Oil Sands' Green Team

By thinking green and reinventing how oil is extracted, scientists at the Centre for Oil Sands Innovation hope to reduce costs and the environmental impact of future oil sands projects

BY BRIAN BURTON

Andy Main has a way of catching people by surprise, sweeping listeners into new ideas with a few well-chosen words. He is a soft-spoken man with a quiet Lincolnshire (U.K.) inflection, but his passion for science is nonetheless palpable. Tall and trim with silvery white hair, he has spent his 25-year career in petroleum research, 21 years in petrochemicals and the past four years in the specialized world of the Canadian oil sands. Main, manager of Facilities and Environmental Research for Imperial Oil, and a handful of his colleagues have a mandate to rewrite the book on how oil is extracted from the vast, tarlike oil sands deposits of northern Alberta. Their assignment is to improve the economics of oil sands extraction and upgrading and, at the same time, reduce the environmental impact of oil sands projects.

Far from daunted, Main says it's a dream assignment for a petroleum scientist. A PhD in chemical engineering, he has no trouble explaining his objectives to the less scientifically inclined.

"There has to be a better way," he says. "At Imperial, we don't believe the current oil sands technologies are the best they can be. We believe oil is essential, but the technologies to mine, extract and upgrade it have to change."

Current mining practices rely on what Main calls "brute force" technologies, which require massive operations to break open the stubborn oil sands and separate a very heavy grade of crude, called bitumen, from the sand. But Main says those technologies require too much steel equipment and energy, leaving too big a footprint on the environment.

The oil sands industry needs "technology breakthroughs" that will lead to "radically new processes," he says. "We're looking for significant reduction in capital and operating costs that will deliver proportionately smaller environmental impacts."

There is a certain urgency to finding these new technologies, Main points out. Oil provides 36 percent of the primary energy the world uses for industrial output, transportation, heat, light, and air conditioning and petrochemical products, which include medical supplies, making it the planet's largest single source of energy and an indispensable ingredient in nearly everyone's livelihood.

Small wonder, then, that Alberta's oil sands are attracting dozens of project proposals with investments totalling approximately $90 billion. These deposits are among the few places on earth where major oil production can actually be increased over the long term. And the oil is there for the taking, no exploration required. In northern Alberta, the oil sands resources that are considered recoverable with today's technology are placed at almost 175 billion barrels second only to those of Saudi Arabia (260 billion). That's less than one-tenth of the total oil in place – some 1.7 to 2.5 trillion barrels – if the right technologies can be brought to bear.

"It's a challenge we have to take on for the sake of the environment and the economy," Main says.

Editor's note: Regretfully, a short time after this article was written, Dr. Andy Main passed away after a lengthy battle with cancer. He will be deeply missed by his family, friends and colleagues. This article is dedicated to his memory.

JOSÉE MASSE

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This dilemma, in fact, was the motivation behind the development of the Centre for Oil Sands Innovation (COSI) at the University of Alberta. In October 2004, Imperial announced it would give COSI $10 million over five years to find new and better ways to extract and upgrade bitumen from the vast sand-laden, tarlike deposits of northern Alberta.

"COSI is about developing more cost and energy efficient processes, specifically in bitumen extraction and upgrading," Main says. Imperial Oil, owner of Alberta's largest steam injection project at Cold Lake, Alta., and a 25-percent owner of Syncrude Canada, the planet's largest oil sands mine, is now planning a major foray into surface oil sands mining. The proposed Kearl project would be a new three-phase mining project on the company's Kearl Lake lease near Fort McMurray in northern Alberta. Main says eventual COSI breakthroughs would find their commercial applications at some stage of the Kearl development.

Main and his Imperial colleagues toil in the cool, hushed offices and labs of the University of Calgary Research Centre, conducting proprietary research and providing oversight to COSI projects, but COSI is set up as a partnership with the University of Alberta (U of A) in Edmonton, and much of the hands-on science is done there. U of A, he explains, has world-class capabilities to conduct oil sands research.

Imperial's COSI investment is the company's biggest contribution to a university and the largest donation received by the U of A engineering faculty. The money is placed into an endowment where the interest is used to fund projects, creating funds for COSI to continue its research indefinitely.

Dr. Murray Gray, a professor of chemical and materials engineering at U of A, is the director of COSI. Gray says COSI is a virtual research centre, operating out of the university's engineering department. U of A provides facilities, so that all COSI money goes directly into attracting and funding the best research proposals within the guidelines established by Imperial and U of A as the most commercially promising.

The oil sands challenge, Gray says, is too big to solve by tinkering and incremental improvements to existing processes. It requires totally new technologies. "We purposely avoid doing research on improving existing technologies," he says. "We've started with a clean sheet of paper."

Main adds that wringing energy from the oil sands is a technical question demanding a technical response. "We believe technology will be key to sustained development of Alberta's vast oil sands resource," he says.

Even environmentalists are starting to express qualified support for Imperial's technological approach. Oil sands policy analyst Dan Woynillowicz of the Pembina Institute for Appropriate Development, Canada's leading environmental policy research group, says technology will be an important part of a better oil sands future.

"The [industry] focus has been on tweaking existing technology," Woynillowicz says. "There needs to be a step-wise change in the technology that leads to a dramatic reduction in the environmental footprint." So, on that basis, he supports Imperial's COSI initiative. But he says technology alone "is not a silver bullet." Pembina is pushing industry to prove and implement new technologies before proceeding with any more projects.

Gray and Main, however, hold a shared vision of the oil sands mining project of the future – one with radically lower water use, no tailings ponds and significantly reduced energy consumption and emissions.

Their vision involves using continuously recycled solvents to separate sand and clay from bitumen and dramatically reduce water consumption, as well as advanced catalysts to enable low-temperature upgrading. That would end the need for brute force extraction and upgrading methods based on high temperature and pressure, with very high capital costs and a lot of energy consumption.

Nanotechnology – the precise design, construction and use of specialized molecules or nanoparticles – could help to create supersolvents for separating clay, sand and heavy metals from bitumen or to fashion new catalysts for upgrading. Scientists liken nanotechnology to using "molecular tweezers" for sorting desirable and undesirable molecules. Despite being in its infancy, practical applications are emerging. After all, Main says, nanotechnology has already had an impact on consumer goods, providing products with novel functions ranging from surfaces that are easy to clean and scratch-resistant to modern textiles that are wrinkle-resistant and stain-repellent. Another field of application is in sunscreens, says Main. Some of today's sunscreens are based on specially selected nanoparticles that don't appear white on the skin after application. Given such varied uses, he says, there's every reason to believe higher-value applications will emerge.

Gray adds that conventional catalysts, which promote desirable chemical reactions in refining and petrochemical manufacturing, are actually examples of nanotechnology that have been in use for many decades.

"There's even the possibility," Main says, "that nanotechnologies might enable us to combine steps in bitumen processing and upgrading, though that might be a tough hill to climb."

Such is the vision. To push it toward reality, COSI is funding several research projects that could eventually provide pieces of the solution. Main says project specifics are highly proprietary but he can talk about general themes.

The first theme is oil sands extraction – the separation of bitumen from sand and clay. These projects involve studying clay mineral composition in order to determine how fine clays can be separated from bitumen and which solvents do this most effectively; studying solvents at the molecular level; and looking at what happens in complex mixtures of clays, water and solvents. Some or all of these efforts could come together to provide a non-aqueous (waterless) means of processing oil sands.

A second theme involves finding new ways to upgrade tarlike bitumen into high-quality light oil without the need for brute force. Current lines of research, Main says, are probing whether the chemistry and engineering can be done differently, at far lower temperatures and pressures, and much lower rates of natural gas consumption.

If, for instance, new catalysts could enable the heaviest hydrocarbons to be cracked at low temperatures, higher-value light oil could be captured with far less energy used and fewer emissions. If the leftover heavy residues could be efficiently gasified, then this manufactured fuel or syngas could significantly reduce the oil sands' consumption of energy.

COSI is still very much at the stage of investigating a range of promising possibilities, and Main believes many of these ideas show real commercial potential. When that happens – and he considers it only a matter of time, money and hard work – one or more pilot projects will be required to prove the commercial feasibility of new processes. Gray says he's confident that necessity will be the mother of invention in the oil sands, but cautions that science rarely responds to strict deadlines.

Main says COSI works to focus research on the key questions and bring together the best proposals, at least at the oversight level, in order to leverage ideas – and funding. The current roster of approved projects involves U of A, the National Institute for Nanotechnology and the National Science and Engineering Research Council (NSERC).

Government funding, at the federal and provincial levels, will increase COSI's ability to finance a large number of research projects. NSERC has recently approved funding of $1.6 million over five years, and COSI is also in discussions with Alberta Ingenuity, a $1 billion endowment established by the government of Alberta that supports leading-edge research and capacity building in the province. Alberta Ingenuity has recently announced approval of the funding request for $7.4 million to COSI over five years.

Main says it took many months to bring together all the major pieces of a first-class research program, but COSI is now well positioned to progress such a program. One project has already led to a patent disclosure. It's the kind of progress that inspires those involved to believe that research will lead to continued oil sands growth and bring about meaningful environmental and economic progress for Alberta and the rest of Canada.

"We are building the intellectual capability in Alberta to be the leaders in oil sands research and development," says Main. "If you look at what they've done at U of A, it gives you tremendous confidence that we really can do it." ■

HOW THE OIL SANDS ARE PRODUCED TODAY

Surface Mining

Near-surface oil sands are developed using enormous truck-and-shovel mining systems and hot water processing to separate bitumen from sand and clay. The wastewater is then discharged to tailings ponds to settle out clay and minerals over long periods.

In Situ Mining

Bitumen is extracted from deeply buried (or in situ) formations by injecting steam or other solvents underground, which mobilizes the molasses-thick oil and separates it from the sand before it is pumped to the surface.

Upgrading

While some bitumen is sold directly to market, few refineries have the capability to process it in its natural state. Most refineries require bitumen to be "upgraded" first into light oil so that the conventional refineries are then able to transform it into fuels, lubricants and a host of other products.

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