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OIL SHALES PROCESS AND THE ENVIRONMENT

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Abstract. There are vast reserves of oil contained in the oil shales of the Americas Brazil, Russia and Eastern Europe but relatively little attention is paid to the energy expended in the mining of these shales and the environmental impacts as compared to the massive discussion on carbon emissions and off-shore oil rig spills.
This paper examines academic papers, mining industry news briefs and polemics in order to highlight the environmental consequences of the current relatively loosely controlled shale mining and processing.
It will look at the political contexts where mining of the shales could make countries independent of Middle East cartels and, in the case of Russia, a super energy-power with significant reserves of gas as well as oil, while in the case of the USA, it would strengthen the climate change deniers and worsen the chance of it signing up to the Kyoto Protocol.
Finally, it will consider the types of prevention policies and remediation strategies which would ameliorate the environmental impacts as against the economic advantages of the full and extended exploitation of the shale resources.

Keywords: oil shale, sustainability, remediate, environment; retort; problem, water, economic.

1. Introduction

Oil shale is a fine-grained sedimentary rock that contains significant amounts of kerogen, an organic matter that has not gone through the 'oil' window" of elevated temperature and pressure necessary to generate conventional light oil, and is a solid mixture of organic chemical compounds that can be converted into synthetic liquid fuel similar to oil, or into shale gas similar to petroleum-derived natural gas. Kerogen has a high hydrogen-to-carbon ratio, giving it the potential to be superior to heavy oil or coal as a source of liquid fuel (National Petroleum Council-USA 2007).

Historically he use of oil shale can be traced back a long way with oil shale being used for healing in Wuerttemburg in the 16th century and, by the 17th century, oil shales were being extracted in several countries. In Sweden the alum shale of Cambrian and Ordovician age, noted for high concentrations of metals including uranium and vanadium. The alum shales were also roasted over wood fires to extract potassium aluminium sulphate, a salt used in tanning leather and for fixing colours in fabrics. In the late 1800's, the shales were retorted (distilled) on a small scale for oils. Production continued through World War II but ceased in 1966 because of the availability of cheaper supplies of petroleum from crude oil. In addition to the oils, some hundreds of tonnes of uranium and small amounts of vanadium were extracted from the Swedish alum shales in the 1960s (Dyni 2005).

As well as oils, energy itself has become a commodity and, as such, is subject to market pressures which have driven up world prices for gas and oil and which are now making the mining of shales for oil more economic. Moreover, because of cartels such as OPEC and the political manipulation of oil and gas supplies by Russia, it has become incumbent on countries such as the USA to exploit their own shales to provide 'homeland security'. The contingent results are that extra emissions and contamination from the mining sites, and even spills from the pipelines, can affect the environment severely. Oil shale extraction is also very energy-intensive, researchers have found that a gallon of shale oil can emit as much as 50 % more carbon dioxide than a gallon of conventional oil over its given lifecycle from extraction to car exhausts.

Concurrently, in the USA the fight between the Climate Change Deniers and the Environmentalists has spilt over into the Senate and the Congress in which, with big business pushing for less environmental legislation driving the Republicans, there is acrimony and indecision and economics, as in other oil shale producing countries, is winning over considerations of the long-term effects on the environment.

The paper is based on narrative analysis as outlined by Alasuutari (1995) and pulls together many of the ramifications of the oil shales industry and it's practical effects on humans, the environment and economics. The structure is formulated accordingly, going from world resources of oil shales, the process of extraction and it's economics, the high use of water and energy, the pathways of pollution and contamination, remediation strategies and the effect on nature and humans.

The first section outlines the distribution and extraction of shale oils.

2. Shale distribution and polemics

2.1. World distribution of oil shales

Environmental Geologists believe there is more oil shale in the rocks of the world (three trillion barrels worth) than there is in currently identified *normal* oil reserves globally (reserves are present but nor necessarily economically recoverable; resources are those oils which are recoverable with current technology). Oil shale has been mined extensively in Brazil, China, Estonia, Germany, Israel and Russia, but up to two-thirds of the world's supply lies in the Green River basin of the Western United States, including parts of Wyoming, Utah and Colorado - to date, these American oil shale resources are only now becoming economically viable, (Earth Talk 2009). In 2004 the USA Department of the Environment produced the figures shown in Table 1 in megabarrels, with the figures below these in billion tonnes.

In Eastern Europe, the Baltic Oil Shale Basin (see Fig. 1.) showing the Estonia and Tapa deposits are in the west of the Basin, the former being the largest and highest-quality deposit. Permanent mining began in 1918 and has continued until the present day, with capacity (both underground mining and open-cast) increasing as demand rose. By 1955 oil shale output had reached 7Mte and was mainly used as a power station/chemical plant fuel and in the production of cement.

Russia owns the biggest oil shale reserves in Europe equal to ~35.5Bte of shale oil and more than 80 oil shale deposits have been identified. The main deposits are located in the Volga-Petchyorsk province and the Baltic Basin and the deposits were worked in the 1930s, but abandoned due to environmental problems.

The main oil shale industry was concentrated on the Baltic Basin in Slantsy, but at the end of the 1990s the Slantsy oil shale processing plant and oil shale-fired power station were converted to use traditional hydrocarbons and mining activities ceased before 2005.

The current mayor of Slantsy says: "*We are waiting for a true owner of the plant, someone who would worry about solving the plant's problems," said Alexander Khopersky, the mayor of Slantsy, home to 35,000 people. "It is closely connected with the town's development: its stability, stable jobs, stable salaries."*

However, it is apparently a State policy to rescue uneconomic oil shale businesses by obliging Russian millionaires to buy such companies from the State, make them profitable, and take up some of the unemployed. As reported in Bloomsberg Business (Khrennikov and Shiryaevskaya 2010), the company Renova owns 40 % of the Zavod Slantsy plant, which was built to produce a petroleum-like fuel from shale rock containing oil. Renova has mines near St. Petersburg that contain oil shale and plans to buy the state's 56 % stake in the factory.

Table 1. Oil shale resources

deposit	country	period	Mbrls
Green River Formation	USA	Tertiary 65-2.6Mbp	1,466,000
Phosphoria Formation	USA	Permian 299-251Mbp	250,000
Eastern Devonian	USA	Devonian 416-359Mbp	189,000
Heath Formation	USA	Carboniferous	180,000
Olenyok Basin	Russia	Cambrian 542-488Mbp	167,715
Congo	Congo		100,000
Irati Formation	Brazil	Permian	80,000
Sicily	Italy		63,000
Tarfaya	Morocco	Cretaceous 144-127Mbp	42,145
Volga Basin	Russia		31,447
St. Petersburg, Baltic Oil Shale Basin	Russia	Ordovician 488-437Mbp	25,157
Vychegodsk Basin	Russia	Jurassic 199-145Mbp	19,580
Wadi Maghar	Jordan	Cretaceous	14,009
Dictyonema shale	Estonia	Ordovician	12,386
Timahdit	Morocco	Cretaceous	11,236
Collingwood Shale	Canada	Ordovician	12,300
			tonnes
	Italy		10.5B
	Estonia		2.5B
	France		1B
	Belarus		1B
	UK		0.5B

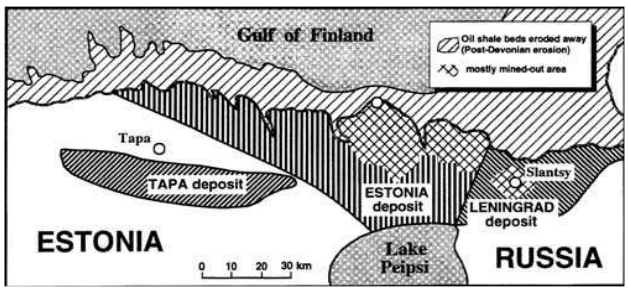

Fig 1. Main deposits in the Baltic Basin

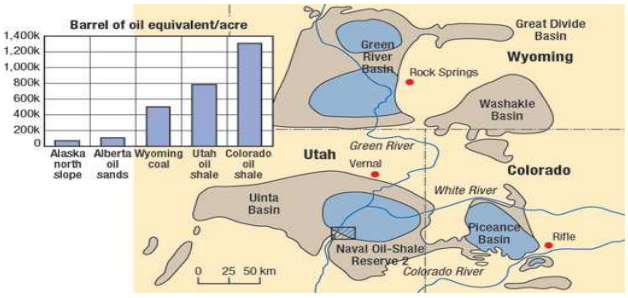

Fig 2. USA oil shale distribution (main)

Within the USA, which has some 70 % of the of the world's oil shale reserves (Perry 2005), the two most important are in the Green River formation in Colorado, Wyoming and Utah (see Fig. 2); the low-grade black shales are in Nevada, Montana, Alaska, Kansas and other states. These were formerly uneconomic but, with Brent Crude (normal oil) reaching $115/brl (7/3/2011) these will now be exploited as, with a full production, the extraction cost could be reduced to some $30/Rand Corporation (Bartis *et al*. 2005)

2.2. Politics and energy

In the USA, all the oil shales are under the control of one sovereign country whereas, for the other super-power Russia, the main shale resources have moved outside it's national remit with the dissolution of the Eastern Bloc, leaving the main reserves in Estonia. As can be noted from the recent dispute between Romania and Russia (October 2010) over gas supplies (WAZ.euobserver.com), energy can be a potent political weapon.

Table 2. Oil imbalances – USA & Brazil

USA oil usage p/a	**Brazil oil usage p/a**
23.4 bbl/person	4.4 bbl/person
USA oil production p/a	Brazil oil production p/a
8.1 bbl/person	3.5 bbl/person
Imbalance: -13.3 brl/person	**Imbalance:** -0.9 brl/person

(brl= 1 barrel of oil = 35 gal [UK] =5.6 ft^3

In the USA, in response to the OPEC embargo and energy problems of the 1970s, Congress passed the Energy Security Act, establishing the US Synthetic Fuels Corp (Bloom *et al.* 2008) It authorized up to $88B for synthetic fuels projects, including oil shale. Further, in 1980, Congress approved $14B for synthetic fuels development and, in the same year, an Amoco experimental in-situ facility produced 1,900Bbrl.

In 1981 construction began on a 50,000 barrels per day plant then, in 1982, there was an oil price/demand collapse which ultimately led to closed mines and the loss of some 30,000 jobs. By 1985, Congress had abolished the Synthetic Liquid Fuels Program after spending $8 billion over 40 years. Only recently has the emphasis developed on oil shales due to the increase in crude oil prices.

2.3. Process

The extraction of the useful components of oil shale usually takes place above ground, with severe contamination, although several technologies operate underground (Weil *et al.* 1979). In either case, the chemical process of pyrolysis converts the kerogen in the oil shale to synthetic crude oil and oil shale gas.

However, two authors (Mitchell 2006; Rapier 2010) have highlighted the world imbalances in synthetic and crude oil, and the effects on the oil market, as well as the type of oil usage differences between the USA and Brazil.

In the long-term this could affect the economics of the oil from shales.

Most conversion technologies involve heating shale in the absence of oxygen (pyrolysis) to a temperature at which kerogen decomposes into gas, condensable oil, and a solid residue. The process of decomposition begins at relatively low temperatures (300 °C), but proceeds more rapidly and more completely at higher temperatures (Koek 2008) and decomposition usually takes place between 450 °C and 500 °C.

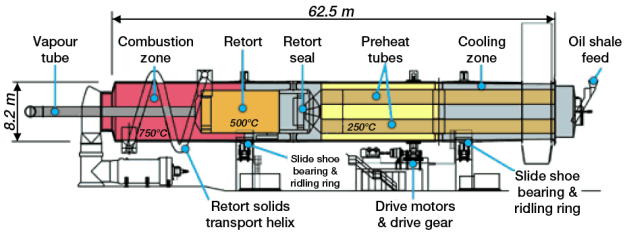

Fig 3. Alberta Taciuk Processor retort

In the past, the most common production technology has been surface mining, followed by processing in above-ground retorts (Figure 3) at a temperature of about 500°C which converts kerogen to oil in about an hour.

This approach is simple, but requires expensive surface facilities, and the disposal of significant quantities of tailings; both of these aspects have significant economic and environmental problems. Moreover, raw product quality is poor compared to conventional crude oil, however upgrading using conventional hydro-processing techniques yields high-quality finished products.

Above-ground retorting processes tend to yield a lower API gravity (American Petroleum Index) shale oil than the *in situ* processes. Shale oil is best for producing *middle-distillates* such as kerosene, jet fuel, and diesel fuel and world-wide demand for these distillates, particularly for diesel fuels, increased rapidly in the 1990s and 2000s.

Innovations are needed that allow oil shale to be processed at lower temperature without an increase in reaction time to ensure improved economics and improved product quality. The in-situ process conversion wherein wells are drilled and the oil shale reservoir is slowly heated to about 350°C, at which temperature kerogen is converted to oil and gas in a time scale of months.

Using an in-situ conversion process at pilot scale, Shell has extracted a good quality, middle-distillate refinery feedstock, requiring no further upgrading. In order to contain nascent fluids, and to prevent ingress of ground water into the reaction zone, Shell generates a freeze wall around the production mass but, while process-economic this does not avoid environmental consequences. Chevron adopts a different approach to facilitate the protection of groundwaters, whereby conversion takes place within an artificially fractured volume, which is separated from nearby aquifers by unfractured and impermeable oil shale (USA National Petroleum Council 2007).

By definition there are *true in-situ* processes and *modified in-situ* processes: *True in-situ* processes do not

involve mining the oil shale whereas *modified in-situ* processes involve removing part of the oil shale and bringing it to the surface for modified *in-situ* retorting. In order to create permeability for gas flow in a rubble chimney, the rubble is created with explosives, even nuclear explosions were considered in the oil-shale (Parker 1971; Lee *et al.* 2007) *In-situ* processing can potentially extract more oil from a given area and depth of land than *ex-situ* processes, since they can access deeper shales than possible (economically) with surface mines (Savage 2006).

Chevron has a simpler technique that takes advantage of the low hydraulic permeability of oil shale formations to isolate heated process volumes from surrounding aquifers. Since in-situ conversion technology is relatively new, it is not yet clear which specific technologies can give the best economics with the least environmental impact in the coming years, however, the efficient use of heat energy will be certain to be an economics issue.

To increase the efficiency of oil shale retorting and hence the economic viability, several co-pyrolysis processes have been designed ane tested, in which materials such as biomass, peat, waste bitumen, or rubber and plastic wastes are retorted along with the oil shale (Tiikma *et al.* 2006; Ozdemir 2006). Some modified technologies propose combining a fluidized bed retort with a circulated fluidized bed furnace for burning the by-products of pyrolysis (char and oil shale gas) and thereby improving oil yield, increasing throughput, and decreasing retorting time which itself will reduce energy usage.

3. Oil shale economics

3.1. Fundamentals

To enable sensible exploitation of shale oil it must be economically viable and any attempt to develop oil shale deposits can only succeeed when the shale-oil production cost is lower than the price of petroleum or its other substitutes.

According to a survey conducted by the RAND Corporation, the cost of producing a barrel of shale oil at a *model* surface retorting complex in the USA (comprising a mine, retorting plant, upgrading plant, supporting utilities, and spent shale reclamation), would range between US$70–95 ($440–600/m^3), adjusted to 2005 values.

Comparing these numbers with those in the Figures 4–6 it can is seen why oil from shales is now becoming economic although the supply risk costing would generate an even higher benefit to the security of any producing country.

One measure used to assess the viability of oil shale as an energy source is the ratio of the energy produced by the shale to the energy used in it's mining and processing, namely "Energy Returned on Energy Invested" (EROEI). A 1984 study estimated the EROEI of the various known oil shale deposits as varying between 0.7–13.3 (Cleveland *et al.* 1984) and some companies and newer technologies assert an EROEI between 3 and 10.

To increase the EROEI, several combined technologies were proposed. These include the usage of process waste heat, e.g. gasification or combustion of the residual carbon (char), and the usage of waste heat from other industrial processes, such as coal gasification and nuclear power generation (Tiikma *et al.* 2006; Aboulkas *et al.* 2007). It is not clear that the energy expended in creating suitable water, perhaps de-salination of sea waters, for the processes has been taken into account, nor of the extra costs in arid countries.

Fig 4. Brent crude price trend

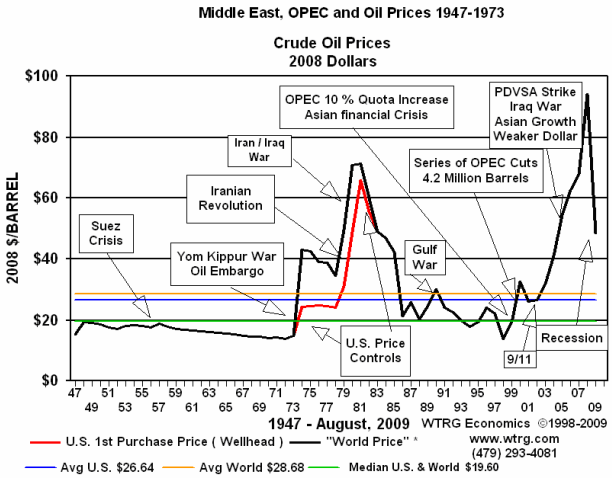

Fig 5. OPEC price trends 1947-1973

Then, assuming a gradual increase in output after the start of commercial production, one general analysis shows a gradual reduction in processing costs to $30–40 per barrel ($190–250/m^3) and after achieving the milestone of 1B barrels, Royal Dutch Shell stated that their technology would realize a profit when crude oil prices are higher than $30 per barrel, while some technologies at full-scale production could reach profitability at oil prices even lower than $20 per barrel (USA National Petroleum Council 2007).

3.2. Economics of extraction

One set of the RAND estimates (Bartis *et al.* 2005) considers varying levels of kerogen quality and extraction efficiency. In order to run a profitable operation, the price of crude oil would need to remain above these levels. The analysis also discusses the expectation that processing

costs would drop after the establishment of an efficient facility.

Such a facility could give a cost reduction of some 35–70% after producing its first 500 million barrels (79×10^6 m^3). Assuming an increase in output of 25 thousand barrels per day (4.0×10^3 m^3/d) during each year after the start of commercial production, RAND predicts the costs would decline to $35–48 per barrel ($220–300/m^3) within 12 years. After achieving the milestone of 1B barrels (160×10^6 m^3), its costs would decline further to $30–40 per barrel (Rex *et al.* 1984).

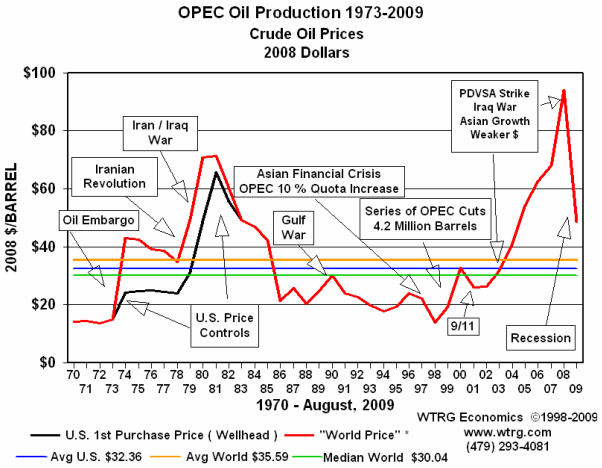

Fig 6. OPEC price trends 1973–2009

As an example, in 1959 an Oil Shale Industrialization Commission was set up to study the construction of a plant in Tremembé in Brazil followed by a prototype oil shale retort plant, at Sao Mateus do Sul, which began operations in 1972. A larger version was built in 1991 that was 35ft in diameter producing some 550 tons of "oil" per day (Fisher 2005). With a combination of the internal resources represented by the oil shales and eco-fuel flora, Brazil is becoming independent of world market prices as Dan Rather says in an article in the 'Ethanol Solution'. If this aggressive independence policy were adopted by the USA then it too could reach a position independent of world markets in oils (Bill Clinton and the New York Times).

4. Environmental impacts

4.1. General environmental consequences

Oil-shale extraction can damage the biological and recreational value of land and the ecosystem in the mining area (US Bureau of Land Management -BLM, 2008). For instance, combustion and thermal processing generate contamination, waste, ash and CO^2 as well as volatile organic compounds and other fugitive gasses (Picard 2010). However, *in-situ* conversion processes and carbon capture and storage technologies may reduce some of these concerns in the future, but at the same time they may cause other problems, including groundwater pollution (USA National Petroleum Council 2007).

Among the water contaminants commonly associated with oil shale processing are oxygen and nitrogen heterocyclic hydrocarbons (ring-structured, both aromatic and non-aromatic) as well as quinoline derivatives (aromatic, contains a benzene ring) and pyridine (aromatic – toxic) (USA Environmental Protection Agency 2000).

Environmentalists oppose production and usage of oil shale, as it creates even more greenhouse gases than conventional fossil fuels, in this context (Cleveland *et al.* 1984) the US Section 526 of the *Energy Independence And Security Act* prohibits government agencies from buying oil produced by processes that give more greenhouse gas emissions than would traditional petroleum (Bloom *et al.* 2008) – this represents an informal and hidden barrier to trade similar to EU regulations affecting USA imports (Porto 2005), other environmental activists, including members of Greenpeace, have organized strong protests against the oil shale industry, in one instance, Queensland Energy Resources put the proposed Stuart Oil Shale Project in Australia on hold in 2004 due to Greenpeace lobbying (Macdonald-Smith 2008).

Concerns over the oil shale industry's use of water have also been expressed as above-ground retorting uses between one and five barrels of water per barrel of produced shale-oil A 2008 environmental impact statement issued by the US BLM (2008) stated that surface mining and retort operations produce 8.4 to 42.3l/t of waste water from processed oil shale.

In 2002, the oil shale-fired power industry used 91 % of the total water consumed in Estonia. (Tallinn 2009). Depending on technology, above-ground retorting uses between one and five barrels of water per barrel of shale oil. In 2008 US Bureau of Land Management stated that surface mining and retort operations produce ~1.9 to 9.1gal of waste water per ton of processed oil shale. *In situ* processing, according to one estimate, uses about one-tenth as much water (also: DOE Office of Petroleum Reserves USA). A different group calculates that the process requires up to five barrels of water for dust control, cooling and other purposes for every barrel of shale oil produced.

Apart from the arid regions of the USA and Israel, in other countries where there is a general lack of water resources to service the population, the oil shale process waters are effectively exported as 'virtual water' in just the same way as this term is applied to fruit and vegetables. While the direct costs of water and energy can be amortized in the cost of production and taken into account in the price per barrel, the cost to a host country of making provision for replacement water resources is not apparent and could be included in the term 'the rape of the commons' derived from Marxist philosophy but filled out by Hardin (1968) - a tenet applied vigorously in the Soviet era industry

Looking at some other environmental problems, USA patent: 4,637,464 (Forgat *et al.* 1987) describes an in-situ retort process in which, during retorting, oil shale retort water is formed from the thermal decomposition of kerogen which is referred to as "water of formation" which, if left untreated, is not suitable for safe discharge into lakes and rivers or for use in the another thirty five downstream shale oil processes, because it contains a variety of suspended and dissolved pollutants, impurities and contaminants such as raw, retorted and spent oil shale

particulates, shale oil, grease, ammonia, phenols, sulphur, cyanide, lead, mercury and arsenic. Further, in the unproven pulsed combustion heating system, the retort water purge can be purified water, condensed steam, or retort water but these are only partially biodegradable as, even when treated, it typically contains oil shale particulates, shale oil, ammonia, and organic carbon at ten times the normal (see also DOE fact sheet).

Issues such as those mentioned above caused environmentalists in the USA,, including the Wilderness Society, Sierra Club and Natural Resources Defense Council, to team up to open proceedings in January 2009 against the federal government bill for releasing all Western USA land to oil shale development; the suit contends that it failed to consider air quality and endangered species impacts in the region properly. The groups also contended that the development would require the construction of 10 new coal-fired power plants in order to retrieve and process the oil shale, thus significantly increasing the carbon footprint of the region.

4.2. Process related impacts

The USA Department of Energy's fact sheet "U.S. Oil Shale Resources" talks about the potential for recoverable oil shale of 1.8 trillion barrels but says, if realized, this would create severe detrimental environmental effects. Also, Grunewald (2006) comments that surface retorting, which requires underground or surface mining would strongly alter the local ecology and current land uses, while strip mining would create some of the largest open-pit mines in the world.

Details of consumption and production figures can be found in the 2008 'Mining Oil Shale' report, this involving example environmental impacts, more pronounced in surface mining than in underground mining (Sabanov 2007). They include acid drainage induced by the sudden rapid exposure and subsequent oxidation of formerly buried materials, the introduction of metals into surface-water and groundwater, increased erosion, sulphur-gas emissions, and air pollution caused by the production of particulates during processing, transport, and support activities. As an illustration of the relative degree of emissions from oil shales is given in Figure 7; it should be noted that methane is some 30 times more potent as a greenhouse gas than CO^2.

For Estonia, in the Baltic Basin Region, Sabanow (2007) reported that the processes in overburden rocks and in pillars have caused significant environmental side effects including significant subsidence of the ground surface. This subsidence causes soil erosion and flooding, swamp formation, agricultural damage, deforestation, changes in landscape, ground water level decreasing and unstable mine cavities. It is also said to create technical, economical, ecological and juridical problems as exemplified by Farber (2009).

The total volume of waste from oil shale mining is 180Mte and covers 188ha from mines and 150ha from open casts in cone-shaped dumps. The volume of waste on used landfills on "Estonia" mine 70Mte, on "Viru" mine 35Mte. About 220km^2 of oil shale has been mined by the pillar and chamber method with 61 % of the total oil shale from the underground mines. One half tonne of waste is created in the process of oil shale enrichment per tonne of extracted oil shale.

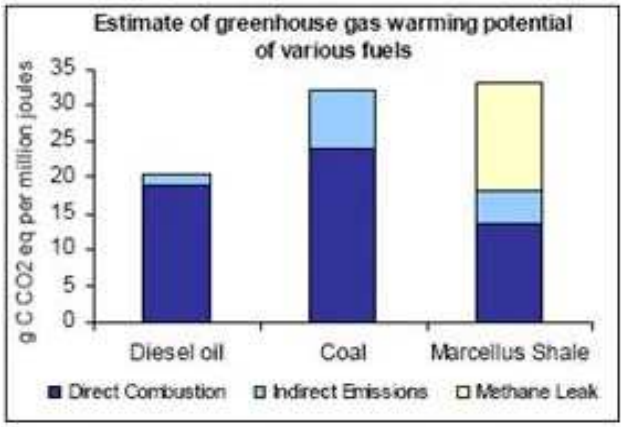

Fig 7. Shale methane (Hansen 2006)

The introduction of heavy and other metals into surface and groundwater, increases erosion, sulphur-gas emissions, and air pollution caused by the production of particulates during processing, transport, and infra-structure. In 2002, about 97 % of air pollution, 86 % of total waste and 23 % of water pollution in Estonia came from the power industry, which uses oil shale as the energy resource for its power production.

In addition, a report from the Soil Science of America (2009) highlights the problems with the oxidization of sulphides in waste piles of mine tailings (eg: shale rock) which produces high concentrations of sulphate, iron, and other metals and frequently has very low pH values ref. In waste rock piles with high permeability and sulphide content, the oxidation of sulphides, an exothermic reaction, produces heat, sometimes resulting in very high temperatures. Air with oxygen is sucked into a pile by convection, and this accelerates the pyrite oxidation rate. Generation of contaminants is much higher than in the case of the oxygen diffusion that typically occurs in mine tailings, and environmental impact may be very severe. There could therefore be a significant danger to the local ground, surface waters and groundwaters and explained in the USA National Petroleum Council paper 2007.

4.3. Contaminant pathways

These are the pathways which connect industrial operations and chemicals with an ultimate destination; damage to the environment, flora and fauna, can occur along the pathway and at the end destination. These pathways can be extended throughout a food chain eg: if a polar bear eats a fish which is contaminated with DDT, then the bear itself becomes contaminated and the chemical (among others) is accumulated as a toxin in the bear's fat. Tamhane (2010).

Similarly, if a human being drinks waters originating from ground waters contaminated with carcinogenic hydro-carbons, then these chemicals will find a home in the human body with the potential to cause illness or a premature death (Carson 1962).

Table 3. Examples of chemicals in and from kerogens

chemical	risk phrases	example effects
kerogen	contains the next two chemicals	tumorigen mutagen
bitumen	R10 R51/53 R65 R66	carcinogenic
naphta	R11 R38 R45 R65	carcinogenic
quinoline	R20 R21 R22 R36 R37 R38 R41 R40.	mutagenic carcinogenic
pyridine	R11 R20 R21 R22.	fertility & other harmful effects
benzene		carcinogenic
toluene		
phenols	R24 R25 R34 R36 R37 R38	toxic, corrosive, systemic
sulphur oxides	R23 R24	toxic, corrosive
cyanide	R26 R27 R28 R32 R34	toxic
lead	R23, R25	toxic carcinogenic
mercury	R21 R22 R23 R33 R50 R53.	tumorigen, mutagen, reproduction

(the risk phrases are readily available on the internet)

5. Discussion

The balancing of the oil shale industry profits against market forces (eg: OPEC) against world-wide 'homeland security' against environmental economics is implicitly encapsulated in the (US) Bureau of Land Management environmental impact report.

The key elements highlighted in this report demonstrate that the environment is going to be severely damaged, but also that it is the number of jobs and the interests of business that form the imperatives. (BLM 2008). Some hope emerges from the change of US administration from the Bush to the Obama era; the current administration is far more environmentally minded, but Republicans in the Senate are vigorously pro-business, and business is vigorously pro-oil shale.

On the other hand Bartis et al (2005) had set out the major environmental problems for the USA, but which could apply to any country, all but the first two the BLM had apparently chosen to ignore:

- management of the oil shale resources;
- socio-economic impacts on local economies;
- surface and groundwater protection;
- air quality protection;
- wildlife habitat quality and fragmentation;
- protection of wilderness, riparian, and scenic values;
- cultural resource protection;
- threatened and endangered species
- multiple mineral development.

Bartis went on to suggest some policies for ensuring a better protection of the environment, among which were:

- develop and implement research plans to establish options for mitigating ecological damage;
- a multiyear hydrological, geochemical, and geophysical monitoring program
- conduct research for analyzing options for long-term spent shale disposal
- model regional air quality to determine preferred locations for federal leasing and inform decisions on air quality permits for initial plants.

These suggestions are worthy, but most internet postings to date do not suggest that there is much hope for environmental protection where national economics, national energy security and 'big business' are driving and controlling the environmental agenda, as with stalling Kyoto (China, Russia, USA), and imposing the home-grown USA economic paradigm on the World Bank and the World Trade Organization.

6. Conclusions

National security considerations, oil dependency, and oil extraction costs will ensure that the oil shale business and it's unwanted environmental impacts are here to stay.

What is uncertain is what the balance will be between company profits (excluding clean-up costs etc) and the cost of environmental remediation. It is likely that the BATNEEC criteria (best available technique not entailing excessive cost) will be severely diluted by company profit and shareholder considerations. 'If a company cannot make sufficient profit, then it cannot pay for remediation'! And, remediation will be counted as a positive element of GDP (gross domestic product).

The environmental impacts will be severe, many times the impact of occasional oil spills from deep water oil wells like the Horizon rig in the gulf of Mexico and the contaminants will end-up in the fatty tissues of *man and beast*. Like coal, oil shale mining and product use is a dirty industry!

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