11.1 Focus

Tar sands and oil shale are “unconventional” oil resources. Unconventional oil resources are characterized by their solid, or near-solid, state under reservoir conditions, which requires new, and sometimes unproven, technology for their recovery. For tar sands the hydrocarbon is a highly viscous bitumen; for oil shale, it is a solid hydrocarbon called “kerogen.” Unconventional oil resources are found in greater quantities than conventional petroleum, and will play an increasingly important role in liquid fuel supply as conventional petroleum becomes harder to produce. With the commercial success of Canadian tar-sand production, and the proving of technology, these unconventional resources are increasingly becoming “conventional.” This chapter focuses on the trends that drive increased production from tar sands and oil shale, and discusses the geological, technical, environmental, and fiscal issues governing their development.

11.2 Synopsis

Oil shale and tar sands occur in dozens of countries around the world. With in-place resources totaling at least 4 trillion barrels (bbl), they exceed the world’s remaining petroleum reserves, which are probably less than 2 trillion bbl. As petroleum becomes harder to produce, oil shale and tar sands are finding economic and thermodynamic parity with petroleum. Thermodynamic parity, e.g., similarity in the energy cost of producing energy, is a key indicator of economic competitiveness.

Oil is being produced on a large commercial scale by Canada from tar sands, and to a lesser extent by Venezuela. The USA now imports well over 2 million barrels of oil per day from Canada, the majority of which is produced from tar sands. Production of oil from oil shale is occurring in Estonia, China, and Brazil albeit on smaller scales. Importantly, the USA is the largest holder of oil-shale resources. For that reason alone, and because of the growing need for imports in the USA, oil shale will receive greater development attention as petroleum supplies dwindle. Growth of unconventional fuel industries will be driven by continuing demand for liquid fuels, for which there are no non-fossil-fuel substitutes on a very large scale.

Economically, oil shale and tar sands are now competitive with petroleum. Current and future technology development seeks reliable, efficient recovery methods that keep emissions, discharges, and solids management within regulatory bounds. Once established, these unconventional oil industries will provide production assurances for decades, since there will be no decline in production, as with oil or gas. These assurances provide long-term social benefit, and support the sustainability of both the economy and the energy supply.
11.3 Historical perspective

Tar-sand and oil-shale deposits are located near the surface, and because of this humans very probably knew about both resources even before historical records were kept. In early times bitumen from tar sands was used to caulk boats and canoes. Oil shale has been used as a heating fuel by burning it directly.

The Green River Formation oil shale of Colorado, Utah, and Wyoming was well known in the pioneer days of the USA. Mining claims were made under the Mining Act of 1872. In 1912, President Taft designated the Office of Naval Petroleum and Oil Shale Reserves within the Department of Defense to manage and develop these resources, most of which occur on federal land. The Mineral Leasing Act of 1920 prohibited further private mining claims for oil shale, and in 1930 President Hoover issued Executive Order 5327, placing a moratorium on leasing of oil-shale lands. Although President Truman lifted the moratorium in 1952 with Executive Order 10355, and the US Department of the Interior took a tentative step in the mid 1970s to lease oil shale, as of the time of writing of this chapter there is no oil-shale leasing program for federal land in the USA. Some development is proceeding on state or privately owned land.

11.3.1 A commercial history of tar sands

The first successful venture in tar sands was the startup of the Great Canadian Oil Sands venture in 1967 at a location north of Ft. McMurray, Alberta, Canada. The Suncor operation of today is a continuation and expansion of this plant. The original design capacity was 50,000 barrels per day of synthetic crude oil. The GCOS venture pioneered the way for Syncrude, Canada, Ltd. to go onstream in 1978.

By the mid 1980s, the Province of Alberta and the government of Canada had realized that certain tax and royalty conditions were unnecessarily adding to investment risk, so these governments adopted fiscal policies that reduced this risk and promoted the growth of the industry. Today, well over 1 million barrels per day of syncrude and bitumen are being produced by a combination of surface and in situ technologies. Products are sold throughout Canada and the USA. The syncrude produced from the upgraders commands a premium price in relationship to conventional crude oil, largely because it contains no distillation residue. About 600,000 bbl per day of bitumen are produced from the Orinoco tar belt in Venezuela.

11.3.2 A commercial history of oil shale

The only continuing, commercially successful oil-shale operations existing today are found in Estonia, China, and Brazil. Estonia has exhibited continuous operations for about 90 years. Each of these ventures is relatively small, with total worldwide production less than 100,000 bbl per day. Several attempts were made to commercialize oil shale in the USA, beginning in the mid 1970s but ending in 1991 with the closure of the Unocal plant in Colorado.

For the most part, failures to achieve sustained commercialization in the USA have derived from two causes. The most obvious factor, which stopped several major projects (Colony, in Colorado, and White River, in Utah, for example, and nearly caused the failure of Syncrude, Canada) was the unexpected, severe drop in oil prices of the early 1980s. The second factor has derived from poor technological reliability. Poor reliability at the startup almost finished the GCOS plant in Alberta, and, had senior management at Sun Oil (the owner) pulled the plug on this operation in 1967–8 when the magnitude of the problems became obvious, it is entirely possible that there would be no tar-sand industry in Alberta today.

The lessons for the future developments of these industries are, in some ways, simple. The investment requires fiscal certainty relative to prices and policies, and they need an efficient, robust technology. Such technological characteristics can be proven only through field experience, which itself requires a significant investment. Until the investor can see the potential for long-term growth, which also requires access to adequate resources in order to support growth, commercialization of oil shale will be constrained.

11.4 Origin and location of tar sands and oil shale

Tar sands contain bitumen, a viscous form of petroleum that does not flow at reservoir temperatures. In the USA tar sand is a sandstone containing a hydrocarbonaceous material with a gas-free viscosity of greater than 10,000 cP (centipoise). Oil shale is a fine-grained sedimentary rock that contains kerogen. For the most part kerogen is a solid that, upon heating, chemically converts to oil that is fluid at room temperatures.

11.4.1 Tar sands

The geochemical origins of tar sands are similar to those of petroleum; that is, remnants of prehistoric life, mostly algae, are co-deposited with sediment in fresh, brackish, or salt water. Certain chemical processes destroy proteins and carbohydrates, which are subjected to hydrolysis and biological activity. Fats resist these processes and persist as oil. Over time these sediments are buried ever deeper and are heated by heat from the Earth’s core. Under high lithostatic pressure, these remaining “oils” are squeezed from the sediment and migrate to nearby sandstones that have greater porosity (larger void spaces between the grains), where the oil is
found today. The process of deposition, chemical changes, squeezing of oil from the shale-like sediments, also known as primary migration, and secondary migration (flowing through porous media until a trap is encountered) is known as petroleum maturation. Tar-sand bitumen is the heavy ends of petroleum, left from near-surface deposition that has allowed evaporation of the light ends, and which has not been exposed to the higher temperatures of deeper deposition over longer periods of time. Hence, in one view, tar-sand bitumen can be considered an “immature” form of petroleum.

Over the years there has been some objection to the use of the word “tar” because the native bitumen differs significantly from pyrolysis products made from coal or petroleum residue, which historically have been called tar (as in “coal tar”). In Canada, the word “tar” was dropped several decades ago because of the negative impression this made when seeking investment. Even in the USA the petroleum geologists made a serious attempt in the 1960s to rename these deposits as “surface and shallow oil-impregnated rocks,” but it is obvious why this arrhythmic definition failed to catch on.

11.4.2 Oil shale

In the simplest of terms, oil shale is an example of the original sedimentary deposits that made natural gas, petroleum, and tar sands. If oil-shale deposits were allowed the time to become buried and heated, the kerogen would be converted into petroleum and gas. As the oil migrates, the shale oil so produced is refined along its migration path, since the most polar, largest molecules are left absorbed on the sand/shale. Trapped in a reservoir, the resulting oil would be petroleum. Thus, kerogen-containing oil shale is geologically a very immature stage of petroleum, and is invariably found at shallow depths, from surface outcrops to about 3,000 feet in depth. All commercially viable oil-shale processes require the application of heat to speed the process of converting kerogen into hydrocarbon liquids, a process that would otherwise require the slow heat from the Earth. Deeper reservoirs of oil shale do, in fact, contain a liquid form of oil. The use of the word “oil shale” as applied to oil produced from deeper reservoirs such as the Bakken (North Dakota), or Eagle Ford (Texas) is a relatively recent event. For the purposes of this chapter all uses of the term “oil shale” refer to shallow occurrences where the kerogen is solid.

11.4.3 The significance of geological history

Geological history is significant for the following reasons.

- Because these oils have not migrated very far, most of the original organic material is still there, leading to quantities of bitumen and kerogen that equal or exceed the quantities of petroleum, at 2 trillion barrels or more. In other words, the sheer magnitude of the resource is significant.
- Because these resources occur in shallow deposits they are easily found and are readily measured, leading to low exploration risk. (In conventional oil production, finding the oil deposits presents a large investment risk, and the number of prospective places on Earth yet to explore is dwindling very rapidly.)
- Once the technology for recovery has been proven, there is a high degree of certainty regarding the quantity of oil that can be recovered. Even though the initial investment can be very large, the fact that the oil can be produced for 40 years or more, without decline in production rate, strongly factors into the investment decision.

11.5 Resources

When discussing unconventional resources, careful attention must be paid to the definition and use of selected terms. “In-place resource” is the amount of oil (bitumen or kerogen) that is actually found in the ground. “Proven reserves” or sometimes simply “reserves” are the amount of oil that can be recovered with today’s technology and under current economic conditions. Other terms such as “measured” mean that there is assay data from coreholes or outcrops to support the quantity cited; “inferred” means that there is evidence that the geological province extends beyond the measured area, and that there is reason to believe the hydrocarbon content continues; “speculative” means that there is a rationale for the presence of hydrocarbon but that great uncertainty exists about the extent of the deposit and the concentration of hydrocarbon. Unfortunately, not all the literature rigorously follows this terminology and care must be taken when interpreting statistics on resources.

11.5.1 Tar-sand resources

According to the US Geological Survey (USGS), the resources of tar sand of Canada and Venezuela alone are 3.7 trillion barrels, in place. Nearly 70 countries have tar-sand resources, totaling about 4.5 trillion barrels. At present, it is not know how much of the in-place resource will eventually become “reserves.” Canadian reserves are about 174 billion bbl. The USA contains measured resources of 21.6 billion barrels, with another 31.1 billion inferred resources. None of the US resources are classified as “reserves.”
Figure 11.1. Estimated world oil-shale resources (courtesy of Jeremy Boak, Colorado School of Mines).
11.5.2 Oil-shale resources

According to J. R. Dyni, of the USGS, total world resources of oil shale are 4 trillion bbls, of which 3 trillion are found in the USA. Figure 11.1 shows the latest estimates of worldwide resources. The thickest resources are located in Colorado. There are locations in the depicenter of the Piceance (pronounced pe̱-ãns) Creek Basin, where the thickness exceeds 1,000 ft at an average of 25 gallons per ton (gpt), potentially yielding more than 1.5 million barrels per acre. It is believed that this deposit is the greatest concentration of hydrocarbons on Earth.

Rich zones in Utah outcrop along the southern and eastern margins of the Uinta Basin. The depicenter of the Uinta Basin contains an intercept of 80 ft that averages 25 gpt. Oil shale in Wyoming is widespread, but generally leaner than that in Utah and Colorado. There are some near-surface deposits that could average 20 gpt that are of commercial interest. Because of their long-running industries, only Estonia, Brazil, and China can claim “proven reserves” of oil shale, albeit there are resources in the USA that possess characteristics of richness and accessibility similar to those of these “proven” deposits.

11.5.3 Classification of “resources” as “reserves”

In December of 2004, the Oil and Gas Journal made a determination that 174 billion barrels of Canadian oil sands would be reclassified from “resources” to “proven reserves.” At the time it was a somewhat controversial determination, but is now generally accepted by the securities and exchange commissions when valuing company holdings. The significance of this reclassification cannot be overstated; it vaulted Canada from obscurity as a reserve-holder to second in the world, behind only Saudi Arabia. Canada is the single largest supplier of imported oil to the USA, greater than Saudi Arabia and Venezuela combined.

In August of 2004, the Oil and Gas Journal published an article that included the relationship of grade to resource quantity. This relationship is recast in Figure 11.2, and shows that there is a sizable amount of oil shale that is rich enough and thick enough to exceed the richness of Alberta oil sands, which are already considered conventional. If the USA could prove the commercial viability of a portion of these resources (400 billion barrels is plausible), it could become the world’s largest holder of proven oil reserves.

11.6 Chemistry

11.6.1 Tar sands

Tar-sand bitumen (pronounced bitch’-u-men, if you are from the petroleum school, and bit-o’-men, if you are from the coal school) resembles the heavy ends of petroleum. There is a remarkable similarity between southern California crude oils (Wilmington, for example) and Uinta Basin, Utah bitumen. Both of these substances are high in alyclic saturates (napthenic) hydrocarbons and both are high in nitrogen-containing compounds, primarily pyridinic and pyrrolic heterocyclics. Most bitumens of the world, including that of Alberta, Canada, are of marine (salt-water) origin and are higher in sulfur and lower in nitrogen, and contain more aromatic hydrocarbons, than those from lacustrine (fresh-water) origins.

11.6.2 Oil shale

When subjected to extraction by organic solvents, the kerogen contained in oil shale does not dissolve. The reason for the insolubility of kerogen is still subject to debate. One school holds that kerogen is actually a polymer of such high relative molecular mass (or, less formally, “molecular weight”) that small-molecule organic solvents cannot dissolve it. Another school holds that the kerogen is so integrally mixed with the mineral particles that the solvents cannot access the kerogen to dissolve it. Yet another school holds that the kerogen is bonded to the minerals and solvents cannot break those bonds.

The facts show that kerogen is not converted to oils without subjecting it to cracking temperatures (generally above at least 575 °F, 300 °C). This observation would imply that there are some strong chemical bonds involved, probably in large organic molecules. Like bitumen from lacustrine deposits, oil shale is high in nitrogen content, also found in pyridinic and pyrrolic bonding structures, and low in sulfur content.

11.7 Technology

The key characteristics of unconventional oil-recovery technology are “effectiveness,” “reliability,” and regulatory “acceptability.”

11.7.1 Recovery from tar sands

Mining and surface processing
The first successful commercial venture, Suncor, formerly Great Canadian Oil Sands, mixed mined ore with hot, caustic water to disengage the bitumen from the sand. The mixture was then subjected to a series of separation steps, including a final cleanup step that involved dissolving the bitumen in a solvent to reduce viscosity and separating the mineral fines by centrifuges, filtration, and the like. Even today, all surface mining processes use some variation on this theme.
In situ technologies

In later developments variations of in situ technologies have been used to recover bitumen. In general, in situ processes add heat to the reservoir to reduce the viscosity of the bitumen, allowing it to more easily flow to the production well.

Steam-assisted gravity drainage (SAGD, pronounced SAG-DEE) is the best-known commercially practiced in situ technology. Two slotted or perforated pipes are positioned horizontally in the bed, with one pipe overlying the other. Steam is injected into the upper pipe, which heats the bed, which lowers the viscosity of bitumen, allowing it to drain to the lower slotted pipe. Bitumen is collected and pumped to the surface for further processing.

Cyclic steam stimulation (CCS) is a variation of SAGD but intercepts the beds with vertical, slotted pipes. Steam is injected for a period of time and then pressure is released, allowing gases and low-viscosity fluids to migrate back to the well. This process is repeated many times, each time the area of influence of the heat grows. This technique is sometimes referred to as “huff and puff.” Eventually the area of influence becomes large enough that it joins with heat from a neighboring well. At this point the system may revert to a “line-drive” in which steam is injected into a pattern of wells, and bitumen is recovered in a different set of wells.

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Vapor extraction (VAPEX) uses light petroleum hydrocarbons (C1–C4) in place of steam. The light hydrocarbons dissolve in the bitumen, reducing its viscosity. Gases injected under pressure provide a drive for liquid once the pressure is released, as in “huff and puff.”

Toe-to-heel air injection (THAI) deploys two perforated pipes laterally along the dip of the bedding plane, one near the top of the intercept and the other near the bottom. Air is injected into the upper pipe and a combustion front is ignited near the source of the air. A portion of the resource is burned to provide the heat that softens the bitumen, allowing it to drain to the lower pipe. The process works best when a near-vertical flame front is maintained as combustion progresses downdip through the bed.

In the Orinoco tar belt, bitumen is either diluted with condensate or subjected to heating with steam to reduce its viscosity and allow it to be pumped from wells.

11.7.2 Recovery from oil shale

Oil shale differs from tar sand primarily in the fact that the recovery process, commonly known as “retorting,” performs the cracking simultaneously with recovery. With some mild stabilization to prevent fouling of pipelines and feed heaters, shale oil can be sold directly to petroleum markets. A price penalty may be paid if the oil contains large quantities of heteroatoms (N, S), but when Unocal fully upgraded its oil in the early 1990s, and removed these heteroatoms, they received a premium price for the product.

There are three basic approaches to retorting of oil shale. These are known as surface retorting, in situ (or sometimes true in situ) and modified in situ. Surface retorts may be configured as vertical cylinders, as with Paraho, Petrosix, Union, and Kiviter technologies. They also may be configured as rotating kilns, such as ATP and Enefit, formerly Galoter, practice. The advantages of surface retorts are the high degree of control and the high yields. The disadvantages are the high capital costs and long lead times from investment to revenue.

Until Shell proved otherwise, true in situ was not viewed as commercially viable. The conventional wisdom held that oil shale needed to be broken into rubble with access for hot gases to penetrate the bed and for oil products to escape. Shell heats the entire bed with resistance heaters, and the formation of oil and gas from the heating creates permeability in the bed that allows the products to flow to a well, where they are recovered. Shell’s ICP process is now the best-known true in situ process.
The various technologies that employ a rubblized bed are generically referred to as modified in situ (MIS). The bed may be directly heated with combustion gas as Oxy and Geokinetics practiced, or indirectly heated with heat pipes as more recently proposed by Red Leaf Resources in their EcoShale process.

11.7.3 Conversion technology

For tar sand bitumen, coking or hydrocracking is needed to reduce the average relative molecular mass to ranges useful for matching the properties of petroleum products. Retorting fulfills this function with oil shale. Subsequent catalytic hydrotreating may also be needed to render the product saleable for conventional petroleum refining.

Because of the rapid growth of SAGD and other in situ processes for recovery of bitumen, there has developed an economic incentive to defer this upgrading step to refineries downstream. This has led to the use of diluents to mix with the bitumen, in order to reduce the viscosity so that they can be pipelined. If natural-gas liquids (NGL) or naphtha are used as the diluent, the mixture is call “dilbit.” If synthetic crude oil is used as a diluent, the mixture is called “synbit.” There are economic pros and cons to each, but at the moment there is insufficient diluent to meet all of the demand to transport bitumen. Hence, in some cases a diluent return pipeline is used to “recycle” NGL or naphtha diluent. Once these products have reached a conventional petroleum refinery they can be co-mixed with petroleum or separately refined to gasoline, diesel, and aviation-turbine fuels.

11.8 Thermodynamics

In the end, all energy production and use (whether renewable or nonrenewable) is about thermodynamics, and thermodynamics will increasingly dictate the economic competitiveness of energy alternatives in the future. If the energy required to produce energy is high, the net energy available for end use must command a higher price, or subsidies, in order to compete. A prime example is the high energy cost of producing biofuels, which, even after 30 years of subsidies, could not exist without that financial help. Thermodynamic efficiency governs the minimum cost of producing energy.

11.8.1 Thermodynamic efficiency in the production of oil

M. King Hubbert famously said in 1982 “So long as oil is used as a source of energy, when the energy cost of recovering a barrel of oil becomes greater than the energy content of the oil, production will cease no matter what the monetary price may be.”

In days past, the amount of energy needed to produce energy was small. Oil and coal, historically the major fossil energy resources, were near the surface and were easily recovered. Today, virtually all of the easily recovered fossil energy has been recovered. Tomorrow’s oil and coal are deeper, higher in sulfur, more remote from the end use, heavier (in the case of petroleum), and lower in heating value per ton (in the case of coal). All of these trends cost more energy to provide specification fuel.

Ultimately, all nonrenewable resources will reach a point where unfavorable thermodynamics forces a cessation of production, and no amount of economic subsidy can overcome this fundamental condition. At that point, unless thermodynamic efficiency can be improved, there will be large residual quantities of hydrocarbon left in the Earth, never to be recovered.

11.8.2 Tar sands

For every 1 million Btu of heating value that enters the process, about 950,000 is in the form of bitumen, and about 50,000 is in the form of natural gas. For this 1 million Btu, 820,000 Btu is produced in the form of synthetic crude oil, and 180,000 Btu is lost as heat for power generation and thermal losses from equipment, or stockpiled as coke. Thus, the first-law efficiency of surface-mined Canadian oil sands is about 82% (820,000/1,000,000). The energy return on energy invested (EROI) defined by Hall is 4.6 (820,000/180,000). The thermodynamic efficiency of Alberta oil sands is currently increasing with time as mining and recovery processes wring out their inefficiencies. Eventually, however, when the mine is forced to recover leaner ore, or encounters greater overburden, the first-law efficiency will begin to decline.

11.8.3 Oil shale

The first-law efficiency for production of 25 gpt oil shale is calculated at 81%. Thermodynamic efficiencies will hold steady or improve with time, as long as the process is able to utilize a dependable grade of ore. Only when the ore grade decreases, as with tar sands, will the energy efficiency be forced to decline. The first-law efficiency for recovery of the full range of grades (barren-to-pay ratios no worse than 1 to 1) is provided in Figure 11.3.

11.8.4 Concepts of self-sufficient production

Professor Charles Hall coined the term energy return on energy invested (EROI), to quantify the demand a given process places on its surroundings. Hall’s definition is meaningful for processes that compete for the same end-use energy demanded by alternative economic processes. Hall’s definition is not as meaningful.
for processes that are self-sufficient in energy. With self-sufficient processes (operating in energy balance), little, or no, energy is purchased/imported from outside the process boundaries. For the most part oil shale and tar sands are energy self-sufficient. In cases of energy self-sufficiency, it is conceivable that a process could remain economical at an EROI of less than 1, but only if the cost per unit of energy consumed is much less than the sale value of the product, per unit of energy. It is generally believed that practical processes will require an EROI of at least 2, or first-law efficiencies of at least 70%.

11.8.5 Future trends in thermodynamic efficiency

If we take Hubbert’s expression as a roadmap for the future, we can conclude that the ultimate limit of fossil energy recovery will occur at the point when the energy requirements equal the energy output. Taking what we know about tar sands, oil shale, and petroleum, we can construct the trendlines shown in Figure 11.4. Here we see that petroleum is about to enter a steep decline in recovery efficiency. More energy is needed for enhanced recovery methods, for exploration and production in remote or deep-water regions, and for upgrading of heavier, higher-sulfur crudes. What is also sobering about this curve is the current rate at which we are depleting our petroleum reserves: roughly 1% of our total endowment, every year. Oil shale initially exhibits a higher thermodynamic efficiency than tar sands because of the many opportunities to recover resources in excess of 30 gpt.

If these projections hold true, there are about 2 trillion petroleum, 2 trillion oil-shale, and 4 trillion tar-sand barrels available for recovery. Economic and technological limitations may cause these ultimate numbers to be much smaller.

11.9 Products and markets

Marketable products from tar sand and oil shale include synthetic crude oil, natural gas, asphalts, chemicals, and electricity. Syncrudes produced from tar sand or oil shale are interchangeable with petroleum, and, indeed, refiners will pay a premium for these syncrudes, over comparable-quality petroleum feedstocks, because of their consistent quality and low residue content. Whereas conventional petroleum is becoming more variable in quality, due to the increasing numbers of different producing wells blended into a single pipeline, unconventional oils maintain their consistency over years of time. This factor alone, together with the ever improving thermodynamic efficiency, virtually guarantees the market value of unconventional oils. Political treatment and regulations could skew this trend, but such manipulation can only come at the expense of consumers and taxpayers.

11.10 Economics and fiscal regime

Getting an unconventional-fuels industry started is economically very difficult. There are technical, regulatory, and fiscal risks that must be overcome for any first-generation facility. The economics are driven by resource characteristics (grade and accessibility), process efficiency and reliability, timing of capital investment,
product values, and tax and royalty treatment. Most observers believe that oil from oil shale and tar sands is economically viable at oil prices above about $60 per bbl. A significant deterrent to investment, especially for first-generation plants, is the prospect that the oil price could fall below this threshold. Nonetheless, for mature industries, capital investment is being made as rapidly as limitations on human and material resources allow.

Government tax and regulatory conditions will affect investment. If public policy determines that development is important to the economy and its citizens, then there are certain steps that can remove investment uncertainty. It has been shown in Canada that allowing investments to be expensed (as contrasted with depreciated), back-loading royalties until after investment payout, and encouraging research and development through tax regulations all accelerate investment, with little or no adverse long-term impact on public revenue. Investment responds to certainty, and policy, regulation, and statutes that are aimed at creating greater certainty help any investment decision.

11.11 Environmental and regulatory

For oil shale the most obvious environmental impact relates to surface disturbance. By mining, whether in situ or modified in situ, with the exception of some special cases of horizontal access in eroded canyons, the total surface is largely disturbed. In the case of oil shale, the disturbed acreage is small because of the great thickness of the beds. Whereas conventional petroleum extraction may recover 10,000 bbl per acre disturbed (taking Alaska North Slope as an example), oil shale will exhibit recoveries of 50,000 to 150,000 bbl per acre in Utah, and may exceed 1 million bbl per acre in Colorado.

Other environmental impacts relate to air emissions, where a permit is needed when emitting above certain regulatory thresholds. It is unlikely that technologies practiced today will discharge large amounts of water. By the time water has been cleaned for discharge, it will be useful for other process purposes such as irrigation during reclamation and dust control for haulage roads, mining, or ore preparation.

There is some question as to whether development of unconventional fuels will be inhibited by climate-change legislation. There is always a possibility that new costs will be added through regulation. However, with respect to carbon, as was shown in the section on thermodynamics above, oil shale and tar sands will be at parity with petroleum in just a few years, and thereafter may actually be superior to petroleum, relative to emission of CO$_2$, on a global basis.

The water-demand issues of tar-sand development are well documented by the Canadian experience. Over the years the net demand for water has gone down from about 5 bbls of water per bbl of oil to about 3. Oil shale, for which water is not used in the extraction process will likely require less water than oil sands. It is true that the western USA has no unused water. However, left to the marketplace, sufficient water rights can be purchased from current rights holders without an adverse impact on project economics and with net beneficial impact to local economies, albeit small ranching operations, for example, may be impacted.

Permitting and regulations for unconventional resources are still evolving. Unlike the situation in the 1970s, however, we now have well-established guidelines for impact on air, water, land use and reclamation, and other environmental values. The political discussion relative to CO$_2$ emissions is sure to be prominent, at least for the next few years, until society decides whether the problem is as serious as some pose, and, if so, what should be done about it.

It is unlikely that the CO$_2$ issue will remain in limbo for very long. Soon, shortages of fossil energy will obviate the projections of exponential growth in CO$_2$ emissions. Further, the world will come to recognize the magnitude of natural biosequestration occurring through accelerated plant growth. The combined effect of these two trends is to attenuate ultimate atmospheric CO$_2$ concentrations below levels of critical concern.

11.12 Socioeconomic factors

11.12.1 Permission to practice

Unconventional resources will be developed only when the local and state communities have given their “permission to practice.” Because of historical, spectacular busts, communities are cautious and the hurdles are high. The most notable bust was the pullout of Exxon from its Colony project on May 2, 1982, known regionally as “Black Sunday,” when the sponsors abandoned investment of more than $1 billion, and left thousands suddenly unemployed.

The situation would have been even worse if Colorado Governor Lamb and other officials had not insisted on prepayment for community infrastructure. Imagine the economic carnage, had local communities been left with bonding debt, in addition to the loss of economy. The lesson from this experience is that front-end money is needed to mitigate financial risk to the communities. Whether that money comes from project financing (making the return on investment more difficult), or from revenue sharing by the federal government (from mineral royalties collected on leases), local communities need to avoid bonding for infrastructure developments or operations.

Local communities have a strong incentive to see these unconventional-resource projects succeed, however. These projects have the same economic characteristics
as a manufacturing business, or a mining business, where steady employment and revenue can be counted on for 50 years and more. Whereas traditional oil and gas suffer from production decline, unconventional oil will give enough long-term assurances that communities can grow and diversify their economies.

The Province of Alberta, Canada and the local community of Ft. McMurray are models for engaging communities in decisions relating to socioeconomic impact. There are several mechanisms in place to build consensus of interested parties, and in complex, high-impact developments, consensus can be difficult to achieve. The USA, which has no unconventional-resource industry today, would benefit by observing how this feature has been managed in Alberta’s real-world situation. Alberta tar sands are pouring billions of dollars into provincial and federal coffers. In fact, tar sands directly and indirectly account for 17% of the total employment of Alberta.

11.12.2 National security and economy

Beneficial impacts of domestic production on economy and security are discussed throughout this book. One significant point should be made, however. If the USA could achieve the goal of reclassifying 400 billion barrels (about 25%) of its vast oil shale “resource” as “reserves,” this would make the USA the holder of the largest proven reserve of hydrocarbons in the world. Additional benefits of unconventional-fuels production, whatever the host country, are a strengthening economy, greater energy self-sufficiency, and improved balance of payments.

11.12.3 World societal benefits

The fact that unconventional resources are so widely dispersed around the world means that these resources are broadly relevant to future human economy. It is easy to think simplistically about energy being the driver of wealth and living standards, and that, given available and affordable energy, the world economy can continue to grow. However, in the face of supply shortages, other factors such as the flow of energy, who holds the control, and impacts on civility move to the fore. It is readily understood why countries are becoming increasingly concerned about future supplies of energy and are looking to their unconventional resources for long-term supply assurances. Two that come to mind are Jordan and Israel, but there are many others.

11.13 Summary

Unconventional resources will become increasingly important additions to our fuel supplies as petroleum supplies become limited. The manufacturing nature of production lends itself to increasing efficiency and lower environmental impact as technological experience matures. The lack of a decline curve provides economic assurances to communities. The sheer magnitude of these resources provides incentive to pursue production.

11.14 Questions for discussion

1. What distinguishes unconventional oil from conventional oil?
2. What are the drivers that dictate the economic competitiveness of one form of energy over another (this can be the subject of an essay)?
3. How do products from tar sand and oil shale compare with petroleum?
4. Geologically, where would you find tar sands, and where would you find oil shale?
5. What is the importance of grade in the production of energy from tar sands and oil shale?
6. How does production of energy help the local, regional, and national economy?

11.15 Further reading

- An interesting summary of the history of Alberta tar sands can be found at http://www.syncrude.ca/users/folder.asp?FolderID=5657.
- World resources of heavy oil and natural bitumen can be found in US Geological Survey Fact Sheet 70–03, August 2003.
- For a list of current oil-shale technologies and activities, see http://www.fossil.energy.gov/programs/reserves/npr/Secure_Fuels_from_Domestic_Resources_-_P.pdf.