WRITTEN STATEMENT

HEARING ON “THE AMERICAN ENERGY INITIATIVE”

SUBCOMMITTEE ON ENERGY AND POWER

FROM

DR. JOHN NENNIGER, FELLOW OF CANADIAN ACADEMY OF ENGINEERING, CEO
N-SOLV CORP

BEFORE THE HOUSE COMMITTEE ON ENERGY AND COMMERCE

U.S. HOUSE OF REPRESENTATIVES

MARCH 20 2012

Summary of Major Points

My Company, N-Solv has developed an energy efficient underground oilsands extraction process that does not use any water. Although the laboratory results are very encouraging, oil production process has not yet been tested in an underground reservoir. In comparison to steam, N-Solv is expected to:

- Reduce extraction energy by 85%
- Reduce Well to Tank GHG's by 205 pounds per barrel
- Increase oil value by 23%
- Reduce capital and operating expenses by 30%
- Double the netback ($profit/bbl oil)
- Triple the capital efficiency ($profit/$ of risk Capital)
- Access an additional 1,300 billion barrels of Canadian bitumen reserves
- Our field pilot is expected to produce first oil in April of 2013
- We expect other significant opportunities for solvent extraction including a portion of the 3,000 billion barrels of stranded heavy oil resource

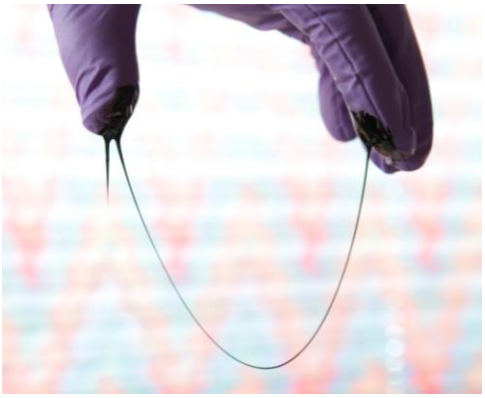
Good afternoon Chairman Whitfield, Ranking Member Rush, and members of the committee. I am John Nenniger, CEO of an technology company called N-Solv Corp. I am a Canadian who has had the great privilege of earning a doctorate in Chemical Engineering from MIT. My energetic and supportive wife is an American citizen whom I met in at MIT, and she also has a doctorate from MIT. My Dad, who is the co-inventor of our technology, also has a doctorate in chemical engineering. His insights, starting with a patent application filed almost 40 years ago, have been enormously helpful.

It's a great honor for me to be here today to discuss clean solvent based Oilsands Extraction Technology. Inexpensive energy is good for the American economy but cheap energy encourages wasteful consumption. The evidence of climate change is compelling and terrifying. This presents a profound moral dilemma. I believe "harm reduction" is the most pragmatic option. This means finding profitable ways to produce cleaner products.

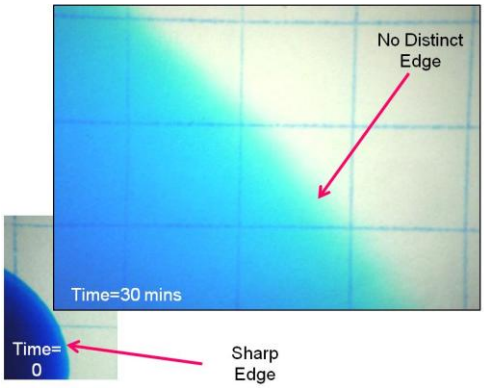
Oil prices are set by surplus or deficit in supply rather than production cost, consequently oil industry psychology on every issue is dominated by price elasticity. Energy efficiency produces $300/bbl of benefits to consumers and new oil supply produces $100/bbl of benefits. Either way, American consumers win. However, the big money is in conservation-energy efficiency which is also good for the planet.

N-Solv Science

The N-Solv oil extraction process is very similar to steam assisted gravity drainage except condensing solvent provides the heat instead of steam. N-Solv promises to provide huge environmental and commercial advantages. To appreciate this opportunity, it is useful to review the science of solvent extraction.



Bitumen has many unusual characteristics. The photograph shows a filament of bitumen which is being stretched. For most fluids, stretching produces a “neck” and the filament then thins and breaks at this neck. However, the bitumen stretches uniformly, which is a rubbery behavior. The filament reveals large scale molecular entanglements within the bitumen.



The two photographs on the left show a drop of dye placed into stagnant water and its progress one half hour later, the dye spreads to a diameter many times larger than the initial drop diameter. The dye gets smeared out.

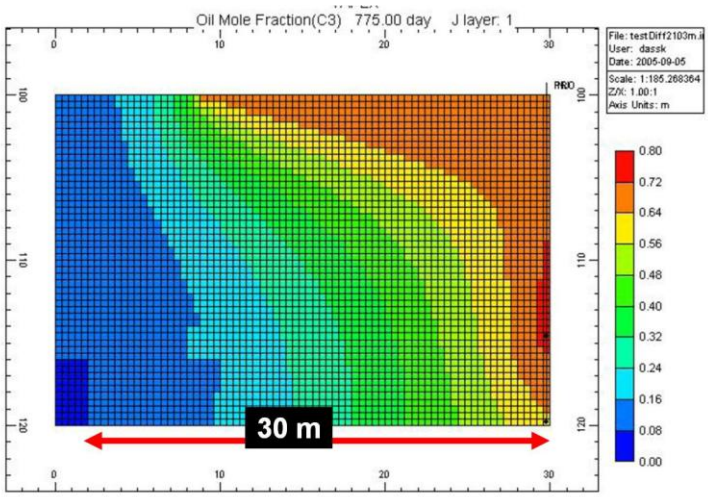
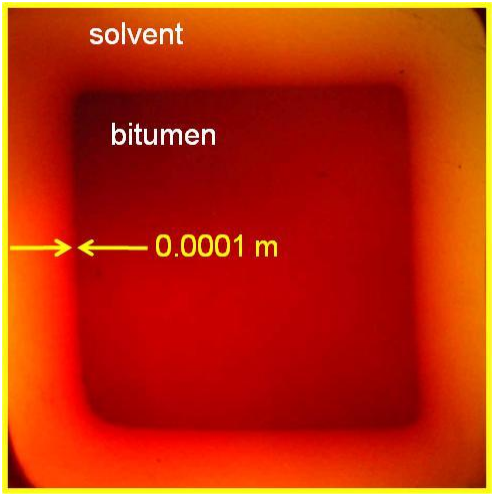


Figure 6. Propane concentration in bitumen at 775 d.

The oil industry thought bitumen dissolution in solvent would resemble this intermingling of water and dye. Consequently, computer models of solvent extraction consistently show the solvent penetrating deeply into bitumen. In the computer prediction to the left, the solvent forms a broad smear that extends 30 meters (100 feet) away from the wellbore.

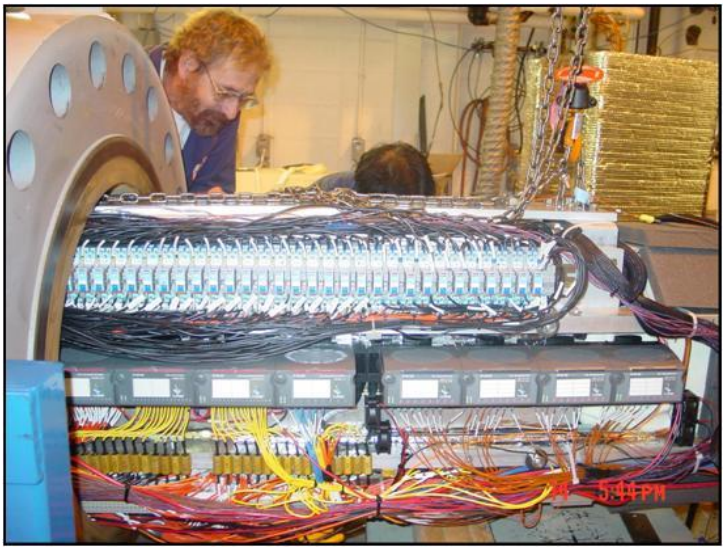
Yet when bitumen is dissolved in solvent, the bitumen slowly shrinks like a melting ice cube. Instead of seeing a “big smear”, there is a very sharp edge between the solvent and the bitumen (yellow arrows). The “smear” is confined to an extremely thin zone roughly the same thickness as a sheet of paper.



This resemblance to melting ice cube is consistent with the rubbery bitumen picture. It’s likely that entangled molecular networks make it difficult to remove molecules from the surface of the dissolving bitumen.

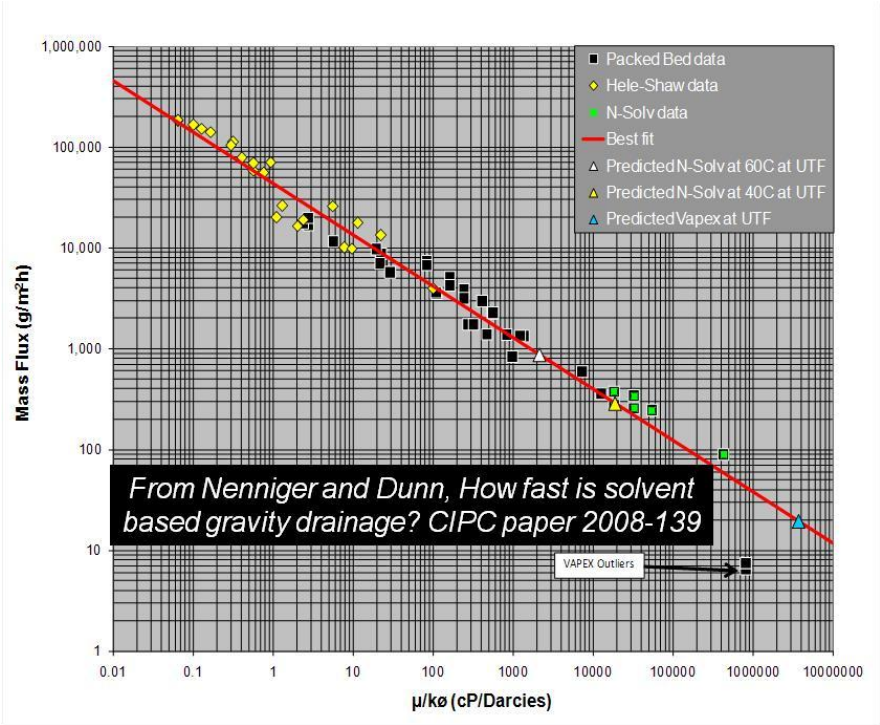
These simple experiments challenge every assumption that the oil industry has made about solvent extraction of bitumen. The interpretation of lab experiments, the prediction of field scale performance, the impact of operating parameters like solvent type, heat, contaminants, etc. needed to be re-examined.

We developed a very sophisticated apparatus that enabled us to reproduce reservoir conditions and ran a series of experiments to track chamber growth rates. The tests showed an extraction rate of just over one inch per day at 100F. By comparison, at 450F steam extraction in the same reservoir provide a chamber growth rate of



1/3 of an inch per day.

So our “fast” growth rate is the thickness of one sheet of paper every 5 minutes. Why is this exciting? Gravity drainage chambers have enormous surface area. The drainage chamber from a single wellpair has a surface area the size of 10 football fields.



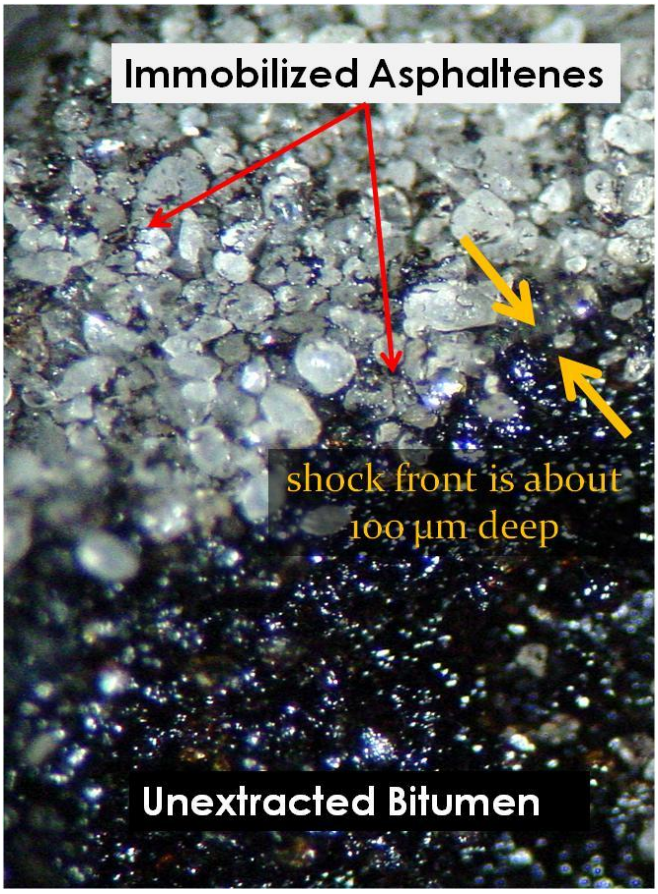
To make sense of our data we compiled a data base of every solvent experiment as that we could find in the scientific literature. We developed a correlation (shown at left) that predicted the oil rate as a function of the experimental parameters. The data base includes experiments on many different crudes at different temperatures, pressures, using different solvents, and sand permeabilities.

The simplicity of our correlation is surprising, the choice of solvent doesn’t matter. The only fluid property that is important is the oil viscosity at extraction temperature. This again fits with the idea that it is very difficult to remove large entangled molecules from the surface of the dissolving bitumen.

So our model of solvent extraction tells us how to optimize the oil rate. Our one inch per day laboratory result fell on exactly the same line as all the other experiments

confirming that our experimental result was credible; and confirming that a condensing solvent process operation at 100F in Athabasca could provide oil rates as fast as a steam extraction process operating at 450F.

Our laboratory experiments consistently showed the sharp boundary between the raw bitumen and the solvent chamber. Typically this edge was exactly one sand grain thick (the thickness of one sheet of paper). Our experiments also showed an unexpected result. The asphaltenes were uniformly distributed throughout the solvent chamber. The uniformity is important because it means that they should not block the drainage of fluids in the chamber.

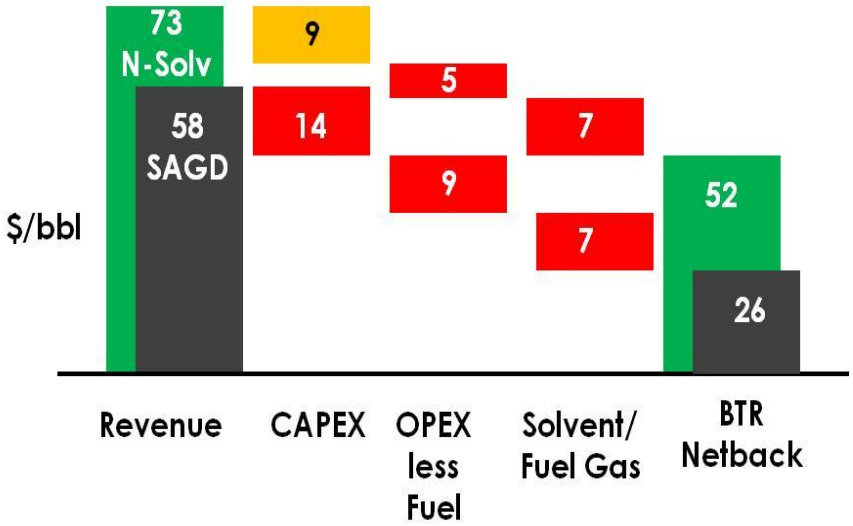


Our experimental results have implications for the oil industry. It seems likely that many solvent floods and miscible floods did not achieve good mixing between solvent and oil. We think that production strategies that create lots of accessible surface area, like foamy heavy oil production, will be particularly suitable for subsequent a solvent extraction. Waterflooding may harm ultimate recovery because the water prevents efficient contact between the solvent and the oil. The US Geological Survey reports that worldwide, there are 3.4 trillion barrels of heavy oil with

an expected ultimate recovery factor of only 13%. The use of solvents for heavy oil recovery may represent an even larger opportunity than the Canadian oilsands.

Economics of Solvent Extraction:

It is early days for our solvent extraction process and we don't have field data yet. So discussion of the economic benefits is speculative. Market prices for hydrocarbons are volatile and subject to change.



The graph compares N-Solv economics to those of steam extraction. The graph shows than N-Solv netbacks are twice as high as SAGD.

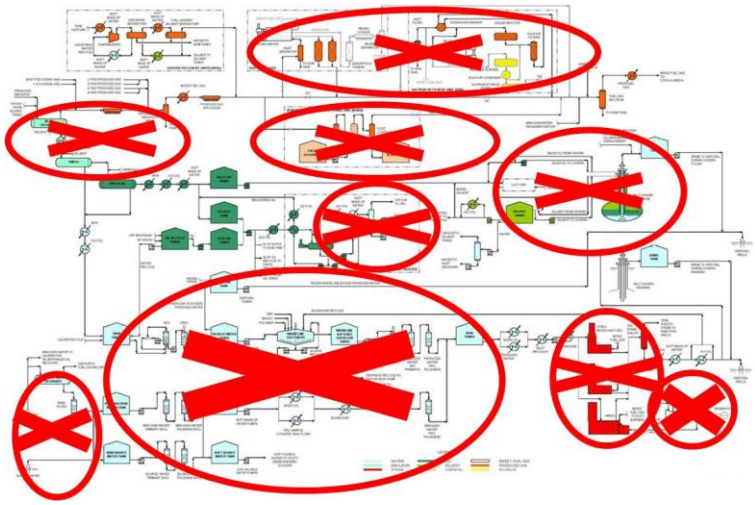
Capital cost is the riskiest portion of an oilsands investment because this cost is incurred years before there is any oil production. The profit to risk capital ratio is often used to assess the payout on an investment. In N-Solv, $9 of risk capital generates $52 of Before Tax and Royalty (BTR) netback. In SAGD, $14 of risk capital generates $26 of BTR netback. N-Solv produces three times more profits for each dollar of investment capital.

Two aspects provide most of N-Solv's commercial advantage. The oil is more valuable because it is de-asphalted. Steam extracted bitumen undergoes considerable shrinkage due to coke rejection. For every pound of synthetic crude production, 0.23

pounds of coke is produced. This coke has no commercial value; it's too dirty to burn without very expensive scrubbers.

The shrinkage of SAGD bitumen in the coker reduces the yield of valuable products like gasoline. Thus, a barrel of deasphalted N-Solv oil should be 23% more valuable than a barrel of SAGD bitumen. This value is captured by integrated companies, but might not be captured by junior producers.

The second great commercial advantage for N-Solv is the cost savings from



process simplification. There is no boiler feed water treatment or steam generation. The process simplifications, shown by red x's in the figure, reduce the capital cost of the N-Solv plant by almost 50% compared to a steam plant and provide a 50% reduction in operating expenses. The well costs for both processes are similar.

In SAGD and in N-Solv each barrel of oil production needs to be replaced with some other fluid. We don't know the exact amount of reservoir holdup for N-Solv. In SAGD, the reservoir holdup is about 0.1 bbl of water per bbl of oil production. We have assumed the solvent holdup in N-Solv is twice that of SAGD. The cost of propane is about $50/bbl, this means a solvent cost of $10/bbl of oil production. The government provides a royalty rebate of 30% if solvent is re-injected into a reservoir. Thus, the net

cash cost of using 0.2 bbl of solvent is about $7 or $8 per barrel of oil. This calculation assumes there is no salvage value so it's quite pessimistic.

We believe our economics are highly understated. We have assumed twice the solvent inventory cost. We have also assumed that the oil production is only 35% of the predicted rates. We also assume the plant is assembled in the field. A factory assembled modular plant would provide substantial cost savings. We have not assumed any debt leverage.

The ability to operate at modest temperature and pressure will provide access to immense bitumen resources that are currently uneconomic for steam extraction. This resource includes "no-man's" land which is too deep to mine and too shallow to SAGD. Another stranded resource is the carbonates, a vast deposit with steam oil ratio's that are currently uneconomic. N-Solv technology could help access 1,300 billion barrels of stranded hydrocarbon resource within Alberta.

Environmental Benefits:

N-Solv doesn't use any water. By comparison, steam extraction consumes about 1 barrel of water per barrel of oil production. Although only 0.1 barrel of water is required for in situ voidage replacement, large amounts of water is sent to disposal wells because it is very expensive to treat,

The big advantage of N-Solv is the reduced energy consumption due to operating the process at a temperature of 100F instead of 450F. This reduces the emissions from the extraction by 85% compared to SAGD.

However this energy savings doesn't capture the entire story. SAGD bitumen produces less refined product per barrel than N-Solv due to coker shrinkage so on a life cycle basis N-Solv performs better than the 85% reduction. We have estimated that N-Solv will reduce the well to tank GHG intensity by 205 pounds per barrel of transportation fuel. This estimate has been externally validated by an outside and independent engineering firm. If we make some fairly modest assumptions about market growth and market share (30% share of in situ, production ten years after commercialization), then N-Solv would reduce oil sands GHG emissions by 120 million tons, We expect the pilot to cost about $60 million dollars, so the average "cost" of GHG reduction is 50 cents per ton.

De-asphalting the bitumen in the reservoir has many benefits, it eliminates the coke disposal problem. Coke contains a number of carcinogens including polycyclic aromatic hydrocarbons and nickel. Using 85% less fuel than a SAGD, also enables N-Solv to reduce NOX and SOX emissions by 85%.

The "BEST" Field Pilot:

We are building a $60 million field pilot to test the N-Solv technology in a reservoir setting. This is at the same site where SAGD was first piloted. We chose this site because there is a lot of published data on SAGD so we can make a good comparison. Suncor Energy has

kindly offered to host our pilot including drilling the wells. Hatch has made major investments in N-Solv, and is providing the Engineering. We have received major financial support from Sustainable Development Technology Canada. I can't say enough good things about SDTC, They have been tremendously supportive and patient through some difficult periods. Enbridge Pipelines has also contributed significant capital towards the pilot. They are industry leaders, and they understood as far back as 2006, that the need to develop cleaner technology was urgent.

We drilled seven observation wells in December and January to help understand the resource. These wells will be equipped with temperature and pressure sensors to track the chamber growth.

The pilot will be use a 1000 foot long horizontal wellpair. This is shorter than a commercial scale well but long enough to see if we achieve commercial scale productivity. The pilot is expected to operate for 3 years. The plant is designed for a maximum rate of 1500 bbls per day of solvent and 500 bbls per day of oil production.

Our analysis of the data from the observations wells is not yet completed. Our preliminary estimate is for an oil rate of 150 bbls of oil per day, which is 35% of the rate

predicted by the correlation. The plant design allows us to operate over a wide range of conditions, to facilitate learning as much as possible

Safety

Loss of solvent from the extraction zone represents a safety risk. However, there are two compelling reasons why N-Solv should always be operated to minimize the risk; solvent loss is dangerous and expensive.

The N-Solv process is somewhat like using a blowtorch to carve a tunnel in a block of ice. The melt water (oil) is continuously drained from the bottom of the tunnel. There is no oil production, unless the solvent is confined and the mobilized oil and condensed solvent can drain downwards. Overpressure and frac'ing are unsafe, unnecessary and economically undesirable.

We expect commercial extraction rates at modest temperatures and pressures, so there is no compelling commercial incentive to operation at pressures above the native pressure. If a higher temperature is needed but this requires too high a pressure to be safe, then the operator can switch from propane to a higher boiling point solvent like butane.

In high temperature steam, the thermal expansion can expand the pay zone by 3 feet. This puts enormous stress on the confining cap rock layer. The modest extraction temperatures of N-Solv mean that the thermal expansion and stresses are almost 10 times smaller for N-Solv than for steam extraction.

The N-Solv plant is a hybrid of a standard natural gas plant and a heavy oil plant. Both of these operations are well known and have a track record of safe operation. Doubtless, we will be learning new things and getting some surprises in our pilot. We follow or exceed all of the safety codes, and we have brought operators into our design team right from the start. The engineers have made a considerable effort to understand and fully address all of the operators concerns, especially if it relates to safety.

Thank you for the opportunity to present this information and I look forward to your questions and comments.

John Nenniger

Resumé: Dr. John Nenniger, FCAE., P.Eng.

Education:

Sc.D. - Doctorate of Science in Chemical Engineering([1]), Massachusetts Institute of Technology, 1983, Graduate studies also include a minor in business with courses taken at Harvard and MIT;

B.A.Sc. Honours, Bachelor of Applied Science Engineering Science, University of Toronto, 1977

Professional Organizations

P.Eng. - Professional Engineer APEGGA

F.C.A.E. - Fellow of the Canadian Academy of Engineering

Professional Experience

2005 to present CEO of N-Solv Corporation([2]) Calgary

1986 to present, Partner, Nenniger Engineering Inc.

- Co-inventor of N-Solv™ technology for oil sand extraction. Author of many patents and patent applications, technical papers and presentations regarding energy efficiency, GHG emissions([3]), solvent extraction mechanism and modeling([4]), heat delivery, solvent phase envelopes([5]) and physical model testing.
- Developed the key enabling technology to enable high pour-point waxy crudes to be pipelined to market at temperatures more than 15 degrees C below their pour-point (gelling) temperature. This technology led to the commercial development of oil production in Sudan via Talisman's Sudan pipeline (1500km x 28in) and carries 500,000 bbl/day (i.e. $16 billion/year).
- Developed and tested a coiled tubing deployed downhole well heater technology to treat oil reservoirs plugged by wax. This was a useful experience but the tech was not commercially viable.
- Analytical Services- Provided n-paraffin analysis, solubility measurements, wax deposition kinetics and rheology studies for characterization of waxy crudes, wax deposits and wax solvents.
- R&D- Developed a novel wax deposition apparatus to investigate fundamental precipitation kinetics and develop an improved predictive model. Schlumberger subsequently licensed this technology.
- Consulting- Provided scale and wax consulting services to more than 50 clients worldwide including engineering, operating and research organizations
- Software- Wrote NWAX and HOTOIL software models. NWAX is a thermodynamic model used to predict n-paraffin solubility in crude oils and solvents. HOTOIL is a transient countercurrent heat exchange model for oilfield wellbore. HOTOIL has been endorsed by Sandia National Labs([6]). NWAX clients include Exxon Production Research, Shell Development, Pan-Canadian, Chevron-Texaco, Schlumberger and Petro-Canada.

1983 –1986 Senior Research Engineer, Petro-Canada Resources, Calgary

- Performed R&D and technical and engineering support for on a wide variety of projects including wet air oxidation, waxy crude characterization, corrosion and inhibitor evaluation. Clients included gas plants, oil batteries as well as offshore developments (Terra Nova and Hibernia)

1978 - 1983 Research Assistant at MIT, Cambridge, Massachusetts.

- Invented a novel, ultra-high intensity combustor, capable of producing 4 megawatts of heat from a 250cc chamber. Studied polycyclic aromatic hydrocarbon (PAH) production in this burner under fuel rich combustion conditions. The toroidal burner design is currently being used for research by NASA([7]), NIST and NREL([8]) and the USAF and Navy([9])as well as research institutes (MIT[10,11,12,13] NJIT[14]). Applications for my burner design include fuels evaluation, chemical kinetics([15]), turbulence studies, gas turbine design, hazardous materials destruction([16]), to nano-material fabrication([17]).

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[1] Polycyclic aromatic hydrocarbon production in a jet stirred combustor
[2] www.n-solv.com
[3] The Profits of Energy Efficiency vs the High Cost of Carbon Capture
[4] How Fast is Solvent Based Gravity Drainage?
[5] Dewpoint vs Bubble Point: A Misunderstood Constraint on Gravity Drainage
[6] http://prod.sandia.gov/techlib/access-control.cgi/1996/962247.pdf
[7] NASA Intelligent Engine Systems
[8] The effects of aromatic species in a well stirred reactor/plug flow reactor
[9] Effects of Reacting Cross-Stream Flow on Turbine Film Cooling
[10] PAH chemistry in a jet-stirred/plug-flow reactor system
[11] Formation of soot and polycyclic aromatic hydrocarbons in a jet-stirred reactor
[12] The chemistry of chlorine in combustion systems and the gas-phase formation of chlorinated and oxygenated pollutants
[13] The formation of polycyclic aromatic hydrocarbons and soot in a jet-stirred/plug-flow reactor
[14] Experimental Studies of Formation of Products of Incomplete Combustion and Chlorocarbon Incineration
[15] Soot surface growth mechanisms in stationary combustion systems
[16] Modeling of Hazardous Waste Incinerator
[17] Nanotube presentation.pdf