OIL SHALE

OILY ROCK THAT CAN BE BURNED, OR PROCESSED TO PRODUCE A LIQUID FUEL.

EXTREMELY **INEFFICIENT** AS A FUEL, RESULTS IN **VERY HIGH** GREENHOUSE GAS EMISSIONS AND SERIOUS WATER **POLLUTION**.

WHAT IS IT?

Sometimes known as "the rock that burns", oil shale is sedimentary rock that is rich in kerogen, a solid tar-like material, which becomes a liquid when heated. It can be burned in its rocky form straight from the ground, or oil and gas can be extracted using a process called 'retorting'. This is done either after the oil shale has been mined, where it is crushed up and refined, or 'in-situ' (in place) underground by directly heating the deposit and extracting the resulting liquid, which then requires further processing. The 'oil' produced from oil shale, sometimes referred to as synthetic crude, synfuel or shale oil (see below) is of lower quality and contains less energy than conventional crude oil. Global resources are estimated at 4.8 trillion barrels.[1]

Oil shale has been used as a fuel for thousands of years, initially burned directly as a source of heat and later to produce steam and electricity. It was not until the mid 19^{th} century in France and Scotland that it was used to produce oil on an industrial scale. As crude oil extraction increased after the Second World War, oil shale became less attractive as a fuel source. Production of synthetic crude from oil shale peaked following the 1973 oil crisis and then fell sharply. It is only recently, with high oil prices, increasing scarcity of conventional crude, and countries' increasing concern over energy security, that there has been a resurgence in interest in oil shale.

Oil shales vary significantly in terms of the quantity of kerogen and the other substances they contain, some of which can be commercially extracted along with the oil shale. Uranium, vanadium, zinc, alumina, phosphate, sodium carbonate minerals, ammonium sulphate, and sulphur are all sometimes found in oil shales.[2]

OIL SHALE OR SHALE OIL?

Confusingly, 'shale oil' can refer to the liquid fuel extracted from 'oil shale' by heating it (this was always the traditional meaning of the term), or to oil extracted from shale rock using techniques such as fracking. The second definition began being used when the US boom in shale gas resulted in shale formations also being exploited for oil (see separate 'Shale Oil' factsheet for more information). A great deal of confusion and disagreement persists, but many have started to use the term 'tight oil' to refer to oil extracted from shale formations using horizontal drilling and fracking. Even more confusingly, the term 'oil shale', which usually means the oily rock rich in kerogen being discussed in this factsheet, is also sometimes used to refer to shale formations which contain oil.

Baffled? Well, you're not alone!

Shell's experimental freeze wall oil shale installation

HOW IS IT EXTRACTED?

Oil shale can be burned in its rocky form, or can be processed, to produce a form of oil. This processing can either be done after the oil shale has be mined, or can take place underground using in-situ techniques.

The raw oil shale is usually extracted using surface mining techniques, such as open pit or strip mining, but underground mining can also be used. When burned directly, oil shale is usually used to generate electricity. In Estonia, which has by far the most developed oil shale industry, 90% of the country's electricity is provided by oil shale fuelled power stations.[3]

However, currently the most financially attractive feature of oil shales is that they can be used to produce liquid fuel.

There are a variety of 'surface retorting' techniques used to extract liquid after mining. These involve crushing up the mined oil shale, heating it to around 450°C which converts the kerogen into liquid which is then removed and processed. Surface retorting methods have been around for a long time and are currently used on a commercial scale in various countries including China and Estonia. Surface retorting results in high greenhouse gas emissions, uses large amounts of water and creates large amounts of solid waste (the shale actually expands during the processing, meaning there is more volume of waste than was dug out the ground).[4]

ⓒ Wikipedia user: PjotrMahh1 2005

An oil shale excavator

Various techniques have either been experimented with or considered for underground in-situ retorting.[5] Methods of heating include placing gas powered fuel cells below the oil shale to heat it; drilling into the deposit and injecting it with super-heated air, steam or gas; using electrical resistance heaters; and heating using radio or microwaves which can penetrate into the deposit instead of slowly heating from the outside. The heating process usually takes a number of years before the liquid can be extracted.

Many methods of in-situ extraction also require breaking up the oil shale to allow fluids to flow more easily. Some include the use of 'fracking' (hydraulic fracturing), explosives, or partially mining the deposit (in the 1960s, nuclear explosions were even considered as a way of breaking up the oil shale!). Fracking is a controversial technology also used in shale gas extraction, which involves drilling into rock and injecting pressurised fluid, creating cracks that allow trapped gasses and liquids to flow. The fracking fluid consists of water, sand and a variety of chemicals which are added for various purposes, such as dissolving minerals, killing bacteria that might plug up pipes and wells, or reducing friction.

Other proposed methods of in-situ extraction include mining into the deposit then setting off explosives to turn the oil shale to rubble (known as rubblisation), then igniting part of the deposit and using the heat to convert kerogen into synthetic crude which is then extracted. Nuclear reactors have also been proposed as a heat source.[6]

Shell have also been experimenting with a 'freeze wall' technology, in which chilled liquid is circulated through a system of pipes, freezing water in the surrounding rock to form a wall of ice. This freeze wall is intended to both keep groundwater away from the area where retorting takes place, and to stop pollutants from the process contaminating groundwater.

Oil shale gas is also produced during retorting and can be either separated and sold off, used as a fuel to provide heat for retorting, or heated and injected underground to convert kerogen to liquid during in-situ retorting.

Many of these techniques have been demonstrated on small scale test sites. However, experiments have been plagued with difficulties and there is currently no in-situ oil shale extraction taking place on a commercial scale. So far it has simply proven to be too difficult, too expensive and too environmentally damaging.

CLIMATE CHANGE

The amount of CO_2 produced from using oil shale for energy varies significantly depending on composition of the oil shale, the method of extraction and how it is used to generate energy. However, regardless of the deposit exploited or method used, oil shale is a highly greenhouse gas intensive energy source.

A major problem with using oil extracted from oil shale as an energy source is the amount of energy input needed in order to get energy out (known as Energy Return On Investment or EROI). A 1984 study estimated the EROI of the various known oil shale deposits as varying between 0.7–13.3;[7] The World Energy Outlook 2010 estimated the EROI of *ex-situ* processing as around 4 to 5 and *in-situ* processing as low as two.[8] The true value could be even lower: a review by Western Resource Advocates found that the most reliable studies, which include self-energy (energy released by the oil shale conversion process that is used to power that operation), suggest an EROI for liquid fuel from oil shale between one and two, but could not guarantee that it was greater than one.[9] These all compare badly with current conventional oil and wind energy which both have an EROI of about 25.[10] [11] Whatever the exact figure, it is clear that oil shale is an extremely inefficient fuel source.

Part of the reason for the low EROI values for liquid fuels derived from oil shale is that kerogen is like an immature form of crude oil, and it requires significant further processing (particularly heating) to make up for the final stage of geological processing that produces oil.

Burning mined oil shale directly to generate electricity produces significantly higher amounts of CO_2 than conventional fossil fuels. Using current methods it produces about one and a half the CO_2 per unit of energy of coal, and even with technological improvements would still result in the same greenhouse gas emissions as coal.[12] One reason for this is that oil shales contain a relatively small proportion of useful fuel (organic material) and carbonate in the oil shale is also burned which adds to the CO_2 produced without providing more energy.

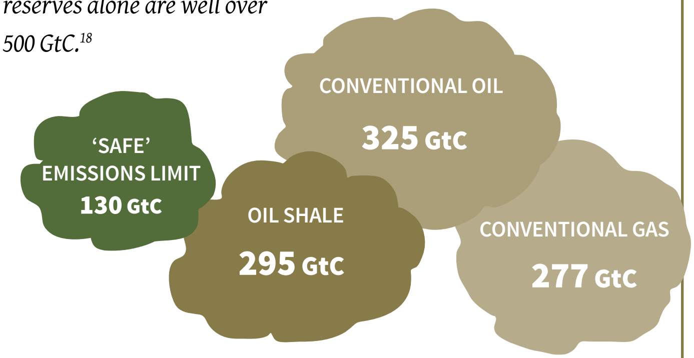
Extracting liquid fuel from oil shale also results in large amounts of CO_2 emissions. A recent study of the full lifecycle carbon dioxide (CO_2) emissions from oil shale derived liquid fuels estimated them to be 25 to 75% higher than those from conventional liquid fuels, depending on the process used.[13] The various sources of greenhouse gas emissions include generating heat for retorting, high temperature decomposition of carbonates, methane release and upgrading and refining of the shale oil crude.[14]

The oil shale industry claims that new in-situ retorting methods will reduce greenhouse gas emissions, however the main sources of emissions will remain, and some methods even create additional sources, such as the huge amount of energy required to create the refrigerated barrier in Shell's 'freezewall' method. It has been estimated that the full-fuel-cycle emissions for fuels derived using the Shell process are 21%-47% larger than those from conventionally produced petroleum-based fuels.[15]

Regardless of how oil shales compare to coal or conventional oil as an energy source, they represent a vast source of carbon which we cannot afford to develop.

If we are to reduce carbon emissions to anything like the levels required to maintain a reasonably habitable planet we must move away from all forms of fossil fuel as fast as possible. Measuring from the start of the industrial revolution (around 1750), a maximum of 500 Gigatonnes of carbon (GtC) can be emitted to the atmosphere while still avoiding most serious impacts and the risk of irreversible and uncontrollable changes to the climate.[16] *Between 1750 and now (2014), we have already emitted about 370 GtC leaving a limit of 130 GtC that could be further added.*[17]

In order to stay within this limit we have to leave the vast majority of the remaining conventional oil, coal and gas in the ground. Estimates vary significantly, but remaining conventional coal reserves alone are well over 500 GtC.[18]



Exploiting the world's oil shale would add around 295 GtC to the atmosphere.[19] This is an enormous amount and is absolutely incompatible with staying below the limit outlined above.

Carbon Capture and Storage (CCS)

There have been investigations into the possiblity of using waste ash from oil shale fuelled power stations to store CO_2. However, even if it works the proportion of CO_2 emissions absorbed would be small (10 – 11%) and it would still be an extremely carbon intensive energy source.[20]

Proponents of unconventional fossil fuels often argue that with CCS technologies, these new energy sources could be exploited at the same time as reducing GHG emissions. However, even if the huge problems with CCS technology are overcome (and this currently looking extremely unlikely), it would not change the fact that we need to move away from all forms of fossil fuel, conventional and unconventional, as soon as possible.

In the most optimistic (and highly implausible) scenario, CCS could be used to reduce a small proportion of emissions from fossil fuels. In reality, the promise of CCS being implemented in the future is being used to allow the continued expansion of fossil fuel production, to prevent alternatives from being developed, and to deflect attention away from approaches which tackle the underlying systemic causes of climate change and other ecological crises. Ultimately CCS is a smokescreen, allowing the fossil fuel industry to continue profiting from the destruction of the environment. *(see 'Carbon Capture Storage' factsheet for more information).*

OTHER SOCIAL AND ENVIRONMENTAL ISSUES

Water consumption

Although estimates of the exact amounts vary widely, producing liquid fuel from oil shale requires a lot of water. Using surface retorting requires between about 2 and 5 barrels of water for every barrel of oil produced.[21] For in-situ methods the amount of water required is anywhere between 1 and 12 barrels per barrel of oil.[22]

When you consider that globally there are trillions of barrels of oil shale resources, that adds up to a lot of water being used.

In 2002, in Estonia, where oil shale provides 90% of the country's electricity,[23] the oil shale-fired power industry used 91% of the total water consumed in the country.[24]

In addition to water directly consumed during operations, underground oil shale mining could also disrupt groundwater flow, as large volumes of water will need to be extracted, potentially reducing water levels in shallow aquifers. The heat required for in-situ extraction is also likely to disrupt groundwater flows, and hot gases escaping during the process could fracture the rock and create new pathways for water (and contaminants) to flow.

Water contamination

Oil shale extraction and processing involves serious risk of water contamination. For mining and surface retorting, this is mainly a result of the used oil shale left after it has been retorted. The waste shale contains various salts and toxic substances such as arsenic and selenium.[25] This is often used to fill the space left after mining (see waste section below). As groundwater comes into contact with spent shale it can leach out the contaminants, polluting the water. Research in China found evidence of soil and groundwater contamination by heavy metals and carcinogenic hyrdocarbons which were traced back to an oil shale waste site.[26] Other potential sources of water pollution from mining and surface retorting include mine drainage, discharges from surface operations associated with solids handling, retorting, upgrading, and plant utilities. Oil shale processing results in waste waters that contain phenols, tar and several other toxic substances.[27]

There is a lack of research into effects of in-situ oil shale production on groundwater, however water pollution is a serious concern. The heat from the process will create and release contaminants from


Kiviõli Oil Shale Processing & Chemicals Plant in ida-Virumaa, Estonia

"IN 2002, IN ESTONIA, THE OIL SHALE-FIRED POWER INDUSTRY USED 91% OF THE TOTAL WATER CONSUMED IN THE COUNTRY" the surrounding rock and as a result retort waters are likely to have high concentrations of soluble organic materials, along with very high concentrations of ammoniacal nitrogen, alkalinity, chlorides, and sulfates.[28] Past studies have found that in-situ production processes could leak contaminated water into adjacent aquifers and surface water.[29 30 31]

Air pollution

Oil shale operations, (mining, burning, refining etc.) can result in a variety of air pollutants. These can include hydrogen sulphide, sulphur oxides, nitrogen oxides, particulates, ozone precursors, and carbon monoxide.[32] Small amounts of other pollutants may also be produced, such as arsenic, mercury, cadmium and selenium compounds.[33] To take the example of Estonia again, in 2002, 97% of air pollution came from the power industry, the vast majority of which is fuelled by oil shale.[34] In short, if the oil shale industry were to be developed on a global scale it would create serious and widespread local air pollution problems.

Other waste

Oil shale production creates large amounts of solid waste. Burning oil shale produces toxic ash, which is sometimes partially 'backfilled' into the cavity that it was mined from, risking groundwater contamination. Surface retorting also produces large volumes of waste, according to the European Academies Science Advisory Council (EASAC) producing a barrel of shale oil can generate 1.5 tons (1.4 tonnes) of spent shale, which occupies 15 - 25% greater volume than the original shale, due to 'popcorn' like expansion during the process.[35]

Waste material can include several pollutants including sulfates, heavy metals, and polycylic aromatic hydrocarbons (PAHs), some of which are carcinogenic.[36 37]

Industrialisation of countryside

Oil shale is often found in remote areas without existing major roads and pipelines, and significant new infrastructure would accompany any oil shale extraction operations. Surface facilities would be required for upgrading, storage and transportation. Roads, power plants, power distribution systems, pipelines, water storage and supply facilities, construction staging areas, hazardous materials handling facilities, and various other buildings would also be required. In addition there would be significant impact on the landscape from associated surface and underground mining. As an example, if quarried in open pits, a single full scale processing plant with an output of 100 000 barrels per day, would require a mining operation similar in size to the largest of the vast brown-coal mines in Germany.[38]

Using in-situ methods still has widespread and serious impacts. The landscape would be dotted with wells, heating holes and installations which will be in operation for 15 to 25 years.[39] Wells would have to be drilled close to each other, and each would have to be connected to a treatment plant by a network of pipelines. It has been estimated that 15 to 25 heating holes per acre (per 0.004 square kilometres) would be required for in-situ production.[40]

Oil shale

WHERE AND HOW MUCH?

There is a well developed oil shale industry in Estonia, which currently consumes the majority of the world's oil shale production to generate electricity. Many are also trying to profit from exporting this expertise to other countries. Oil shale is also exploited on an industrial scale in China (which is rapidly expanding its capacity), Brazil and to a lesser extent in Russia, Germany and Israel. By far the largest deposits are found in the US, with one deposit alone, the Green River formation, containing the equivalent of 3 trillion barrels of oil, over 60% of the total oil shale resources found in the world.[41]

There have been several failed attempts at commercial development of oil shale in the US. For example Exxon invested $5billion in the 1970s, but pulled out in 1982 when oil prices fell again.[42]

Oil prices have also largely driven global production, which peaked following the 1973 oil crisis and then fell with the price of oil. It is only recently, with high oil prices, conventional crude becoming more scarce, and countries' increasing concern over energy security, that there has been a resurgence in interest in oil shale.

In 2003, an oil shale development program restarted in the United States. Having lifted a previous moratorium, Australia is similarly beginning to re-start oil shale activities. Many other countries are also currently investigating or have plans to exploit their oil shale resources. Jordan for example has signed memorandums of understanding with various companies and has plans to rapidly develop its resources.[43] Israel and Morocco also have plans to develop oil shale industries aiming to achieve greater energy security or even independence. Mongolia has shown interest in the resource and several companies including Total now have an oil shale presence in the country.

Despite this recent interest, difficulties remain. For example, Chevron stopped its oil shale research in Rio Blanco County, Colorado, US in February 2012,[44] and Shell recently closed its experimental oil shale plant, saying it planned to focus on other activities.[45] One factor hindering the industry in the US is the surge in domestic tight oil production which has made oil shale less economically attractive (see above for an explanation of the terms 'oil shale', 'shale oil' and 'tight oil').

Despite the enormous total global oil shale resources (estimated at 4.8 trillion barrels),[46] there is still a great deal of uncertainty over the exact amount and what proportion of it could be economically extracted, as much of it is found in found in extremely low grade rock.

COMPANIES INVOLVED

Several of the multinational 'super major' oil companies are involved in oil shale development in the US, particularly Shell, Chevron and Exxon. Many 'national' or semi public oil companies, such as Petrobras in Brazil, PetroChina in China and Jordan Oil Shale Energy Company are leading development in their respective countries.

RESISTANCE

Grassroots opposition to oil shale extraction in Australia resulted in a 20-year moratorium on development of the McFarlane oil shale deposit. However, the government recently announced that it will allow the development of a commercial oil shale industry in Queensland.[47] Development in the US has also been met with resistance from environmental groups.[48]

For more information on resistance see the Corporate Watch website (corporatewatch.org/uff/resistance)

ENDNOTES

1 'World Energy Resources: 2013 Survey'. *World Energy Council* (2013). ‹http://www.worldenergy.org/publications/2013/world-energy-resources-2013-survey ›

2 'Oil Shale: A fuel lifeline'. *Oil Shale Information Centre*. Accessed 26 Feb 2014. ‹http://www.oilshale.co.uk/oilshaleguide.pdf›

3 Francu, Juraj; Harvie, Barbra; Laenen, Ben; Siirde, Andres; Veiderma, Mihkel. A study on the EU oil shale industry viewed in the light of the Estonian experience. A report by EASAC to the Committee on Industry, Research and Energy of the European Parliament. *European Academies Science Advisory Council*. pp.14–15; 45 (May 2007). Retrieved 2011-05-07. ‹http://www.easac.org/fileadmin/PDF_s/reports_statements/Study.pdf›

4 [ibid]

5 'An Assessment of Oil Shale Technologies'. *Office of Technology Assessment, Congress of the United States* (June 1980). ‹http://www.princeton.edu/~ota/disk3/1980/8004_n.html›

6 'Nuclear energy proposed for production of shale oil'. *Oil and Gas Journal* (07/10/2006). ‹http://www.ogj.com/articles/print/volume-104/issue-26/general-interest/nuclear-energy-proposed-for-production-of-shale-oil.html›

7 Cleveland, C. J., R. Costanza, C. A. S. Hall, and R. Kaufmann. 'Energy and the U.S. Economy: A Biophysical Perspective'. *Science* 225, no. 4665 (31 August 1984): 890–897. doi:10.1126/science.225.4665.890. ‹http://www.sciencemag.org/content/225/4665/890 ›

8 'World Energy Outlook 2010'. *Paris: International Energy Agency*, 2010. ‹http://www.worldenergyoutlook.org/media/weo2010.pdf›

9 'An Assessment of the Energy Return on Investment (EROI) of Oil Shale '. *Western Resource Advocates* (June 2010). ‹http://www.westernresourceadvocates.org/land/oseroi.php›

10 Kubiszewski, I., & Cleveland, C. 'Energy return on investment (EROI) for wind energy' (2013) ‹http://www.eoearth.org/view/article/152560›

11 'Oil Sands Mining Uses Up Almost as Much Energy as It Produces'. *Inside Climate News*. Accessed 26 February 2014. ‹http://insideclimatenews.org/news/20130219/oil-sands-mining-tar-sands-alberta-canada-energy-return-on-investment-eroi-natural-gas-in-situ-dilbit-bitumen›

12 Op cit (Francu et al 2007)

13 Adam R. Brandt et al. 'Carbon Dioxide Emissions from Oil Shale Derived Liquid Fuels'. Chapter 11 in *Oil Shale: A Solution to the Liquid Fuel Dilemma*, pp.219-48 (2010). ‹http://pubs.acs.org/doi/abs/10.1021/bk-2010-1032.ch011›

14 Op cit (Francu et al 2007)

15 Brandt, Adam R. 'Converting Oil Shale to Liquid Fuels: Energy Inputs and Greenhouse Gas Emissions of the Shell in Situ Conversion Process'. *Environmental Science & Technology* 42, no. 19 (October 2008): 7489–7495. doi:10.1021/es800531f. ‹http://pubs.acs.org/doi/abs/10.1021/es800531f›

16 Hansen, James, Pushker Kharecha, Makiko Sato, Valerie Masson-Delmotte, Frank Ackerman, David J. Beerling, Paul J. Hearty, et al. 'Assessing "Dangerous Climate Change": Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Nature'. Edited by Juan A. Añel. *PLoS ONE 8, no. 12* (3 December 2013): e81648. doi:10.1371/journal.pone.0081648. ‹http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0081648›

17 Ibid

18 Ibid

19 See ‹www.corporatewatch.org/uff/carbonbudget›

20 Uibu, Mai, Mati Uus, and Rein Kuusik. 'CO2 Mineral Sequestration in Oil-Shale Wastes from Estonian Power Production'. *Journal of Environmental Management* 90, no. 2 (February 2009): 1253–1260. doi:10.1016/j.jenvman.2008.07.012. ‹http://www.sciencedirect.com/science/article/pii/S0301479708002053›

21 J. T. Bartis, T. LaTourrette, L. Dixon, D.J. Peterson, and G. Cecchine. 'Oil Shale Development in the United States Prospects and Policy Issues'. *RAND Corporation*, MG-414-NETL (2005). ‹http://www.rand.org/content/dam/rand/pubs/monographs/2005/RAND_MG414.pdf›

22 'Impacts of Potential Oil Shale Development on Water Resources'. *GAO, Energy Development and Water Use*, GAO-11-929T, p.8 (August 24, 2011). ‹http://www.gao.gov/assets/130/126827.pdf›

23 Op cit (Francu et al 2007)

24 Raukas, Anto. 'Opening a new decade'. Oil Shale. A Scientific-Technical Journal (Estonian Academy Publishers) 21 (1): 1–2. ISSN 0208-189X. (2004). ‹http://www.kirj.ee/public/oilshale/1_ed_page_2004_1.pdf›

25 Op. Cit. (Francu et al 2007)

26 Ding, Aizhong, Jiamo Fu, Guoying Sheng, Puxin Liu, and P. J. Carpenter. 'Effects of Oil Shale Waste Disposal on Soil and Water Quality: Hydrogeochemical Aspects'. *Chemical Speciation and Bioavailability* 14, no. 1 (10 November 2002): 79–86. doi:10.3184/095422902782775353. ‹http://www.ingentaconnect.com/content/stl/csb/2002/00000014/F0040001/art00010›

27 Kahru, A.; Põllumaa, L. 'Environmental hazard of the waste streams of Estonian oil shale industry: an ecotoxicological review'. *Oil Shale. A Scientific-Technical Journal* (Estonian Academy Publishers) 23 (1): 53–93. ISSN 0208-189X (2006). ‹http://www.kirj.ee/public/oilshale/oil-2006-1-5.pdf›

28 Harding, B.L., K.D. Linstedt, E.R. Bennet, and R.E. Poulson. 'Study Evaluates Treatments for Oil Shale Retort Waters'. *Industrial Wastes*, Vol. 24, No. 5 (1978).

29 Amy, Gary, and Jerome Thomas. 'Factors That Influence the Leaching of Organic Material From In-situ Spent Shale'. Proceedings of the Second Pacific Chemical Engineering Congress, Denver, CO (August 1977)

30 Parker, H.W., R.M. Bethea, N. Guven, M.N. Gazdar, and J.C. Watts. 'Interactions Between Ground Water and In-situ Retorted Oil Shale'. *Proceedings of the Second Pacific Chemical Engineering Congress*, Denver CO (August 1977)

31 'White River Resource Area Resource Management Plan Final Environmental Impact Statement'. *US Bureau of Land Management*, pp. 4-5 (1996)

32 Op. Cit. (Francu et al 2007)

33 Ibid

34 Raukas, Anto. 'Opening a new decade'. *Oil Shale. A Scientific-Technical Journal* (Estonian Academy Publishers) 21 (1): 1–2. ISSN 0208-189X. (2004). ‹http://www.kirj.ee/public/oilshale/1_ed_page_2004_1.pdf›

35 Op. Cit. (Francu et al 2007)

36 Mölder, Leevi. 'Estonian Oil Shale Retorting Industry at a Crossroads'. *Oil Shale. A Scientific-Technical Journal* (Estonian Academy Publishers) 21 (2): 97–98. ISSN 0208-189X. (2004). ‹http://www.kirj.ee/public/oilshale/1_ed_page_2004_2.pdf›

37 Tuvikene A., Huuskonen S., Koponen K., Ritola O., Mauer U., Lindstrom-Seppa P. Oil shale processing as a source of aquatic pollution: Monitoring of the biologic effects in caged and feral freshwater fish. *Environ. Health. Persp. 1999*;107:745–752. doi:10.1289/ehp.99107745. ‹http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1566439/›

38 Op cit (Francu et al 2007)

39 Ibid

40 'Oil Shale Research, Development, and Demonstration' *Bureau of Land Management*, Environmental Assessment CO-110-2006-117 EA, p. 132. (November 2006). ‹http://www.co.blm.gov/wrra/wrfo_os_eas.htm›

41 'Survey of Energy Resources 2010'. *World Energy Council*. ‹http://www.worldenergy.org/publications/3040.asp›

42 'Oil Shale Never Stays down Long'. *High Country News*. Accessed 8 March 2014. http://www.hcn.org/wotr/oil-shale-never-stays-down-long/print_view

43 'Karak International to Develop Oil Shale Projects'. *'Jordan News Agency (Petra)*. Accessed 7 March 2014. ‹http://www.petra.gov.jo/Public_News/Nws_NewsDetails.aspx?Site_Id=1&lang=2&NewsID=140237&CatID=13&Type=Home&GType=1›

44 'Chevron Leaving Western Slope Oil Shale Project' *Denver Business Journal*. Accessed 8 March 2014. ‹http://www.bizjournals.com/denver/news/2012/02/28/chevron-leaving-western-slope-project.html?page=all›

45 'Shell Abandons Western Slope Oil Shale Project'. *trib.com*. Accessed 26 February 2014. ‹http://trib.com/business/energy/shell-abandons-western-slope-oil-shale-project/article_f8e1dee8-a04f-5444-ba86-9585b3340f74.html›

46 Op. Cit. [WEC 2013]

47 'Newman Government Approves Oil Shale Industry' *The Queensland Cabinet and Ministerial Directory*. Accessed 26 February 2014. ‹http://statements.qld.gov.au/Statement/2013/2/13/newman-government-approves-oil-shale-industry›

48 for example see: http://www.tarsandsresist.org/stopenefit/