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Ideas for a More Prosperous Nation

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# INNOVATION AND THE GREENING OF ALBERTA'S OIL SANDS

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# Executive Summary


Alberta's oil sands have been mired in controversy ever since forecasts of rapidly growing world demand for petroleum, rising crude oil prices, technical advances and political instability in other jurisdictions ushered their large-scale exploitation about a decade ago.

Whether supportive or critical, however, discussions of the subject typically lack a broader historical perspective on the environmental and social benefits of petroleum, and the long-standing capacity of human ingenuity to turn unpromising raw materials and polluting production residuals into valuable resources.

The goal of this paper is twofold. Part I looks at the historical experience and illustrates how current "cleaner" sources of liquid fuels were anything but in the first stages of their development. Rather than simply turning their back on these raw materials, however, early oil industry pioneers forged ahead with innovative responses and eventually managed to deliver significant economic, environmental and social benefits.

Petroleum remains our least undesirable source of transportation fuels and feedstock for countless synthetic products ranging from medical instruments made of plastic and detergents to vitamins and disinfectants. Replacing products made out of petroleum by alternatives grown on agricultural land or extracted from the wild would have severe environmental consequences. While many critics describe our reliance on crude oil as an addiction, in reality it is much more similar to a dependence on healthy food. After all, during the petroleum age, humanity's overall standard of living drastically increased as did our life expectancy and overall health.

Among other benefits, petroleum-derived products removed horses from cities where their excrements and dead bodies were major public health threats. They made less dependable and productive mules and horses redundant on farms, in the process also redirecting the portion of the crops they consumed (perhaps as much as 20%) towards other uses. Petroleum-based products were also essential in drastically increasing agricultural yields which, in turn, allowed much marginal agricultural land to revert to a wild state. By greatly facilitating the movement of food over long distances, they also helped eradicate famine in most parts of the world as regions that experienced bad years were increasingly able to rely on those that had experienced good ones.

While not perfect, petroleum-based products were clearly superior alternatives to the technologies they displaced and are still superior to the heavily-subsidized alternatives now touted as substitutes. For instance, wind and solar power can only deliver small and intermittent volumes of electricity. They are useless in virtually all segments of the transportation sector and provide no feedstock to other lines of work. Biofuels for their part have always been limited in terms of potential supply and can only constitute a small fraction of the fuel used in internal combustion and diesel engines without seriously damaging them.

No current energy and synthetic feedstock source or combination of sources are presently technically superior and greener alternatives to crude oil. Lifting and maintaining billions of humans out of poverty is currently unthinkable without the continued exploitation of petroleum resources.

Part II of this paper describes how Alberta's oil sands are being exploited and illustrates how "win-win-win" innovations are now taking place that are making this industry more efficient and more environmentally friendly.

That an increasing portion of our future petroleum supply will have to come from what are now described as unconventional sources cannot be held against their development. In the oil sands as with earlier petroleum deposits, human ingenuity has delivered and can continue to deliver ever greater output ever more efficiently, in the process providing both economic and environmental benefits.

Oil sand extraction provides a valuable resource for which there are currently no better alternatives. Today's production challenges in Alberta are not fundamentally different from those of earlier times. They should therefore be tackled creatively rather than considered insurmountable.

# Introduction

Alberta's oil sands[1] have been mired in controversy ever since forecasts of rapidly growing world demand for petroleum,[2] rising crude oil prices, technical advances and political instability in other jurisdictions[3] ushered their large-scale exploitation about a decade ago.

Their defenders point to the economic benefits that flow from the production of a vital economic input[4] and to Canada's superior environmental and ethical record (be it in terms of freedom from oppression, workers' and women's rights and treatment, absence of violent conflict and sponsorship of terrorist organizations, and environmental performance[5]) when contrasted to that of most other significant crude oil exporters.

Opponents of the exploitation of oil sands remain unmoved by this rhetoric and urge Canadians instead to break free from their addiction to a dirty, costly and ultimately unsustainable fuel that inflicts massive local environmental damages and will tip the scales towards catastrophic climate change. Other, more moderate critics, meanwhile complain about insufficient governmental oversight and long-term planning, insufficient local refining jobs, negative impact on Canada's manufacturing sector, and foreign investments that drain profits abroad.[6]

Whether supportive or critical, however, discussions of the subject typically lack a broader historical perspective on the environmental and social benefits of petroleum, and the long-standing capacity of human ingenuity to turn unpromising raw materials and polluting production residuals into valuable resources.

Our goal in this paper is thus twofold. First, we will illustrate how current "cleaner" sources of liquid fuels were anything but in the first stages of their development. Rather than simply turning their back on these raw materials, however, early oil industry pioneers forged ahead with innovative responses and eventually managed to deliver significant economic, environmental and social benefits. We then illustrate how similar "win-win-win" innovations are now taking place in Alberta's oil sand projects.

Our main conclusion is that oil sand extraction provides a valuable resource for which there are currently no better alternatives and that today's production challenges in Alberta are not fundamentally different from those of earlier times. They should therefore be tackled creatively rather than considered insurmountable.

1. Unfortunately, the technically correct term "bituminous sands" has, for all intents and purposes, disappeared from popular discourse and been replaced by "oil sands" and "tar sands," partly depending on whether or not one supports or opposes their development.
2. Although the word "petroleum" (liquid crude oil) is usually used in a geological context and "crude oil" (unrefined petroleum) in a commercial context, they essentially refer to the same reality and will be used interchangeably throughout this document.
3. Approximately 80% of the world's petroleum reserves are owned or controlled by national governments and more than half of the remaining 20% are in the Canadian oil sands.
4. For an industry perspective on oil sands, see: Robert Bott, *Canada's Oil Sands, 3rd edition*, Canadian Centre for Energy Information, November 2011.
5. Ezra Levant, *Ethical Oil: The Case for Canada's Oil Sands*, McLelland & Stewart, 2010. See also the related website: http://www.ethicaloil.org/.
6. Numerous links to activist websites are found on the Climate Action Network Canada's website: http://climateactionnetwork.ca/issues/getting-off-fossil-fuels/tar-sands/. For more detailed policy discussions, see the Pembina Institute's various reports: http://www.pembina.org/oil-sands; Greenpeace Canada, *Does the World Need Oil from the Tar Sands?,* 2010; Andrew Nikiforuk, *Dirty Oil: How the Tar Sands Are Fueling the Climate Crisis,* Greenpeace, September 2009; Benjamin J. Wakefield and Matt Price, *Tar Sands: Feeding U.S. Refinery Expansions with Dirty Fuel*, Environmental Integrity Project, June 2008; Peter R. Sinclair, *Energy in Canada*, Oxford University Press, 2011, chapter 5. On the case for creating more refining jobs in Alberta, see: Andrew Nikiforuk, "Nikiforuk: Yes, Refine Oil Sands Crude Right Here," *The Tyee,* September 2011. For a discussion of some of these criticisms, see also Michel Kelly-Gagnon, Germain Belzile and Youri Chassin, *A Plea For a Quebec - Alberta Dialogue*, Montreal Economic Institute, May 2011.

# PART 1

# Liquid Fuel Production in Historical Perspective

## 1.1 Energy, resources and standards of living

Almost eight decades ago, the economist Erich Zimmermann observed that before the emergence of humans, "the earth was replete with fertile soil, with trees and edible fruits, with rivers and waterfalls, with coal beds, oil pools, and mineral deposits; the forces of gravitation, of electro-magnetism, of radio-activity were there; [and] the sun set forth his life-bringing rays, gathered the clouds [and] raised the winds." Despite all this, he added, "there were no resources."[1] "Resources are not, they become," Zimmermann famously added, pointing out that they are not fixed and permanent things waiting to be picked, but rather that they "expand and contract in response to human wants and human actions."[2]

As the anthropologist Leslie White further observed at the time, creating resources in order to increase material wealth and standards of living had always and everywhere required that "the amount of energy harnessed per capita per year is increased, or… the efficiency of the technological means of putting the energy to work… increased."[3]

The development of better ways to use energy gives us the ability to accomplish more of a certain task with fewer resources while freeing up resources to accomplish other tasks. An unavoidable result is that the more efficient humans become at using energy, the more energy they produce and consume. As we will argue in more detail later, increased energy consumption can be entirely compatible with greater wealth and diminished environmental impact as long as new and better ways of doing things are being developed.

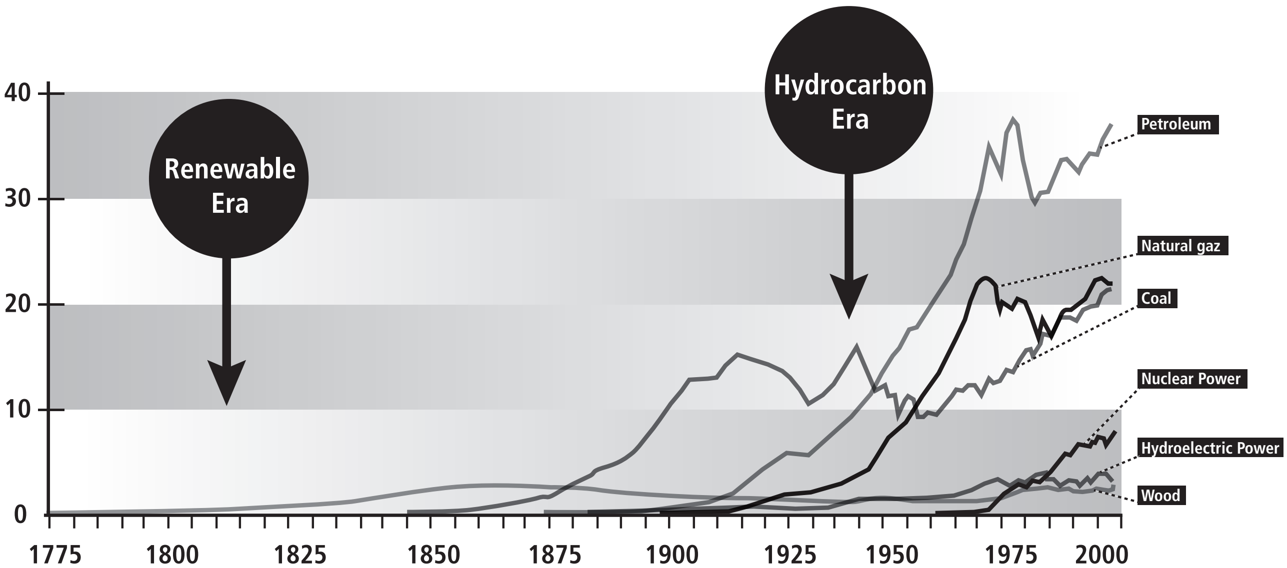
Our remote ancestors' first major step towards drastically improving their daily lives was to capture fire, in the process not only solving the problems of the dark and the cold, but also drastically extending their range and food supply (by making it possible to live permanently beyond the sub-tropical belt, making it possible to digest foodstuff that could not be eaten raw, and facilitating the digestion of other foodstuff). The next giant leap forward occurred about 10,000 years ago with the emergence of the first agricultural settlements. In time, humans not only grew crops for themselves, but also for domesticated animals such as oxen, horses and mules that drastically increased their capacity to do work and transport things.

Until about two centuries ago, most human societies relied on low-density biomass fuels (from twigs and crop residues to animal dung) and human and animal muscles. In a few locations wind (sailing vessels and windmills) and water (waterwheels) power played a role, but despite sometimes impressive numbers,[4] their overall contribution remained limited. Life in the "renewable" age was at best comparable to today's less developed economies where, among other things, farmers stand a one in three probability of being malnourished and average incomes hover around $1 a day.[5]

Societies built around renewable energy were also often "unsustainable" as many suffered from excessive deforestation and soil erosion. To give but one famous account, Plato complained over two thousand years ago that if Athens' hinterland (Attica) had once been "covered with soil," the plains "full of rich earth," and the mountains displaying an "abundance of wood," by his time many mountains could "only afford sustenance to bees" while, as in small islands, all the "richer and softer parts of the soil [had] fallen away, and the mere skeleton of the land [was] being left."[6]

Humanity's third great energetic advance came as creative individuals found ways to tap ever more widely and efficiently into our planet's vast stores of coal, petroleum and natural gas (Figure 1.1). Coal had been used long before the late eighteenth century, but because burning it in the open filled rooms with smoke and gas, it had typically been a last resort answer to insufficient or inadequate biomass.

**Figure 1.1**
USA Energy Consumption: 1775-2000




During the past 225 years the United States has experienced two distinct energy eras: the renewable era and the (current) carbon-fuel era. **Source:** U.S. Energy Information Administration, *Annual Energy Review 2001*, pp. 355-357.

**Source:** Robert L. Bradley and Richard W. Fulmer, *Energy: The Master Resource*, Kendall Hunt Publishing Company, 2004, p. 186.

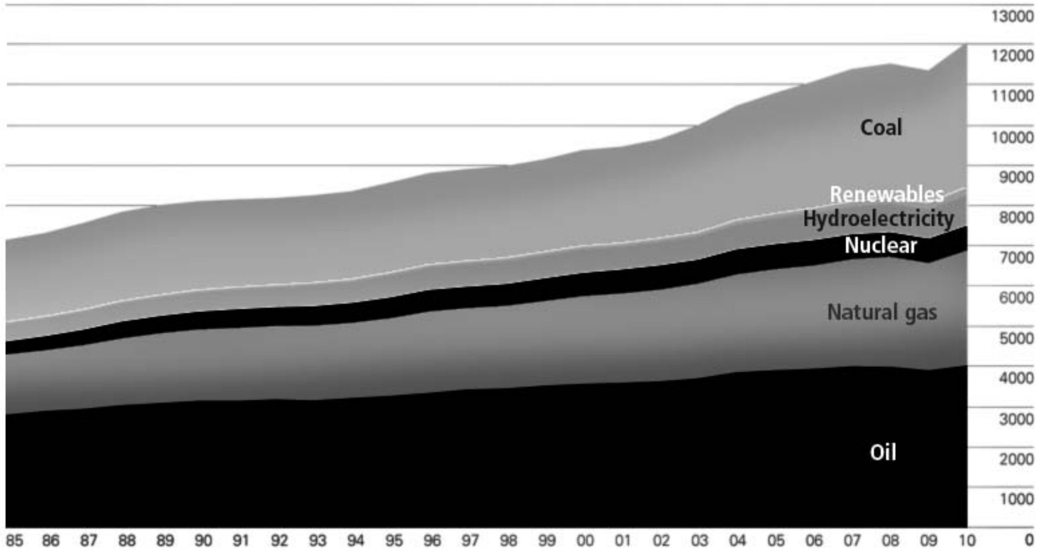
Paradoxically, bitumen was often a more desirable raw material than crude oil and coal as it could be used for paving roads, caulking the bottom of ships, waterproofing roofs, sealing ropes against moisture and as an input in weapons such as Greek fire. Unlike petroleum, bitumen does not flow and cannot be pumped under natural conditions without being heated or diluted. It comes in the form of viscous, dark, and sticky matter and is as hard as a hockey puck at 10°C.

The transition from renewables to carbon fuels delivered obvious benefits. As William Stanley Jevons observed in 1865, with coal "almost any feat is possible or easy" while "without it we are thrown back in the laborious poverty of earlier times." Looking at potential alternatives, he dismissed wind power as "wholly inapplicable to a system of machine labour, for during a calm season the whole business of the country would be thrown out of gear;" too irregular (we would now say intermittent) to be relied upon on a continual basis; unable to supply the "force required in large factories or iron works;" and too limited in terms of potentially suitable locations.[7] (Of course, none of these basic problems has since been solved.)

Coal was the first carbon fuel used on a massive scale. It remained globally dominant until the middle of the twentieth century when it was bypassed by petroleum. As shown in Figure 1.2, coal, crude oil and natural gas now account for over 85% of the world's commercial energy consumption. Crude oil remains the most widely used (33.6%) despite losing share for at least a decade. Coal usage keeps increasing (mostly in Pacific Asia, especially China) while natural gas is more abundant than ever thanks to the development of shale gas technology.[8]

Despite sometimes massive subsidies per unit of power produced, electricity generated from wind turbines, solar panels, geothermal power stations, biomass (such as lumber and paper mill residues) and waste (such as electricity generated from methane emissions from landfills or the deliberate burning of waste for electricity production) remains insignificant overall at around 1.3% of the total, while energy from liquid biofuels such as ethanol and biodiesel accounts for 0.5%.

**Figure 1.2**
Primary World Energy Consumption by Source




World primary energy consumption grew by 5.6% in 2010, the strongest growth since 1973. Growth was above average for oil, natural gas, coal, nuclear, hydroelectricity, as well as for renewables in power generation. Oil remains the dominant fuel (33.6% of the global total) but has lost share for 11 consecutive years. The share of coal in total energy consumption continues to rise, and the share of natural gas was the highest on record.

**Source:** BP, *Statistical Review of World Energy*, June 2011.

# 1.2 Petroleum and Its Uses

## Historical Developments

From the late 1850s onward, petroleum (or more accurately *crude oils* in light of the different nature of the raw material found in different oilfields) began to displace liquid fuels, lubricating oils and other products previously created out of coal, coal tar (a by-product of the manufacture of gas from coal), bitumen, sperm whale's spermaceti and blubber, other animal fats and various plants.

Among other advantages, crude oil was more abundant; had a higher energy density (i.e., the amount of energy stored in a unit of volume); burned more cleanly (i.e., its combustion produced much less polluting gases and particulate matter); was easier to extract (in particular, it did not need underground work by humans), handle (through pumping), transport (through trucks, pipelines, ships, barges and trains) and store (in tanks, underground reservoirs and natural caverns); and was a more desirable feedstock, or raw input, for the production of a wide range of items.

In the late nineteenth century, petroleum refiners produced primarily kerosene, lubricating oils, greases, paraffin, petrolatum (or petroleum jelly, better known by the trademark Vaseline), candles and a few other items such as insect repellents for livestock. These products were largely extracted from what oilmen referred to as the "middle of the barrel." By contrast, gasoline (found in the "top of the barrel") and heavy residuals (found in the "bottom of the barrel") had few uses. For instance, while gasoline could be used as a solvent for paint, it proved too flammable and too volatile to be used for household lighting and heating. Similarly, while some of the heavier components had limited uses for road surfacing and roofing, no adequate furnace technology had been developed to burn heavy oil for space heating.

In time, those polluting production residuals were converted into valuable inputs of all kinds, both as a way to reduce the damage to the property of others (and therefore avoid lawsuits) and, more importantly, as a way to increase profitability. A few illustrations taken from popular writings penned around a century ago, which cannot be charged with being modern "greenwashing" (i.e., deceptive marketing by polluting corporations), will help illustrate these processes.

In his 1908 book *Wealth from Waste*, the pastor George Powell Perry observed that the achievements of the Standard Oil Company had less to do with financial shenanigans and deceptive practices than with the "wise use of that which was once regarded worthless." A case in point was paraffin that could be traced back to a "sticky, slimy stuff… left over from the refining business." As he tells the story:

> At first [the residual] was thrown into the river. But soon the authorities complained because of the pollution it produced. Then it was put into a deep trench and they tried to burn it. It made such a furious flame that the heat became unendurable and the strongest wall could not resist it. In great perplexity the company finally sought the help of some expert chemists to see if some way could not be found to get rid of the nuisance. It was at that time that a process was discovered whereby this disagreeable refuse could be converted into paraffine. Then it was found that this troublesome refuse could be made a good source of revenue.[9]

Writing in 1920, the journalist Frederick A. Talbot observed in his book *Millions from Waste* that "forty years ago the boring of [an oil] well was followed with mixed feelings" as a successful strike would unavoidably "[crash] through the roof of an underground reservoir of petroleum gas" that might then blow up and cost the lives of the crew. "Ignorant of the value of this product, though painfully aware of its danger," he writes, "the early seekers for oil led this gas through a pipe to a point some distance away" where it was then ignited and "allowed to burn merrily in the open air." It was only when "the flame flickered and expired" that the "boring for the precious liquid" would proceed ahead.

In time, however, the flaring of natural gas was recognized for what it was, the waste of a valuable resource. As Talbot observed, "with passing years and progress came enlightenment. The gas is no longer wasted; it is trapped. In some instances it is led through piping for hundreds of miles to feed hungry furnaces engaged in the making of steel and other products."[10]

Later on, the development of the internal combustion engine ensured that the "volatile spirit which hitherto had been spurned and burned wastefully by the refineries was immediately discovered to be invested with a value which had heretofore escaped attention. It formed the ideal fuel for the new motor. Forthwith wanton destruction of the volatile spirit was abandoned. Every drop was carefully collected, and, as time went on and the demand for the light liquid fuel increased, the refiners put forth great effort to wring every possible dram of [gasoline] from the crude petroleum."[11]

Far from being exceptional, the development of paraffin, natural gas and gasoline out of production residuals are but a few (although obviously significant) cases in a long list of creative innovations through which ever more value was added to every fraction of materials found in petroleum reservoirs. To mention one other instance, the boom in plastics production can be traced back to the development of the cracking of crude oil to produce high quality gasoline, a process which generated residual gases first burnt as waste, but which eventually became a cheap feedstock for the production of polymers.[12] As an applied chemist wrote almost eight decades ago, "the object of all fuel research is either to eliminate waste and increase efficiency in the mining, preparation and utilization of fuels, or to convert the raw fuel by treatment or processing into a more convenient or effective form for use with, in many cases, the recovery of valuable by-products for other purposes."[13]

Of course, the same pattern had long been observed in all competitive sectors of market economies. In the words of Karl Marx: "With the advance of capitalist production the utilization of the excrements of production and consumption is extended" and the "so-called waste plays an important role in almost every industry" because finding new uses for previously unmarketable residuals ultimately increased "the rate of profit." In his opinion, industrial waste recovery had become "the second great branch of economy in the conditions of production" after economies of scale.[14] The result was wealth creation, greater quality of life and reduced environmental impact over time.[15]

## Current Uses and Potential Substitutes

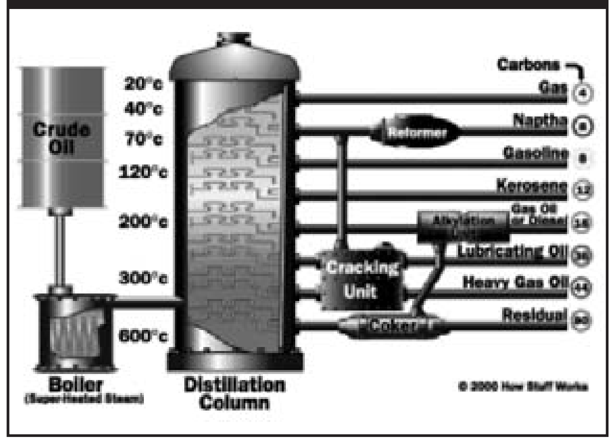
Refined petroleum products are categorized as light distillates (aviation - propeller engines - and motor gasolines, light distillate feedstock), middle distillates (jet and heating kerosenes, diesel), fuel oil (marine bunker fuels and heavy oils) and other products (from refinery gas and fuel, liquefied petroleum gas, petroleum coke and paving material to solvents, lubricants, wax and other refined products) (Figure 1.3). Nearly two thirds of the world's refined petroleum products are used in land, water and air transportation, accounting for nearly 95% of all energy consumed in this sector.[16]

In an advanced economy like the United States, about 11% of crude oil is used as feedstock for petrochemical syntheses that make possible the manufacture of thousands of products, from synthetic rubber, plastics, polystyrene, synthetic fabrics, lubricants and building materials (from PVC pipes and vinyl sidings to asphalt shingles and insulation material) to pharmaceutical drugs, vitamins, fertilizers, pesticides and cosmetics.[17] Road paving asphalt is the second most voluminous non-fuel use of a refined petroleum product, but asphalt is also an input in roofing, industrial coating, adhesives and batteries. Even much sulphur, the most common undesirable element of crude oil because its large-scale combustion causes acid rain, can be recovered and used in the preparation of fertilizer and other useful products such as pharmaceuticals and construction materials.

Perhaps the best illustration of the inherent advantages of petroleum products over potential alternatives is the century-old triumph of gasoline over electric engines in the automobile market. Indeed, despite massive governmental subsidies, battery electric, hybrid electric and plug-in hybrid vehicles have failed to gain any meaningful market shares because of their limited range and power, long charging time, security concerns (especially in collisions) and inadequate electricity production and delivery infrastructure.

Biofuel production has increased significantly as a result of government mandates, but ethanol and biodiesel cannot currently be blended without serious technical concerns at respectively more than 10% and 5% with petroleum-based fuels. The limited availability of agricultural land and animal fats further insures that they can only ever displace a very small fraction of petroleum-based fuels. Furthermore, the food shortages and soaring prices they cause prompted the UN Special Rapporteur on the Right to Food, the sociologist Jean Ziegler, to describe them as nothing short of "a crime against humanity."[18]

**Figure 1.3**
Simplified Drawing of a Petroleum Refinery's Most Important Processes




**Source:** Craig Freudenrich, *How Oil Refining Works*, http://science.howstuffworks.com/environmental/energy/oil-refining5.htm.

Shale gas extraction technology has in recent years delivered (or will soon deliver in some jurisdictions) significantly larger natural gas supplies at much lower prices, thus making compressed and liquefied natural gas more attractive options. Yet, a number of technical challenges (from lower energy density, more challenging storage requirements and longer payback times to lack of refueling infrastructure, higher manufacturing costs and greater safety risks) still need to be overcome before their use becomes significant in land, maritime, and air transportation.

Synthetic liquid fuels can also be manufactured from coal and the industrial leader in this technology, South Africa's Sasol, now produces a completely synthetic jet fuel from this abundant input. Whether or not it will prove a technically and economically viable alternative to petroleum-based jet fuel, however, has yet to be demonstrated conclusively.

In short, today as was the case a century ago, in Canada as elsewhere, gasoline, diesel and kerosene remain the most flexible, useful, safe, simple, convenient, reliable, energy dense and affordable transportation fuels at our disposal.

Another fundamental problem with alternatives to petroleum-based products is that while environmental activists are fond of reminding us that the sun shines and the wind blows abundantly and freely, they are much quieter on the fact that they only deliver electricity and no by-products. They cannot thus be expected to have any impact on the transportation sector until a radically new battery design is developed, nor can they offer any alternatives to non-fuel petroleum-based products. At the moment, with the exception of a few small and out of the way power stations whose main feedstock is heavy oil, the only carbon fuel market shares they can hope to gain are occupied by coal and natural gas.

Unfortunately, wind and solar-based electricity generation is typically distant, costly, intermittent and unreliable while having a low energy density. In practice, this means they cannot exist without massive support for the building of increased transmission capacity and back-up power generation (ideally natural gas or hydroelectric power that can be quickly turned on and off) for when the sun doesn't shine or the wind doesn't blow or blows too hard. Their environmental impact in terms of land use per unit of power produced and, in the case of wind power, bird mortality, is also significant.[19]

Finally, while it is true that some plastic substances can be manufactured from biomass (about a century ago, the Ford company made plastics out of soybeans and some German firms out of cow's blood), they are simply not competitive in terms of quality, costs and available feedstock—which is why petroleum-based products displaced most biomass-based plastic substances and animal bones a long time ago.[20] This is not to say though that the increased availability and affordability of natural gas might not have some significant impacts in this market in the near future.

Wishful thinking aside, there are currently no adequate "renewable" alternative energy and synthetic feedstock source or combination of sources available that provide a superior alternative to crude oil. The fact that an increasing portion of future petroleum will have to come from unconventional sources cannot be held against their development.

# 1.3 Myths and Misconceptions

## Myth #1: Petroleum is ever more expensive and dirtier

Petroleum producers have always exploited what to them were the most easily accessible sources. Once these were no longer productive, they moved on to more distant or less accessible oilfields. Yet, one cannot infer from this that petroleum producers were forever left "scraping the bottom of the barrel" nor that petroleum must inexorably become more expensive to find, extract, refine and bring to market, resulting in higher production costs, declining availability and increased environmental damage.

The first people to collect crude oil gathered it in locations where it naturally seeped to the surface of ponds and streams. From then on, if there was typically nothing "easy" about pumping large amounts of petroleum out of the ground, human ingenuity always found ways to keep costs reasonable over time. As the energy analysts Peter Huber and Mark P. Mills observed: "Oil extracted today from beneath 2 miles of water and 4 miles of vertical rock, with 6 additional miles of horizontal drilling beyond that, costs less than the 60-foot oil Colonel Drake was extracting a century ago and about the same as one-mile oil cost in 1980."[21]

To be more specific, the American petroleum pioneer Edwin Drake only disposed of percussion (cable-tool) drilling technology which severely limited the depth he could reach and the type of rocks he could bore through when he went looking for crude oil in northwestern Pennsylvania in the late 1850s. In later decades, the development of rotary drilling, offshore technologies and other advances of all kinds made it possible to tap into ever more remote and deeper oilfields. The "easily accessible oil" of yesterday only seems so in light of later technological advances.

The same principle applies to the notion that some oilfield deposits are "inherently" dirtier than others. Some have indeed less sulphur and other more desirable quality than others, yet except in the most primitive conditions, no crude oil could ever be used directly as it came out of the ground. As discussed earlier, the high quality crude oil extracted from northwestern Pennsylvania over a century ago was anything but clean in the early phases of its exploitation while later advances in refining operations ensured that lesser quality raw materials could be handled more cleanly and efficiently.

It is also sobering to consider that petroleum was once considered an unconventional fuel which could never possibly substitute for coal. In 1865 William Stanley Jevons thus rejected the suggestion of "some American inventors" to consider petroleum as a potential alternative for marine steam-engine boilers as the internal combustion and diesel engines were still a few years away at the time. Despite some theoretical potential, crude oil was impractical, Jevons argued, because its natural supply was "far more limited and uncertain than that of coal" and its price much more expensive.[22] Yet, within a few decades, "King Coal" would cede its throne to crude oil, first in the United States, and then later the world over.

## Myth #2: Petroleum is inherently unsustainable

Over the last century and a half, unending waves of doomsday forecasts have been supplied by scientists, activists and journalists, only to be soon disproved by the discovery of new oilfields and advances in drilling, transportation and other technologies.[23] Perhaps because of this long history of failed prognostics, "depletionists" now generally embrace the more moderate "peak oil" rhetoric which does not predict imminent shortages, but rather a decreasing supply over the next century that mirrors the supply curve of the industry since its beginning. Yet, like other critics before them, *all* prominent peak oil advocates have produced mistaken forecasts in the last two decades.[24]

The problem with peak oil rhetoric, the energy analyst Vaclav Smil tells us, is that it is ultimately based on "interpretations that lack any nuanced understanding of the human quest for energy, disregard the role of prices, ignore any historical perspectives, and presuppose the end of human inventiveness and adaptability."[25] Technological advances such as shale oil production keep unlocking what once looked like unprofitable deposits, in the process expanding petroleum reserves despite increased consumption. Indeed, some reputable analysts now predict an imminent glut of petroleum and an imminent collapse in crude oil prices.[26]

Ultimately, as engineer Étienne Bernier observes, a shortage of synthetic petroleum is simply impossible for it can "be produced with any source of carbon and any source of heat. It is impossible to run out of carbon because it is a basic component of limestone."[27] Of course, humanity will most likely have developed better power sources before this option ever needs to be considered. In our opinion, the greatest paradox of depletionism is that if crucial resources are indeed finite and without potential substitutes, then reducing their consumption can only *delay rather than prevent* a future crash of epic proportions, thus making sustainable development a theoretical impossibility. By impoverishing every one, imposed conservation measures (beyond the incentives to conserve already present in a context where private property is protected) could deprive us of the means to develop better sources of energy in the future.

As for climate change, the notion that a world with reduced carbon fuel usage would be more desirable for human beings is hard to reconcile with the historical evidence. Before the beginning of the carbon fuel era, unseasonable heat or cold, excessive or insufficient rainfall, floods and other problems regularly resulted in malnutrition and famines. It was only with the advent of long distance transportation that humanity finally vanquished them as the surplus of regions which had enjoyed good harvests could be channeled to those that had experienced mediocre ones.

Writing in 1856, the British historian George Dodd observed that in the "days of limited intercourse, scarcity of crops was terrible in its results; the people had nothing to fall back upon; they were dependent upon growers living within a short distance; and if those growers had little to sell, the alternative of starvation became painfully vivid."[28] More recently, the economic historian Cormac Ó Gráda similarly pointed out that "the historical record suggests that the integration of markets and the gradual eradication of famine are linked."[29] "In short," a group of British food policy experts stated two years ago, "international trade is a key underpinning of food security at all levels."[30]

Even if humanity completely turned its back on carbon fuels, bad weather events and their attending misery and starvation in the absence of international trade would not go away and would only be made worse by shortages of petroleum-based agricultural inputs. On the other hand, as long as economies develop, scientific and technical knowledge expands, people are free to adapt and petroleum-based international trade allows the movement of foodstuffs between regions, humanity will thrive as it did in the last century and a half, a period of warming.

## 1.4 Environmental and Social Benefits of Petroleum

As with any other significant extraction and heavy-industry manufacturing activity, petroleum can be the cause of sometimes significant environmental problems during its extraction (such as disturbing fragile ecosystems), transport (oils spills), storage (leakages), and combustion (air pollution). The existence and magnitude of such problems, however, is not inherent to the material itself, but is rather a function of the available technologies and level of care in human handling. Besides, petroleum-based products and other carbon fuels have also delivered significant long-term environmental benefits, the most noticeable being the afforestation or reforestation of much marginal agricultural land in advanced economies in the last two centuries.

Contrary to a widespread belief that massive deforestation is a recent occurrence, perhaps as much as nine-tenths of all deforestation caused by human beings since the emergence of civilization occurred before 1950 as people needed to clear massive amounts of forested land in order to provide themselves with shelter, food, warmth and a multitude of objects. The significant increase in the use of coal in the early decades of the nineteenth century, however, marked the beginning of a reversal of this trend.

France was perhaps the first major country to experience what has since been termed a "forest transition" as its forest area expanded by one-third between 1830 and 1960, and by a further quarter since 1960. Similar processes, although of varying intensity and scope, have been occurring in all major temperate and boreal forests and in every country with a per capita Gross Domestic Product now exceeding US $4,600 (roughly equal to the GDP of Chile) and in some developing economies, most notably China and India.[31]

Carbon fuels made this expansion of the forest cover possible in various ways. With the development of more sophisticated combustion technologies, coal, heavy oil and natural gas proved vastly superior alternatives to firewood and charcoal. Through their role as long-distance land and maritime transportation fuels, coal and later petroleum-based fuels (diesel and marine bunker fuel) encouraged agricultural specialization in the most productive zones of the planet, in the process making much marginal agricultural land superfluous. Coal, petroleum and natural gas were indispensable to the extraction, production, transportation and spray of synthetic fertilizers and irrigation water. Petroleum was a key component in a wide variety of agricultural inputs and tools such as plastic sheeting, synthetic pesticides and veterinary medicines that drastically curtailed losses to pests and diseases.

The advent of tractors eliminated the need for millions of horses and mules for crop production. Tractors were not only more effective tools that never got sick nor required care when not working, but they also did not consume as much as a fifth of the amount of food they helped farmers grow.[32] The development of a wide range of synthetic products, from textile fibers to dyes, also eliminated the need for many non-edible agricultural crops and commodities from wool and silk to natural dyes and flax. These advances were at the heart of the forest transition.

**Figure 1.4**
**"Grand Ball Given by the Whales in Honor of the Discovery of the Oil Wells in Pennsylvania"**


**Source:** *Vanity Fair*, April 20, 1861, p. 186.

The most immediate environmental benefit of crude oil drilling, however, was that it rapidly killed the whale oil market, an outcome best illustrated in an 1861 cartoon[33] (Figure 1.4).

Fossil fuels in general and petroleum in particular also delivered dramatic improvements in air quality and public health. None was more beneficial than the replacement of urban work horses by cars and trucks as a typical city horse would produce something along the lines of twenty kilograms of manure and seven liters of urine per day. Apart from their stench, excrements and dead carcasses left to rot were a source of deadly pathogens and a much more significant public health threat than car exhaust fumes and particulates.

In their heydays, urban horses were also significant sources of noise pollution (especially when iron shoes hit cobblestone streets), made significant demands on agricultural lands in terms of feeding and bedding, attracted significant concentration of pests and insects of all kinds (from rodents to flies) in close proximity to human beings and were more likely to kill people than cars.[34] Once urban horses had been displaced, asphalt paving significantly reduced the concentration of dust particulates in urban areas.

Another significant environmental improvement delivered by carbon fuels (including kerosene and heavy oil) was the displacement of poor quality domestic fuels such as firewood and dung that filled houses with soot, particles, carbon monoxide and toxic chemicals that caused significant mortality through ailments such as chronic pulmonary obstructive diseases and acute respiratory infections. Sadly, indoor air pollution created as the result of the incomplete combustion of poor quality fuels still kills millions of people in developing countries every year, a death toll that could be significantly reduced with, among other things, more abundant domestic liquid fuels.[35]

As with any other natural resource, petroleum can be a source of conflict in human societies. Yet, as jurisdictions from Texas and Alberta to Norway and Australia demonstrate, there is no such thing as an unavoidable "resource curse" (i.e., the notion that significant natural resource endowments result in poor economic performances and bad political outcomes). By and large, the main contribution of fossil fuels to human welfare has been to significantly reduce the amount of back-breaking labor required in agriculture and industry and to make possible entirely new and better employment opportunities. Even in less advanced economies, the replacement by plastic containers of heavy vats made of stone or clay used to carry water has often been described as a minor miracle.

Through the development of plastics and its multiple uses in modern medicine (from operating room equipment to replacement hearts, valves, limbs and joints) and with its key role in making food more abundant, cheaper, safer and nutritious than ever before (from crop and vitamin production to packaging and transportation), petroleum has delivered significantly longer life expectancy and superior quality of life.

While petroleum exploitation has generated tremendous wealth, petroleum-based products were obviously never perfect. Yet, critics of our alleged crude oil addiction typically display little appreciation for the fact that petroleum-based products arguably created much less significant environmental problems than the technologies they displaced or that could at present be considered as substitutes. They also played a crucial role in drastically improving humanity's standards of living and overall health.

As such, increased crude oil production in our current technological state is not an option, but a necessity that will increasingly have to be supplied from what in historical perspective look like unconventional sources. Shale oil is one. Alberta's oil sands are another. We now turn to a more detailed discussion of the latter's rise, current challenges and present and potential solutions.

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# PART 2

## Green(er) Innovations in the Oil Sands

### 2.1 From Oil Springs to Oil Sands: Some Highlights from the History of the Canadian Liquid Fuel Industry

The Canadian contribution[1] to the launching and development of the petroleum industry is too significant to be summarized in a few lines. Among other facts that should be more widely known is that the acknowledged true father of the industry was the Nova Scotia-born and raised medical doctor and geologist Abraham Pieno Gesner (1797-1864) who, after much trial and error, developed in 1846 a lamp fuel first called "keroselain" (from the Greek *keroselaion* for wax oil), but soon rechristened kerosene (Figures 2.1 and 2.2). Gesner's lamp fuel was a significant improvement in terms of price and illumination over competing products when first manufactured from coal and bitumen, and became even more affordable when derived from petroleum. As one website puts it, Gesner saved more whales than Greenpeace ever will.[2]

The first crude oil well from which kerosene and other products were refined on a commercial scale was dug in 1858 by a crew under the direction of James Miller Williams in Oil Springs in southwest Ontario. (Truth be told, however, Williams' goal was to produce kerosene from a nearby bed of bitumen and he hit upon crude oil when his crew dug for water.) The material was then processed in North America's first crude oil refinery in Hamilton, making Ontario the first North American jurisdiction where commercial petroleum was produced, refined and marketed.

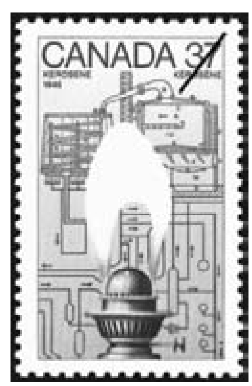
Because of its higher sulphur content, however, Ontario's crude oil and kerosene were often disparaged as dirty and inferior alternatives

**Figure 2.1**
Canada Post Commemorative Stamps, "Abraham Gesner: Father of the Oil Industry," issued March 17, 2000

**Source:** Canada Post.

to the sweet petroleum pumped in western Pennsylvania, at least until an economically viable way was found to remove it during refining. Interestingly, Ontario still produces small amounts of crude oil to this day.[3] Canadians can also boast of having built the world's first modern crude oil pipeline when in 1862 such a structure connected the Petrolia oilfield to the nearby town of Sarnia.

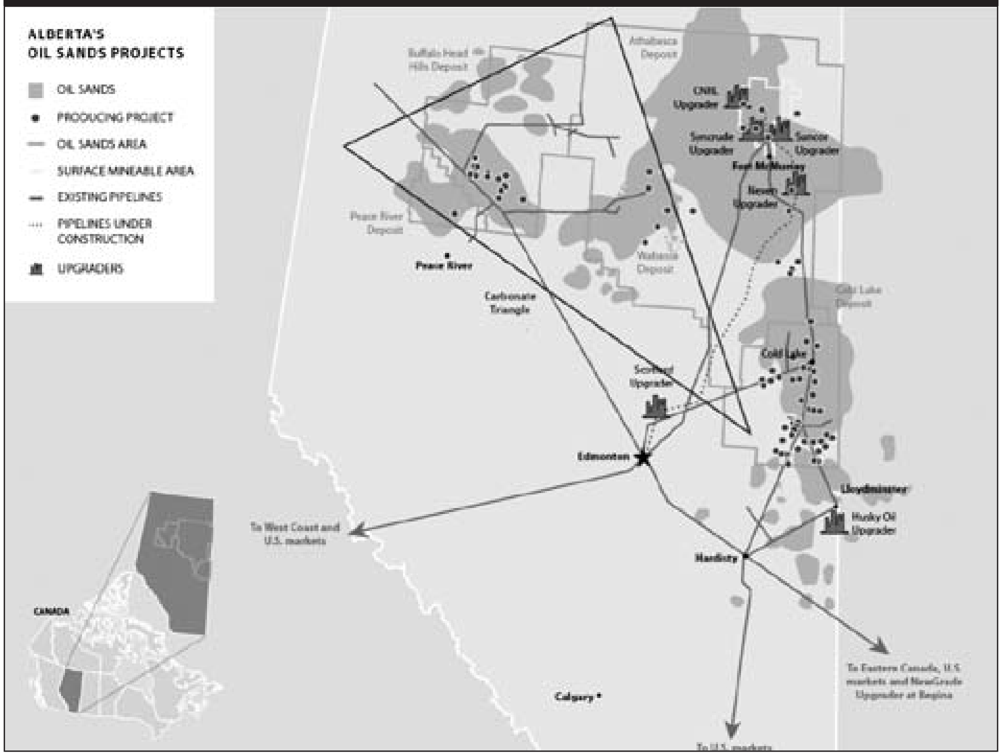
**Figure 2.2**
Canada Post Commemorative Stamps, "Kerosene 1846," issued June 17, 1988




**Source:** Canada Post.

The next significant stage in the historical development of the Canadian petroleum industry took place in the Western Canada Sedimentary Basin that stretches from northeastern British Columbia to southwestern Manitoba. Despite

**Figure 2.3**
Alberta's Oil Sands Projects



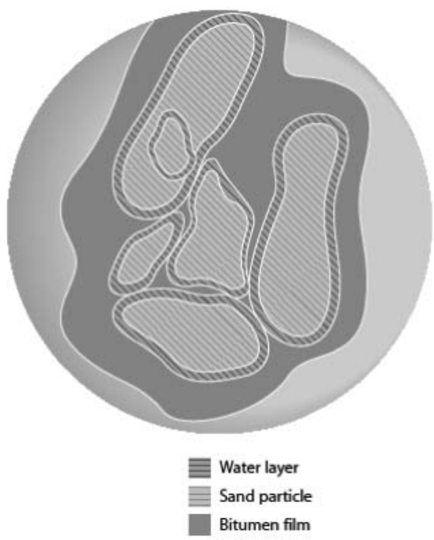

**Source:** Robert Bott, *Canada's Oil Sands,* 3rd edition, Canadian Centre for Energy Information, 2010, p. 4.

containing abundant supplies of conventional crude oil and natural gas, along with heavy oil and oil sands, the exploitation of the Basin required much time and resources. The pivotal event was the gusher that sprang out of the Leduc no. 1 well about 30 kilometers south of Edmonton in 1947 from a depth and type of rocks then thought unlikely to harbor crude oil. The drilling operation had been financed by Imperial Oil and was a last-ditch attempt in a 30-year effort through which 133 wildcat wells in the province had delivered mediocre results at best.[4] Indeed, Imperial Oil executives were about to re-orient their Alberta activities towards the manufacturing of gasoline from natural gas at the time.

The last significant Canadian petroleum producing region was developed nearly five decades later in the Jeanne d'Arc Basin off the eastern shore of Newfoundland where crude oil production is now concentrated in three oilfields: Hibernia, Terra Nova, and White Rose. Once again, local developments proved laborious as nearly 40 costly dry holes were drilled before the discovery of Hibernia in 1979. Its commercial exploitation, however, would have to wait for almost two decades, in part because of extremely harsh operating conditions that include icebergs, fog, rogue waves, sea ice, hurricanes and nor'easter winter storms.[5]

Although Canada always had plenty of conventional petroleum resources, they only look "easily accessible" in retrospect. In recent years, the decline of conventional oilfields in the Western Canada Sedimentary Basin has encouraged various advances in the development of unconventional sources (such as the Bakken and Spearfish shale oil formations in southern Saskatchewan and Manitoba) and locations (such as the Gulf of Saint-Lawrence). No unconventional resource, however, has up to this point in time drawn more investment and resulted in greater production than Alberta's oil sands.

**Figure 2.4**
Oil Sands Composition




**Source:** Robert Bott, *Canada's Oil Sands,* 3rd edition, Canadian Centre for Energy Information, 2010, p. 6.

## 2.2 From Oil Sands to Synthetic Crude Oil[6]

Alberta's massive oil sands deposits are found in an area larger than the island of Newfoundland and are concentrated in a few significant deposits (Athabasca, Cold Lake, Peace River, Buffalo Hills and Wabasca) (Figure 2.3). In percentage by weight, they consist of a mixture of bitumen (between 8 to 14 wt%), water (between 3 to 5 wt%) and coarse white sand, fine silts, clays and traces of dissolved metals and organic compounds. Each oil sand grain has three layers: an "envelope" of water surrounding a grain of sand and a film of bitumen surrounding the water (Figure 2.4). At room temperature bitumen remains virtually immobile, but at 50°C its viscosity decreases approximately 100-fold, which is why thermal energy is a necessity for bitumen production. As with conventional oilfields, each Albertan oil sands deposit has a unique set of characteristics, from sulphur content to density, and these characteristics also vary within one deposit.

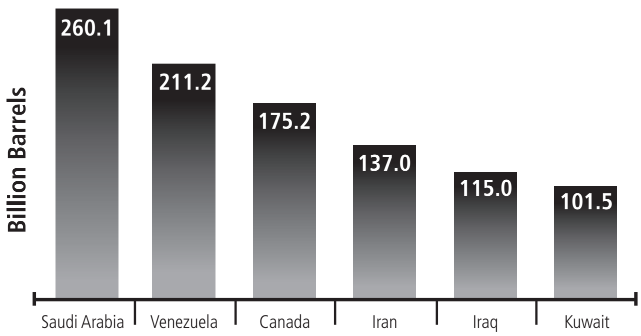
Oil sands had few uses until recent times. Bitumen from seeps along the Athabasca River was used by native people to caulk the seams of their canoes. It might also have been used to dress wounds, waterproof garments and ignite fire. Although the first of numerous experiments to extract bitumen began in the late nineteenth century, the production of synthetic crude oil derived from bitumen (a blend of naptha, kerosene, gas oil and a few other elements similar to many conventional crude oils) only occurred on a relatively small scale in the 1960s. Another quarter of a century would pass before such an operation became reasonably profitable.[7]

Between 1967 and 2009, more than 7 billion barrels of synthetic crude oil were delivered to refineries and in 2010 daily production hovered around 1.6 million barrels. Just like conventional petroleum, synthetic crude oil is turned into a wide range of products. As such, the key differences between oil sands and conventional petroleum deposits are at the extraction and processing stages, not in the final products they deliver.

Under current economic and technological conditions, about 10% of the oil sands are considered economically recoverable (approximately 170 billion barrels) which, along with approximately 5 additional billion barrels of conventional oil, now puts Canada in third place globally in terms of proven oil reserves behind Saudi Arabia and Venezuela (Figure 2.5).[8] In 2004, Canada became the largest oil exporter to the United States and in 2010 Canadian crude oil export reached 1.97 million barrels per day, accounting for approximately 22% of U.S. imports.[9] Because of its geographical proximity, Alberta's oil sands production is expected to remain the largest source of US imports for the foreseeable future.

Bitumen is extracted in two different ways depending on how close to the surface deposits are. The closest ones are recovered through open-pit mining operations that nowadays use large electric shovel scoops to extract the raw material and load it onto giant trucks. The oil sands are then brought to processing and upgrading facilities where they are first crushed and then treated with hot water, heat, catalysts and pressure (Figure 2.6). Approximately two tons of oil sands are required to manufacture one barrel of synthetic crude oil.

**Figure 2.5**
*Oil & Gas Journal:* Top Proven World Oil Reserves, January 1, 2011




**Source:** U.S. Energy Information Administration, *Country Analysis Brief: Canada*, April 2011.

This method is applicable to the approximately 20% of the oil sands deposits found within 75 meters of the surface. Despite what might seem like a significant volume, these deposits are concentrated within approximately only 3% of the oil sands area. Surface mining (like mountaintop removal for coal mining) yields very high bitumen recovery rates (typically above 90%, although the rate ultimately depends on the quality of the raw material and on the technological sophistication of the recovery method used) and is currently limited to the Athabasca deposit where the most easily accessible raw material is located.

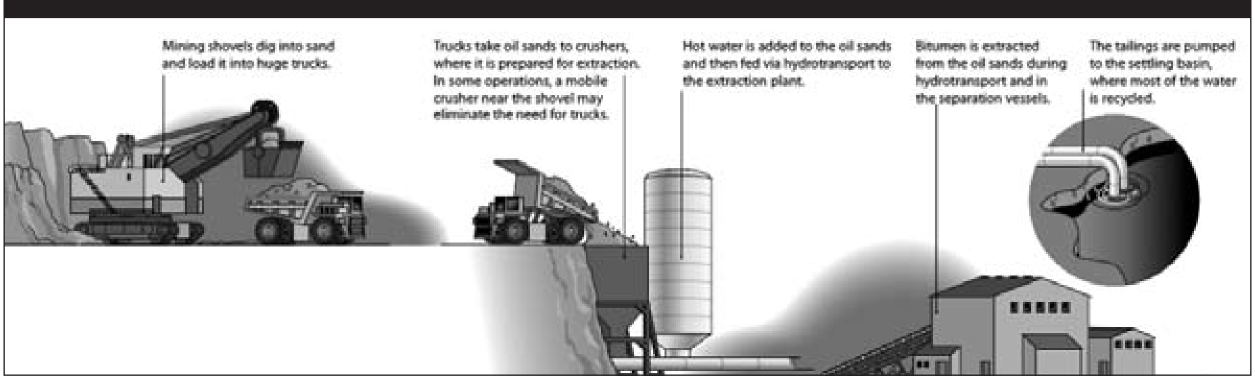
In the process of digging up an area, the topsoil, muskeg and waste rock (overburden) are set aside for later reclamation, to which will also be added the sand recovered in the crushing and upgrading operations. Needless to say, the tailing ponds and alterations to the landscape created as a result of mining operations have drawn much criticism.

Approximately 80% of the oil sand deposits are located too deep for surface mining. Provided the overburden is significant (at a minimum in the 100-150 meters range, although it might be less depending on the nature of the overburden material), they can be exploited through so-called "thermal in situ recovery" methods ("in situ" means in place, in this case underground).

The first in situ technologies go back to 1918 and various approaches were tried in the following decades. The two main underground technologies are known as cyclic steam-stimulation (CSS) and steam-assisted gravity drainage (SAGD). Both revolve around the injection of steam into oil sand deposits to liquefy some of the bitumen and enable it to flow towards the surface in a production well. Once extracted, raw bitumen is either diluted with lighter hydrocarbons to flow through pipelines or upgraded into lighter crude oil before being sent to refineries.

In situ technology uses mostly natural gas-fired boilers to generate steam, a process which requires much water—up to three cubic meters for each cubic meter of bitumen produced—but

**Figure 2.6**
Oil Sands Mining




**Source:** Robert Bott, *Canada's Oil Sands,* 3rd edition, Canadian Centre for Energy Information, 2010, p. 11.

more than 80% of this water is recycled. Current in situ production technologies allow the recovery of between 25 and more than 60 percent in the best operations of the bitumen in a given deposits—a percentage which is somewhat higher than in most conventional light crude oil operations.

The CSS and SAGD methods differ in the following ways. In short, cyclic steam-stimulation is a three-stage process (repeated a number of times on a deposit) in which steam is first injected then left to soak for several weeks. During this second phase, the bitumen is softened and diluted while cracks and channels are created through which oil will flow to the wellbore and will eventually be pumped to the surface by the same wells in which the steam was injected. This process can involve vertical, horizontal and deviated wells (Figure 2.7).

By contrast, stream-assisted gravity drainage involves drilling two horizontal wells, one above the other. Steam is continuously injected through the upper wellbore in order to soften the bitumen, which is then drained into the lower wellbore and then pumped to the surface (Figure 2.8). The technique makes it possible to recover bitumen continuously and is currently the dominant in situ method as it can extract more value from lesser quality deposits.

## 2.3 Environmental Critiques of Oil Sands Exploitation[10]

Large-scale projects such as oil sands extraction have obvious impacts on the local landscape. Try as one might, powering a large number of off road trucks, operating separation processes, generating large volumes of steam and upgrading bitumen to synthetic crude oil require large volumes of fuel, water and greenhouse gas emissions.

As with other large-scale projects (think of large dams and accompanying water reservoirs or large open-pit coal mines), the real issue is whether such large-scale disturbances can be justified in terms of their expected benefits and whether all efforts are made and precautions taken to minimize local environmental impacts.

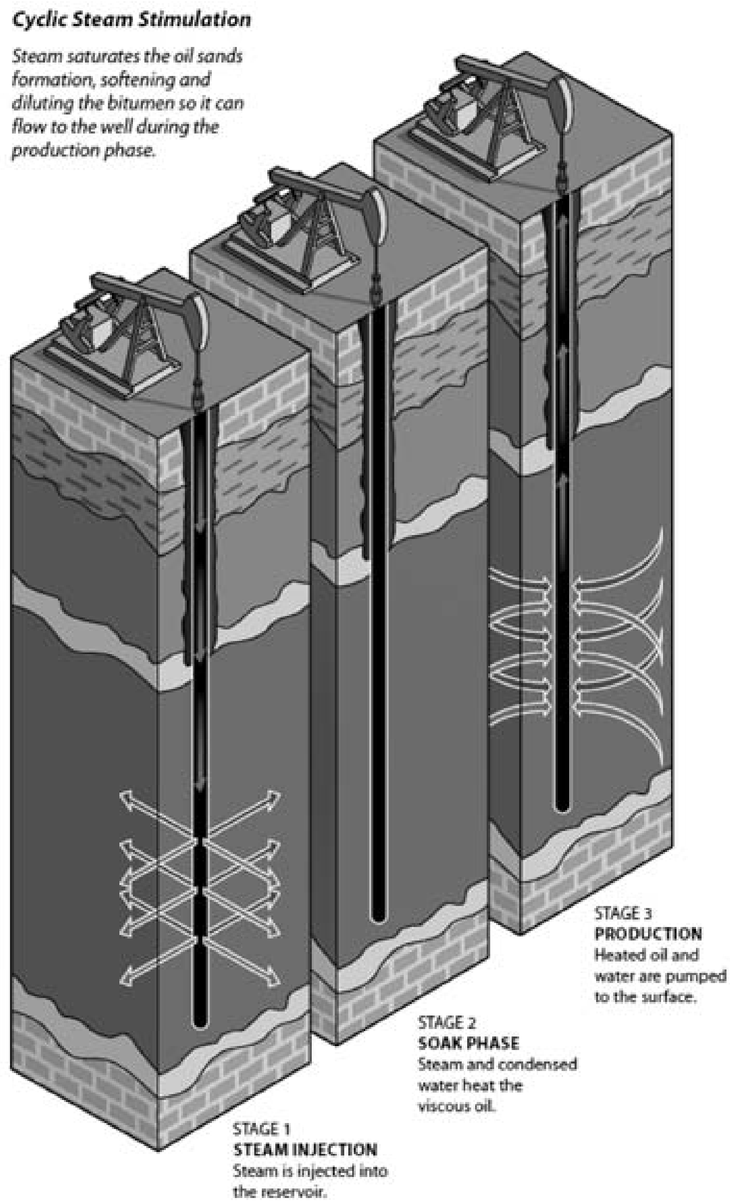
The most visible impact of oil sands exploitation is the more than 600 $km^2$ subjected to surface mining. These wildlife habitats losses make for breathtaking cinematography, but they must be put in a larger context. To summarize, about 4% of Canada's boreal forests, watersheds, wetlands and muskeg (or peat bogs) are underlain by oil sands while only approximately 2.5% of that land (approximately 0.02% of Canada's total surface area) are mineable. So far, this area is comparable to the surface area of the city of Edmonton.[11]

Developers are required by law to reclaim these lands once mining is completed. This obligation, however, does not mandate the (re)creation of an ecosystem similar to the previous one, but rather of another one with an equal or greater productive capacity. In practice, this can amount to replacing flat wetlands by drier and hillier forestland, although at the insistence of nearby Native Canadians, Syncrude has created a wetland ecosystem in a portion of its reclaimed area. Some landscape ecologists are uncomfortable with all reclamations that don't deliver this outcome,[12] but even if this was always the case, this disturbance would prove rather minor in the broader context of the Canadian boreal forest and of humanity's long-standing practice of transforming wetlands into agricultural lands the world over.[13]

By comparison too, the land disturbance in the form of wells, power plants, roads, electric power lines and pipelines inherent to in situ exploitation are much less challenging, at least inasmuch as it only amounts to 10 to 15 percent of a similar sized mining operation and does not require tailing ponds.[14]

Another broad set of complaints by environmental activists is that there is "nothing ethical about oil;"[15] that producing synthetic crude oil from oil sands amounts to "scraping the bottom of the barrel" and "signals the end of cheap oil;"[16] and that synthetic crude oil is one of the "dirtiest fuels on Earth."[17] While rhetorically powerful, this line of thought conveniently omits the undeniable benefits of petroleum discussed in Part 1.

**Figure 2.7**
Cycle Steam Stimulation

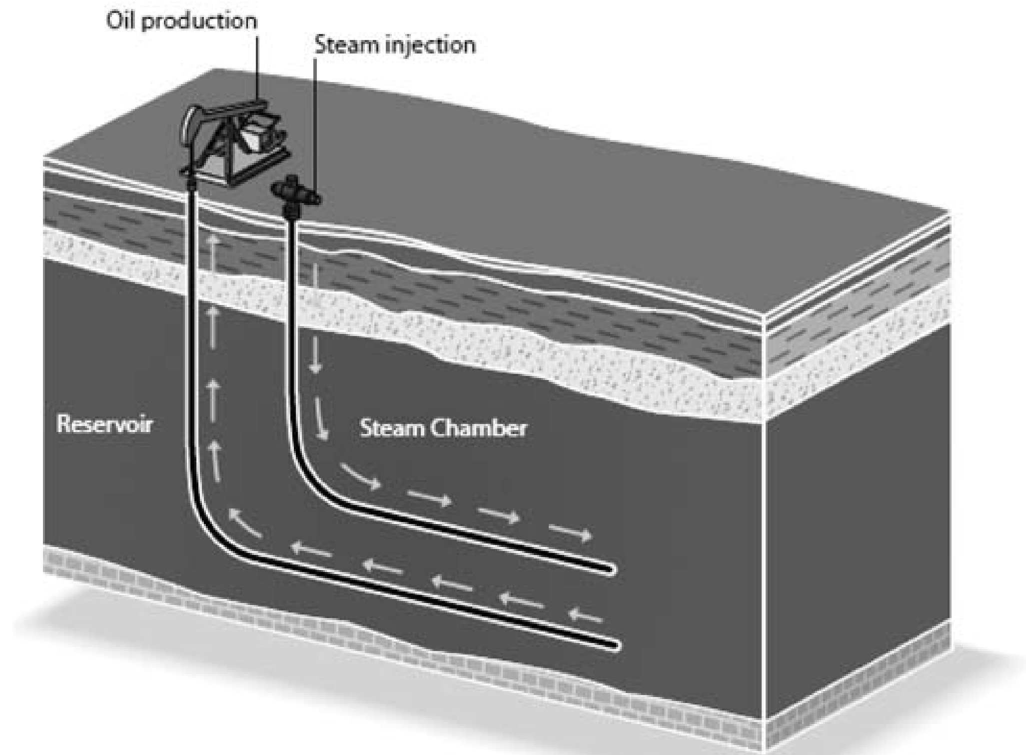



**Source:** Robert Bott, *Canada's Oil Sands,* 3rd edition, Canadian Centre for Energy Information, 2010, p. 14.

Much environmental controversy also revolves around the real greenhouse gas footprint of synthetic crude oil. Activists routinely claim that the average greenhouse gas emissions for such a barrel are between 3.2 to 4.5 times those of a barrel of conventional light crude oil. Synthetic crude oil producers, however, argue that the difference is more typically on the order of 5 to 15%. Although seemingly irreconcilable, the wide discrepancy between these numbers can ultimately be traced back to the boundaries of the systems studied and the type of fuel used as a basis of comparison.[18]

Obviously, synthetic crude oil production requires much more processing than the best quality light, sweet crude oil. Yet, the crucial factor about liquid fuels is that tail pipe exhaust amounts to between 70 to 80% of all greenhouse gas emissions while upstream production, refining and distribution account for the remaining portion.

**Figure 2.8**
Stream-assisted gravity drainage




**Source:** Robert Bott, *Canada's Oil Sands,* 3rd edition, Canadian Centre for Energy Information, 2010, p. 13.

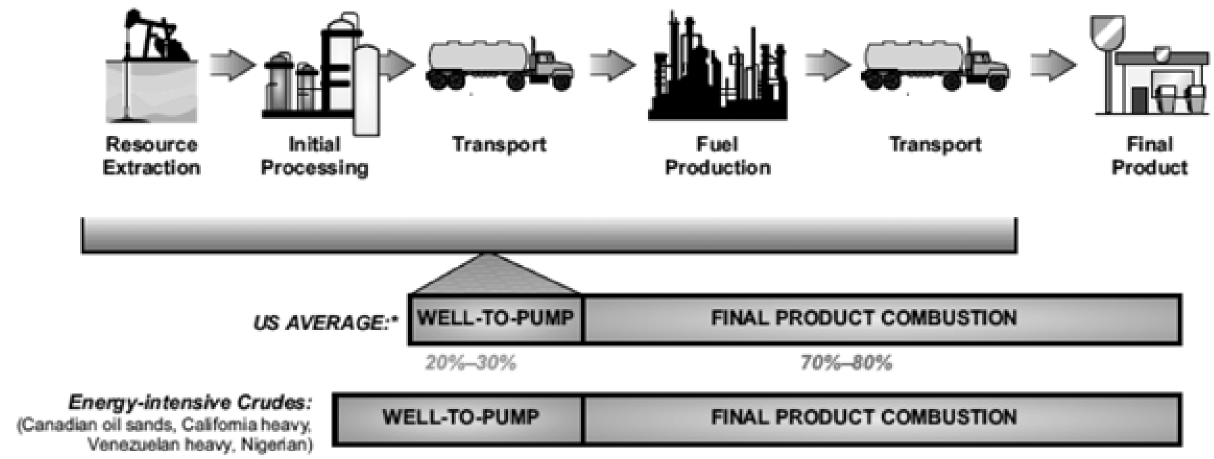
In other words, critics of oil sands typically use numbers limited to the "well-to-pump" segment (i.e., that do not factor in the emissions associated with the burning of the fuel in vehicles) while their defenders use instead numbers from "well-to-wheels" (or perhaps more accurately, from well to exhaust pipes) (Figure 2.9). Some critics complain that these latter assessments do not factor in issues such as landscape degradation. On the other hand, some researchers and consultants claim that if cogeneration—more on this below—is taken into consideration, synthetic crude oil has a carbon footprint comparable to (if sometimes still slightly greater than) some conventional crude oils.[19]

Be that as it may, there is widespread agreement over the fact that greenhouse gas emissions per synthetic crude oil barrel have diminished substantially in the last two decades (along the lines of 29% between 1990 and 2009), but have simultaneously risen in the aggregate because of increased overall production. The same trends will hold for the foreseeable future.[20]

Moreover, considered in a broader perspective, greenhouse gas emissions in the oil sands are a peripheral issue. Barring epoch-making breakthroughs in both non-carbon energies and carbon-storage capture,[21] the trends observed on our planet in the last few decades are unmistakable. Much of humanity clearly wishes to improve its standards of living and this cannot be achieved at the moment without drastically increased energy use and greenhouse gas emissions.

Some jurisdictions might profess to choose a "lighter" energy footpath, but this will not prevent their inhabitants from consuming an ever wider array of goods produced in the likes of coal-powered China.[22] Greenhouse gas emissions are of no significant concern to poor and hungry people while fuel poverty is. Our ancestors escaped the

**Figure 2.9**
Life-Cycle GHG Emissions




**Source:** IHS CERA, *Oil Sands, Greenhouse Gases and US Oil Supply: Getting the Numbers Right*, September 2010, p. 8.

widespread misery of the "renewables" and "local food production" era by embracing carbon fuels and so will citizens of less advanced economies for the foreseeable future.

At any rate, shutting down the exploitation of oil sands would be inconsequential on a global scale as they account for something on the order of 6.5% of Canada's total greenhouse gas emissions and 0.1% of global emissions (Figure 2.10).[23]

Two additional concerns of anti-oil sands activists are the toxicity of tailing ponds and alleged unsustainable water usage. These issues, however, are better addressed in a broader discussion of the development of innovative responses to oil sands challenges.

## 2.4 Innovations and Technologies for Greener Energy

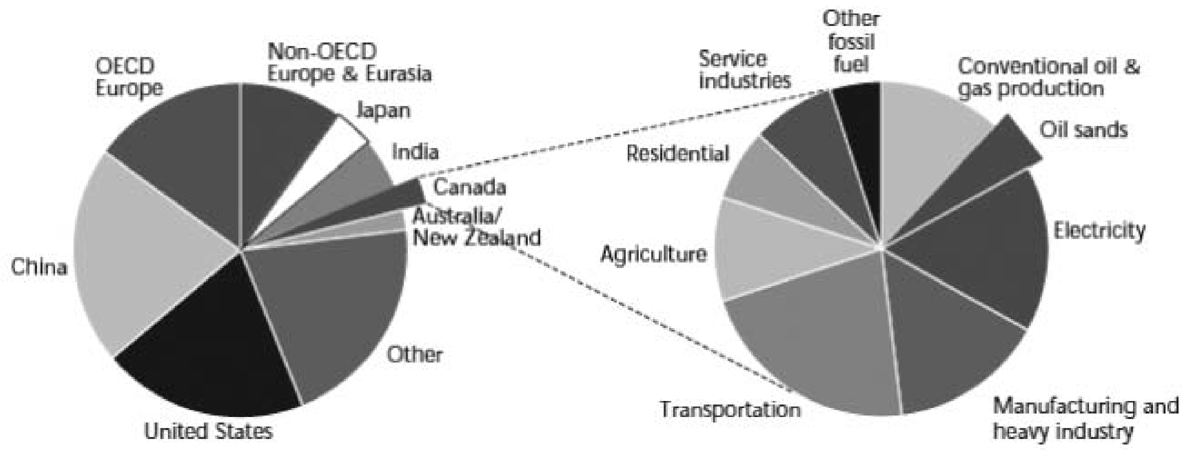
The profit motive has long provided manufacturers in all lines of work with a strong incentive to create as much value as possible from costly inputs rather than releasing residuals wastefully into the environment. Recent developments in the exploitation of oil sands once again illustrate this pattern. Suffice it to say here that since the early 1990s, the energy use per barrel of synthetic crude oil produced has been reduced by about 45%, greenhouse gas emissions by about 29%, and in recent time the cumulative steam-oil ratio (i.e., the average volume of steam used over the entire life of the operation required to produce one barrel of bitumen) by 17%.[24] What follows are short descriptions of some advances through which these results were achieved, as well as recent and upcoming developments that are likely to bring further progress.

### Increased efficiency

As with creative individuals in other lines of work, engineers and technicians working in the oil sands business have found numerous ways to improve results while reducing input use. For instance:

***Hydrotransport***: Hydrotransport is a system first implemented in 1996 which uses pipelines rather than conveyors or trucks to carry oil sands to processing plants. Trucks collect oil sands in open-pit mines and bring them to a crusher where they are broken up in lumps and rocks are removed. The sands are then mixed with warm water and the resulting slurry is transported

**Figure 2.10**
Greenhouse Gas Emissions by Country/Region and By Canadian Sector




**Note: Canada's total GHG emissions are 2% of global emissions, and the oil sands account for 6.5% of Canada's emissions.**

**Source:** Bruce Carson, "Sustainable Solutions in the Oil Sands," *Policy Options*, February 2011, p. 18.

by pipeline to an extraction plant. A benefit of this hydrotransport is that bitumen begins to separate from water, sand and minerals before being delivered in the next phase and extraction process temperatures can be lowered from 75-80°C to between 40 and 55°C, almost halving the energy requirement for bitumen extraction.[25]

***Co-generation***: Co-generation is the simultaneous production of heat and electricity from a single facility (Figure 2.11). All oil sands mining operations and several of the larger in situ projects include either natural gas or synthetic gas-fired co-generation. The electricity is used to operate machinery and pumps. Excess power is sold to the provincial power grid. The heat is used to separate bitumen from sand at either mining or in situ operations. The main environmental advantage of co-generation is that it produces fewer air emissions per unit of energy produced compared to other thermal-electric generating facilities.[26]

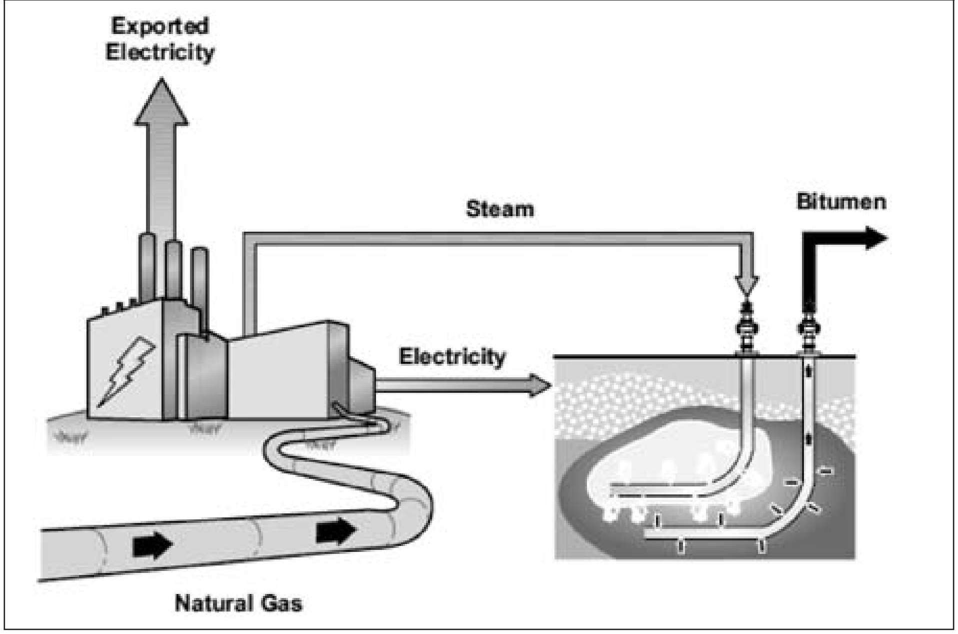
***Improved steam technologies:*** Since the widespread adoption of steam assisted gravity drainage (SAGD), well-to-retail greenhouse gas emissions have declined approximately 8% per barrel. New hybrid steam-solvent technologies could reduce these emissions by another 5 to 20% per barrel produced.[27]

## Water recycling

Although in its popular usage the term "recycling" now largely refers to the recovery of domestic waste, its first recorded usage in the Oxford English Dictionary dates back to 1926 and had its roots in crude oil refining. This old-fashioned meaning is most pertinent in the discussion of water use in oil sands operations.

While most water used originally came from the Athabasca River, the Water Management Framework for the Lower Athabasca River only allowed all oil sands projects combined to withdraw 3% of the average yearly flow of the river for their business use and only 1.3% during periods of low river flow (mainly winter). In 2010, however, the total usage by all oil sands-related activities was only 0.74% of the long-term average annual flow. This result can largely be attributed to significant water recycling throughout the industry and to increased use of saline water drawn from deep underground aquifers. Here are some advances which have made this result possible:

**Figure 2.11**
Co-Generation for In-Situ Production




**Source:** IHS CERA, *Oil Sands, Greenhouse Gases and US Oil Supply: Getting the Numbers Right*, September 2010, p. 17.

***Water use and recovery in mining operations***: Oil sands mining operations require significant volumes of water to isolate the bitumen from the sand and other solid materials. Between 40 to 70% of the water used for these operations is now recycled. As detailed below (see tailing ponds), the water that ends up in tailing ponds is ultimately recovered and reused in separation processes.

***Water use and recovery in in situ production***: Steam generation in in situ bitumen operations still uses surface water, but they have increasingly tapped into saline groundwater. (One project, Devon's Jackfish, even uses 100% saline water.) SAGD operations typically recycle 75% of their water and CSS operations around 80%. Overall, between 70 and 90% of the water used in in situ projects is recycled for further use while the remainder is treated and re-injected back into saline ground water formations so as to avoid impacting either the surface or other groundwater systems.[28] There is, however, a penalty in terms of energy use and higher costs for using brackish as opposed to fresh water.[29]

## By-product recovery and development

A hallmark of all creative businesses is the ability to turn otherwise noxious production residuals into valuable inputs for either their own or other customers' use. Many such examples can be observed in the oil sands:

***Fuel consumption in mining operations***: The Suncor and Syncrude projects power the diesel engines of their off road trucks and other equipment from their own synthetic crude oil production, thus avoiding the need to import diesel from other locations.[30]

***Fuel consumption in in situ production***: In an attempt to reduce natural gas consumption for steam generation in in situ production, some technologies were developed to use not only crude bitumen as fuel, but also some by-products of bitumen upgrading such as asphaltenes and carbon residue (or coke). (These fuels do not burn as cleanly as natural gas, but there are ways to manage their air contaminants and they do reduce natural gas demand.)[31]

***Fuel consumption in upgrading processes***: As in conventional refineries, most of the energy used in the process that converts bitumen into synthetic light crude oil is derived from burning the heaviest and least valuable portion of the main input.[32]

***Solvent recovery***: In bitumen processing plant, the mixture of sand, water and oil goes through a large separation vessel where tiny air bubbles trapped in the bitumen are separated from sand granules and float the bitumen to the surface. A thick froth composed of bitumen (60 wt%), water (30 wt%) and fine solids (10 wt%) forms at the top of the vessel which is skimmed off, mixed with a solvent and spun in a centrifuge to remove water, dissolved salts and remaining solids from the bitumen. The solvent is then recovered and reused.[33] Operating at a different geographical scale, Shell's Athabasca Oil Sands Project pumps diluted bitumen by pipeline over 300 miles away to an upgrader and refinery complex near Edmonton where the dilutant is removed, piped back to the mine and the bitumen further processed.

***Sulphur:*** Sulphur can make up to 5% of the composition of the bitumen produced in major oil sands deposits. As in conventional (sour crude) refining operations, it is an undesirable element in fuels with multiple uses in other lines of work. Because of market saturation, Syncrude only sold small amounts of the substance from the mid-1990s to 2005 and stockpiled most of it. Business then picked up and the company now produces fertilizer from it. Suncor and other companies have sold most of their sulphur directly on international markets. As a result of these and other activities (such as sour gas production), Canada is now the world's largest producer and exporter of elemental sulphur.[34]

## Tailing ponds

Like open-pit mining operations, tailing ponds provide shocking images and statistics, invoking images of toxic and rapidly expanding "lakes of industrial mining waste" containing cancer-causing agents.[35] Tailing ponds contain the residuals left over from the synthetic crude oil extraction process. They are mostly made up of water mixed with left-over bitumen, sand, organic matter, solvents used during the separation process, and minerals. As the tailings gradually settle, the water can be reused in the separation process and the remaining solids can be disposed of.

The tailing ponds now cover something on the order of 170km$^2$ of land. Of course, the best way to address them is not to create them in the first place, which is the case with 80% of oil sand deposits exploited through in situ methods. Nonetheless, where they are being used in open-pit mining operations, the speed at which the ponds work has been much improved over time, thus reducing their numbers and potential risks:[36]

***Fine clay particles recovery***: Recovering the fine clay particles is what traditionally took the longest time. The addition of gypsum to the water two decades ago first considerably sped up the sedimentation process—a matter of years rather than decades in its absence. The resulting slurry was called consolidated tailings and could be disposed of in mined-out areas. In 2010, Suncor began marketing a process which again accelerated the process, this time to a matter of weeks instead of years. Known as Tailings Operation Reductions, it revolves around a completely safe polymer flocculent long used in municipal water treatment that adheres to clay particles, causing them to bundle together and separate from the water.[37]

## Future developments

As in any other competitive sector, oil sands producers are not only competing against each other, but also against other actual or potential alternatives such as conventional and shale oil. As a result, they have a lot of incentives to explore and develop ever more efficient ways of doing things. Here are a few short descriptions of developments thought to be promising.

***THAI and propane injection***: THAI ("Toe-to-heel air injection") is a new form of in situ technology that would use air instead of water to heat up underground bitumen. It would drastically reduce the amount of natural gas required and minimize the amount of water used while producing 50 per cent less greenhouse gas emissions. The injection of propane is similarly thought to be promising.[38]

***Ore transport***: A new system by which a mobile crusher located next to a power shovel is connected to a slurry pipeline could considerably reduce the use of trucks and related air emissions. Trucks would still be needed to reach less accessible parts of mines and to carry overburden, but their number would be greatly reduced.[39]

***Steam technology***: New hybrid steam–solvent technologies could reduce well-to-retail pump water usage by 10-40% per barrel.[40]

***Electromagnetic heating technology***: This is a drilling method similar to steam-assisted gravity drainage particularly adapted for the bitumen located deep under the surface. Instead of using steam to extract bitumen, this technology would use radio wave to heat the hard bitumen. This has a huge potential to reduce water usage, greenhouse gas emissions, and cost.[41]

***RHS*** (***Re-usable hydrocarbon sorbent) technology***: Using recyclable bi-polymer beads to treat oil sands tailings, this technology separates the bitumen from the water and solid particles, allowing for bitumen to be recovered, clean water to be re-used and the solids to be re-introduced into the environment. This technology, developed by the Montreal company Gradek Energy, is in pilot phase but its inventor claims it could eliminate all tailings ponds within ten years if applied on a large scale.[42]

***COSIA***: Perhaps the most significant environmental innovation in oil sands exploitation will turn out to be institutional rather than technological. In March 2012, executives from the 12 biggest oil sands producers announced the creation of the Canada's Oil Sands Innovation Alliance (COSIA).[43] Their goal is to create an "overarching collaborative hub" in order to break down barriers in the areas of funding, intellectual property enforcement and human resources that may otherwise impede progress in terms of environmental performance. The organization promised to help signatory companies work together and with smaller firms, governments and universities.[44]

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# Conclusion

That an increasing portion of our future petroleum supply will have to come from what are now described as unconventional sources cannot be held against their development. In the oil sands as with earlier petroleum deposits, human ingenuity has delivered and can continue to deliver ever greater output ever more efficiently, in the process providing both economic and environmental benefits.

We illustrated a number of these technological developments along with some promising avenues for the near future. While energy forecasting is an uncertain art, past achievements certainly point the way towards a cleaner and more affluent future if we do not turn our back on innovation. Human beings are not only mouths to feed or energy consumers, but also brains to develop resources out of once unpromising raw materials. Alberta's oil sands are only a case in point. Resources are not, they become —and they can also become greener in the process.

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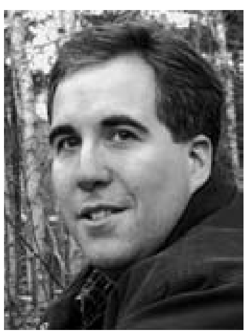

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