than welcome, Adriana, I'm happy to do it.

AD: Now, can you tell me your birth date and place of birth and then give me a summary biography including education and career high points, and then of course we'll drill down -- excuse the metaphor or simile, and with respect to your work in the oil sands. So could you begin?

SHAW: Sure. I was born in St. John's, Newfoundland on August 30th 1959 and I lived there till I was ten or so and then moved to Montreal and subsequently Vancouver, educated a little bit in each place. I have a PhD in Metallurgy and Material Science from UBC and an undergraduate degree in Chemical Engineering from the same institution. By way of background and getting into the oil sands business, it was by the back door. I started out doing my PhD work studying hydro-metallurgically-produced dendritic catalysts, very high-surface area catalysts for coal liquefaction when that was fashionable in the late 70s and through the early 80s. But what fascinated me in the research work that I was doing was the behaviour of the organics and the catalyst I could care less about, much to the chagrin of my PhD supervisor. And so my career kind of wandered off with parallel paths in fluid mechanics and reaction chemistry and phase behaviour of organic materials from that point onward.

And so I started my career as a professor at the -- assistant professor at the University of Toronto and then in 2001 I moved to the University of Alberta where I founded the Industrial Research Chair in Petroleum Thermodynamics, which is funded by the Natural Science and Engineering Research Council, among other organizations. At that point AERI [Alberta Energy Research Institute] was also involved; it's now Alberta Innovates Energy Environment Solutions and a collection of companies. Along the way I ended up spending stints in the French Petroleum Institute at the Technical University of Delft where in the early 90s I learned an awful lot about phase diagrams from the descendants of the Van der Waal School and so on.

So it's been a fairly, in hindsight, linear progress toward working in heavy oils and oil sands. The work that I do now is partly related to oil sands but it also applies to heavy oils and tar sands around the world and these are enormous resources relative to conventional oils, which we're going to need over the next 20 to 50 years.

AD: Thank you, that's very succinct. Now, we were discussing this that in terms of the oil sands, and I mean petrol -- all petroleum products, there have been errors of research and you're very much the researcher of today, at least the last 10, 20 years. Do you want to begin by discussing your own research interest vis-a-vis these other eras of research; you know, the Karl Clark extraction, etc.

SHAW: Sure. I think that we need to start a little further back.

AD: Okay.

SHAW: We've been getting various kinds of hydrocarbons out of the ground through pipelines, refineries and into cars and other industrial applications and consumer applications for over 100 years. What's happened in that time though is that our -- the nature of the materials we call hydrocarbon resources has changed. We no longer poke a hole in the ground and out comes light crude -- crude oil like on the Clampett's from the 1960s, or natural gas. We're now working with a lot of very heavy materials, heavy oils that don't flow on their own, and so whether we're talking shale, which is now up and coming, or we're talking about the tar sands, it's, the processing conditions for their production and for their transport and their refining are very different.

The other thing that's changed too is our interest in, in the transport piece even of diluted or partially refined products, the Keystone pipeline being a case in point. So there's a lot of concern about properties and there's also a lot of concern about the environmental footprint. So these are totally different drivers and totally different materials than we had 100 years ago. Unfortunately, what's happened is that often we are applying the same technologies to these new materials that were used 100 years ago. A good example is coking. In the late 90s and early 2000s we were still adding coking capacity to the refineries in, in Fort McMurray for example. That technology was first developed prior to 1900 and many of the patents expired 100 years ago. And so in some cases the technologies we're using may well be inappropriate because they're based on either a limited understanding or a misunderstanding of the natures of the material and could apply that to production technologies, whether it's SAGD, the Steam-Assisted Gravity Drainage, or mining technologies.

So my role in the, in this research community, is in part a policeman and, in part, a discoverer of phenomena. So, for example, the presumption is that all oils are Newtonian fluids. When I first started talking about, and making measurements and demonstrating that these heavy oils are non-Newtonian, there were a few people, serious researchers, who laughed. Fortunately for me, I got to laugh second and much better than they did. And so, and the reason for that is that the fluids were not simple fluids but multi-phase fluids with very complex structures that change and evolve with conditions of temperature and pressure and whether you add (?) or whether you do various other kinds of manipulations.

And so gaining an appreciation for the thermophysical properties of these fluids across diverse link scales from sub-molecular to molecular to the nanoscale through to bulk properties is where my research is focused, and the goal of that research is to provide basic information and enabling technologies so people can develop processes that are more appropriate. And, in many other contexts, we've already demonstrated that it's quite possible to have significant breakthroughs in emissions, in processing costs, both capital and operating, by having better understanding of the materials. And that's really where my research is focused. So my goal is to help provide basic information so that technologies that are inappropriate are debunked and so that we can move forward with the best possible technologies. I'm not the only one working in this area, but that's certainly the area where I'm at.

AD: Now, in terms of your research background, which - or your training as it were, at the PhD level, you've already mentioned that you, there was a shift in interest that then focused you on the heavy oils and, and oil sands. Now, what was that "Eureka" moment? What, you know, what then guided you towards the shift in research interests?

SHAW: Okay, yes, because I had been targeting non-ferrous metallurgy and hydrometallurgy …

AD: Yes.

SHAW: … as being areas of focus when I was starting my research career. Well, it was new to me but it might not have been new -- certainly wasn't new overall. But the idea that like dissolves like was something that was very much ingrained, and when I concluded and then began to read about incompatibilities and liquid/liquid behaviour and so on, in organic mixtures, it'd be like taking olive oil and sunflower oil; you give them a shake and they don't mix with each other. That, to me, was bizarre. But it turns out that, depending on the molecular structures of hydrocarbons, when you mix them together they form two liquid phases. They're both hydrocarbons. And we're, that was so foreign to my basic understanding that I was more or less compelled to start looking at that direction. And so that was the piece that I took away from my PhD. And then I started trying to understand well, if, in these hydrocarbon systems you have multiple phases, well that opens up whole areas for study, whether it be computing equilibria, whether it be fluid mechanics, whether it occurs in reservoirs or refineries or formulations for cosmetics, it doesn't really matter; it would have very many potential applications. And so that was cool.

And then as we were discovering more and more about nanostructure within these fluids, the questions that arose about how do the nanostructures differ by two phases in equilibrium and these are questions that are very compelling because the physics and chemistry of what happens at the nanoscale is quite different than what happens at a molecular scale or at a bulk scale. So, it opened up a whole plethora of possible directions for research. And shortly after I got my PhD, or about the same time, the bottom fell out of the oil business and we had a period of many, many years where there was very little money. But what actually happened at that time was that as the research centres were closing, the various companies … and as the number of staff was diminishing, the people working there were looking for people to pass their knowledge to; and so I was very lucky early on with companies like Amoco and Syncrude and so on, basically taking me on as a repository. And so I benefitted greatly from those relationships and they were sustaining, intellectually, as well as financially during what would have otherwise been an impossible time to do work on that subject.

And so when the pricing structure for oil turned around in the mid-to-late 90s, I was ready with a host of ideas and a host of potential projects that with the trust that I developed over time, the companies were prepared to fund, and that made it much easier to establish an industrial research chair than you would imagine for a - how can we say? - very academic academic and about as far from an industrial person as you could imagine.

AD: Now, this kind of research, I mean, is light years away from Karl Clark's …

SHAW: Absolutely.

AD: … research, which was really around the separation, and clearly that was the first puzzle that had to be resolved and, you know, the Eureka moment, and I've looked at the Research Council of Alberta annual reports where some - I think in the mid-20s he's saying this is an oil source rather than, you know, a roofing or paving material …

SHAW: Material, mmhm.

AD: … you know, this Eureka moment. So basically, you know, you talked about mentorships and, that generation, I suppose it would've been scientists of the 60s and 70s, passing on and, I'm thinking of AOSTRA. Do you want to talk about some of those mentors that you built a relationship with?

SHAW: Well, most certainly. I think the other thing we need to - the other piece that we need to think about here too, is the role that coal and coal liquefaction, which is a much harder problem. When the price of oil hit some huge peak in, by 1981, people were trying to get blood out of turnips but, but coal, because of the history with Fischer-Tropsch was one, and direct coal liquefaction, another processing route, were very topical and very important. And it turns out that a lot of the learning that took place there was then ready for application in the oil sands. So, from a refining point of view, you're quite right. So the process of getting oil products from the tar sands would include some kind of mining step or a production step, whether it's SAGD, followed by then a separation step. In the case of the steam-assisted gravity drainage work, which came later, it's less of an issue. But from a mining point of view, then you have the sand, oil, water separation. And it turns out that while one could do it in a way by brute force, and that's certainly the approach that Karl Clark took, it became clear by the 1980s, certainly, that new ideas were needed because of the high costs associated with those processes. It's people like Jacob Masliyah played a pivotal role here. AOSTRA funded small projects, sustaining projects during periods where the price of oil was very low, and I certainly benefitted from AOSTRA-funded projects.

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What was also interesting about the AOSTRA project was they were very hand's on, and so before they gave money to researchers they would interview them; telephone interviews or in-person interviews if there was enough money to justify travel, but they would prefer not to spend the money in that way. And so they were then testing ideas and testing new concepts at all the stages along the way. And so in the work that I've been doing, I've not really focused on one application, whether it's refining transport or production; I'm interested in the physics and chemistry of the materials. And so I've … I, there are questions that arise as you follow the materials through all of those processes that are common.

And so AOSTRA was a pivotal funder for me. People like Ted Cyr, Eddy Isaacs and so on were very, very helpful and very supportive from Alberta; there's no question. In fact it's their fault that I'm here. By 2001 it was clear that the best place for me to be part of the community was if I were placed within it. And the University of Alberta is a very critical part of that community and so the accumulation of people with diverse but overlapping interests in oil sands and the role that organizations like AOSTRA or the Natural Sciences and Engineering Research Council, which has been also pivotal in supporting work in this area, has caused a cluster of wonderful colleagues to assemble over time and I think it's absolutely clear that AOSTRA played a very big role in bringing all these people together.

Others as well. We tend to think about - David Lynch [current Dean of Science, University of Alberta] was also - he's a builder and brought help to bring people together and help to broker deals, if you will, that would permit things to occur. But there was an assemblage -- Fred Otto was another person I would speak to quite often. I remember also many, many years ago phoning Alan Mather, who has, I'm sure, still forgotten more than I will ever know about many subjects, and saying well, I don't understand this … was a particular problem related to hydrogen solubility, it was a refining problem, and he had data and I had data with somewhat related fluids and they didn't agree, not so much numerically but in terms of trends with temperature that were troubling, and so -- but the community was always very open.

Syncrude was a huge hub in the 90s. I remember when I visited them in '97 there were a number of people there partly-funded by Syncrude, but also by AOSTRA and others who -- it was like a, almost a free-flowing, very deep discussion forum and all of the players, Alberta-based players, fulfilled very important and strategic roles, but AOSTRA was there with some incredibly thoughtful people to make sure that good decisions were made and that advances were made, and the guide to bringing people together was, was very important.

AD: Now, you started your professorial academic career at the University of Toronto and what took you there? I mean one understands that of course these were lean years in terms of hydrocarbon research, but you were hired to do what specifically at, at …

SHAW: Well, the position that I had at the University of Toronto was an open research position. I could study …

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AD: Okay.

SHAW: … as I wished.

AD: Yeah.

SHAW: At that point I was doing some batch fluid mechanics and some oil, heavy oil, coal-related work, and at the very beginning Canmet was one of the key funders and collaborators and their labs were at Bell's Corners in Ottawa. Amoco had a large research centre in suburban Chicago and Don Cronauer was a key mentor and advisor and funder for my work at the beginning. Also we have to remember that at that time that Imperial Oil kept many of their researchers and top technical people in Toronto. Shell had a research centre in suburban Toronto, and Petro-Canada had a presence there as well, and so from the point of view of being able to conduct research in the area of - whether it's oil sands or heavy oil or hydrocarbons more generally, it was as good a place as any, and perhaps better than, than most. It wasn't an obvious thing.

You also have to remember if you look at the University of Alberta in 1985, which is when I started at the University of Toronto, it was a very small crew, and it wasn't obvious. I mean Jacob Masliyah was not really underway at that point. Murray Gray was there and he and I would chat from time to time about hydrocarbon research and research more broadly and we've become close collaborators by this point, but that was a very - it just wasn't obvious where you should, should be. And so that was why I started there. But within ten years all of these research centres that I've mentioned and collaborations were either non-existent or had moved out west.

AD: And I mean there's a direct correlation between the excellence in research that improved understanding of processes and the boom and development. I mean certainly, of course, there is the regulatory regimes that enabled the expansion of the industry from the 1990s onward, but the science was there.

SHAW: Mmhm, it has played a pivotal role in the development.

AD: And do you want to talk about that?

SHAW: Can do. I think the easiest way to summarize the results of the impact of science would be that in less than 20 years the CO_2 emissions per barrel produced dropped 40 percent. That's a huge improvement. You don't make money by putting carbon in the atmosphere; you make money by putting carbon in the pipeline. So when you drop emissions that significantly, it's not just a question of scale; the processes got bigger and so, you know, if you have a, a larger animal or a larger object, heat loss is a bit of a smaller item because the surface area per unit volume goes down. But there were significant improvements in technology at all levels and they accumulate. Sometimes it's as simple as a small adjustment to an operating condition and existing process because it was designed around material that had very different properties.

If I pick on a refining example, a typical response to any kind of perturbation would be to reduce the temperature and raise the pressure of hydrogen to increase the rate of reaction and to minimize products you would like and to minimize coke formation. I remember providing advice based on the phase diagrams that I understood, which contradicted that, which basically said you needed to increase the temperature and drop the pressure somewhat to avoid a poor phase behaviour regime where you can plug a vessel in hours and generate the wrong kinds of products. And so sometimes it took a while to convince people once they tried everything else and it didn't work, they said well, this crazy academic, maybe the idea's not as stupid as it seems because it was contrary to conventional wisdom based on the properties of hydrocarbons from a former era.

And so when you start accumulating these impacts, we had massive changes in the operability of processes, their productivity and so on. And so being able to push turnarounds in different parts of processes from a few months to a few years is a huge - has a huge impact. And then there are changes in various aspects of the processing. The oil separation part - Jacob Masliyah played an incredible role there; that alone in terms of energy costs. They're much more subtle things which we sometimes miss out on. There are these knife edges of conditions where if the temperatures are too low, if you're adding a solvent to try and separate oil from the rock, the temperatures are too low, the separation's very inefficient because the oil itself undergoes phase transitions and it's harder to remove. If you raise the temperature too high, the solvent losses are enormous and it doesn't make sense to conduct the process. But quite often these are at a knife edge - a few degrees one way or another have enormous impacts in identifying these optima – I was part of that, and Jacob succeeded with a number, but they're many others as well that proved to be pivotal in making change.

There's a lot more that I think can be done. One of the things that people, many people are not aware of is that the CO2 emissions from steam-assisted gravity drainage-produced bitumen are higher than from mined bitumen. We think about the land disturbance as being a major item from an energy point of view and an environmental point of view, but if CO2 is a target, well then the CO2 emissions from that other process are higher. And at the moment there's a huge move to try and reduce the operating temperature of those processes and to switch to adding solvent, so injecting some light hydrocarbon or some other fluid into the ground and produce much more bitumen that way, rather than using heat. There are a lot of issues related to that, but there are a lot of directions that are being explored that will lead to further technological - not just improvement but replacement.

AD: Now, as you know I've interviewed Ted Cyr from AOSTRA, who headed the innovation, invention. I mean he was charged with nurturing and funding researchers and he mentioned gleefully that, you know, getting - you were a prize and that, you know, that they were looking for people who were doing out of the box research, but also had graduate students because basically when you get someone like that and you bring them to an Alberta university, in this case the University of Alberta, that you're able to really develop a whole research stream with applications. Do you want to talk about what attracted Ted and Eddy Isaacs and others to the research that you were doing and that then when you came to the U of A, what your research team looked like and that how it has evolved over the years?

SHAW: Well, that's a big set of questions. I don't know what attracted people to the research other than I did not do what was conventionally done. I asked very basic questions. Are the definitions that underlie our understanding of these materials correct and are they based in good physics and good chemistry? And then conducting experiments and developing models that would allow us to test ideas about the natures of these materials. And so, from the point of view of what was attractive about the research, we did not fall into the conventional oil research programs in a meaningful way. They're very standard process procedures for separating oils; they're various standard notions about the properties of some of these fractions that we were blissfully unaware of and concluded that they were not founded well in chemistry and physics. We demonstrated many of these things so the idea was that the work that was being developed and the intellectual thread that was being developed basically was looking at the fluids in a completely different way than people looked at them before. And, if you do that, yes, you can face-plant. But you can also come up with new ways of doing things that were not envisioned based on the prior understanding. So I suspect that's what they saw.

The kinds of people who were attracted to my research program are not readily intimidated. I have the outward appearance of a puppy dog or of a teddy bear, but I'm ruthless. And so I fire graduate students.

AD: (*Laughs*).

SHAW: So, but I've been very, very fortunate that even young people could see somehow that this crazy person was doing interesting things and so I've been so fortunate in the graduate students who have found me, and they've passed on their friends and colleagues. The same is true of the post-docs that I've had who've worked with me. They've always tried to find someone in their sphere from their former universities or among their friends who would be a great person to replace them. And so I've been a real beneficiary of the personal relationships that have arisen. And that has allowed me to place, not just PhD students or post-docs for my group, but even summer students who come through, because I take on WISE [Women in Science and Engineering] students; these are girls in Grade -- who finish Grade 11 and are potentially interested in pursuing science or engineering as a career, and I take those. I take undergraduate students. This summer I have one student from Clermont-Ferrand in France; I have another undergraduate from Princeton, and she was the principal violinist, Caitlin Wood, of the Vancouver Youth Orchestra, and so she was not intimidated to come and she'll spend the summer with us. She started a week or so ago. And Jean is on a *stage* [French for internship] as part of his second or third year of program. I have another summer student in the lab this summer who will start at UBC in Business. He thought he might do Engineering last summer but now that he's graduated from high school he's going to do football at UBC and Business, but he's fabulous.

And so these are just examples and the PhD students, it's easy to help place them when they go, so virtually every member of my research team over the years has been placed within the industry or within a university, and particularly among my sponsors. And so Imperial Oil hired two within the last year; Shell has hired two within the last two years; and the list goes on. Schlumberger, a former sponsor, has hired I don't know how many. And the list goes on, all the way back to 2001. I think of the 60 or so, 70 people who have passed through the lab perhaps two aren't involved in the industry in some way.

AD: Now, you've used the word "sponsor" and the whole issue of funding for such research that doesn't have immediate applications. This is a contested issue, isn't it?

SHAW: Yeah.

AD: Verily as we speak, with the Federal government, you know, dictating, and even the provincial government. I mean the shift of the Research Council of Alberta to Alberta Innovates, and so on. Do you want to talk about the whole politics, the funding?

SHAW: That's a very tough one. I'm a very fortunate researcher in that I'm well-funded and along with that comes a responsibility, of course, to help others and of course you don't want to make a mistake because the last thing you want to do is to provide an example for a funding agency - well, this doesn't work. But the funding for industrial research chairs comes from the partnership program where the Federal government links with industry. So in order to be part of the partnership's program, industrial sponsors, companies must be willing to put up something like a half, roughly, of the research funding. And so they use that as a marker for industrial relevance.

The industrial - interestingly enough - the industrial people look at the work we do as theoretical, sometimes heretical, but they do value it because they know that there will be impacts and we frequently find things they were completely unaware of. A good illustration of that would be as recently as 2010 we were finding categories of materials in oil sands that were unknown. So we were finding organic liquid crystals that comprise about five weight percent of the oil sand - bitumen. And this was completely unknown. And of course if you're producing by steam-assisted gravity drainage - behaviour of this material, if you think you're separating oil and water molecules from one another, but in fact you've got liquid crystals that are microns in dimension, it affects how you go about doing it, what chemicals will or not work, and whether or not you'll have trouble in the process of reusing the water because, if these liquid crystals find their way to the boilers that are then used to generate steam from the produced water, that will destroy their operating capabilities, and of course these have been all observed.

But identifying what the source of the problem is and making sure we understand that basic physics, it's just an illustration, but that was as recently as 2010, a whole new category of material. So in some respects we're still in the discovery phase; so they know that every year there will be something of use coming from the lab. But for them, I think, the most important thing is they look upon it as fairly theoretical research with no direct application today, but they have access then to fabulously trained students who then - because there was a real need for well-trained, smart people who want to work in that industry. There's … a real shortage. And we see that. Every year we have an annual meeting with our industrial sponsors and, you know, every other student's graduating it seems we almost auction them off on the stage.

AD: (*Laughs*).

SHAW: It feels like that some days. But it's easy to establish relationships so these students, the first year they're a part of their PhD or Master's program, they may have a poster. The next year it'll be a presentation and people go "Oh, maybe we should interview this one." Until the student applies, there's a good chance there's someone pulling on the inside. Whether they get the position or not they'll certainly have a really fair hearing. And the more industrial people you have in the room, the more likely it is. And so I think that's partly why - the main reason perhaps why they fund research of the type that I do is because of the fabulous training that the students get, and that they then value them and they're now onto multiple generations, in some cases, in each of the companies that have been sponsoring.

AD: Now, you currently hold the Natural Sciences and Engineering Research Council Industrial Research Chair in Petroleum Thermodynamics and …

SHAW: It's a pretty long title! (*Laughs*).

AD: Yes, yeah.

SHAW: Not my fault.

AD: And, and of course, you're a professor in the Department of Chemical and Materials Engineering at the U of A. In your bio that you supplied to me, it says that your focus is on the development of enabling technologies from an x-ray view cell to detailed acoustic mapping to phase diagrams and energy models for complex hydrocarbons to the discovery of new classes of materials comprising major innovations that have assisted industry around the world to develop and debunk production transport and refining technologies. Now, you've given me some instances, examples of that. I mean the enabling technologies is … is a key word. I mean you're studying theoretical physics and chemistry but always there is that potential for an application in various aspects of the petroleum industry but coal and other, all the complex …

SHAW: But the focus is on …

AD: … hydrocarbons.

SHAW: … heavy oils and of course oil sands is one of the key …

AD: One of the …

SHAW: … sustaining …

AD: Yeah.

SHAW: … applications, but it's not just limited to that because …

AD: Yeah.

SHAW: … all of these heavy resources around the world share as we're learning more about them -- commonalities. And so what one learns from one, one can begin to apply to other, to the others if it's a technique or even a set of values and measurements. But to give you an idea: so if you're doing steam-assisted gravity drainage of a, of bitumen, viscosity and diffusivity are two key properties. Before we started working on mutual diffusion coefficients for heavy oils or heavy oil plus solvent mixtures - if you're planning to add things like CO2 to reservoirs or methane or propane and so on. It was simply a fitting parameter in the heavy oil models because the academic community could only provide values that were good to plus or minus a couple of orders of magnitude. So diffusivity determines time scales for movement over distance. So do you need 1/100th? Or 1/10th? Or ten times the infrastructure? It's a big question. And so it turned out people just used that as a fitting parameter in their model.

And viscosity is important because that affects the way things move. So if I have a fluid that, that has structure, if it stops flowing it takes a lot of energy to get it to move. Think ketchup. But once it's moving, it's all over your plate and all over your lap. But if it stops … so understanding these behaviours that that affects how things mix, it affects your blending; it affects how you design a pipeline and so on. So with each of the things that we work on there are specific applications; the detailed acoustic mapping we're developing, that's a current development. We're looking at how to make measurements of composition and flow within porous media, so within a sand bed, let's say, you want to see how fluids move when I start adding one fluid to something that's already there, or if I want to track compositions as well as fluid movement. If I can make speed of sound maps like ultrasound for a baby, you can watch little arms and legs move; well we want to watch what goes on inside the pores in real time. And it turns out that the quality of the images we generate is very much like that, that you would see in the best of medical imaging. But because we're doing it in two dimensions the math is a little simpler but also we're able to get measurements very quickly.

And so that's something that's still now being developed but it's … a whole new set of applications because it's one thing to measure fluid properties in bulk in a bucket in a lab, but that may or may not be relevant to what happens in a reservoir because in order to get the sample into the lab you have to separate it from the reservoir rock or sand, and all those processes you apply to the sample affect it, and so you may not be measuring what you need to measure. So that's an issue.

The x-ray view cell technology that we developed over time has a history that goes even beyond me. Using x-ray video to study sedimentation problems, and that came out of Amoco and I really value - they helped a lot in getting me going in that area. They said, John, you might be able to use this for organic phase behaviour because it turns out x-rays are very precise in terms of being able to

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distinguish fluids from one another. It's one thing to look at bone and cartilage, let's say, you can distinguish, but fluid, they're very similar and you think it's difficult. It is but it's quite possible and so with that technology we were able to mimic the conditions in reservoirs and mimic the conditions in refineries over very broad ranges of pressure, temperature and composition and be able to discover phase behaviours and other phenomena that were arising in refining processes or in visioned production processes. And that, until very recently, was the only technology that would allow you to make those kinds of measurements at extreme conditions, and so there's now in some private - there's some private equipment that will come close but it's not as good as ours.

And one oil company VP took me aside within the last year and said, "It really bothers me, John, that we spend X millions of dollars per year on this subject area and you're working effectively alone and you're about five years ahead of us, at least."

AD: Isn't that interesting.

SHAW: And so they also see us as developers of technologies that would allow them to study things as well. So there's a -- they're interested in the people; they're interested in the ideas; and we're driven by curiosity and so we end up with mostly ideas - that we think about it a lot before we start spending money on a new technique. But the new techniques are critical to give us a clear understanding of the physics and chemistry of the materials.

AD: So just to extrapolate from that, the relationship with the companies is important for a number of reasons.

SHAW: Yeah.

AD: Funding is …

SHAW: One.

AD: … one aspect of that.

SHAW: Yeah.

AD: But it's also that they bring to the research establishment, your research establishment and others that, you know, not only the U of A, but the U of C and other universities that conduct hydrocarbon research, they bring problems …

SHAW: Absolutely.

AD: … as well …

SHAW: Yeah.

AD: … that then …

SHAW: And insights.

AD: And insights.

SHAW: Yeah.

AD: Because what I was going to ask you to do next is you've provided a number of ideas as to the nature of the research, which is pure research.

SHAW: Mmhm.

AD: It isn't about separation processes, refining process …

SHAW: Although it could …

AD: … none of it …

SHAW: … be implied to all of these.

AD: … these …

SHAW: It's applicable to all but it underlines them.

AD: Okay, well that's my next question: can you take us that extra step …

SHAW: Yeah.

AD: … and show how then these key research pieces have actually changed processes in the actual industry?

SHAW: Or at least process thinking and process design …

AD: Okay, okay.

SHAW: … yes. The short answer is yes. So I'll give two examples: one is more theoretical and the other is more practical. Is that okay? So a theoretical example: one of the areas where we are active is in trying to understand the heat capacities or the enthalpies of organic materials. And if you were to look at the literature you would see that it emphasizes the impact small variations on molecular structure have on the heat capacity of a liquid or a gas or even a solid. And we started doing some calculations with the idea that we would measure heat capacities and use that as a way of discriminating structure of fluids, of molecules in fluids. Why? The idea behind that was that you be able to distinguish ideas about molecular structure that were prevalent, but also if you understand the molecular structure then you can target refining processes to produce specific products or new products directly, so it would by underlying.

But what we found was that the literature for the last 100 years was going in the wrong direction and that in fact 95 or more percent of the heat capacity of solids, liquids and gases that are organic are not determined by molecular structure at all, but simply by the elemental composition, the number of atoms per unit mass. It's a scaling variable a common thread that would allow you to make very detailed and very accurate estimates.

We were able to use that underlying concept to predict heat capacities of heavy oils, bitumen and so on, very accurately. And this was a major step, which has found application in industry. Why? Well, if you're trying to design heat exchanger networks that minimize the entropy production, minimize the wasted energy, you must have a very good idea about what the heat capacities of the fluids are. And if you have the wrong ideas about what the values are, you'll get the wrong networks and you will not capture the efficiencies that are there. And these, it's a very important part of an industrial process for refining and so on to minimize the wasted energy.

So when my PhD student, Nafisa Dagostar, first proposed that she was going to work on this subject, the heads, the technical head of the DIPRA [Ductile Iron Pipe Research Association] database, senior researchers and engineers from virtually all the major oil companies stood up one after another and said we don't think you can do it; we tried, we failed. A year later she came back and said here you go. And so that's … it's theoretical but it's also very practical.

Another example where we've contributed to model development - it's not exactly a heavy oil application, but it's related to the software that is used in the industry to develop operating conditions for processes. Another one of my PhD students identified a systematic problem in all of the industrial commercial software that meant that it provided the wrong phase diagrams, the wrong phase information for mixtures of methane and H2S and light hydrocarbons, nitrogen and so on. Under cryogenic conditions - they're using a lot of cryogenic conditions now to separate natural gas. If you have a liquid going into a compressor it blows up. He was able to show that the models gave you the wrong information, so it was a huge safety issue. When we first presented this information you should've seen the jaws drop. These are just two applications.

I mentioned one in a qualitative way earlier - the operating, operating conditions for some of these refining reactors where the conventional wisdom actually made problems worse and were able to help identify conditions where these reactors work much better. They are numbered applications I can't discuss where we were able to identify precisely where the optimum conditions were for technologies, refining technologies that we did privately with some of the companies, so we have a publicly-funded and publicly-visible aspect of our research and we do some work directly with companies that link with these concepts but with specific targets.

AD: With respect to their own.

SHAW: With their own processes, yes.

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AD: And it's proprietary and …

SHAW: It, it is proprietary - some of the …

AD: Yeah.

SHAW: … some of the work there relates to technology suppliers to oil sands and elsewhere, and some of it is the operators themselves, but I can't talk about some of those applications.

AD: Those aspects.

SHAW: But there … but qualitatively we, I can give you a number of illustrations that the phase diagram for these heavy oils, they're … they differ one from the other but they share many features and that if you use these phase diagrams you can actually target - if the goal is to reduce the energy going into a process, but you still want to be working with hydrocarbon liquids as opposed to mixtures of liquids and solid, then this would give you absolute minimum temperatures that you could work with and still be able to operate.

AD: Now, it's - I think that in terms of the public's understanding of these issues and of course I mean, you know, you're dealing with concepts that are alien to the general public, which is in terms of *The Canadian encyclopaedia*, the readership level was determined - the mean readership level of the Canadian public was Grade 8, age 13. So that is not what the public sees through the lens of the press and the environmental groups is not, is nowhere related to any of this.

SHAW: No.

AD: And so they're looking at the science of the oil sands almost like the first generation industrial revolution, you know, and your basic steam engine and, and those processes and you've talked about some of those, the coker technology, I mean …

SHAW: Yeah, they're very old, yes.

AD: It's very old. But what is happening in terms of the science is that it's really … it's post-industrial science and …

SHAW: Yes.

AD: … and do you want to talk a bit about that?

SHAW: Well, I think the communication piece is a very difficult one. Last week I was at the International Student Energy Summit in Norway, which is a student-led global conference and even among that select group - this was a mix of engineering students and law students and social science students - with speakers either technical- or policy-driven from around the world. Some of the very top people in the fields that were represented were there. And so even at that meeting with such a select group of very bright people, the communication piece is difficult. And so one of the illustrations would be, you know, the oil sands would be considered a dirty oil, but if we were to compare it with coal, for example, it's clear that because it has a much higher hydrogen content than coal, that the CO_2 emissions per kilowatt of electricity generated or per any other - if you want to use electricity as an illustration, but in the combustion process would much lower. But the perception is it's dirty oil and so in a discussion I made a comment that I'd much rather that we worked with oil sands bitumen than with coal and there was some derision from the audience. Well, the mass balances are clear, from an engineering perspective it's very clear.

The other thing that's very clear from an engineering perspective is that, you know, while it is a heavy oil certainly, coming from the oil sands, there's not a great deal of difference because virtually all of the CO_2 emissions come from the consumer at the end that the difference between the heavy oils from California or Venezuela or elsewhere in the world, it's within the margins in terms of difference of net-net, in terms of the global emissions. But of course you wouldn't know that if you read the public press. Okay? So that was one part of your question, so the public communication piece, and I have to remember, I have - honestly say I've forgotten what the second part of the question was. Apologies!

AD: Well, I mean, well it's basically that really we are looking at …

SHAW: The nature of the research, post-industrial research - that was it.

AD: Exactly.

SHAW: Yes.

AD: Yeah.

SHAW: And so you're quite right, and so it's very difficult sometimes to explain to people the nature of the work because the link scales are not visible to the naked eye. And in fact very little of what we do is visible to the naked eye, whereas some of the work that people like Karl Clark or even some of the work that - early work that Jacob Masliyah and other worked on, you could see it. You could, we could give you examples, but it's very difficult to show difference at the nanoscale to people who are not trained in interpretation of whether it's small x-ray scattering data or ultrasonics or other techniques, technologies or theoretical concepts that relate to these other link scales. And so it is tough for people to actually see.

But I would go back to my comment about, over time, we're seeing significant reductions in the amount of waste generated by processes, and this is a real measure of success at an industrial scale. Now, it too is invisible in a way, but the other way they could measure it would be by the dividends they receive from the shares that they hold in companies and the well-being of the economy. It's clear that this has been a real success story in terms of technological development because the costs, the actual number for mining for the actual number for steam-assisted gravity drainage in terms of production, or if we talk about refining, have dropped dramatically.

Now some of that relates to the scale of the processes being increased, but the other is there's been real improvements, real changes in the depth of understanding so that the processes are in fact better than what we had before. But you look at a refinery from the outside or you look at a production facility from the outside and, you know, it's just aluminum swab piping and vessels and it doesn't look any different. But what goes on inside them is quite different and how they're organized is quite different; the operating conditions are quite different; and the outcomes are quite different than what they might have been 30 or 40 years ago.

But it's very difficult to convey that. Any scientific concepts or engineering concepts, and even their applications, it's very difficult to convey that to a general public; even a well-educated, self-selected quasi-general public.

AD: Now, you know, you've used the terminology "tar sands" and …

SHAW: Oil sands.

AD: … "dirty oil" and …

SHAW: Of course, these are …

AD: … and, and so on.

SHAW: … words used in the, in the -- yeah.

AD: And, of course, you know, in terms of the public perception, the negative public perception, it is around the mine sites, I mean strip mining sites are huge and ugly so that the extent of the disturbance …

SHAW: Yeah.

AD: … then they look at the tailings ponds and then birds landing on tailings ponds.

SHAW: Yeah.

AD: And they then, and then of course the profitability of the industry in the last 15 to 20 years, and that they see - I mean, you're balancing these two - environmental impact, profitability to companies - and what's left out of the equation is the public good; the jobs created, all of those other things; the fact that the products are necessary to our way of life and well-being. But, you know, the oil sands are the environmental bad guy.

SHAW: Well, there's a perception of that, I would agree, but I think there are many advocates of specific positions that may present part of the picture but not the whole one in a totally different context. Let's - we'll step back from, from this one; let's talk about global warming in a general sense. Well, people who are very concerned about the impacts of global warming often talk about

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excess deaths, particularly older people or young children in different parts of the world, but they never talk about deaths related to cold weather. And if you were to crunch the data - I'm not an expert - but the "sceptical environmentalist," [Bjorn] Lomborg from Denmark, would argue that more people die because of cold weather by one order of magnitude than by hot weather, and would it be better to spend money on CO2 reduction or just providing air conditioning, central air conditioning for those few people affected. Now, it's "few" in quotation marks, but relatively speaking to the numbers of people who die because of cold weather.

So, if you apply that to the oil sands, well we could, we could say. "well, we strip-mine coal; we strip-mine many minerals. Australia is dug up; much of the central part of the US - they're huge strip mines. Coal is strip-mined in central Europe and so on and so on. Even the coal industry in Alberta doesn't get the bad rap, even though it's fairly close to here. We have large strip mines near Lake Wabamun, for example. That's not in the news and it hasn't been since I've been here since 2001. Why? It's a huge strip mine.

[Pause for technical adjustments.]

SHAW: So there is environmental impact. I would argue that Toronto's an environmental impact; Vancouver, all of our major cities are huge environmental impacts and so we're human so we can either - we can eliminate the problem in two ways: remove ourselves, which, you know, who knows? Or we can try and do our best to minimize impacts.

I agree. Certainly the tailings ponds are an issue. There has been some work on reclamation; it's not an area where I'm an expert at all. But stabilizing the sands, the beaches and then growing grasses and then eventually trees and having fauna return. It's something that's worked on actively and I gather there's a fairly large site that's already been returned to the province as a re-naturalized space. But there's no question that that is a key subject and there are many people working on it. There are different avenues for tackling that problem but it is, it's a difficult problem and one expects that it will become a legacy problem as more and more of the oil sands production is from steam-assisted gravity drainage or some yet to be defined technology where there's less ground disturbance.

AD: You know, lovely transition because I was going to ask you: I mean, you know, you are not directly involved in reclamation processes or environmental re-design, but what you've said repeatedly is that the research that you and your colleagues do, further refine the processes.

SHAW: Yeah, or develop new ones.

AD: Exactly. And that has implications for efficiency, not only in the extraction process - less use of water …

SHAW: Yeah.

AD: … diluent, whatever, you know, all, all of those things. So putting on your thinking cap, which you don't have to put on because you wear it all the time, I mean what will the new oil sands science look like … is the overall overarching question that I'm putting to you now. But as we've also moved from, you know, molecules to atoms to subatomic structure and nanotechnology, can you address that aspect as well and the potential that that offers and keep in mind, you know, the, the lay researcher …

SHAW: Sure, no, I understand …

AD: … that is going to be listening to this.

SHAW: All right. Well, I mean it's a difficult one because once we delve into the details, it becomes quite arcane in many respects, but before we move on about processes there's a small company headed in part by Catamaran, which is trying to separate minerals from the slurry which goes into the ponds in Fort McMurray, and it has a secondary benefit of recovering waste oil, so if there's an inefficiency in the separation process with respect to oil, it generates that as a by-product and it's not clear at this point if the value of the minerals they're looking for - vanadium, titanium and so on - is greater or less than the, the secondary recovery; while there have been some interesting developments there, but having said that the spinoff from better concepts of separation mean that instead of doing ambulance chasing at the end in terms of the environmental impacts, you build the improvements into the process so that you generate less waste. Not because you've been able to hide it somehow or store it but you don't generate it in the first place.

So the way I see the evolution of the technologies, it's no question that water use is a problem in Alberta. Despite the fact that it's been raining the last several days, water is in relatively short supply. We use a lot of it in conventional oil and even gas production, and the way the regulations are now written, oil sands producers must not make use of, or essentially not make use of water in the rivers and, if they're using steam-assisted gravity drainage they have to recycle the water and so on and so on. So water use minimization is a big issue. I think land disturbance ought to be a significant issue. I also think that efficient production of heavy oil and bitumen from the tar sands should be an issue.

To take a counter-example of the heavy oil in the eastern part of the province, let's say Lloydminster and so on, these processes, while profitable because the reservoirs are relative shallow, five percent maybe to ten percent of the oil in place in the reservoir is actually sold and the bulk of it remains in the reservoir, and perhaps those technologies are inappropriate and perhaps what that tells us is that we shouldn't be producing those resources with those technologies. Yes, it's profitable but it's akin to opening a bottle of champagne, letting the fizz come out, capturing it in a glass and then leaving the rest …

AD: Ignore the rest.

SHAW: … of the bottle. I mean, and that's a problem. So use of infrastructure, so the kinds of understanding that is necessary to make sure we do very efficient processing, because that all come back to energy emissions and so on. The less efficient your processes are, the more waste is generated of all types. And so the goal would be to ensure that the best physics and the best chemistry go into the development of processes and process concepts so that we produce efficiently and that we then refine efficiently. A goal one could set for researchers would be to simply produce from these oil sands reserves the product we're interested in. The product is energy, so why not just produce energy? So there's a stream of research or a line of research where the goal is, in effect, to produce energy directly. Whether it's electricity or high-pressure steam so that you can run turbines at the surface, it's an issue.

The other possibility would be to produce fluid products - transport fuels is something that we will need to have from hydrocarbon sources for the foreseeable future. We cannot produce enough in any other way and we're addicted to carbs or transport; and so making sure that we produce a product that we want only. So that means, in effect, doing refining underground or doing separation so that you only produce a product that you could then sell easily. There are a number of concepts there that would minimize surface environmental impact, but there will always be impacts; the question is we're well beyond cowboy developments or brute force developments and so we have to be much more subtle.

But the other thing we need to think about is that as we are developing those ideas, even if we have an idea that leads to a one percent improvement in any aspect of these processes, the economic, environmental and well-being spinoffs for the province, for the people, for the nation, for the world, are huge because of the scale of the industry. And, again, I reinforce that the learning that we develop related to the oil sands or other heavy oil resources around the world, hydrocarbons of all sorts, they're linked. And so you learn something in one location, well then it may well be applicable elsewhere and so what you see as a one percent improvement in a process for Company X may be repeatable at a hundred sites or more around the world, and so the impacts can be enormous, even though they're incremental. And so both types of things will take place.

The kind of work that I'm doing is more targeting, let's say "breakthroughs" in quotation marks, but we're very happy if as an outcome it's a one percent improvement of anything. So I don't think there's one direction, but I think conceptually we need to frame things around efficient use of resources and minimizing environmental impacts.

Winning the PR battle is also perhaps a goal. It's not obvious how one does that. Once you're a demon it's very difficult to become something else. It goes the other way. If we think about historical stories, it's easy to go from being an angel to being a devil, but it's much harder, I suspect, to go the other way no matter how well behaved one is.

AD: Now, do you want to talk about the nanotechnology …

SHAW: Sure.

AD: … which again, I think is ill understood and what potential is there?

SHAW: Certainly. So much of the structure that exists in bitumen and many other heavy oils -we talk about asphaltenes. That fraction amounts to something like 20 weight percent of material, and this is nanostructured. It exists as objects that are - let's say - a few nanometers in cross section that would be collections of molecules. There's an awful lot of discussion now about what those collections of molecules look like, whether they can be divided into molecules, because if they continue to exist as these nano-aggregated structures, when you heat them or try and process them, they tend to react with one another to form coke as opposed to - which is an undesirable product - as opposed to breaking them into molecular fragments, which could then be used for transport of petrochemicals or whatever you might want to use them for.

So that is a really difficult problem, but a really cool problem because at the moment we don't know exactly what the individual molecules look like. We don't know exactly what these structures look like, and we don't know what their properties are; we just know they exist. And one of the difficulties we face is that one of the research threads was to separate these structures out chemically from the oils and to study those. But if you separate them physically, they tend to have different properties and perhaps comprise different molecules and structures and so on, so there's a debate going on there. But it represents 20 percent of the material. At the moment less than half of this material is being converted to usable products and we could potentially get most of it as a useable product and the materials that are not usable are either burned to generate energy, which is a surplus, or they're buried. And burying something you spent a lot of energy and a lot of time and a lot of money to get out of the ground seems odd. But that's; so this nanostructure piece presents challenges from reaction; it presents challenges from a transport perspective because how these structures can be - and then be assembled and be broken at least in part, affects pipelining an many other things we might do. It affects catalysis and reactions; it affects a whole bunch of things. And so I think that's a truly exciting aspect of what we might work on next and in detail. I suspect Murray will talk more about that when you interview him.

AD: Yeah. You know, that was going to be my next question: is nanotechnology the next science frontier for the oil sands?

SHAW: Well, nanotechnologies are link scale basically, but what's interesting is that it presents different kinds of physics and chemistry …

AD: Yeah.

SHAW: … than at the molecular scale or at the bulk scale, and it's very poorly understood. And some people might misconstrue these objects that are nanoscale as something that can be treated using either theoretical models or processing ideas that are linked to the properties of molecules. But there are different kinds of physics that drive these - either separation processes or suspension processes or other kinds of behaviours that don't exist at that small link scale or at a larger link scale. I won't go into all details but, for example, asphaltenes are supposed to be this, this fraction; it's supposed to be soluble in something called toluene, which is a small molecule, but if you actually do detailed experiments, they're nano-particulate and you can cause them to generate fluid equilibria in these materials; in toluene by applying the physics of nano-particles, which, if you were to work with concepts related only to molecules you wouldn't even do the experiment because you know the answer would be nothing would happen. But if you do the experiment, you discover that there's a complexity of behaviours that could easily lead to the development of new separation processes that will be much less energy intensive then were currently being used and make it much simpler to fractionate this fraction from the balance of the oil, which can be processed in a very different way and that will allow you to tailor new technologies to this, at the moment, intractable fraction.

AD: Okay. So this is the Everest of …

SHAW: Absolutely, it's really a big -- because it represents such a significant fraction of the material. It's 20 percent, roughly.

AD: Yeah.

SHAW: And so it's a huge prize, but it's not strictly an oil sands prize, but it is an oil sands prize.

AD: Yeah. So in, you know, again, when looking ahead, the projections have been, in terms of the oil sands as an energy resource and you've got projections 20, 25 years out in terms of the status quo, but with this new science it could change things dramatically, couldn't it?

SHAW: Well, we don't know. I mean one of the nice things about the future is we don't know, and virtually all projections will probably be wrong. If you were to look at book production just before the development of the printing press, your projections would've been completely wrong. There are disruptive technologies. I don't know if there is a disruptive technology here for us. I simply don't know. But the pursuit of ideas will lead to developments, some of which may or may not be industrially viable, but sometimes ideas -- it's a great idea but it doesn't work on an industrial scale.

AD: In terms of the university, you're part of this era where you have massive research establishments related to the oil sands.

SHAW: Absolutely.

AD: And the named chairs with NSERC and monies from the companies, all of that, which is visible …

SHAW: Yes.

AD: … and it's visible on the U of C campus as well. Do you see that continuing?

SHAW: I would hope so. I think one of the drivers would be preparing students with knowledge so that they could develop expertise and become members of that industry as employees or technology leaders, or choose a topic. We need a level of investment to ensure that we have excellent people. One of the things that I see increasingly though is at the high-tech side of that, a relatively small number of what we call "Canadians" in quotation marks - holders of Canadian passports at the time of graduation with expertise in these areas. We have enormous influxes of people from around the

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world; China in the west, Iran on the east, Venezuela or somewhere in the south; I don't know -- Europe. But we have a … the folks who have grown up here and are in effect part of the story because their parents probably wouldn't be in the province if it weren't for this industrial development, are not really taking as big a role in the high-tech side. Many of them have undergraduate degrees and are in some way linked to this enterprise but are not taking lead roles.

When I look at the people I interact with at the companies, and for me, my industrial partners are pivotal. If I have an idea or a question, it funnels out into the companies and there's someone at each company who's responsible for our relationship and they manage. So if there's a question I have that's not related to them but it could be someone in another part of the world, well, you know, the question will go, the answer will come back and sometimes it'll be a, a direct call and so on. And when they have questions - they've tracked me down while I was skiing in Banff or on holiday in France as easily as when I'm at work in Edmonton.

But they, the role that - I mean as a province and as individuals we haven't conveyed to our children collectively that they should be involved and that the best should be involved beause the scope of the enterprise is enormous. It's not just obvious researchers such as me or Dick Amazia, Murray Gray and so on. But there are people working on pipelines; there are people working on infrastructure, whether it is physical infrastructure or enabling infrastructure - hospitals, schools, the social fabric, the artists who are a necessary part of making a community work, because it's not just one piece. But from a research side there are a lot of people doing superb work which links in some way, but it's not an obvious link.

AD: Now, it's interesting, the whole Canadian aspect. You know, Mel Hurtig and the Company of Canadians and so on, and -- but you know, de facto, the research in the past 30 years or more has been international …

SHAW: Yeah.

AD: … and that AOSTRA nurtured that.

SHAW: Absolutely.

AD: I mean there were the special relationships with Japan, with China …

SHAW: Which still exist as …

AD: … with Venezuela, France, and of course you've been a part of that …

SHAW: Of many of these relationships.

AD: … I mean of many of those relationships. So this acknowledges that research is without frontiers in a sense, isn't it?

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SHAW: It's true, but there's different attitudes about research in different countries and so engineering students in Canada, because of the job market and so on, tend to complete bachelor degrees and go to work, and relatively few, certainly in chemical engineering, pursue graduate degrees.

AD: Okay.

SHAW: And so the bulk of our graduate programs is bringing people from abroad. I think at the moment I have two graduate students on my team who are Canadian citizens. And while the Canadian story is all about immigration, it's - one would like to see the young people of Canada or of Alberta even, more focused on developing the technologies that will shape their future. Right? In Japan or in Europe and even the US, there's a greater focus on research and development. We - first, more money is spent nationally and within companies, but also there's a focus, there's understanding that what works in those areas, there are significant benefits. So the high-tech sector, if you will, in the US is a real success. Why - and it's driven in part, in large part, by local people. They do bring in people from abroad. If we look at the professors at U of A or U of C or go around, we see a significant fraction are from abroad, but not all. But, when we look at our graduate student population, relatively few are home grown. And so a lot of this talent, which we need, because we have real needs for people with talent, is coming from abroad. And I wonder about the future of our children because many of them will not be able or will not be successful within this environment because the others will be coming in ahead of them because they're better trained and more knowledgeable in the areas that are important to the economy and to the oil sands development.

AD: You know, that's a very interesting issue. When I started as a science editor of *The Canadian Encyclopaedia* in September of 1980, you know, there, the hot issues were around science education and careers in science and technology transfer from academe to industry. Now, in terms of popular culture, which is really an indicator of how people think, there is a distrust of science. The heroes of science, which you could do 25, 30 years ago, today, and certainly oil sands science, I mean "rapers and pillagers," and the whole distrust of science. You look at science fiction and it's always the evil scientist. And, so that, you're not going to get young people pursuing careers in science when it's being devalued in the popular media. So I think, just your take on that.

SHAW: Yeah, I mean if you - I don't know if you've looked at the Eiffel Tower in Paris, but just below the main observation deck they've got little medallions and on each of those medallions is the name of a famous scientist, mathematician and so on, going all the way around. And we don't have a culture of celebrating science. How many people will have heard of John Polanyi, for example?

AD: Well, me, because I did the interview (?) …

SHAW: Yeah, but of course, but …

AD: … but you're absolutely right.

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SHAW: And the thing is that, that there's no reason why his name shouldn't be one of those medallions, it's just that …

AD: Yes.

SHAW: … we don't celebrate …

AD: Yeah.

SHAW: … our scientists. Occasionally people will show up in the, in the public medium -- media as a, as a hero and [Chris] Hadfield would be a recent example, conducting very basic but illustrative experiments …

AD: Yeah.

SHAW: … in space …

AD: Space, yeah.

SHAW: … and showing how things differ in space from on Earth. That should excite people, and it may well; I don't know how many. But I think a lot of our best and brightest kids elect to study disciplines other than, we'll call them hard science or engineering. There is a, there is one aspect which would be neuroscience, which is quite popular at the moment and, and there are few others. We call them bright spots, but by and large people shy away from physics and chemistry and mathematics. It's tough. And even computer science. It was a hot subject area and it's disappeared. Electrical and computer engineering are no longer hot pursuits among youth, where they used to be. It used to be extremely hard to get into electrical and computer engineering or …

AD: But the …

SHAW: … or computer science and …

AD: But then you look …

SHAW: … less so.

AD: … you look at the films, you look at the television programs …

SHAW: Sure, of course. Yeah.

AD: … and there, there is that distrust of science and technology …

SHAW: And, and as a consequence is a distrust of an economy that's based on science and technology.

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AD: Yes.

SHAW: And so you have lots of examples of youth who their livelihood - the medical system that they enjoy, the school systems that they enjoy, the roads that they like to drive their cars on, which they have and so on - is provided by a society which is technologically-based. They play some role in it but they refuse to recognize the importance of it. It's like, I don't know, vegans who wear leather or environmentalists who use hair dye but wouldn't think of using harsh cleaning products on their sinks and bathtubs at home, but they will apply them to their heads.

AD: So there's a, there's a …

SHAW: There's a, there's a tremendous schizophrenia …

AD: Around that.

SHAW: … that comes from ignorance.

AD: Yeah.

SHAW: And that's really difficult to combat, and so this comes back to the discussion around the communication piece. It's very difficult to convey scientific ideas to a general audience for which there is antipathy towards science, as opposed to near ignorance, and an openness. And I was interested in that in this conference I was at, this international student energy summit. Parts of the audience were highly politicized, but not as knowledgeable as other parts, and these are self-selected students who paid their own way there from around the world - perhaps 500 students - and then a collection of experts. There was a lot of very good discussion but there's also some fairly highly-politicized discussion where not all of the - we'll call them the facts - were presented. So if you only have one part of the picture it's very easy to jump to a conclusion; whereas if you have the full picture it's much more nuanced. And so, but I think from the communication point of view, we'll say the hydrocarbon industry has not done itself a great service in many cases.

Good housekeeping would prevent spills from pipelines. If we think in the context of the Alberta through BC to the coast where BC is proposing to put natural gas liquefaction plants in very sensitive environmental locations along the coast, and then these large natural gas pipelines going through and of course there's no debate. No discussion of that subject. But if I replace natural gas with oil, which is much easier to contain - if there's any problem with a liquefaction plant with gas pipelines, the damage is broadly distributed; whereas with oil it's much more containable. And so from a safety point of view I think it would be fairly easy to argue that an oil pipeline is much safer than a gas one.

AD: But, you see, people are looking at the Gulf coast spill, which is …

SHAW: Of course.

AD: … very different.

SHAW: Of course.

AD: It isn't, you know, and so that's what stays in their minds.

SHAW: Absolutely.

AD: I'm …

SHAW: I agree.

AD: … I'm going to change the subject …

SHAW: Sure.

AD: … slightly and I note that, of course, you've got a number of patents. Do you want to talk a bit about the whole patent process?

SHAW: Sure. When you generate a patent from a scientific enquiry, once the lawyers are through you may not recognize what it is you've developed. And so one of the patents I have relates actually to pulp and paper processing, and so it's less relevant but the story is exciting. It was - my undergraduate thesis was patented, and so the goal there was to improve energy recovery and reduce water use within craft pulp mills and aspects of the technology have been adopted by others, but less so than one might choose. So that was an interesting story but I've not gotten rich from that patent. Fact: I've not seen any money other than salary-related of consulting-related revenues at all, which is a pity; I would love to be rich. But anyway, I suppose I need a reason to get up in the morning.

So another patent relates to making "green" methanol, so we now have an awful lot of natural gas, which is quite cheap. It's not going to go to "zero" but it's quite inexpensive. And so converting natural gas to a liquid fuel that can be used in - for transport - is, I think, a growing area of interest and so the particular patent relates to getting "out of the box" of these processes being hydrogen starved, and so the goal there would be to consume CO_2 in addition to methane, but having some source, supplemental source of hydrogen so that you could, in effect, convert CO_2 to fuels, but you need, you need sources. And so there are energy penalties to pay for that. But overall the process works and has not been adopted by industry. It requires fairly-low natural gas prices for it to work, and you need some driver from the point of view of a CO_2 tax.

AD: But I mean, it …

SHAW: … these are things that may happen, certainly, and so …

AD: Yeah, exactly.

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SHAW: But the concept is, is very sound. Who knows what will happen with that? But as far as oil sands-related work, nothing has been patented; it's very fundamental and so one of the ways we've been able to sell the research program to industry is that for them it is pre-competitive and we …

AD: Okay.

SHAW: … we provide a forum for companies, in effect, to exchange ideas or provide samples and gain understanding that then can be applied.

AD: Okay.

SHAW: And so if we did patent something based on this line of research, it would be by accident, and it would be interesting to see how we tackled it. It's not clear but, under the rules, if we have such an accident, a happy accident, the technology would be owned by the university and they would have royalty-free use; others would have to pay. But given the way we've targeted things, it's not a likely outcome. But all the work is public and published. So there's the mac - to maximize the benefit to the community in general, and they understand that, and so if you were to look at what the knowledge we generate and how does it – itself - get valued by the companies? It's the time value of information. So normally the life cycle is one or two, three years between the concept, experiments and results through to a publication that is in a peer review journal. And they have access at all stages so they know what's coming. And so they have a one or two years lead-time and that, in itself is a huge value.

AD: Absolutely. Now, just final area: can you identify colleagues, whether at the U of A or elsewhere in Alberta, that are doing this kind of leading-edge research that you have some relationship with?

SHAW: I think I'm linked to all of them in some way …

AD: Yeah.

SHAW: … and preparing a list would be tough. Among the other roles I have is as an associate editor of *Energy and Fuels* where a significant fraction of the research actually gets published. So I don't want to risk forgetting anybody so I'll leave a few names but I will acknowledge that I will - at the moment they may not all pass through. There are collections of researchers in different locations and so Hassan Hamza's team at CanmetEnergy in Devon, there are a number of people there; Kirk Michaelian was a chemist who is doing some really interesting work on understanding the molecular structures that exist in asphaltenes or in other parts of the oil that we really need to know more about. So, check.

But there are many others there working on all aspects, whether they're nanoscale or process level. Kevin Moran's company, the name of which escapes me, is doing a pilot there. There's also a pilot being run there by the - it's a Japanese consortium - basically they're using water plus bitumen instead of trying to separate them and making the oil water-free; they're processing and refining in a water-rich environment at high temperatures; very interesting potential technology. And so there are people at Canmet working with them and so on, these teams. It's not an individual activity. Yes, you have an idea but sometimes to fulfill those ideas you need a team. Sometimes it's a provincial team or a local team, but it's quite often an international team. So that's just one, one site, and there are probably 30 or 40 people there I haven't named yet who play a role and play an important role in different aspects.

I could pick on U of C. We're not supposed to do that, but we should, so Harvey Yarranton there is someone with whom I work closely. We write papers together. Sometimes we disagree. In fact, we have a paper that's probably through the peer review process at the moment where we're comparing different techniques to measure a particular set of properties, in this case also about asphaltenes, and we have about six or eight labs from around the world and we don't agree on anything. And so that's a very interesting - so sometimes you work with people because you agree and want to work with them; other times you just want to share ideas and say, look, this is what all these different techniques show but they're not showing anything common, so that tells us there's something wrong with the techniques or understanding of what the techniques provide. So he's an example at U of C but there are many others working in different parts of the program.

So Steve Larter leads the Carbon Management Canada team [University of Calgary], but he's also a geological engineer I think, or a geologist; works on many aspects of oil sands - in situ measurement, properties of fluids, as well as the geology and so on. There are many people, there's no shortage. I've been mentoring and supporting different points in his career but he's a wonderful colleague, David Sinton, now at the University of Toronto and he's been developing some really cool microfluidic techniques for making measurements in, in the spaces that are equivalent to the pores in reservoirs.

The list is huge. Within U of A we have in chemical engineering alone, we have at least ten industrial research chairs - Canada Research chairs - a bunch of fabulous colleagues who one often doesn't hear about. Janet Elliott would be one. Some up and coming ones would be people like Hongbo Zeng and so on. There's, there's, there's this list of, of people and it's growing, the enterprise is huge. And many of them are working in areas that are not what we think of as conventional take oil, mix with something, hope something happens and you get. This studying is taking place, as you pointed, in a post-industrial way with very fundamental measurements and application of wonderful theory.

But we can go beyond the borders of Canada. We can keep going to the US and then I work closely with a group at Florida State University - it's the National High Magnetic Flux Lab in Florida; the French Petroleum Institute in Paris with (? Beret?), there are people with expertise in ultrasonics; Jean Daridon, others at UPPA [Université de Pau et des Pays de l'Adour]. I work with people who do molecular simulation to go after structure based on measurements of spectra that we can then compare with calculations and the list goes on. There's a group at Tohoku University in Japan with whom I work on water-plus heavy oil properties and bitumen properties. There's a - the world is a

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very integrated place and there are a few conferences that many of us attend and we work together and we try and meet there but we also meet in one another's labs to, to talk about research.

But it is a global - research is global. The days of the lone scientist working in the equivalent of a garage or lab - it's unlikely that they'll make the breakthroughs that are needed because for that you really need a team.

AD: And you know, it's interesting to look at the early days of AOSTRA and Clem Bowman's vision and others - the big international conferences where new discoveries that they were making in the lab were being shared collegially and so that Alberta has played a very significant role …

SHAW: Absolutely.

AD: … in terms of oil sands research and then sharing it internationally.

SHAW: Well, there is an oil sands conference which started out with, I guess, Jacob Masliyah's industrial research chair …

AD: Yeah.

SHAW: … and then in collaboration with Murray Gray …

AD: Yeah.

SHAW: … which then grew into the oil sands conference. AOSTRA had a series of reports which were commissioned and these were, and remain, extremely valuable documents.

AD: Yes.

SHAW: And then other conferences have themes that relate to different parts of the bitumen, whether it's the out-water separation piece which relates to secondary recovery in a conventional oil well; so there's a petro-phase series of conferences where many aspects of heavy oil and bitumen are picked up, but it's not, it doesn't say oil sands.

AD: No.

SHAW: But it's - if you actually get underneath the cover, the packaging outside, you realize ah, well these, all these interfacial phenomena …

AS: Yeah.

SHAW: … that are being studied and are necessary parts of secondary oil recovery in a conventional well, apply to bitumen, water, sand separation from a mined operation or mining operation as much

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as it does for the focused application of the research itself. So there's many of these things. Asphaltenes would be another example where this is done. So there's an awful lot of overlap.

The other thing I find interesting - it's an interesting trend - is the merging of the conditions in the reservoir in terms of pressures and temperatures and even compositions once you start adding things *vis a vis* what happens in a refinery where it's, you know, tends to be high temperature or moderate to high pressure, add chemicals and catalysts, but it's - the conditions are merging in some way - and so this is also an interesting trend. And so, you know, where does refining and production - what's the boundary between them and sometimes it's not all together obvious. And so that's why there are a lot of people like me who really don't distinguish between those different kinds of processes.

AD: Well, the capacity when you do in situ extraction to actually control some of those processes to determine the products, I mean I think this is my layperson's …

SHAW: It'd be nice if we could do it in the reservoir. No, true!

AD: (*Laughing*).

SHAW: But it would be, it would be nice.

AD: Oh.

SHAW: And the thing is that there is, I mean there is a thread which is just that.

AD: Yeah.

SHAW: Or if you can imagine using electrical heating inside the reservoirs to actually crack the fluids before they're produced. There's a long list of ideas that are being tested, sometimes at a very large scale and sometimes hidden away as pilots underground, whether it's in the Peace River or in the far north or …

AD: Yeah.

SHAW: … hidden away in a, a government lab in suburban Edmonton. I mean it's there's - a lot going on that's not obvious. And most of the people involved in these kinds of research activities are very thoughtful people. Not all of them, but some – many - have a fairly holistic perspective and I think you need that holistic perspective because sometimes you make an improvement in one part of a process, but it makes things much worse elsewhere, and so that's no good. So that's why you need - you need teams and why it tends to be integrated either across disciplines and so having an assemblage of diverse researchers is an important piece. I really value my colleagues and if I have a question I go down the hall or send an email because they're not likely to be in their office; they're out and about.

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And so if you have a critical mass of people it sparks ideas, so even though there may not be a budget for a project, just a conversation over coffee - cool, let's get a PhD student. If we can find one, or a Master's student or a summer student and explore the idea further. And so you advance much more quickly in that environment than you would, again, if you were on your own. And so that was part of the AOSTRA vision, certainly, and part of the NSERC vision of creating these industrial research chairs and certainly U of A in particular has exploited these programs to create an incredible collection of researchers.

AD: Gosh, that sounds like a summative statement. Is there anything else that I've forgotten to ask you or any concluding remarks that you'd like to make?

SHAW: No, I think that's pretty much it. If we think of something we can always add it to the tape later, right?

AD: Well, thank you very much for …

SHAW: You're more than welcome.

AD: … sharing your story and that of a whole bunch of other people by really making the case for pure research. Thank you.

SHAW: You're more than welcome. Thanks, Adriana.

AD: Good.

[THE INTERVIEW CONCLUDES.]

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