Every day, more than a million barrels (bbls) of bitumen are produced from the oilsands surrounding Fort McMurray in northeast Alberta; the Canadian Association of Petroleum Producers expects that figure to climb to over three million bbls per day within a decade. But continued expansion is facing a range of headaches, including rising costs, depleting resources (such as natural gas and fresh water) and environmental impacts. Clearly, business-as-usual is not an option; new ways of producing and refining bitumen that are more efficient, cost-effective and environmentally-friendly are needed, and fast.

Enter AERI to the rescue. The Alberta Energy Research Institute is boldly going where no tarry lump of sand has ever gone before. "AERI's vision for Alberta is to become a world leader in commercializing new technologies to utilize heavy hydrocarbons with positive economic, social and environmental impact," says Duke du Plessis, a senior advisor and research manager for AERI. "Another objective is to develop these technologies in Alberta with Alberta expertise and to have the benefits of the best technologies."

In 2005, the provincial government closely examined the state and future of the oilsands and coal industries in Alberta and realized that "next generation" technologies were not being developed and commercialized at a rate sufficient to meet the challenges ahead. They announced a new initiative called the Hydrocarbon Upgrading Demonstration Program (HUDP), and pledged up to $100 million in matching R&D funds over the next five years to kick-start promising ideas.

"The purpose of HUDP is to work in partnership with industry to develop the next generation of upgrading technologies, to bring them to the commercial stage faster through sharing the development risks with industry," says du Plessis. "For example, for some technologies it could take five years to reach commercial stage, instead of 10 years."

AERI screened 100 different nascent heavy oil technologies to pick the ones with breakthrough potential. They then requested expressions of interest and received 23 proposals, finally settling on eight candidates. "Three were residue upgrading, three were gasification, one was bitumen-to-petrochemicals and one was CO_2 capture," says du Plessis.

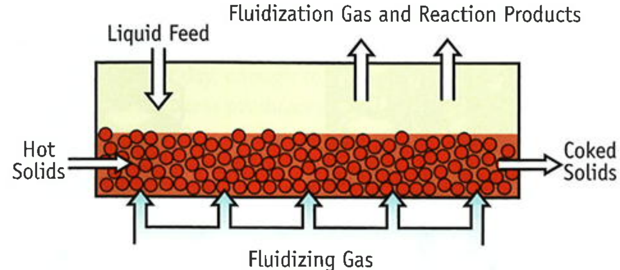
Under the terms of the program, HUDP advances funding on a sequential basis. "The technologies are stage-gated," says du Plessis. "We invest in an early stage — bench testing. Then, if it shows promise, we move to the piloting stage, then finally to the near-commercial size."

It's still early days, but HUDP has already accelerated the pace of development for the eight key technologies under its wing. Most of the projects have passed through bench testing and are either completing small scale pilots or entering the commercial demonstration stage. Will they evolve into genuine breakthroughs? "Some might not be as successful as first envisioned," cautions du Plessis. "Sometimes that happens when you scale up a new technology."

Some of the projects include:

Residue upgrading

Unlike conventional oil, bitumen from the oilsands is tough, tarry stuff that doesn't give up its energy value easily. One of the major commercial upgrading processes is known as delayed coking, in which the heaviest portions of bitumen are loaded into giant drums and subjected to heat until they give up most of their remaining vapours and liquids, leaving behind a solid carbon residue known as coke. The process is messy and energy intensive, and produces relatively low value products.



CROSS-FLOW COKER
ETX says its upgrading process achieves advantages by decoupling gas and solid (liquid) phase residence times.

HUDP Funding

Residue Upgrading

- **ETX Systems** will test a new type of cross-flow coker, which converts bitumen to lighter products.
- **UOP** will advance its slurry phase hydrocracking design to increase the yield and quality of synthetic crude oil.
- **A solvent deasphalting process** based on new concepts developed in Phase 1 of HUDP.

Gasification

- **Pratt & Whitney Rocketdyne** will advance its gasifier, a rocket engine that converts coal and bitumen byproducts into hydrogen and electricity.
- **GreatPoint Energy** will test a catalytic gasification technology to convert petroleum coke and coal to synthetic natural gas (methane) in a single step.
- **Alter Nrg** will build a plasma gasification demonstration plant to produce electricity and chemicals from biomass and waste feedstock.

Bitumen-to-petrochemicals

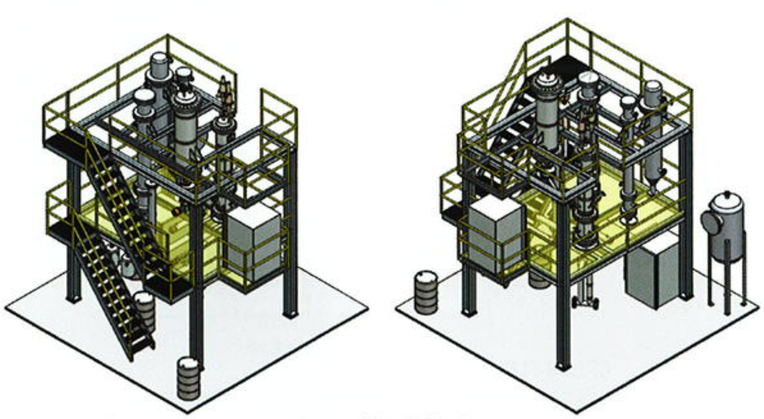
- **NOVA Chemicals** will scale up patented technology that converts bitumen fractions into valuable petrochemical feedstocks.

CO_2 Capture

- **OPTI** is studying systems that will allow it to capture CO_2 from the Long Lake oilsands plant.

ETX Systems Inc. is one of many firms searching for better alternatives. The Calgary-based company has its genesis with Syncrude Canada Ltd. alumni who wanted to explore some promising ideas on their own. "I was at Syncrude until 1999," says Gerard Monaghan, CEO of ETX. "After that, we formed a development company with a number of ideas, including heavy oil upgrading. Three years ago, we spun the idea off to ETX."

ETX wanted to check out some promising leads with fluid bed coking. "Delayed coking is the dominant technology in the industry, but Exxon developed fluid bed coking in the 1970s, and Syncrude uses fluid bed coking," says Monaghan. Fluid bed coking relies on injecting, or "sparging," a gas into a bed of tiny solids so that it flows like a liquid. Bitumen bottoms are then injected into the coker at high heat, causing valuable products to vaporize, and the leftover coke to flow out of the bottom.



Two views of the ETX pilot unit.

"With a fluid bed coker, you want to make sure the heavy oil going into the reactor is in there long enough to react fully, but, at the same time, as soon as it is cracked, you want to get the vapour out and quench it," says Monaghan. "There are a lot of fluid bed designs, but our design is unique due to the configuration that allows you to decouple the time in the reactor and the time the vapour is in there."

After receiving a one-third funding grant from AERI under the HUD program in 2007, ETX constructed a small experimental cross flow coker at the National Centre for Upgrading Technology (NCUT) in Devon, Alberta. For over a decade, the research facility (a partnership between the federal and provincial governments) has been exploring dozens of exciting technical leads in an effort to increase energy efficiency and reduce greenhouse gas emissions in the heavy oil upgrading and refining sector. "We have a special relationship with NCUT," says Monaghan. "They have been very supportive — it would be difficult to duplicate what they have at hand."

ETX and NCUT built a steel container and prepared a bed of small petroleum coke spheres possessing the consistency of fine sand. The container was heated to a mean temperature of 500 C. The sphere bed entered from one end along with the liquid feedstock (consisting of the bottom end of the bitumen barrel). Steam was injected beneath the spheres, causing them to flow like a fluid under the force of gravity along the length of the coker. The model worked to expectations.

"You can orchestrate the residence time perfectly," says Monaghan. "You can leverage to get better yields and quality. You get a lot more valuable products in which the margins are larger."

Building and testing the experimental model cost $6 million; ETX is now ready to move on to the commercial level. "A commercial demonstration plant will cost over $100 million," says Monaghan. Fortunately, AERI is backing the next step with a further one-third funding. "If I have to raise over $100 million, and I have one-third of that from AERI, it's a significant benefit. HUD is very helpful."

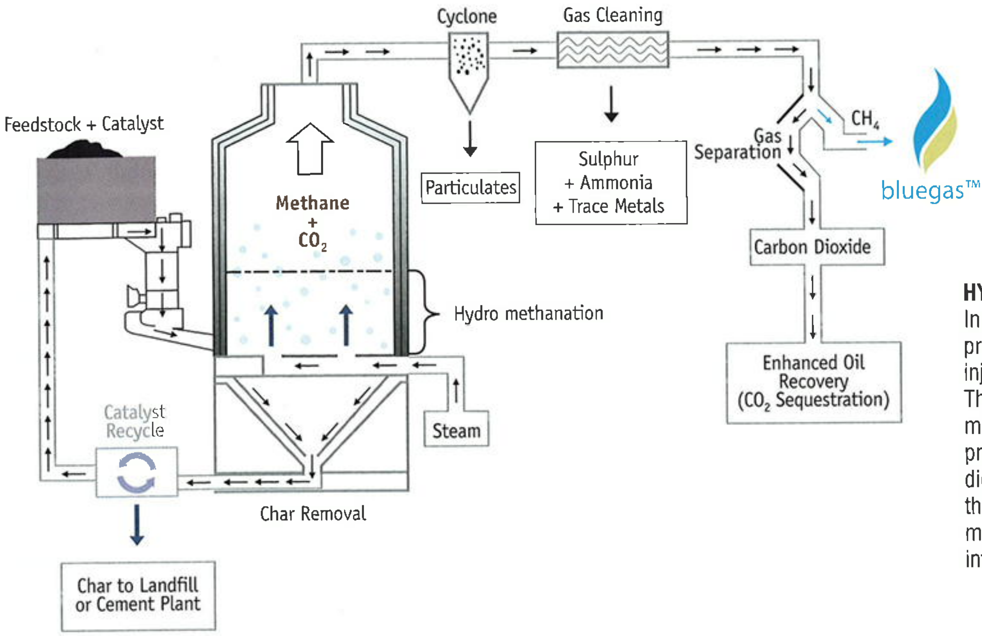
Gasification

Unlike conventional crude, bitumen needs a lot of upgrading to make valuable transportation fuels, such as diesel and gasoline. Most oilsands upgraders rely on hydrogen made from natural gas to boost the quality of bitumen, but increased costs and dwindling supplies of natural gas have convinced some operators to look to alternative sources of hydrogen, like gasification.

A gasifier injects waste products such as petroleum coke into an oxygen-starved environment along with steam, creating a stream of synthetic gas consisting of hydrogen and CO. The major drawback to gasification is that a plant sufficiently large enough to supply an oilsands operation costs more than $1 billion to build.

Pratt & Whitney Rocketdyne (PWR) thinks it has a solution. The California-based aerospace company has modified a rocket engine to produce hydrogen. "Our gasifier is very compact, about one-tenth the size of existing technology," says Jim Hartung, director, energy systems, for PWR. "This lowers costs and allows modular factory construction. It has higher efficiency, improved reliability and availability. It's easy to repair." It's also cheaper. "We think it will be much less cost than existing technology," says Hartung. "The Department of Energy did an analysis of capital costs and calculated that this would be 25% cheaper for the entire hydrogen plant than existing technology."

In a rocket engine, fuel and air are injected at high volume and pressure into an ignition chamber. When the fuel ignites, it converts into CO_2 and water vapour; the expanding gases provide propulsion. The PWR gasifier engine injects a stream of finely ground petroleum coke, coal or even biomass into the ignition chamber, along with a small amount of pure oxygen and steam. There is only enough oxygen to produce hydrogen and CO; the synthetic gas output can then be used to power a turbine for electricity, or power SAGD operations, or upgrade bitumen into transportation fuel. The carbon can also be separated



HYDRO METHANATION
In GreatPoint's hydro methanation process, steam and a catalyst are injected into a single, large reactor. The steam reacts with carbon molecules in the coke to directly produce methane and carbon dioxide. The catalyst is stripped off the ash residuals and re-used. The methane and CO_2 are separated into two pure streams.

out into a highly pure stream of CO_2 that can be sequestered underground.

PWR's design is actually more than a quarter-century old. "We did a proof of concept back in 1980 during the OPEC oil crisis," says Hartung. When energy prices began to rise again in the early 2000s, PWR dusted off the old design and went searching for R&D partners. It became involved in AERI's HUD program after submitting a research proposal in 2006. By then, it had already investigated the best construction materials and built a 400 tonne-per-day (t/d) cold-flow test facility in North Dakota. AERI accepted the company's proposal to define an integrated, full-flow demonstration plant in Alberta, and is approving $17 million toward the project.

Beyond the financial support, PWR has benefited from AERI in several ways. "We have made excellent contacts with potential customers in Alberta, and they have been extremely useful," says Hartung. "We've talked to a dozen companies to understand what size and features they would want." PWR hopes to have a demonstration plant operating by the end of 2012, and a full commercial replicate by 2015.

PWR's device has potential to not only reduce natural gas consumption, it can do it all on oilsands waste. "There could be up to 100 000 t/d of petroleum coke; we could gasify all that waste, which would produce all the energy and hydrogen needed for in-situ production and upgrading," says Hartung.

Meanwhile, U.S.-based GreatPoint Energy is also working on a solution to reduce natural gas use in oilsands developments and upgrading facilities.

It takes around 700 cubic feet to mine and upgrade a barrel of bitumen, and roughly 1,000 cubic feet (mcf) to steam it up enough to wrest it from the ground in SAGD operations. The Canadian Association of Petroleum Producers estimates oilsands operations currently consume around 700 million cubic feet (mmcf) per day; as oilsands production triples to more than three million bbls per day in the coming decade, that figure is expected to rise past two billion cubic feet (bcf) per day. In a basin where conventional supplies of natural gas are dwindling rapidly, that could spell big trouble.

"We refer to our process as hydro methanation," says Dan Goldman, executive vice-president of GreatPoint. "It uses a catalyst to convert coal or petroleum coke into methane."

The company was formed when a group of Boston-area scientists and entrepreneurs decided to improve upon an older hydro methanation design. "The process has been around since the 1970s, when a number of oil companies were working with the U.S. DOE [Department of Energy]," says Goldman. "It was uncovered during university-sponsored research five years ago, and a company founded in 2005."

The hydro methanation device is relatively simple, on paper. Steam and a catalyst are injected into a single, large reactor. The steam reacts with carbon molecules in the coke to directly produce methane and carbon dioxide. The catalyst is stripped off the ash residuals and re-used. The methane and CO_2 are separated into two pure streams. "We use a widely available earth-alkali metal in solution as a catalyst," says Goldman. "The big improvement in our gasifier is the way we impregnate the catalyst and recover it from the ash."

GreatPoint, seeing the oilsands potential for its invention, made an application to AERI in early 2007. The company was accepted in the HUD program, and was granted $3 million to test and build a $6-million, one-t/d pilot plant. The prototype proved successful, and GreatPoint is now moving ahead to build a commercial-scale, 1 500-t/d plant using funds raised with partners that have experience building complex power facilities. "We hope to have the 1 500-t/d train running by 2012," says Goldman. "We think we will be comparable in price with new gas and LNG, around $8 per mcf."

If GreatPoint's invention can deliver as promised, the potential for the oilsands is enormous. A full-scale hydro methanation train would consume about 3 500 t/d of petroleum coke and produce about 80 mmcf per day. Multiple trains could be tailored to individual mining and in-situ operations, or built to serve multiple clientele. Currently, the oilsands produces about 35 000 t/d of petroleum coke waste and that would rise to over 100 000 tonnes as production triples; 30 trains would consume 100 000 tonnes and produce 2.4 bcf per day, enough to meet all projected needs. In addition, the process produces a pure stream of CO_2. "We would like to look at optimizing the capture technology and the best way to sequester it," says Goldman.

At least one major oilsands producer recognized the potential of the technology early on. Suncor invested $15 million in GreatPoint last year. "I still see gasification of petcoke as a key part of the energy supply to this upgrading complex we're building here. It will be a post-Voyageur issue, but very important," Suncor president Rick George said last October when questioned during a conference call about the investment.

"The reason we haven't been really moving quick is we are not really comfortable with the state of the technology in this gasification field.... We have done a lot of work on this and feel this particular company has a bead on some new technology that looks robust to us, it looks efficient, it looks like it could be a lower maintenance kind of technology."

George cautioned that it was early in the process and, like any early investment, still "very uncertain. But I will tell you this; it's kind of our support of trying to (sic) drive a new technology that could be very important to this company... So we don't take the $15 million lightly. But on the other hand, it's one of a bet that we will make around technology that hopefully helps increase our efficiency in this business, i.e., energy supply, but also reduce our environmental footprint."

At the moment, GreatPoint wants to get beyond the first commercial plant and disseminate its technology throughout the oilsands. "What we are really focusing on right now is a pipeline of additional projects," Goldman says. "By 2015, we want to have several projects on the go."

Bitumen-to-petrochemicals

Oil and gas may get all the attention, but when it comes to Alberta's petroleum industry, there is a third valuable leg: the petrochemicals sector. A vast array of plastics, fertilizers and industrial feedstocks are manufactured each year, adding value and creating jobs within the province.

NOVA Chemicals is one of the largest petrochemical producers operating in Alberta. "The main part of our business is stripping off natural gas liquids, ethane and propane, from the natural gas stream," says Eric Kelusky, vice-president of Technology for NOVA Chemicals. "Before, the ethane faced a long transportation cost, and it was just fuel value. Now, Alberta gains the advantage that comes from upgrading ethane to petrochemical feedstock."

Most ethane is now stripped from gas shipped from Alberta and, in order to expand, the petrochemicals sector must seek out new sources of overlooked molecules. "We look for opportunities where a person isn't getting the full value out of a product," says Kelusky. "We look to find the right use at the right cost in order to create an advantage."

One obvious candidate is the lower value fraction produced by the oilsands. "They can sell the upgraded synthetic crude oil to markets in Ontario and the U.S., but a lot of fractions on the bottom of the bitumen barrel don't have much value," says Kelusky. "We wondered if we could use the bottom of the bitumen barrel for feedstock for petrochemicals in a way that supplies an advantage."

NOVA had two catalytic technologies it wanted to research: NOVA Heavy Oil Cracking (NHC) technology, a fluid catalytic cracking process that converts heavy bitumen-derived gas oil into olefins, gasoline and diesel; and Aromatic Ring Cleavage (ARORINCLE), an industrial trickle bed technology that converts low-value cycle oils into valuable petrochemical feedstock containing mainly light paraffin. NOVA applied to AERI for support under the HUD program and received funding to back one-third of the $8-million research project.

Working in its Calgary labs, NOVA started experimenting with the technologies at the bench-scale level, then used small quantities of real oilsands samples, then larger quantities. "We are now at the level of piloting on very small plants," says Kelusky. "The next stage is making it work on a bigger pilot scale." At this stage, NOVA is still uncertain if and when a commercial plant might be built. "We're still several years away from proving everything," notes Kelusky. "Assuming everything does work, the challenge of building a full-sized unit is that it has to be coupled with a full-sized steam cracker; a three-billion-pounds-per-year ethylene cracker costs several billion dollars."

Another major hurdle is making the bitumen bottoms work as cheaply as ethane. "Alberta crackers are quite competitive because of the ethane source from natural gas," says Kelusky. "The Middle East is the lowest cost, and Alberta is second." Will the oilsands be as good a source? "Right now, the uncertainties are very wide, but our research is narrowing that down. We keep going because the range is good enough to keep us considering it."

And, if NOVA can make it work economically, the potential prize is very big. "Alberta's ethylene output is around nine to 10 billion pounds per year," says Kelusky. "This would push it 25-30% beyond. It's a pretty big step."

To date, the company's work has led to three patents. "The work is quite promising and might lead to a new source of feedstock for Alberta," says Kelusky. "That way, we can do more upgrading here."

CO_2 capture

The Long Lake in-situ development, developed by Nexen Inc. and OPTI Canada Inc., is at the vanguard of a new generation of bitumen projects. The 70,000-bbl-per-day plant (which came onstream this year) is the first to use a gasifier to produce hydrogen and fuel gas. Gasification takes low-grade fuel, such as coke or coal, and reacts it with oxygen and steam to produce hydrogen and CO synthesis gas. The hydrogen can be separated and used to upgrade the produced bitumen into high-quality, synthetic crude oil. The synthesis gas replaces natural gas in the SAGD heating process.

Gasification also has another benefit — the ability to produce a stream of pure CO_2 as a byproduct.

OPTI Canada thinks as much as 10,000 tonnes per day of CO_2 could be captured from gasifiers at future Long Lake expansion phases, but since capture has never been done on a commercial scale before, it had few ideas of how to go about it. "I've attended conferences and seen a lot of people speaking and theorizing, but you have to do some design work and site specific-applications," says Jim Arnold, COO of OPTI Canada. "We wanted to look at technologies and equipment."

OPTI applied to the HUD program to investigate means of capturing CO_2 at its plant, and AERI financed half of a $3.6-million study. "We talked to vendors and processing groups," says Arnold. "We narrowed it down to the optimum process and equipment, and what the impact would be on the upgrader."

Although much of the study remains proprietary in nature, Arnold could discuss the findings in general terms. "We found that it was technically feasible to make it happen with equipment that already exists," says Arnold. "The equipment hasn't been used for this purpose, but it has been used in other, analogous situations. We now have enough knowledge to be reasonably confident that it would work."

OPTI credits much of the impetus of its study to the HUD program. "It really helps to move along the thinking and understanding of what it would take to do capture," says Arnold. "Instead of theorizing, it deals with a physical plant and what it really looks like. It gets rid of the arm-waving." ntm

CONTACTS FOR MORE INFORMATION

Duke du Plessis, AERI, Tel: 403-297-3635, E-mail: Duke.duplessis@gov.ab.ca
Dan Goldman, GreatPoint Energy, Tel: (617) 230-8701
Gerard Monaghan, ETX, Tel: (403) 265-3155 x221
Eric Kelusky, NOVA, Tel: (403) 250-4500 or (412) 490-4543 (Pittsburgh), E-mail: keluskec@NOVAchem.com
Jim Hartung, Pratt & Whitney Rocketdyne, Tel: (818) 586-2808, E-mail: James.Hartung@PWR.utc.com
Jim Arnold, OPTI Canada, Tel: (403) 218-4707