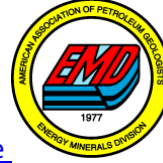


## EMD Oil Shale Committee



### **2017 EMD Oil Shale Committee Report**

**Justin E. Birdwell (Chair), U.S. Geological Survey**

**November 29, 2017**

#### **Vice-Chairs:**

- **Gerald Daub (Vice-Chair: Industry), Daub & Associates, Inc.**
- **Dr. Lauren Birgenheier (Vice-Chair: University), University of Utah**
- **Michael D. Vanden Berg (Vice-Chair: Government), Utah Geological Survey**

#### **Advisory Group:**

- **Dr. Alan K. Burnham, Stanford University**
- **Dr. Jeremy Boak, Oklahoma Geological Survey, University of Oklahoma**
- **Mr. Ronald C. Johnson, U.S. Geological Survey**

#### **Special Consultants to the Committee:**

- **John Parsons, QER Pty Ltd**
- **Gary Aho, Sage Geotech**
- **Indrek Aarna, Eesti Energia**
- **Rikki Hrenko-Browning, Enefit American Oil**
- **Ryan Clerico, Enefit American Oil**
- **Alex Boccock, Red Leaf Resources**
- **Christopher Hopkins, Canshale Corp.**
- **Steven Kerr, Millcreek Mining Group**
- **Steven Odut, Thyssenkrupp**
- **Pierre Allix, Total S.A.**

### **EXECUTIVE SUMMARY**

Low oil prices continue to hamper oil shale development around the world. Although new production capacity in Estonia and China has come online recently, efforts in other places are on indefinite hiatus or are well behind schedule relative to what was anticipated just a few years ago. The current status remains in flux, and recent developments in conventional and unconventional crude oil plays in the United States and elsewhere indicate this will not change anytime soon.

Oil shale continues to be mined processed in China and Brazil, but production updates for 2016 were not available as of the preparation of this report. In Estonia, Eesti Energia (Enefit) continued development of their co-generation Auvere power plant that is designed to utilize both oil shale and other fuel sources (wood chips, peat, gas). The plant is anticipated to be capable of providing up to one-quarter of

electricity use in Estonia at full capacity. Enefit produced 2.03 million barrels of oil in 2016 and the recently completed Enefit280 plant continues to operate at or near design capacity.

In Jordan, projects timelines continue to be affected by economic conditions, but development continues. In 2016, Enefit's electricity production project progressed, with investors and Chinese banks completing financing agreements worth approximately 1.6 billion dollars. The Chinese export credit agency, Sinosure, approved the necessary credit guarantees for the deal in January 2017. The project introduced a new shareholder in May 2016, with Enefit signing an agreement to sell 55% of its shares and maintaining a 10% shareholding.

In Australia, Queensland Energy Resources (QER) continues efforts to develop a full scale production plant. However, due to low global oil prices QER has changed their focus to improving the process engineering and design aspects of their proposed commercial plant on the Stuart "kerogen shale" deposit. Engineering and design will continue through 2017 with a major focus on achieving significant energy efficiency improvements in the process design.

In Utah, Enefit American Oil (EAO) announced achievement of reserve status in Q4 2016 for 514 million barrels of proven and probable ("2P") reserves at their Utah project sites. EAO will complete their Utility Corridor EIS process with the BLM in mid-2017, and will begin preparation of their state Large Mine Operation permit application in 2017 as well.

Red Leaf Resources is in the process of negotiating a separation from TOTAL, which they hope to bring to a conclusion in the next several months. Additional updates on the EcoShale project at Seep Ridge, UT will not be available until the separation is completed.

Most of efforts in Colorado were related to decommissioning previous RD&D projects. Shell has plugged and abandoned all drill, core and rotary holes on their oil shale leases and their private property. All surface facilities have also been decommissioned and removed. Each of these locations has undergone extensive surface reclamation in accordance with local regulatory agency requirements. There are no plans for any further oil shale activity by Shell in the Piceance Creek Basin at this point in time. American Shale Oil, LLC (AMSO) also ended operations in Colorado in 2016 and all facilities have been decommissioned, leveled, and reclaimed. Two cores collected or owned by AMSO were donated to the USGS Core Research Center in the summer of 2016. The Chevron oil shale RD&D lease expired and has been inactive for a number of years. The Chevron lease site is in reclamation/monitoring status waiting for successful re-vegetation. Exxon Mobil's second round RD&D oil shale lease has been relinquished back to the BLM. There was no surface or subsurface activity/disturbance on the ExxonMobil federal RD&D oil shale lease. There are no plans for any future oil shale activity by Exxon-Mobil in the Piceance Creek Basin at this point in time. Simple Oil LLC drilled a ground water monitoring well on their oil shale RD&D Lease to help establish background ground water quality. Other ground water monitor wells already constructed and in operation by Natural Soda LLC are being used by Simple Oil LLC to further expand and establish historical ground water quality background conditions. The project and process is under review by federal regulatory agencies and is in the permitting process.

Two International Symposia were held in 2016, one in Estonia (September, <http://oilshalesymposium.com/>) and the other in Jordan (November, <http://www.jioss.org/>). The Estonian meeting celebrated 100 years of oil shale activity in that country.

In early 2017, the National Oil Shale Association (NOSA) will be releasing a white paper encouraging the new Federal Administration and Congress to resurrect Section 369 of the 2005 Energy Policy Act, which deals with Strategic Unconventional Fuels, including oil shale. The white paper also recommends the government implement the recommendations of the Task Force presented in its 2007 Final Report. NOSA is also working on a new 2017 Oil Shale Primer intended to: educate the public on facts

surrounding oil shale; summarize the many benefits of developing a domestic oil shale industry; dispel the many misconceptions associated with shale oil production; and describe challenges facing the new industry.

In February 2017, Springer published a new book authored by Alan Burnham titled “Global Chemical Kinetics of Fossil Fuels: How to model maturation and pyrolysis”. The book includes a wide variety of information relevant to oil shale process modeling.

In late 2016, the Rocky Mountain Association of Geologists published a new book titled “Hydrocarbon Source Rocks in Unconventional Plays, Rocky Mountain Region”, edited by Mike Dolan, Debra Higley, and Paul Lillis. Five chapters related to Green River and Elko Formation oil shales were included (see References section for more information).

Background information and expanded discussion of oil shale development and production in countries with existing or prospective oil shale industries can be found in the Appendix.

### **Research Focus**

Current research on oil shale is best identified through presentations at International Oil Shale Symposia that have been held recently in Estonia and Jordan. The U.S. based annual meeting, previously held in October at the Colorado School of Mines in Golden, CO, is currently on hiatus. Although organizers intended to begin rotating the meeting to different locations, starting with the 2015 symposium in Salt Lake City, no plans are currently being made for additional U.S. meetings. Abstracts, presentations, and papers for the 26<sup>th</sup> through 32<sup>th</sup> Oil Shale Symposia along with a proceedings archive (1964-1992) are available at: [http://www.costar-mines.org/oil\\_shale\\_symposia.html](http://www.costar-mines.org/oil_shale_symposia.html). Programs from more recent meetings are available at the following sites (proceedings are currently accessible by attendees and are available for purchase from CSM SPACE):

Proceedings of the 33<sup>rd</sup> Oil Shale Symposium will be made freely available in the near future. The Program for the 33<sup>rd</sup> Oil Shale Symposium is currently available online at <http://mines.conference-services.net/programme.asp?conferenceID=3736&language=en-uk>

Proceedings of the 34<sup>th</sup> Oil Shale Symposium are currently available to attendees of the meeting only, but will be made freely available sometime in the future. The Program for the 34<sup>th</sup> Oil Shale Symposium is currently available online at <http://mines.conference-services.net/programme.asp?conferenceID=4255&language=en-uk>

Proceedings of the 35<sup>th</sup> Oil Shale Symposium will be available for sale once assembly is complete and will be available sometime in near future. The program and abstracts for the 35<sup>th</sup> Oil Shale Symposium are posted at <http://mines.conference-services.net/programme.asp?conferenceID=4640&language=en-uk>

According to Scopus, 1,096 scholarly articles, book chapters, and other products with some mention of oil shale were published between the beginning of 2016 and March 2017. However, it is not clear how many of these publications were actually referring to unconventional petroleum systems (i.e., shale-oil).

### **Other sources of oil shale-related information**

Research at the University of Utah under USTAR and other activities in oil shale are covered in the University of Utah Unconventional Fuels Conference:

[http://www.icse.utah.edu/assets/archive/2013/ucf\\_agenda.htm](http://www.icse.utah.edu/assets/archive/2013/ucf_agenda.htm) .

The National Oil Shale Association (NOSA) is a non-profit organization dedicated to getting out factual information on the vast oil shale resources of the United States, including the Devonian shales of the eastern United States and the very rich oil shale of the Green River Formation of Colorado, Utah and Wyoming. The Association maintains a website at [www.oilshaleassoc.org](http://www.oilshaleassoc.org). NOSA membership is open to corporations, non-profits, and individuals. The membership application form is available on the NOSA website: [www.oilshaleassoc.org](http://www.oilshaleassoc.org) .

International research in oil shale processes and impacts is published in the journal Oil Shale, published in Estonia. The journal can be accessed at: <http://www.kirj.ee/oilshale> .

Information on oil shale research conducted by the U.S. Geological Survey Energy Resources Program is available at the Oil Shale Research Homepage:

<http://energy.usgs.gov/OilGas/UnconventionalOilGas/OilShale.aspx> .

### **Research Funding Sources**

Funding for oil shale research in the United States had come primarily from corporations actively pursuing oil shale development or by companies developing oil shale technology with the goal of selling technology/equipment to developers. Most of that funding has been discontinued. The Stanford-Total Enhanced Modeling of Source Rocks (STEMS) project funded by Total still continues but with an increasing emphasis on natural petroleum source rocks. U.S. Federal sources include the USDOE through its National Energy Technology Laboratory, as part of the Fossil Fuel program. However, such funding has been essentially zero for oil shale the past few years. USGS work specifically on oil shale is scheduled to end in FY2017, but will likely continue as part of a more general source rock geochemistry project. The ACS Petroleum Research Fund is a potential source of support.

### **Critical Technology Needs**

Critical technology needs mainly concern the development of more energy efficient and environmentally friendly and less costly methods of extraction, production and upgrading of oil shale and shale oil. Especially in the U. S., issues have been raised about the greenhouse gas emissions and water consumption of an oil shale industry. The primary source of emissions for in situ production is power plant emissions of CO<sub>2</sub>, and power plant water consumption is the largest use for some in situ operations as initially conceived.

Internationally, there is a lack of consistently structured resource assessments. As the energy security of the world stands to benefit from enabling otherwise resource poor developing countries to develop indigenous energy sources, it may be beneficial to support the development of resource assessment tools for countries that do not have the large database of Fischer assay and other measurements available in the U.S.

### **Critical Environmental and Geohazard Issues and Mitigation Strategies**

The critical environmental issues are how to extract, produce and upgrade shale oil in an environmentally friendly and economically sound way such that:

- 1) The use of energy to pyrolyze the kerogen is minimized;

- 2) The greenhouse gas emissions are reduced or compensated for by carbon trading or CO<sub>2</sub> sequestration;
- 3) The water used in construction, operation, power generation, and reclamation is minimized and does not deplete the water resources of arid regions;
- 4) The extraction, production and upgrading of the shale oil does not unduly affect the quality of the air, the native biological communities, or surface and ground water of the region;
- 5) Any Subsidence caused by mining or in-situ retorting does not cause unacceptable disruption of natural surface features or human structures;
- 6) Socioeconomic impacts are also a major concern. It is important that projects are conducted in a manner that meets community expectations by keeping the public apprised of progress, being transparent, and being sensitive to changes in social dynamics

### **Relevant EMD Technical Sessions and Workshops**

The primary conferences covering oil shale science and technology in 2016 were the International Oil Shale Symposium in Estonia, September 20-23, and 3<sup>rd</sup> Jordan International & 36<sup>th</sup> Colorado School of Mines Oil Shale Symposium, November 21-22, at the King Hussein Bin Talal Convention Center, Dead Sea, Jordan. Program summaries are provided in the following section.

There are currently no plans for additional U.S. based Oil Shale Symposia. However, a Theme related to Lacustrine Systems is currently planned for the 2018 AAPG ACE meeting in Salt Lake City. Kevin Bohacs and Jenni Scott will be the Theme Chairs. Subthemes will include:

- 1) Lacustrine hydrocarbon systems of the South Atlantic region
- 2) The Green River Formation and other ancient mixed carbonate and siliclastic lake systems
- 3) Modern lacustrine analogues: Great Basin saline lakes, East African rift lakes
- 4) Contrasting lacustrine and marine systems: Stratigraphy, reservoir, and source
- 5) Stratigraphic analysis of lake basins: Approaches and controls

**PROGRAM: International Oil Shale Symposium 2016 “100 years” hosted by Enefit**

*Tuesday, September 20, 2016*

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08:00 Arrival of Guests, Registration

Room A: Welcoming Plenary

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09:00 Hando Sutter

09:20 Taavi Rõivas

09:30 Academician Jaak Aaviksoo

09:40 Prof. Volli Kalm

09:50 Margus Vals

10:20 Zulandi van der Westhuisen

10:45 Networking and Refreshment Break

Room A: Shale Oil Retorting, Moderated by Ryan Clerico, Enefit

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11:15 Proof of the Enefit280 Technology, Dr. Indrek Aarna

11:40 Combining Bitumen and Minerals Extraction on Toolebuc Formation Shales, Jim Schmidt, Nathan Cammerman

12:05 Shale Tech Is Actively Working to Advance Paraho System Technologies, Justin Biliyeu, Larry Lukens

12:30 Progress Towards Advancement of Computational Models to Predict Hydrocarbon Extraction, Tom Plikas, Jim Patten

12:55 Adaptation of Enefit280 Technology and Opportunity Analyses, Hermann Sieger, Taavi Lauringson, Robert Mergler

Room B: Oil Shale Power Generation, Moderated by Raine Pajo, Enefit

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11:15 Innovative Solutions for Oil Shale Power Generation, Tõnu Aas

11:40 Oil Shale – Where Industry Meets Research, Dr. Alar Konist

12:05 Co-Combustion of Different Fuels in Narva Power Plants, Dr. Raivo Attikas, Dr. Mohamed Yacine Layachi

12:30 Combustion of Fuel Mixtures in Oil Shale Fired CFBC and PC Boilers, Dr. Tõnu Pihu, Dr. Alar Konist, Dmitri Neshumayev, Lauri Loo, Rain Veinjärv

12:55 Experimental and Modelling Studies of Oil Shale Oxy-Fuel Combustion, Can Rüstü Yörük, Tõnis Meriste, Andres Triikkel, Rein Kuusik

13:20 Lunch

Room A: Reducing Environmental Impacts, Moderated by Meelis Münt, Ministry of the Environment, Republic of Estonia

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14:20 Oil Shale Industry in the Light of Changing EU Regulations, Tõnis Meriste

14:45 Release of Trace Elements From Oil Shale Fly Ash of PF and CFB Boilers, Dr. Janek Reinik, Natalja Irha, Jekaterina Jefimova, Eiliv Steinnes

15:10 Oil Shale Open Cast: Making Sustainable Places for Future Generations, Andrew Sumner

15:35 New Opportunities for Closed Mines, Veljo Aleksandrov

Room B: Geology, Moderated by Kalle Kirsimäe, University of Tartu

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- 14:20 A Century of Geological Setting Studies of the Ordovician Kukersite Oil Shale of Estonia, Prof. emerit. Väino Puura, Eduard Pukkonen
- 14:45 Lithostratigraphic and Geochemical Build-Up of the Attarat Um Ghurdan Oil Shale Seam, Hardi Aosaar, Prof. emerit. Väino Puura, Alvar Soesoo, Margus Voolma, Sigrid Hade
- 15:10 Hydrocarbon Potential, Depositional Environment and Economic Viability of the Oil Shale Deposit in the Abakaliki Fold Belt, Southeastern Nigeria, Prof. Olubenga Ajayi Ehinola
- 15:35 Hydrocarbon Potential of Goynuk (Bolu-Turkey) Oil Shale Resources and Investment Research Project of TKI-TP, Abdurrahman Murat, Elif Kabadayi, Ali Sari, Feridun Alp Ugur

16:00 Networking and Refreshment Break

Room A: History and Future of the Estonian Oil Shale Sec , Moderated by Mihkel Härm, World Energy Council Estoniator

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- 16:30 Estonian Oil Shale Industry in the Whirlwinds of the World Fuel Market and Global Policy in 1920-1930s, Dr. Erkki Tammiksaar
- 16:55 Policy Options to Utilize Estonian Oil Shale Until 2050, Kalev Kallemets

17:20 End of Day 1

19:00 Group Dinner at Kultuurikatel

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*Wednesday, September 21, 2016*

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08:00 Arrival of Guests, Registration

Room A: International Projects and Industry Developments, Moderated by Hazem Al-Ramini, Ministry of Energy and Mineral Resources, Jordan

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09:00 Enefit American Oil Project Update, Ryan Clerico, Rikki Hrenko-Browning

09:25 Jordan Oil Shale Company: Jordan Field Experiment – 2016 Update, Thomas Fowler, Mariela Araujo, Dave Burns, Anton Verdel

09:50 Buried Gas Injection and Collection Pipe Design in Ecoshale Oil Extraction Process, Dr. Hamid Ghorbani, Majid Maleki, Maher Al-Dojayli, Jim Patten, Keith Johns

10:15 The Latest Development of Oil Shale Activities in China, Dr. Qingqiang Wang, Shuyuan Li, Yue Ma, Jialin Qian

Room B: Oil Shale Mining, Moderated by Andres Vainola, Enefit

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09:00 Enefit Mines: Improving Mining Efficiency Through Continuous Development, Andres Vainola

09:25 Technological Innovations to Increase Mining Efficiency: Longwall Mining in Narva Open Cast Mine, Dr. Oleg Nikitin, Erkki Kaisla, Ljudmilla Kolotõgina

09:50 Risks Assessment Matrix and Its Importance in Oil Shale Mining Projects, Dr. Sergei Sabanov

10:40 Networking and Refreshment Break

Room A: From Resource to Reserve, Moderated by Andres Anijalg, Enefit

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11:10 Enefit American Oil Utah Project Reserve Classification, Ryan Clerico, Rikki Hrenko-Browning

11:35 An Approach for Taking Oil Shale Resources to Reserves, Dr. Thomas Sladek, Steven Kerr, Alister Horn

12:00 Oil Shale Resource and Reserve Evaluation Project, Erkki Kaisla, Hardi Aosaar, Einar Kivimäe, Ain Anepaio, Julia Kuznetskaja, Egne Pilt, Andres Kask, Muwafaq Al-Zoubi

12:25 The Approach and Process of Reporting the Mineral Resource and Ore Reserve for the Attarat Oil Shale Power Project, Sabine Anderson, Anna Fardell

Room B: Utilizing By-Products, Moderated by Tõnis Meriste, Enefit

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11:10 Oil Shale Ash – Hazardous Waste or Valuable By-Product?, Dr. Erik Puura

11:35 Estonian Oil Shale Ash – A Material to Use in Different Applications, Arina Koroljova

12:00 Basics of New Utilization Processes for Oil Shale Combustion Residues, Rein Kuusik

12:25 The Behaviours Under Freezing-Thaw Effects of Concretes That Are Made with Blended Cements with Oil Shale Ash, Dr. Alper Bideci, Prof. Dr. Sabit Oymael, Assist. Prof. Dr. Özlem Salli Bideci

12:50 Lunch

Room A: Economic Sustainability and Project Financing, Moderated by Kadri Haldre, Enefit

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13:50 Oil Shale Project Development Journey, Andres Anijalg

14:15 One Thousand Years of Oil Shale Mining, Dr. Thomas Sladek

14:40 Oil Shale Investment Projects in Jordan and the Current Challenges, Ghussaina Al-Hilu

Room B: Shale Oil Upgrading, Moderated by Margus Lopp, Tallinn University of Technology

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13:50 Increasing the Value of Shale Oil, Arto Juntunen

14:15 Alternative Solvents in Oil Shale Studies, Dr. Mihkel Koel

14:40 Cleaner Liquefaction of Oil Shale - Is It Feasible?, Dr. Hans Luik, Lea Luik

15:05 Break

Room A: Socioeconomic Impacts and Policy, Moderated by Hando Sutter, Enefit

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15:35 Introduction, Barry K. Worthington

16:00 Discussion: Oil Shale 200 - Scenarios for the Future, Kristen Michal, Marko Pomerants, Barry K. Worthington

16:40 Thank you Notes by Hando Sutter

17:00 End of the Symposium

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**PROGRAM: 3<sup>rd</sup> Jordan International Oil Shale Symposium 2016 & 36<sup>th</sup> CSM Oil Shale Symposium**  
**Day One – Monday 21<sup>st</sup> November**

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08.30 Registration and morning refreshments

09.00 National anthem and reading from the Quran

09.10 Opening remarks by the Chairman Dr. Ghaleb Maabreh, Chairman, National Petroleum Company

09.20 Official opening speech by the Minister of Energy and Mineral Resources

09.40 The role of oil shale in the broader energy environment, Speaker: Ms. Zulandi van der Westhuizen, Deputy Director of Resources, World Energy Council

10.00 Continued Evolution of our Oil Market – Within the Context of the IEA 2016 World Energy Outlook, Speaker: Nathan Frisbee, Senior Analyst, Global Energy Economics, International Energy Agency 'IEA'

10.20 Distinguished Panel 1

Panel Discussion: Government Efforts to Encourage Oil Shale Investment

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Moderator: Dr. Maher Hijazin, Former Director General, Natural Resources Authority Jordan

Panellists:

Dr. Ibrahim Saif, Minister of Energy and Mineral Resources

Ahamd Qatarnah, Secretary General, Ministry of Environment

H.E. Thabit Al Wir, President, Jordan Investment Commission

10.50 Morning Networking Break & Refreshments

11.20 Oil Shale Project Development Journey, Speaker: Andres Anijalg, Chairman of the Management Board, Attarat Power Company

11.40 Jordan Oil Shale Company Production Pilot - Jordan Field Experiment, Speaker: Yusuf Siddiqui, Shell Country Chairman & General Manager, Jordan Oil Shale Company

12.00 KIO Oil Shale Project: Progress & Challenges, John Fraser, Director Karak International Oil

12.20 SACOS Leads a New Era of Oil Shale Exploitation, Dr. Trad Mohammed Al-Ahmed, Saudi Arabian Corporation for Oil Shale

12.40 Enefit - Operating the World's Largest Oil Shale Industry, Hando Sutter, Chief Executive Officer, Enefit

13.00 Lunch & Networking

TRACK A: Resource Assessment, Oil Shale Chemistry, Geology and Mining, Moderator: Ruslan Salikhov, Deputy Chief Engineer Designer, TTU Galoter LP, UK

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14.00 The Isfir-Jafr deposit in Southern Jordan and The Resource Assessment of the Isfir-Jafr Oil Shale Deposit in Southern Jordan, Speaker: John Brodylo, Questerre Energy Corporation

14.20 Oil Shale Sulfur Content Variations with Different Analytical Methods, Speaker: Birgit Maaten, Tallinn University of Technology

14.40 Characterisation of Shale Oil Produced by Retorting Sultani Oil Shale, Speaker: Dr. Omar Ayed, Al-Balqa Applied University

15.00 Assessing the Geochemical Variability of Jordan Oil Shale: Laboratory Geochemistry Vs. Multivariate Statistics, Speaker: Prof. Alvar Soesoo, University of Tartu, Estonia

TRACK B: Oil Shale Processing, Retorting, Firing and Upgrading, Moderator: John Fraser, Director Karak International Oil

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14.00 Extractive De-sulfurization of High Sulphur Shale Oil by Thio-phenes Extraction, Speaker: Abdelhafid Foughalia, TTU Galoter

14.20 Appraising the Jordan Oil Shale, an example of novel subsurface disciplines integration, Speaker: Wasfi Omari, Jordon Oil Shale Company

14.40 Design Considerations of Oil Shale Semi Coke Combustion in Circulating Fluidized Bed, Speaker: Dr. Yiqun Huang, Tsinghua University

15.00 Sensitivity Analysis of Oil and Gas Production in the In-Situ Pyrolysis of Maoming Oil Shale, Speaker: Dr. Peng Guo, SINOPEC

15.20 Afternoon networking break

TRACK C: Environmental Impact and Mitigation Measures, Moderator: Dr. Jamal Jaber, Faculty of Engineering Technology, Al-Balqa' Applied University

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15.50 EIF Onshore Discharges Tool. A Modelling Tool to Assess Environmental Risk to Soil, Groundwater and Surface Water from In-Situ Kerogen Oil Production, Speaker: Randi Hagemann, Statoil

16.10 Geophysical Alterations And Groundwater Flow Implications Of In Situ And Ex Situ Conversion Of Oil Shale In The Piceance Basin, Colorado, With Applications For Other Oil Shale Basins Via Semi-Advanced Groundwater And 3D Geologic Computer Models, Speaker: Paul Quinn, International Consultant, Ambet LLC

TRACK D: Oil Shale Strategies, Policies and Challenges, Moderator: Dr. Tom Sladek, Director, Ockham Energy Services

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15.50 Engaging in Public-Private Partnerships with Oil Shale Developers, Osama Sulieman, Director PPP Unit, Ministry of Finance

16.10 Jordan Oil Shale Industry - Making Progress in Difficult Times, Eyas Shuaibi, Partner, Trowers & Hamllins LLP

16.30 End of Symposium Day One

19.00 Dinner

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## **Day Two – Tuesday 22<sup>nd</sup> November**

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08.30 Registration and coffee

09.00 Opening comments from the Chairman: Dr. Ghaleb Maabreh, Chairman, National Petroleum Company

09.10 Panel: Government Involvement and support to Investment Projects

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Panellists:

Secretary Generals of Relevant Governmental Authorities

H.E Eng. Amani Azzam, Secretary General, Ministry of Energy and Mineral Resources

Eng. Wijdan Al Rabadi, Commissionaire, Energy and Mineral Resources Commission

Abdel Fattah Al Daradkeh, General Manager, National Electric Power Company

Dr Khair Hadidi, Water Authority of Jordan

Hussain Al Mansi, Director of Exemptions Affairs, Jordan Customs

Dr. Waleed Bawaneh, Income and Sales Tax Department Jordan

09.40 Challenging Oil Shale Geology of Central Jordan, Dr. Vaino Puura, Professor Emeritus, University of Tartu

10.00 Panel: Financing oil shale projects and the Current Challenges

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Moderator: Dr. Maher Hijazin, Former Director General, Natural Resources Authority Jordan

Panellists:

Nathan Frisbee, Senior Analyst, Global Energy Economics, International Energy Agency 'IEA'

Andres Anijalg, Chairman of the Management Board, Attarat Power Company

Dr. Adli Kandah, Director General, Association of Banks in Jordan

Chris Nurse, Director /CEO, Karak International Oil

10.30 Morning Networking Break and Refreshment

11.00 Oil Shale Economics -- Updating a Legacy, Dr. Tom Sladek, Director, Ockham Energy Services

11.25 The Ways to Achieve Independence from the Oil Price Volatility for Oil Shale Projects in Jordan, Ruslan Salikhov, Deputy Chief Engineer Designer, TTU Galoter LP, UK

11.45 Red Leaf Resources Update: TOTAL Update, Technology Update, Future Plans and Reusable Capsules, Lance Lehnhof, Director and Vice President of Corporate Affairs, RedLeaf Resources Inc

12.10 Financing Oil Shale Projects in the Current Macro Environment US\$50/Barrel Oil: Challenges and Path Forward, David Argyle, Managing Director, Global Oil Shale Holdings Inc (GOSH)

12.30 Lunch & Networking

TRACK A: Financing Oil Shale Projects and enhancement of Projects Economics, Moderator: Lance Lehnhof, Director and Vice President of Corporate Affairs, RedLeaf Resources Inc

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13.30 APCO Oil Shale Power Project and Chinese Financing, Speaker: Jason Pok, APCO

13.50 Integrated Development of Renewable Energy and Oil Shale, Speaker: Dr. Jamal Jaber, Faculty of Engineering Technology, Al-Balqa' Applied University

14.10 Ways and Means for Oil Shale Economic Enhancements, Speaker: Munther Bseiso, Al-Qamer for Energy and Infrastructure Ltd

TRACK B: Commercialisation and Industry Developments, Moderator: Dr. Omar Ayed, Al-Balqa Applied University

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13.30 The Isfir-Jafr Oil Shale Project Status

Speaker: Pete Coldham, Questerre Energy Corporation

13.50 Oil Shale Development in Jordan, HSSE/SP and Operational Excellence to Achieve Goal Zero, Speaker: Malek Abu Rumman, JOSCO

14.10 Al-Qamer Oil Shale Project at Attarat Umm Ghudran, Khaled Khraisat, Geology and Mining Manager, Al-Qamer for Energy and Infrastructure Ltd

14.30 Afternoon Break and Refreshment

15.00 Panel: Outlook for the Oil Shale Industry

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Moderator: Dr. Maher Hijazin, Former Director General, Natural Resources Authority Jordan

Panellists:

Yusuf Siddiqui, Shell Country Chairman & General Manager, Jordon Oil Shale Company

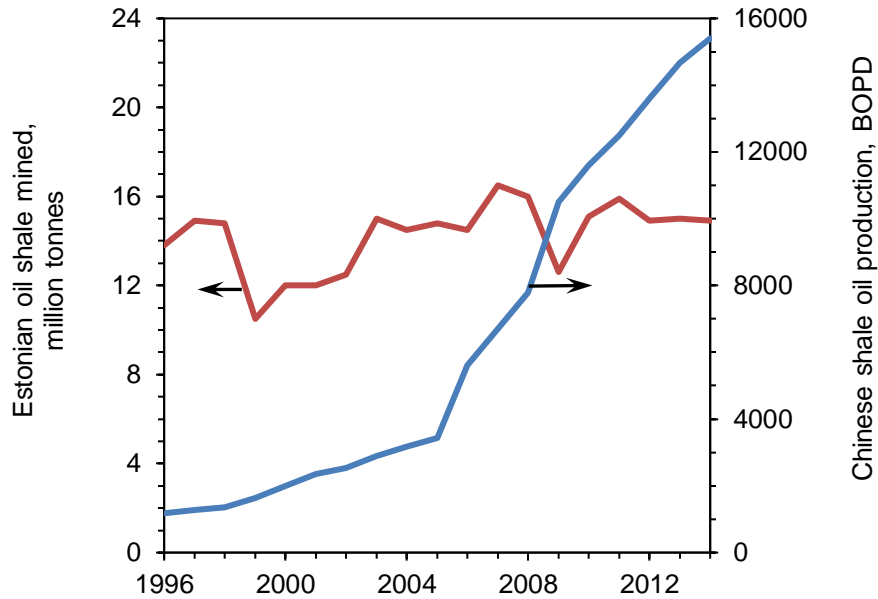
Munther Akroush: Vice Chairman, Karak International Oil  
Andres Anijalg, Chairman of the Management Board, Attarat Power Company

15.30 Closing Remarks and Close of Symposium

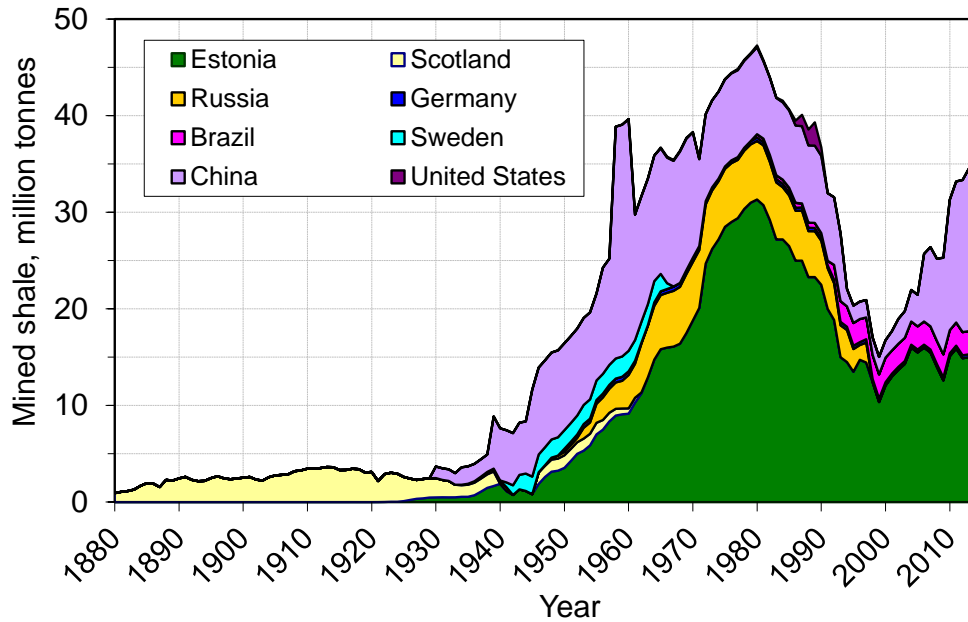
## Appendix: Additional Information on Oil Shale Commodity Activity

### Current and Projected Oil Shale Production

Current activities include both production and development projects, with active oil shale production most important in Estonia and China (each about 15 million tonnes/year), and with Brazil a distant third (2.4 million tonnes/year). A summary of recent activity in Estonia and China (Hou, 2014) is shown in Figure 1. Figure 2 puts these figures in context with historical production around the world.

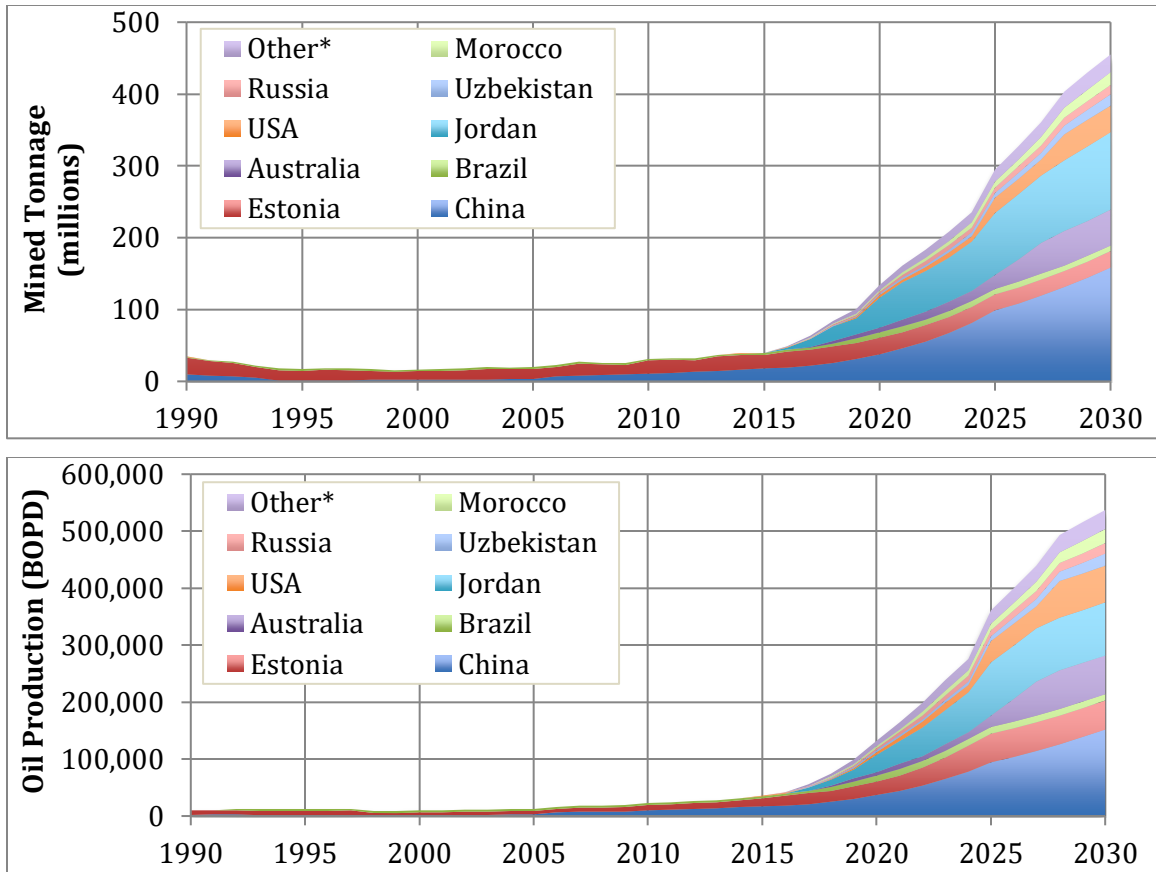


**Figure 1.** Recent history of oil shale mining in Estonia and shale oil produced in China.



**Figure 2.** History of oil shale extraction updated from Dyni (2006) using a variety of industry and government sources.

Production projections up to 2030 are shown in Figure 3 (Boak, 2014). These projections do not include potential in-situ projects, as that technology is still being developed. However, it does include projects that propose surface retorting technology that has not been demonstrated at a commercial (>5,000 BOPD) scale. Even so, it is plausible that a more mature surface-retorting technology could be substituted with less disruption if the proposed technology does not come to fruition. Then again, these projections do not take the recent decline of crude oil prices into account. In brief, there are many factors that make these projections optimistic.



**Figure 3:** Current and projected quantities of mined oil shale and shale oil produced by pyrolysis. Much of the mined oil shale is burned directly to produce electricity.

Total global production of shale oil for 2015 is estimated to be about 46,000 BOPD, all from China, Estonia, and Brazil. Chinese production is estimated to be about 17,000 BOPD, Estonian production about 25,000 BOPD, and Brazilian production about 4,000 BOPD. Current projections show that oil shale will not be a significant part of global production (>500,000 BOPD) for at least another decade. However, projects are in line over the next several years that could increase production significantly over current levels.

## Estimated U. S. and International Resources/Reserves and Strategic Importance

The standard reference for world resources of oil shale places them at ~3.0 trillion bbls, of which about two trillion bbls were located in the U.S.A. (Dyni, 2003).<sup>1</sup> The largest oil shale deposit in the world is the Green River Formation of Colorado, Utah and Wyoming. Dyni noted that the estimate was conservative because several deposits had not been adequately explored. Consequently, it is not surprising that some have proposed major upward revisions in some countries. For example, China just discovered a billion bbl resource in Heilongjiang Province. Additional updates to the projected resources of oil shale come from Israel and Jordan. Each now estimates the potential for more than 100 billion bbls of oil in place. Yuval Bartov of IEL suggested resources as high as 250 billion bbls, and JEML reports an estimated resource of 102 billion bbls for Jordan (pending peer review). Other increases are likely as more exploration and resource characterization is performed.

If one takes the largest number from recent estimates, the U.S. has the largest resource at 6 trillion bbls, China is second at 330 billion bbls, Russia third at 270 billion bbls, Israel fourth at 250 billion bbls, and Jordan and DR Congo tied for fifth at 100 billion bbls. The next four, with resources from 30 to 80 billion bbls, are Brazil, Italy, Australia, and Morocco. Estonia, which became the largest producer of shale oil this year, is 11<sup>th</sup> at only 16 billion bbls. These estimates should be taken with due caution, and a new assessment using consistent criteria is sorely needed.

The U.S. resource estimate depends on whether one includes formations besides the Green River Formation and whether a grade cutoff is used. The most recent evaluation of the Green River Formation in Colorado, Utah, and Wyoming (summarized in Birdwell et al., 2013) places the total resource, regardless of grade, at 4.3 trillion bbls. Colorado resources increased from the 1.0 trillion bbl previous estimate to 1.52 trillion bbls, with Utah estimated at 1.32 trillion bbls of oil in place, and Wyoming with total resources of 1.44 trillion bbls. If one includes the Eastern Devonian shales and the Phosphoria shales in the U.S. resources, one gets a total resource closer to 6 trillion bbls. While it is true that the other formations are not as rich as the Green River Formation, one should also recognize that they are as rich as resources considered in other countries and that an Eastern Oil Shale Symposium was held for 13 years in the 1980s and 90s to discuss recovery technology for those resources.

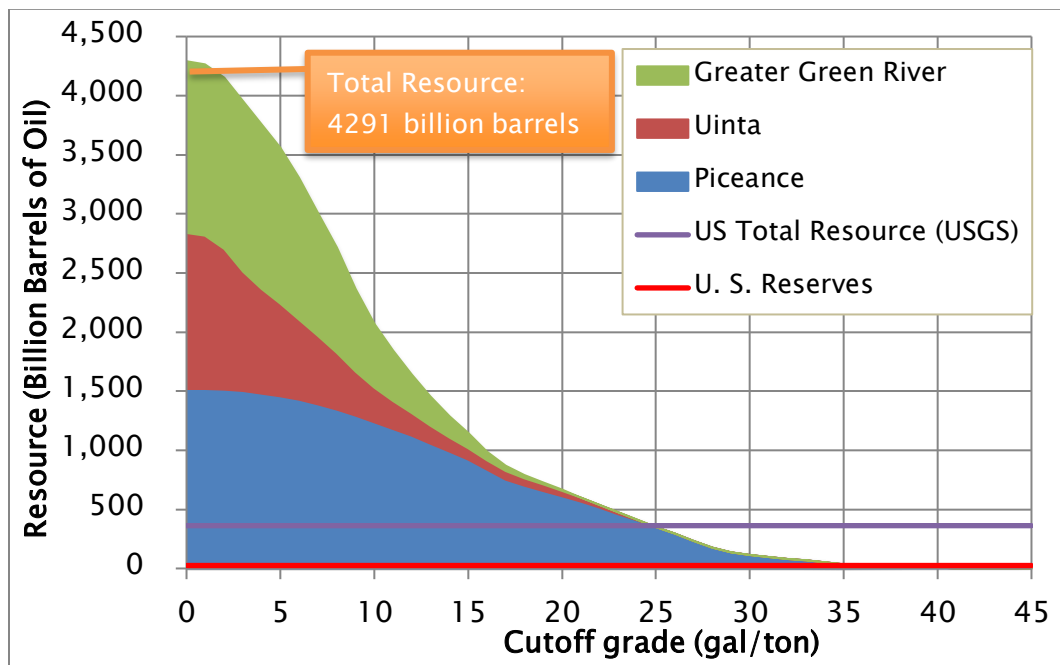
A recent fact sheet on the resource available at various cutoff grades indicates that the marginally prospective resources (those with Fischer Assay oil yield above 15 gal/ton) in the Green River Formation are closer to 1.0 trillion bbls and are generally located in the Piceance Basin. Figure 4 shows the USGS estimates of these amounts. It should be noted that these estimates are fairly conservative and were determined on a per acre basis with grade averaged over stratigraphically defined intervals (rich and lean zones in the Piceance and Uinta Basins, more general intervals in the Greater Green River Basin). Additional analyses of the oil shale resource in the Piceance and Uinta Basins are available in other USGS Fact Sheets on issues related to in-situ development and mining (Birdwell et al., 2014, 2015). Even

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<sup>1</sup> Measurements of shale oil yield by Fischer Assay, a method designed to approximate the recovery of surface retorting methods, provide the basis for most resource estimates. Recovery estimates for different processes will be different and are usually referenced to the Fischer Assay value. Most processes recover less than Fischer Assay oil, but some processes that focus on hydrogenation of the kerogen can recover amounts greater than the Fischer Assay. In addition, because the Fischer Assay calculates the gas fraction by difference, this measure does not adequately account for non-condensable hydrocarbon gases potentially present in the mass fraction lost during assay. In situ processes tend to have a higher gas/liquids ratio. Thus, it is difficult to provide consistent estimates of the potential resource of oil shale available at this time. The lack of estimates of the gas fraction can be of special significance, as this resource is likely to be used in the heating process, and therefore affect the external energy return of the processes.



though the recoverable resource in the Uinta Basin looks tiny in Figure 4, it is still estimated to be tens of billions of bbls, which is larger than the US proved crude oil and condensate *reserves* (36.5 billion bbls, EIA, December 2014). A closer examination of the Uinta Basin resource was conducted by the Utah Geological Survey (Vanden Berg, 2008) yielding a range of estimates based on grade cutoffs, interval thicknesses and overburden in the upper Green River oil shale resource. It is worth noting that the >20 gal/ton resource total for the Formation of about 700 billion bbls dwarfs the proven crude oil reserves and illustrates the potential importance of future oil shale development. One caution is that the remaining undiscovered and technically recoverable crude oil resource is considerably larger than the proved reserves for a variety of reasons and is more comparable to the amount of oil recoverable from oil shale.



**Figure 4:** Oil Shale resource estimates for different grades of oil shale, from U.S. Geological Survey data (presented at the 32<sup>nd</sup> Oil Shale Symposium and summarized in a USGS Fact Sheet, Birdwell et al., 2013) compared to U.S. crude oil reserves.

The strategic significance of oil shale resources varies from country to country. In the U.S., much has been made of the size of the resource. However, its availability remains uncertain in large part due to regulatory uncertainty. Technology to produce the vast quantities of oil potentially recoverable is being tested, but only two developers still have production plans, both using above ground technology in Utah. Current operations in other countries form a firm foundation for concluding that commercial technology is available for production in the U. S., but the recent drop in crude oil prices has reduced the urgency of oil shale development. In contrast, development of this resource can be very important strategically for smaller countries with lower energy demands and no other liquid hydrocarbon resources (Estonia, Jordan, and Morocco, for example). Estimates of the oil shale resource in Israel have increased dramatically in recent years, but recent discoveries of off-shore natural gas and Golan Heights oil may reduce its sense of importance to that country in the near-term.

## Production and Development Activities around the World

**China** produces shale oil and electric power from oil shale mined in the Fushun, Huadian, Huangxian, Junggar, Maoming, and Luozigou Basins, and from the Dalianhu and Haishiwan areas. Operating oil-shale retorting plants are located in Beipiao, Chaoyang, Dongning, Fushun, Huadian, Jimsar, Longkou, Luozigou, Wangqing and Yaojie. Evaluation is continuing in four other basins and a number of other areas, with a billion-tonne resource recently discovered in Heilongjiang Province. The major producing and developing companies are the Fushun Mining Group, the Maoming Petrochemical Co. (owned by SINOPEC), Longkou Coal Mining Co, Longteng Energy Company, Gansu and Saniang Coal Companies, Julin Energy & Communication Corp., and Petrochina. The gas-combustion Fushun retort is the dominant technology, and the Fushun district is responsible for about half of Chinese production. A new open pit mine opened in 2014 in Fushun. Over the last few years, new retorts were being built rapidly—about 130 in 2014. Most of them use lump oil shale, but some retorts are now being built to process fines. An ATP retort in Fushun tripled its operational time to 300 days, including 115 days of continuous operation between turnarounds, and has nearly reached full design capacity. Oil shale fines are also burned at various locations in fluidized beds for power production. Total oil production and mined oil shale updates were not received in time to include in this report, but in 2015 oil production increased from 830,000 to 850,000 tons, which corresponds to about 17,000 bbl/day.

In **Estonia**, the three producers are Viru Keemia Grupp (VKG), Eesti Energia (internationally known as Enefit), and Kiviõli Keemiatööstus. VKG, the largest oil producer in the country, commissioned a second Petroter plant in August 2014 and a third unit in September 2015, which raising their capacity to about 14,000 BOPD. VKG continues efforts to reduce air emissions and produce building material from spent shale. Enefit produces 80% of Estonia's electricity from oil shale and operates two Enefit140 retorts producing shale oil at a combined rate of about 4,000 BOPD. Enefit achieved design-capacity operation of its new Enefit280 retort in September 2015, which brings its total production capacity to nearly 10,000 BOPD. The Enefit280 is a new generation oil shale retorting plant developed for processing Estonian oil shale. The oil, gas and power co-generation plant includes state-of-the-art solutions for oil shale retorting. The new plant has been successfully put into operation and has shown the lowest environmental impact and the highest energy efficiency compared to the other industrial retorting plants in Estonia. The route to a successful operation of the plant involved solving of numerous challenges including ash imbalance, design flaws in equipment, process fluctuations, operational problems, etc. Long term operational experience from the old retorting plants has allowed finding working solutions to all challenges identified. Proof of the Enefit280 process concept is the basis for selling Enefit280 technology for processing of other oil shales around the world. Enefit is also developing the Auvere power plant, which is a modern 300 MW circulating fluidized bed (CFB) power plant where oil shale fuel can be supplemented with wood chips (to the extent of 50%), peat (to the extent of 20%) and oil shale gas (to the extent of 10%). This allows reducing its emissions to the level of a modern gas-fired plant. The maximum annual net generation of the power plant is around 2.2 TWh, i.e. the plant can cover around one fourth of Estonia's annual electricity consumption. Construction of the Auvere plant started in 2011 and began operating in 2015 but delivery of the plant has been delayed because during the testing and commissioning period it appeared that under certain circumstances the dust emissions of the plant exceed the regulatory limit. The contractor, General Electric, plans to install an additional baghouse. According to the agreement, the plant must meet all contractual parameters and be delivered to Enefit in October 2017. Enefit produced a total of 2.03 million barrels of shale oil in 2016. Oil production decreased because at the beginning of the year the market prices of oil were exceptionally low and in the summer the Enefit280 was closed for extended maintenance. The work done was productive – in the second half of the year the plant operated steadily at close to designed capacity and at the end of the year yielded its best-ever 90-day output: 325 000 barrels. Enefit expects

strong output from Enefit280 also in 2017.

In **Brazil**, Petrobras continues mining and retorting Irati oil shale, producing about 4,000 BOPD using the Petrosix technology, but it has no expansion plans. However, startup Irati Energy Limited, owned by Forbes & Manhattan, controls >3,100 km<sup>2</sup> in Southern Brazil, with over 2 billion barrels (bbls) of potential oil shale resources. It plans an initial start-up production of 8,000-10,000 BOPD using two Petrosix retorts. Future project expansion will use the PRIX technology, which is an incremental improvement over the Petrosix technology. It has completed its exploration phase and is looking for investment in the engineering phase based on market and economic assessments completed by Ernst & Young and Millcreek Mining Group, respectively.

**Jordan** is pursuing oil shale aggressively, although economic forces will delay its goal of producing 14% of its energy from oil shale, including all of its currently imported oil, to about 2025. It currently has numerous Concession Agreements, Memoranda of Understanding, and a Power Purchase Agreement in place. Enefit has electricity and oil production development projects in Jordan that were launched in 2006 with a view to building an oil shale power plant and an oil industry in Jordan. Jordan's first oil shale fired power plant with a gross capacity of 554 MW and net capacity of 470 MW should be completed by 2020. In 2016, Enefit's interest in both projects was 65%. The projects' co-investors are YTL Power International Berhad from Malaysia with a 30% interest and Near East Investment from Jordan with a 5% interest. In 2016, the investors and Chinese banks signed financing agreements for the Jordanian electricity project of 1.6 billion US dollars (approx. 1.5 billion euros) and agreements required for obtaining a credit guarantee. The guarantee needed the approval of the government of China. In January 2017, China's export credit agency Sinosure notified Enefit of the fact that the government of China had approved the credit guarantee. In May 2016, Enefit signed a share sale agreement with Guangdong Yudean Group Co by which Enefit's interest in the electricity project will decrease to 10%. The transaction will be finalised when the official guarantee policy has been issued and the preliminary terms of the financing agreements have been fulfilled. Enefit is also negotiating a separate agreement with Jordan to construct a 40,000 BOPD shale oil plant. Jordan Oil Shale Company (JOSCO, owned by Shell) has drilled and characterized 340 wells to support the selection of its final 1,000 km<sup>2</sup> lease hold. It activated a small-scale in-situ pilot in September 2015 to demonstrate its in-situ technology in the resource and to calibrate its subsurface models for potential commercial development. Karak International and parent Jordan Energy and Mining Ltd (JEML) have completed an interim funding agreement underwritten by Sentient Group funds to pursue a shale oil production project. Karak holds a concession for the Lajjun deposit that contains approximately 300 million bbls of oil in place, where it proposes to use the ATP technology, and it also has a Memorandum of Understanding (MOU) to explore oil shale at Al Nadiyya. Another MOU has also been signed between Jordan and a consortium of China's Shandong Electric Power Construction Corp and HTJ Group and Jordan's Al-Lajjun Oil Shale Company to produce 900 MW of electric power. Jordan also signed a MOU in 2014 with China's Fushun Mining Group Co to conduct geological and geophysical studies in the Wadi Al Naadiyeh area. Jordan approved a concession in March 2013 to the Saudi Arabian Corporation for Oil Shale and a production agreement in March 2014 that is projected to produce 3,000 BOPD by 2019 and 30,000 BOPD using the Russian UTT-3000 technology. Other companies holding MOUs for shale oil production are Aqaba Petroleum for Oil Shale Co, which also proposes to use the UTT-3000 process, Global Oil Shale Holdings, which proposes to use the PRIX process, and Whitehorn Resources and Questerre, which propose to use the Red Leaf EcoShale Process.

In the **United States**, Red Leaf Resources has leases on 45,000 acres of Utah state lands and projects at both Seep Ridge and Holliday Block. They obtained the necessary permits from the State of Utah and started construction in 2014 of a 5/8<sup>th</sup> commercial-scale demonstration of its EcoShale<sup>®</sup> technology.

However, due to the decline in oil prices, the project was halted and the process was re-optimized for the new economic environment. The current design changes from indirect to direct heating to reduce capsule construction costs, increase retorting rate, and increase thermal efficiency. Construction is currently delayed indefinitely as the company is currently in the process of separating from TOTAL. Red Leaf settled a lawsuit in 2014 with Living Rivers in return for sharing ground water monitoring information. Meanwhile, TomCo Energy received temporary approval from the State of Utah in September 2014 for its Notice of Intention to Commence Large Mining Operations using the Red Leaf EcoShale process, but they will wait for the demonstration-scale process validation.

Enefit American Oil (EAO) has 3.5 billion bbl of in-place oil shale resources associated with both private lands and an RD&D Lease from the U. S. BLM and SITLA leases from the state of Utah, with about 2/3 on private land. It made progress on getting permits for development of its private lands in Utah. In Q4 of 2016 it was announced that 514 million barrels for the Utah project was given reserve status (proven and probable). The company will complete their Utility Corridor EIS process with the BLM in mid-2017, and will begin preparation of their state Large Mine Operation permit application in 2017 as well. The draft EIS for its industrial utilities corridor was published in April 2016. It successfully resolved a potential environmental roadblock in 2014 by working with local officials, who created a conservation plan for a potentially rare plant (Beardtongue), culminating in USFWS deciding not to list the plants on the endangered species list. Signed just one year ago, a landmark Conservation Agreement to help protect two sensitive species of flowering plants living on or near oil shale outcrops is already showing promising signs of success. Not only have more plants been identified throughout Utah's southern Uinta Basin – and, importantly, in areas previously thought to be outside their growing range, nearly 90 percent of penstemon plants transplanted to an EAO conservation area in 2014 have survived the move, based on 2015 survey data. EAO re-optimized its demonstration plans by switching to its smaller and already demonstrated Enefit280 design and developed an alternative conceptual plan that would include process changes allowing better heat and gas liquids recovery. EAO is also evaluating a possible alternative site development plan that would transition more quickly to underground mining of richer oil shale and includes moving their plant site. In 2016, EAO contracted Millcreek Mining Group to prepare an initial review and subsequent possible reserve statement for EAO's proposed oil shale mining and mineral processing project located on the Enefit South parcel. If the screening causes EAO to proceed with the full reserve statement, this could potentially allow EAO to advance the status of a portion of its property from a measured and indicated oil shale resource to proven and probable oil shale reserve classification. This would be the first oil shale to shale oil project to achieve the reserve classification.

Further efforts in the United States occurred on the BLM RD&D Leases. Enefit used shale both from its RD&D lease holding and its private lands to demonstrate the applicability of the Enefit process to Utah oil shale through pilot testing in Germany. In Colorado, American Shale Oil LLC (AMSO), a partnership of Total and Genie Energy, encountered problems with its downhole heater in 2013. In 2015, AMSO qualified an electrical heating system for restarting its pilot test. However, economic forces caused the partners in 2016 to discontinue work and move toward site reclamation. In 2013, Shell cancelled its multi-mineral test of sequential production of nahcolite and shale oil on one of its three RD&D leases. They plan no development activities on their other two RD&D leases and are currently reclaiming both their private and public lands along with disposing of all of their Colorado holdings. Terra Carta purchased all the Shell oil shale land, minerals, and infrastructure except small areas around the Shell pilot tests. Simple Oil LLC, formerly known as Natural Soda Holdings Inc. (NSHI), and ExxonMobil received approval from BLM of their Development Plans for in-situ projects on their second-round RD&D leases awarded in 2012. Simple Oil has continued its permitting and development activities. However, ExxonMobil has relinquished its 160-acre RD&D property back to the BLM and has ceased all oil shale

operations in Colorado. All work to date had been at their Colony Mine site, so no reclamation was needed on their RD&D site.

In other activities, Shale Technologies International Services LLC continues to maintain a small staff at their facilities in Rifle, CO. Great Western Energy secured leases on over 13,000 acres of Utah state lands. Meanwhile, Orion Reserves is offering to sell its 3000 acres of private Utah oil shale lands.

In **Australia**, Queensland Energy Resources (QER) successfully completed the operation of its demonstration plant near Gladstone in early 2014. A draft Environmental Impact Assessment has been prepared for an 8300 bbl per stream day commercial plant located at the Stuart oil shale deposit near Gladstone, Queensland. Given the current economic climate, QER identified and adopted cost savings of up to \$100 million to improve project returns and position the company favorably to move forward with a commercial plant when oil prices recover. QER recently completed extensive fuel trials of both jet fuel and ultra-low sulfur diesel (ULSD) extracted from oil shale and manufactured using the Paraho retorting process. Both these QER shale derived fuels have now been accepted for commercial use. In the wake of depressed global oil prices, QER has quietly advanced the process engineering and design for its proposed first commercial plant on the Stuart kerogen shale deposit. Engineering and design will continue during 2017 with a major focus on achieving significant energy efficiency improvements in the process design. QER remains well placed offer security of supply in the liquids fuels market for Australia well into the future.”

In **Morocco**, San Leon Energy determined in 2012-2013 that a yield of 17 gal/ton was achievable in two reservoir zones of the Tarfaya oil shale using Enefit Technology, and it began investigating Timahdit oil shale in 2013. They reported in August 2014 that shale oil had been produced successfully using bench tests of the Enefit280 process. San Leon Energy signed a MOU with Chevron Lummus Global to examine upgrading of Timahdit shale oil. The Abu Dhabi National Energy Company (TAQA) is also currently working on the Timahdit area in order to evaluate a potential development using the EcoShale<sup>®</sup> Technology. Global Oil Shale PLC has established a fully owned subsidiary in the country and is continuing the evaluation of the Tarfaya oil shale resources by open pit mining.

**Mongolia** Petroleum Authority entered into an exclusive five-year oil shale development agreement in April 2013 with Genie Mongolia to explore and evaluate the commercial potential of oil shale resources on a 34,470 square kilometer area in Central Mongolia. Genie Mongolia has begun surface mapping and other geophysical evaluation work as well as drilling exploratory wells, and has secured permits for additional exploratory wells. Further plans depend on both technical and regulatory developments. In September 2014, Mongolia held an international investors forum, with over 300 attendees from corporations such as Rosneft, Petrochina, British Gas, Sinopec and many other companies. The Prime Minister gave an opening speech describing legal reforms intended to increase investment.

In **Israel**, the government issued directives in April 2013 for the environmental impact statement that is required as part of Israeli Energy Initiative’s (IEI) pilot test permit application in the Shefla Basin. IEI, a subsidiary of Genie Energy, prepared and initially submitted its pilot application in June of 2013 to the Jerusalem District Building and Planning Committee and supplied additional information in November. In August 2014, the Israeli Environmental Protection Ministry recommended against the project. In September, the Jerusalem District Committee for Planning and Building declined to issue IEI a permit for its pilot project. IEI is currently evaluating alternatives to determine the best course of action to advance the project and develop the resource covered by the exploration license.

In **Canada**, Chapman Petroleum Engineering Ltd. completed in February 2013 an NI 51-101 Engineering Evaluation Report of Contingent Resources and Commerciality Factors for Xtra Energy’s Pasquia Hills oil shale permit located in northeastern Saskatchewan, estimating about 2 billion bbls of potential oil. In

December 2013, Cencor acquired a 55% working interest in a Pasquia Hills oil shale project with a resource of 1.2 billion bbls of oil. Canshale was formed and organized in 2010 to acquire and develop exploration permits over a large, near-surface oil shale deposit in northeast Saskatchewan. The land area for the “Golden Plain Project” includes 52,131 ha (128,819 ac) currently being held by Saskatchewan Exploration Permits (Conversion to Lease in process). The resource is estimated at 10 billion barrels, based on a best estimate of contingent resources for a 20 LTOM grade cutoff. The oil shale deposits occur as two near surface kerogen-rich beds within the marine shale of the Colorado Group – the Boyne and Favel Formations, both of Late Cretaceous age. Since 2010, Canshale’s Management has secured exploration permits for surface mineable hydrocarbon and mineral rights near the town of Hudson Bay, Saskatchewan and drilled, delineated and evaluated a world class, surface mineable oil shale deposit, with a third party reporting 10 billion barrels of recoverable oil. This has confirmed the results of legacy drilling and defined the extent, depth and thickness range of the deposits. Canshale has obtained core samples of oil shale for analysis and determined the yield of recoverable hydrocarbons (FA, MFA and batch test). Recovery testing has been undertaken by employing two leading, proven hydrocarbon recovery processes. Based on independent engineering of a mining plan and project design, management has confirmed technical and economic feasibility. Questerre and Whitehorn have options for licenses.

**Uzbekistan** could become the first Central Asian country to produce from oil shale as part of plans by the government to address dwindling oil production and domestic fuel shortages. The national oil and gas company Uzbekneftegaz plans to develop a \$600 million oil shale processing complex (mine and processing plant) with a capacity of 8 million tons per year, producing 1 million tons of shale oil annually (~17,000 BOPD). The feasibility study was planned for completion in 2015. In the first phase, one million tons per year would be processed in a solid-heat-carrier unit of a design yet to be chosen. Future expansion may include preliminary hydrotreatment, but final refining to motor fuels would take place in the existing Bukhara refinery.

### ***Leading Companies in Development of Oil Shale***

Efforts by major international oil companies in the U.S. are generally led out of Houston, Texas. Currently, Petrobras is the only international oil companies with notable activities in oil shale as Total and Shell have ended most if not all of their oil shale projects. There is some indication that BP and ConocoPhillips have interests in revisiting microwave technology as a means of in situ retorting oil shale in the US, but these reports have not been substantiated by the companies (Ozy Magazine, 2016).

In addition, three other large oil companies have significant land holdings underlain by oil shale, and one major oilfield service company has acquired technology for oil shale evaluation and conducts research on the petrophysical properties of oil shale:

- Anadarko Petroleum Corporation
- ConocoPhillips
- Chevron
- Schlumberger

Smaller U.S. companies pursuing development, mostly in the U.S. include:

- Combustion Resources, Inc.
- Enefit American Oil
- General Synfuels International
- Genie Oil (Israel/Mongolia)

- Great Western Energy (Colorado/Utah)
- Independent Energy Partners
- Simple Oil LLC
- Red Leaf Resources
- Shale Tech International
- CanShale (Canada)
- Centor Energy (Canada)
- UMATAC/ThyssenKrupp (China/Jordan/Canada)
- TomCo Energy (Utah) (EcoShale licensee)
- Anadarko (Wyoming)
- Orion Reserves (Utah lease holdings)
- Encana (has resource holdings in CO)
- Uintah Gateway/Partners – property in CO and UT, developing regional upgrader project in UT that would start with black wax then expand for shale oil.

International leadership is held mainly by companies producing oil shale at the present time and also currently pursuing development of oil shale:

- Eesti Energia/Enefit (Estonia)/Outotec (Finland)
- Fushun Mining Group (China)
- Petrobras (Brazil)
- Queensland Energy Resources (Australia) [demonstration plant]
- Viru Keemia Grupp (Estonia)
- Canshale Corporation (Canada)
- Altius Resources (Canada)
- Aqaba Petroleum for Oil Shale (Jordan)
- Global Oil Shale Holdings (Canada)
- Irati Energy Limited (Brazil)
- Israel Energy Initiatives Limited (Israel) – owned mostly by Genie Energy
- International Corporation for Oil Shale Investment (Incopin) [MOA in Jordan]
- Jordan Energy Minerals Limited (England) [Agreement in Jordan]
- San Leon Energy (Ireland) [concession in Morocco]
- TAQA (Abu Dhabi) agreement in Morocco

National agencies/oil companies involved in developing oil shale include:

- China National Petroleum Corporation (China)
- National Resource Administration (Jordan)
- Organization National des Hydrocarbures et des Mines (ONHYM), Morocco

## **Current Research**

Current industry research focuses on development and testing of a variety of techniques for extracting oil from oil shale and on minimizing the environmental impacts of these techniques. These activities fall into three main categories: 1) mining and retorting, 2) in situ heating and extraction, and 3) in-capsule extraction.

The first is the traditional method of oil shale extraction, which has been pursued with some intermittency for more than one hundred years. Developments in this area generally relate to increasing the energy efficiency and decreasing the impact of retort operation by reducing water use and CO<sub>2</sub> emissions. The development of advanced fluidized bed reactors is a current area of research and development. In addition, research continues on the impacts of past mining and retorting, and on utilization of spent oil shale and oil shale ash from burning of oil shale in power plants. The most obvious applications involve use of spent shale and ash in cement and brick manufacture, but more advanced techniques involving extraction of various constituents from the material have been investigated. The Fushun Mining Group in China has set as an objective no net waste products from oil shale production.

The second method, in situ heating and extraction, is the focus of intensive research to develop a method to heat and pyrolyze kerogen-rich rocks underground and efficiently extract the resulting oil and gas from the formation. Shell has been a leader in this area using their In situ Conversion Process (ICP), and ExxonMobil, AMSO (a partnership of Total and Genie Oil), IEI (Israel Energy Initiatives, a Genie subsidiary) have investigated different processes. In situ heating takes longer (on the scale of years), but as a consequence pyrolysis occurs at lower temperatures, and additional reaction at depth leads to a lighter oil with a larger gas fraction. The amount of secondary processing to meet refinery requirements is generally considered to be less than for products from surface retorts. Research on in situ processes and on processing the resulting material is ongoing at companies developing these methods, but results are generally proprietary. Symposium presentations have described general results in containment, heating, extraction, refining, and reclamation.

The third method, in-capsule extraction is the method being pursued by Red Leaf Resources of Cottonwood Heights, Utah. It involves mining of oil shale, encapsulation in a surface cell akin to a landfill, heating and extraction of the products, and final sealing of the exhausted retort. The process is described in more detail at Red Leaf's website: <http://www.redleafinc.com/>. Red Leaf is not currently involved in supporting external research on its method, although it is working with engineering firms on process design. Its plans for a 2015 demonstration project have been delayed at least a year due to low oil prices, and the delay is being used to re-optimize the process. The company had anticipated producing 10,000 BOPD by 2017 and 30,000 BOPD sometime in the 2020s, but no new schedule information is available. If it does occur, it would be a globally significant development for oil shale.

The U.S. Geological Survey (USGS) continues to conduct research evaluating the nature and extent of oil shale resources in the United States. Research continues at the USGS on the process of generation of oil from organic rich sedimentary rocks, both naturally and under simulated conditions of in situ production. General research on the geology, stratigraphy, geochemistry and rock physics of oil shale are under way at a number of institutions, including the Colorado School of Mines, University of Utah, University of Wisconsin, Binghamton University (New York), University of New Brunswick and other North American and international universities.

Independent Energy Partners is testing its Geothermic Fuel Cell unit at the Colorado School of Mines in Golden, Colorado, in partnership with Delphi and Total. A downhole test of 30-ft module started in October 2014 and operated successfully for a month with a combined heat and power efficiency of 55%.



Shale Tech International Services LLC (STIS) continues oil shale processing research at its R&D Center in Colorado with a scaled back staff. STIS provides analytical laboratory services and batch testing for client resources, as well as a technology licensing and project development program.

The Stanford-Total Enhanced Modeling of Source rocks (STEMS) project started in 2014 to address the fundamentals of oil and gas formation for in-situ oil shale production and natural petroleum formation. Research relevant to both applications is being pursued, but the only explicit applications currently under consideration are unconventional oil and gas production from mature source rocks and natural generation and expulsion from source rocks.

The Grossman Group at MIT has opened an experimental research program on kerogen and is working on projects focusing on its characterization and the exploration of new applications of it as material substitute. The effort started in 2013 and is currently sponsored by Shell and Schlumberger.

#### *List of Specialists in the United States*

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##### ***Amec Foster Wheeler***

- Konrad Quast, Green River Formation geochemistry

##### ***Colorado School of Mines:***

- John Berger, COSTAR, modeling of fracturing in oil shale
- Mark Kuchta, underground methods for in situ production of oil shale
- J. Frederick Sarg, stratigraphy and sedimentology of Green River Formation, Colorado
- Wei (Wendy) Zhou, Geographic Information Systems for oil shale water resource evaluation

##### ***Daub & Associates, Inc.***

- Gerald J. Daub, geology and oil shale resources of the Piceance, Uinta, and Green River Basins, hydrology, environmental, permitting, well optimization, rock mechanics, and project management.

##### ***Enefit American Oil***

- Rikki Hrenko-Browning, , oil shale development
- Ryan Clerico, environmental issues and regulatory affairs

##### ***ExxonMobil Upstream Research Company***

- William Symington, thermal behavior of Green River Formation oil shale and technology for application of heat in situ

##### ***Idaho National Laboratory***

- Hai Huang, geomechanical behavior of oil shale
- Earl Mattson, Idaho National Laboratory, Idaho Falls, ID, hydrology of oil shale deposits and water consumption patterns for oil shale production
- Carl Palmer (emeritus), mineralogical and chemical effects of pyrolysis on oil shale

##### ***Los Alamos National Laboratory***

- Daniel Levitt, hydrology of oil shale deposits
- Jonathan Mace, explosives application to fracturing of oil shale
- Donatella Pasqualini, energy systems analysis for Western Energy Corridor

### ***Millcreek Engineering/Mining Group***

- Andrew Maxwell, oil shale properties, retorting
- Alister Horn, mining
- Greg Gold, oil shale properties, mining, retorting
- Steven Kerr, oil shale exploration and resource characterization

### ***Schlumberger Doll Research Center***

- Drew Pomerantz, pyrolysis of oil shale, kinetics, and characterization
- Michael Herron, mineralogic and chemical characterization of oil shale
- Malka Machlus, stratigraphy of Green River Formation oil shale
- Robert Kleinberg, characterization and pyrolysis of oil shale

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- Mariela Araujo, Extraction technology, thermal modeling
- Dave Burns, Heater development
- Tom Fowler, in situ production of oil shale, oil shale piloting
- John Karanikas, Chief Scientist unconventional technology
- Etuan Zhang, In situ oil characterization and generation

### ***Red Leaf Resources LLC***

- James Patten, Properties of Oil Shale, Ex Situ Retorting processes
- James Bunger, Geology, properties and kinetics, Lab and Modeling
- Les Thompson, Oil Shale Retorting Operations

### ***Sage Geotech***

- Gary Aho, Rifle, CO, geology, mining, and oil shale production technology
- Ed Cooley, ERTL Inc., Rifle, CO, ex-situ oil shale processing technology
- Glenn Vawter, ATP Services LLC, oil shale extraction technology
- Bob Loucks, former VP of OXY oil shale's Cathedral Bluffs Project C-b Tract
- Howard Earnest, former manager of AMOCO's Rio Blanco Project C-a Tract
- Bob Faulkner, former pyro-process manager at METSO Minerals/Allis Chalmers
- Glen Sykes, underground mine development, C-b mine construction in Colorado and White River Mine development in Utah

### ***Shale Tech International Services LLC***

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- Larry Lukens, ex-situ oil shale technology

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- Justin Birdwell, U. S. Geological Survey, Lakewood CO, organic geochemistry of oil shale and other source rocks
- Michael Brownfield (emeritus), U. S. Geological Survey, Lakewood CO, geology, stratigraphy, sedimentology and resource evaluation of Green River Formation oil shale
- John Dyni, U. S. Geological Survey (ret.), Lakewood CO, geology and resource evaluation of oil shale
- Ronald Johnson, U. S. Geological Survey, Lakewood CO, geology, stratigraphy sedimentology and resource evaluation of Green River Formation oil shale
- Michael Lewan (emeritus), U. S. Geological Survey, Lakewood CO, organic geochemistry of oil shale and other source rocks

### **University of Utah**

- Lauren Birgenheier, University of Utah, Salt Lake City UT, stratigraphy of oil shale
- Milind Deo, Institute for Clean and Secure Energy, University of Utah, Salt Lake City, UT, chemistry and simulation of oil shale retorting processes
- Michal Hradisky, University of Utah, Salt Lake City, UT, oil shale process modeling
- Ronald Pugmire, University of Utah, Salt Lake City, UT, chemistry and kinetics of oil shale pyrolysis
- Jan Miller, University of Utah, Salt Lake City, UT, micro-CT scan of pre and post pyrolysis products
- John McLennan, University of Utah, Salt Lake City, UT, in situ geomechanical properties of oil shale
- Philip Smith, Institute for Clean and Secure Energy, University of Utah, Salt Lake City, UT, chemistry and simulation of oil shale retorting processes

### **Others**

- Jeremy Boak, Director, Oklahoma Geological Survey, Norman, OK, assessment of CO<sub>2</sub> emissions and water consumption by oil shale production; geologic characterization of oil shale
- Adam Brandt, Stanford University, Stanford CA, assessment of CO<sub>2</sub> emissions from oil shale production
- Alan Burnham, consultant to Total, Consulting Professor, Stanford, University, Stanford, CA, oil shale retorting technology; chemical kinetics.
- Alan Carroll, COSTAR, University of Wisconsin, Madison, WI, stratigraphy, sedimentology and geochronology of Green River Formation, Wyoming; lacustrine stratigraphy and sedimentology
- Mike Day, Independent hydrologist, Piceance Basin hydrology
- Roger Day, geology, drilling, and operations expertise in the Green River formation
- Jim Finley, Telesto Solutions Inc, Green River Formation hydrology & geochemistry
- Thomas Fletcher, Brigham Young University, Provo, UT, oil shale chemistry
- Terry Gulliver, oil shale hydrology
- John Hardaway, Environmental restoration for in situ production
- Benjamin Harding, AMEC Environmental, Boulder CO, water use for oil shale production
- Timothy Lowenstein, COSTAR, Binghamton University, Binghamton NY, chemistry and formation of evaporite minerals and spring deposits of the Green River Formation, Colorado and Wyoming
- Seth Lyman, Bingham Research Center, Utah State University, Vernal, UT, Air quality measurement and instrumentation
- Glenn Mason, Indiana University Southeast, New Albany, IN, geology of Green River Formation oil shale
- Bill Merrill, Western Water and Land, hydrology of the Green River Formation
- Jim McConaghy, Antero Engineering, Salida CO, ex-situ and in-situ oil shale extraction technology
- Judith Thomas, U. S. Geological Survey, Colorado Water Science Center, Grand Junction, CO, hydrology of Piceance Creek Basin
- Michael Vanden Berg, Utah Geological Survey, Salt Lake City, UT, geology, stratigraphy, and hydrogeology of oil shale, Uinta Basin
- Henrik Wallman, ProCo, Modeling of in situ and ex situ oil shale processing
- Glen Miller, USGS-retired, oil shale geology and mineral resources

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- Tarvi Thomberg, ex-situ oil shale processing technology
- Erkki Kaisla, oil shale mining
- Oleg Nikitin, oil shale mining
- Tõnis Meriste, environmental issues
- Andres Anijalg, oil shale development (Jordan)

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#### **Israeli Energy Initiatives**

- Yuval Bartov, lacustrine stratigraphy, Green River Formation and Israel
- Harold Vinegar, general oil shale technology, development of Israeli oil shale

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- Pierre Allix, geology, oil shale properties, resource evaluation, retorting processes
- Jean Deridder, oil shale project development
- Olivier Garnier, retorting processes, oil shale development, upgrading
- Samuel Lethier, ex situ oil shale process engineering
- Eric Chabal, ex situ oil shale project development
- Francoise Behar, geochemistry, oil shale kinetics
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#### **QER**

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- Steven Odut, ex situ oil shale processing technology
- John Barge, ex situ oil shale processing technology
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- Daniel Melo, ex situ oil shale processing technology

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- Omar Al-Ayed, Al-Balqa Applied University, Faculty of Engineering, Amman Jordan, properties of Jordanian oil shale and shale oil
- Mohammed Bencherifa, Organization National des Hydrocarbures et des Mines (ONHYM), Rabat, Morocco, engineering and geology of Moroccan oil shale
- Jaan Habicht, University of Tartu, Estonia, Environmental effects of oil shale ash and spent shale
- Uuve Kirso, Tallinn Technical University, Tallinn, Estonia, Environmental effects of spent shale and oil shale ash
- Shuyuan Li, China University of Petroleum, Beijing, China, Properties of oil shale in China

- Zhaojun Liu, Jilin University, Changchun, China, Geology, stratigraphy, and resource evaluation of Chinese oil shale
- Tsevi Minster, Geological Survey of Israel, Jerusalem, Israel, Resource characterization for Israeli oil shale
- Väino Puura, University of Tartu, Resource assessment of oil shale
- Erik Puura, University of Tartu, ash leaching, contaminant transport and ash utilization
- Jialin Qian, China University of Petroleum, Beijing, China, Properties of oil shale in China
- Aya Schneider-Mor, Ben-Gurion University of the Negev, Beer Sheva, Israel, Geology and stratigraphy of Israeli oil shale
- Walid Sinno, San Leon Energy, London England, Development of Tarfaya oil shale
- Jyri Soone, University of Tartu, Tallinn, Estonia, Environmental effects of oil shale ash and spent shale
- Kati Tanavsuu-Milkeviciene, Statoil, stratigraphy and sedimentology of Green River Formation, Colorado
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