ANNALS OF ECOLOGY

UNCONVENTIONAL CRUDE

Canada's synthetic-fuels boom.

BY ELIZABETH KOLBERT

The town of Fort McMurray occupies a set of irregularly spaced hillsides on either side of the Athabasca River, in northern Alberta. It has a dozen check-cashing joints, a roughly equal number of hotels, and a gaming center called the Boomtown Casino. It also has a museum, which is devoted to the region's most important resource, the Alberta tar sands. Exhibits include an eight-foot-long rotor, half of a hundred-and-fifty-ton truck, and a pump of Brobdingnagian proportions. Near the entrance to the museum sits a black mound covered by a clear plastic dome. A sign invites visitors to scratch around in the mound with a little retractable rake, then lift up a flap and take a sniff. Tar sands look like dirt and smell like diesel fuel.

The tar sands begin near the border of Saskatchewan, around the latitude of Edmonton, and extend, in three major deposits, north and west almost to British Columbia. All in all, they cover—or, more accurately, underlie—some fifty-seven thousand square miles, an area roughly the size of Florida. It is believed that they were pushed into their present location seventy million years ago by the uplift of the Rocky Mountains.

For the most part, the tar sands consist of quartzite, clay, and water. The other ingredient—the "tar"—is a mixture of very heavy hydrocarbons known as bitumen. Bitumen can be used as a sealant—supposedly the word "mummy" is derived from the term in ancient Persian—and as a paving material. With the right technology, it can also be converted into a form of petroleum known as synthetic crude.

There are two ways to assess the world's oil supply. One is to consider only conventional reserves—the sort of oil that comes gushing out of the ground. Estimates of conventional reserves vary widely, but most analyses suggest that their output will begin to decline sometime in the next few decades (if it hasn't already)—a development that so-called "peak oilers" predict will lead to a variety of gruesome consequences, including blackouts, food shortages, and general economic collapse. The second way is to look beyond conventional reserves to unconventional ones, like the tar sands.

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Suncor's Millennium Mine. The shift to new sources of oil could significantly increase greenhouse-gas emissions.

JIRI REZAC/POLARIS

It is estimated that there is enough bitumen in Alberta to yield 1.7 trillion barrels of synthetic crude. Assuming that only ten per cent of this is actually recoverable, it still represents the second-largest oil reserve in the world, after Saudi Arabia's, and more oil than is contained in the reserves of Kuwait, Norway, and Russia put together. Unconventional crude can be found in many other parts of the globe besides Canada; these include eastern Venezuela, which is home to a huge tar-sandslike deposit called the Faja Petrolífera del Orinoco, and portions of Colorado, Utah, and Wyoming, where there's a thick layer of oil shale known as the Green River Formation. Even coal can be converted into liquid fuel. During the Second World War, the Nazis employed a technique called the Fischer-Tropsch process; the same process is now in use in several countries, most notably South Africa, which invested heavily in coal-to-liquids technology during the apartheid era. Build enough coal-to-liquids plants and places like Montana and West Virginia could one day become major petroleum producers.

In Fort McMurray, what might be called the world's first unconventional oil boom is already under way. Since 2002, Shell, ConocoPhillips, Chevron, and Imperial Oil, which is primarily owned by ExxonMobil, have all received approval to construct major projects in the tar sands; Total has announced its intention to follow suit. Over the next five years, investment in the Fort McMurray area is expected to amount to more than seventy-five billion dollars. Residents of the town have taken to calling it Fort McMoney.

Thanks in large part to what's happening in the tar sands—output now tops a million barrels a day—Canada has become America's No. 1 source of imported oil; the country supplies the United States with more petroleum than all of the nations of the Persian Gulf combined. (If you have bought gas recently in Colorado, Ohio, or Indiana—states where tar-sands oil is refined—you are probably driving around with a piece of northern Alberta in your tank.) By 2010, the tar sands' yield is expected to double, and by 2015 to triple. Crude from the tar sands and other unconventional sources could keep oil flowing well into the middle of the century, and perhaps beyond. Depending on how you look at things, this is either a heartening prospect or a terrifying one.

The company that has been producing oil from the tar sands the longest is known as Suncor. (Suncor used to be a part of Sun Oil, now Sunoco, but today it is owned and operated independently.) One day this summer, I went to take a tour of its operations, which sprawl across several hundred square miles. I was picked up at the entrance to the site by a grandmotherly guide named Gloria Jackson, and together we went to fetch another Suncor official, named Darin Zandee. "There's no blasts today, so that's good," Zandee said, referring to the charges that are periodically set off to loosen the sands. We drove up to a lookout, from which we could see, spread before us, Suncor's newest mine, the Millennium. Rings of jet-black earthworks were scattered across an enormous pit, an arrangement that might have been based on a blueprint from the Inferno.

The Millennium Mine opened in 2002. Suncor expects to continue to pull tar sands out of it for the next twenty-five years. By then the pit, which is now roughly two miles in diameter, will be six miles across. We drove over the edge of the mine and slowly made our way down to the bottom. There a huge, Mike Mulligan-esque shovel was standing idle. Its bucket hung in midair, steel teeth glinting. Zandee said that to lift one of the teeth would require thirty men—"That gives you a sense of the scale." A gargantuan truck rumbled by. Zandee estimated that it was carrying about three hundred tons. "That's some of our smaller equipment," he said. The largest truck in the mine—the Caterpillar 797B—can haul more than four hundred tons. It has twelve-foot-tall tires, and its cab sits twenty-one feet off the ground. Driving one, I was told, is like trying to steer a house while peering out the window of the upstairs bathroom.

At the Millennium, the tar sands start at a depth of roughly a hundred feet and extend down in a more or less continuous layer, known as the "feed," for about a hundred and fifty feet. Before mining begins, everything above the feed—trees, bushes, grass, soil, rocks, wildlife—gets scooped up and carted away. (The material is delicately referred to as "overburden.") Below the tar sands, there's a thick layer of limestone, the remains of an ancient ocean that once covered Alberta. Suncor mines some of the limestone, too, and uses it to shore up the roads in the pit. What with the overburden and the tar sands and the limestone, Zandee said, "We try to move a million tons a day." He pointed out a truck in the distance that was dumping a load of tar sands onto what looked like a large platform. The platform was actually a grate, through

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which the sands were being fed into a giant tank of hot water.

In any given load of sands, only about ten per cent is bitumen; to produce synthetic crude, the other ninety per cent has to be separated out. In the hot-water tank, the sands get spun around; the liberated bitumen is then siphoned off. For every barrel of synthetic crude that Suncor eventually produces, forty-five hundred pounds of tar sands have to be dug up and separated.

We made our way out of the pit and headed on, following the bitumen to its next stop, the upgrader. Along the way, we passed a murky expanse of water with oily scum on the surface. A few dozen scarecrow-like creatures, fixed to empty barrels, were bobbing on top. This, Gloria Jackson explained, was a tailings pond; it held water that had been used in the separation process and was too contaminated with mercury and other toxins to be released back into the Athabasca. (Suncor has nine such ponds, which collectively cover an area of eleven square miles.) The scarecrows, known as "bitu-men," were supposed to discourage birds from landing on the pond and poisoning themselves. Every minute or so, a dull boom filled the air. This was the sound of a propane cannon, another bird-intimidation device.

The primary difference between bitumen and ordinary crude is the size of the hydrocarbon molecules: in liquid oil, these molecules contain between five and twenty carbon atoms, while in bitumen they contain more than twenty. (At room temperature, pure bitumen is so viscous that it will not flow.) The main job of the upgrader is to break down the oversized hydrocarbons into smaller units. We drove along roads with names like Sulphur Street and Diesel Alley and pulled up to a huge refinery-like complex that covered several square blocks. There were dozens of smokestacks and tanks, and more pipes than could possibly be counted. Jackson explained that somewhere inside this maze the bitumen would be "cracked," at a temperature of nearly nine hundred degrees. After that, in the form of synthetic crude, it would be piped to specially outfitted refineries, either in the United States or Canada, to be converted largely into transportation fuels—gasoline for cars, diesel for trucks, and jet fuel for planes. (Suncor owns a refinery near Denver that processes tar-sands oil.) I had told Jackson that I had twin boys at home, and at the end of the tour she handed me two yellow Matchbox-size versions of the 797B.

American accounts usually give the start of the oil age as 1859, the year that a former railroad conductor named Edwin L. Drake drilled his first successful well, near Titusville, Pennsylvania. Canadian accounts go back a year earlier, to 1858, when a businessman named James Miller Williams decided to dig a well for drinking water outside the town of Bear Creek, Ontario. Instead of water, he struck oil.

Efforts to extract oil from the tar sands soon followed. Entrepreneurs and con men sunk dozens of wells around Fort McMurray in the second half of the nineteenth century. (One enterprising German immigrant who claimed to have struck oil apparently poured the stuff down the hole himself.) Eventually, it became clear that there was no oil, and attention turned to mining the bitumen. In 1930, a former farmer named Robert Fitzsimmons set up the first commercial separation plant in the tar sands; in 1938, Fitzsimmons had to flee Canada to avoid his creditors.

In 1956, an American geologist, Manley Natland, came up with the idea of streamlining the process by using atom bombs. Natland reasoned that "thermal devices" could be lowered into the limestone beneath the tar sands and exploded. This would create cavities into which the bitumen, heated to more than a thousand degrees, would flow and from which it could then be collected. The idea was taken seriously at the highest levels in both Ottawa and Washington—the United States Atomic Energy Commission even agreed to supply a bomb to test Natland's theory—but it was never implemented. (Beginning in the mid-nineteen-sixties, the Soviet Union actually tried the experiment, setting off half a dozen nuclear explosions to stimulate conventional oil production; production increased, but, unfortunately, much of the oil turned out to be radioactive.)

The technology for removing bitumen from the tar sands is probably still best described as a work in progress. Where the feed lies closest to the surface, as, for example, at the Suncor site, the bitumen is strip-mined and then separated. But most of the tar sands lie too deep to be mined profitably. In these zones, a method known as in-situ extraction is used. In-situ extraction is based on much the same principle as Natland's scheme, minus the atom bombs. Typically, two horizontal wells are drilled into the sands, one above the other. High-pressure steam is injected into the top well; eventually, the tar sands grow hot enough—nearly four hundred degrees—that bitumen begins to flow into the bottom well. The technical name for this process is Steam Assisted Gravity Drainage, or SAGD (pronounced "sag-dee").

Whichever method is used, a great deal of energy is required. To produce a barrel of synthetic crude through mining takes roughly eight hundred and ten megajoules, which is the energy content of about an eighth of a barrel of oil. To produce a barrel of synthetic crude through SAGD takes more than sixteen hundred megajoules, which is the energy content of more than a quarter of a barrel of oil. This means that, for every three barrels extracted via SAGD, one has, in effect, been consumed.

Tar-sands oil itself could, in principle, be used to power the operations; in fact, most of the energy used to generate the steam for SAGD, as well as to run all the upgraders and separators, now comes from natural gas. It is estimated that by 2012 tar-sands operations will consume two billion cubic feet of natural gas a day, or enough to heat all the homes in Canada. Such is the demand for natural gas around Fort McMurray that a consortium of companies, including Shell Canada and Imperial Oil, has proposed building a seven-hundred-and-fifty-mile pipeline from the Arctic Ocean through the largely undisturbed wilderness of the Mackenzie River Valley and down into northern Alberta. The proposal, which has been challenged by native and environmental groups, has yet to receive regulatory approval; meanwhile, a variety of other plans have been floated. As it happens, while I was visiting Fort McMurray a company called the Energy Alberta Corporation filed an application to build a pair of nuclear reactors four hundred miles west of town. Early reports stated that the company already had a "large industrial off-taker" lined up to buy nearly three-quarters of the twenty-two hundred megawatts that the reactors would generate. Energy Alberta would not disclose the identity of this "off-taker"; in the local press it seemed to be taken for granted that the power would be going to the tar sands.

There are several reasons that companies like Chevron and ExxonMobil are now rushing to develop the tar sands, the most obvious being that it's increasingly profitable to do so. Converting the sands into synthetic crude costs around thirty dollars a barrel; last week, the price of a barrel of oil on the New York Mercantile Exchange was over ninety dollars. Other synthetic fuels require more elaborate processing, and are commensurately more costly to produce; converting coal into oil, for example, requires gasifying the coal under intense pressure and heat, then condensing it into a liquid. To extract oil from shale, meanwhile, involves basically rewriting geological history. (Shell has been experimenting with a process that involves baking the shale with electric heaters until it reaches a temperature of nearly seven hundred degrees while, at the same time, freezing the area around it.) If the price of oil remains above ninety dollars—many analysts expect it to hit a hundred dollars a barrel soon—then these and other unconventional forms of fuel can also be developed at a profit, and, all other things being equal, they will be.

No matter how it is carried out, oil extraction is a destructive business. Conventional oil wells require pipelines and drill pads and roads for heavy equipment; all of these fragment (or destroy) the landscape. The flaring of natural gas, which often accompanies oil production, produces an array of air pollutants, and leaks and spills release toxins ranging from volatile chemicals, like benzene (a known carcinogen), to much heavier compounds, like benzopyrene (another known carcinogen). With unconventional oil, the damage tends to be higher all around—more land gets disturbed, more pollutants are produced, and more opportunities arise for contamination. And then there are the greenhouse gases.

Alex Farrell is a professor in the Energy

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and Resources Group at the University of California at Berkeley who studies the impacts of unconventional oil. A few years ago, Farrell realized that all the major climate models were based on the same faulty premise: they assumed that in the future increased oil demand would be met with increased supplies of conventional crude. Together with a graduate student named Adam Brandt, Farrell decided to try to come up with projections that more accurately reflected reality. For their calculations, the two assumed that where there was a gap between demand and conventional supply it would be filled with synthetic fuels, first with tar-sands oil and later with oil from coal and shale. (According to high-end estimates, coal and oil shale could together yield some ten trillion barrels of unconventional crude.) They then calculated what the impact would be on global carbon-dioxide levels.

"All unconventional forms of oil are worse for greenhouse-gas emissions than petroleum," Farrell told me. "And it's pretty easy to understand why. It's not so hard to turn liquid petroleum into liquid fuels. Turning a solid material like coal into a liquid—it sounds hard to do, and it *is* hard to do. And that extra effort shows up in higher energy consumption and higher water use and higher emissions." In the case of tar-sands oil, total greenhouse-gas emissions per barrel—which is to say, the carbon dioxide produced in creating the oil and then burning it—are between fifteen and forty per cent higher than those from conventional oil. In the case of coal-to-liquids, or C.T.L., total emissions are almost two times as high as with conventional oil, and for oil shale they can be more than twice as high.

"Let's take coal-to-liquids," Farrell said. "You're talking about nearly doubling the greenhouse-gas emissions. Think about this—we're talking about a world in which over-all greenhouse-gas emissions should start to go down, and this is a technology that doubles emissions. They don't go together too well, do they?" Farrell and Brandt found that the shift to unconventional oil could add somewhere between fifty and four hundred gigatons of carbon to the atmosphere by 2100.

"The environment and climate change are what are called 'externalities,'" Farrell continued. "And at the moment we don't have effective ways of including these externalities in market transactions of any sort. Until we do, the market won't solve them, since by definition they're external to the market. They're a social good—government has to step up and say, 'We're going to take this into account.'"

One way that a government could take greenhouse-gas emissions into account would be to tax them. This would encourage producers of unconventional fuels to cut their emissions, by, for example, employing "carbon capture and storage" technologies. Ideally, it would also prompt entrepreneurs to develop alternatives to oil, like biofuels. Many analyses, though, suggest that, to have an appreciable effect on the oil sector, carbon taxes would have to be quite high—in the neighborhood of two dollars on a gallon of gasoline—precisely because today there are no readily available substitutes for gas or diesel or jet fuel. Farrell favors federal fuel standards, which would function somewhat like vehicle-efficiency standards, requiring oil companies to achieve a certain emissions target across all the products that they sell. (This target could be adjusted over time, much as auto-efficiency standards were ratcheted up during the seventies and eighties.) California is now in the process of drawing up such a plan—the California Low Carbon Fuel Standard is supposed to take effect on January 1, 2010—and several bills have been introduced in Congress that would impose such standards nationally.

At the same time, there is a great deal of support in Washington for measures that would, in effect, subsidize high-carbon fuels. One such measure, the Coal-to-Liquid Fuel Promotion Act, introduced earlier this year by Senators Jim Bunning, of Kentucky, and Barack Obama, of Illinois, would encourage companies to invest in C.T.L. plants by providing tax incentives and federal loan guarantees. (Although C.T.L. would be profitable at today's oil prices, building the plants requires large capital investments, which are considered risky as long as there's a chance that oil prices will fall.)

"If companies could lay off the risk of oil prices dropping below forty dollars a barrel, there would be enormous investment in this," Farrell told me. "But, when policies are proposed to promote C.T.L., I think the question to ask is, Is this an industry we want to start now?"

The Athabasca River flows north, into Lake Athabasca, which spans the Alberta-Saskatchewan border. In the winter, it is possible to drive the hundred and fifty miles from Fort McMurray to the lake on an ice road. (Because of rising temperatures, the number of days that the road is passable has been steadily shrinking.) In the summer, the only way to make the trip is by boat or by prop plane. One day when I was visiting Alberta, I flew up to a village on the edge of the lake, Fort Chipewyan, in a six-seat Cessna. As the plane gained altitude, I could see the vast black pits of the tar-sands mines that surround Fort McMurray. Farther north, the pits gave way to regularly spaced square-shaped clearings in the trees—signs of preparation for in-situ operations. Finally, these, too, gave way, and below was nothing but the wild green of the boreal forest. (Spread over 1.4 billion acres, Canada's boreal forest is considered one of the largest still intact ecosystems on the planet.)

Fort Chipewyan, which was founded in the seventeen-eighties as a trading post, is a native village; about half its twelve hundred or so residents are Mikisew Cree, and the other half are Athabasca Chipewyan. It has a few hundred houses, a post office, and two churches—one Anglican and one Catholic—both perched near the edge of the lake. To a certain extent, Fort Chip, as it is known locally, has shared in the tar-sands boom; many residents of the village work construction jobs in Fort McMurray and return home only on their days off. At the same time, there's a good deal of concern in the village about what is happening. A peculiarly high number of cases of a rare cancer have been reported in town; this has prompted speculation that toxins from the tailings ponds are working their way downriver into the lake, which provides the village with drinking water as well as with staples like whitefish and pike. Meanwhile, both the Chipewyan and the Cree consider many of the tracts that the Alberta government has leased to oil companies to be their ancestral lands. The week before I visited Fort Chip, there was a rally at the local community center, calling for a moratorium on new projects.

"It's sad to see this thing destroyed, you know," Ray Ladouceur, a fisherman I met, said. We were standing by the lake, which is more than two hundred miles long. It was a still afternoon, and billowy white clouds were reflected in the water. "A lot of the fish are getting—I might as well say it—scabby.

"I don't know what we have to do to try to prevent them from destroying any more," he said, referring to the oil companies. "They try to say they can clean it. There's no way. It'll take a thousand years before it flushes itself out, and I think I'll be too damn old for that."

Over the past year or so, opposition to new tar-sands projects has been steadily growing. Around Fort McMurray, the emphasis is on local impacts; town officials have fought recent expansion proposals by several oil companies on the ground that there's already a shortage of housing and hospital beds in the area. In the rest of Canada, the focus is on the destruction of the boreal forest and the implications for the climate. Canada, in contrast to the United States, was an early signatory to the Kyoto Protocol, but it will be all but impossible for the country to meet its CO_2-reduction goals, in part because of the tar sands. (A recent Toronto *Globe & Mail* op-ed piece on emissions from the sands was titled "The Gassy Elephant in Our Living Room.") The former Canadian Environment Minister Charles Caccia has compared the country's position on greenhouse gases—pledging to reduce emissions on the one hand while increasing tar-sands production on the other—to "attempting to ride two horses galloping in opposite directions."

Meanwhile, development in northern Alberta continues unabated. All the applications opposed by Fort McMurray officials were ultimately approved, and just a few months ago an American company, Hyperion Resources, announced plans to build the first new oil refinery in this country in thirty years, to handle increasing volumes of tar-sands crude. Stéphane Dion, the leader of Canada's Liberal Party (which is currently out of power), has said, "There is no environmental minister on earth who can stop the oil from coming out of the sand, because the money is too big."

When I first landed at Fort Chip's tiny airport, the place was deserted. When I returned there for the flight back, I found a few dozen people standing on the tarmac. The crowd, I was told, was waiting for a corpse; a village elder had died the previous day in a hospital in Fort McMurray, and his body was being brought home. Everyone was quiet as the casket was carried out of the plane and then loaded onto the back of a pickup truck. As soon as the crowd dispersed, I and three other passengers climbed into the Cessna, and two minutes later we took off. Below was the wilderness, then the perfectly square clearings in the trees, and, finally, as we headed into Fort McMurray, the vast pits and the black ponds, with the bitu-men bobbing on top. ♦