Oil Shale Development from the Perspective of NETL's Unconventional Oil Resource Repository

Mark W. Smith[+]
Lawrence J. Shadle
Daniel L. Hill[+]

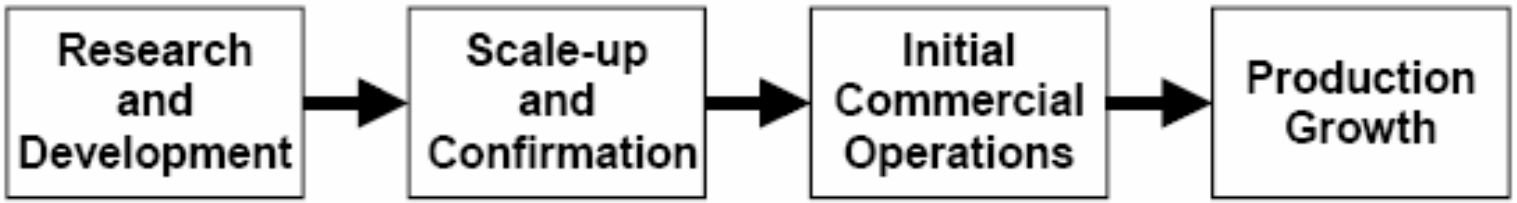
National Energy Technology Laboratory
Office of Research & Development

[+]REM Engineering Services, PLLC

October 18, 2006

"The goal is to promote a measured program for gradual, yet sustained, industrial development."

Stages of Oil Shale Technology Development



Development Stage	Research and Development	Scale-up and Confirmation	Initial Commercial Operations	Production Growth	Strategic Production
Facility Size	Laboratory to Pilot Plant	1000-5000 bpd	>50,000 bpd	>100,000 bpd	>100,000 bpd
Years to Transition*	--	0	6-8	14-20	25-30
Total Production (million bpd)		N/A	N/A	>0.1	>1

*Beginning with the transition from *Research and Development*

Figure from J.T. Bartis, et. al (2005) RAND Report.

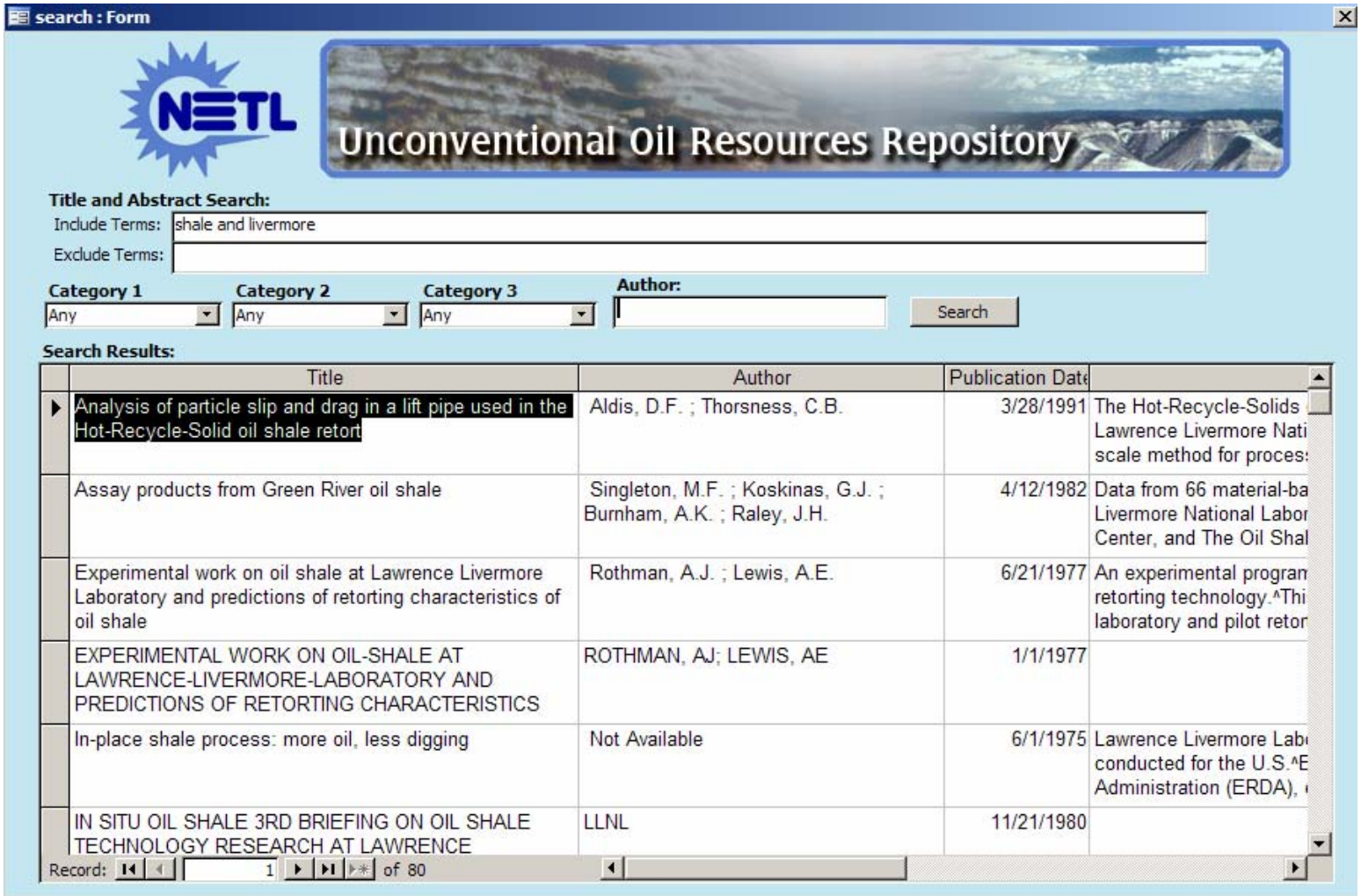
UOR Repository

- Purpose
  - Document R&D efforts related to unconventional oil resources including oil shale and oil sands
  - Provide a portable means to find, retrieve, and view R&D efforts
  - Identify additional R&D needs
- Provided
  - Bibliographical information (>17,000 records)
  - Full documents (>800 pdfs)
  - Resources (>1000)
  - Links to additional documents

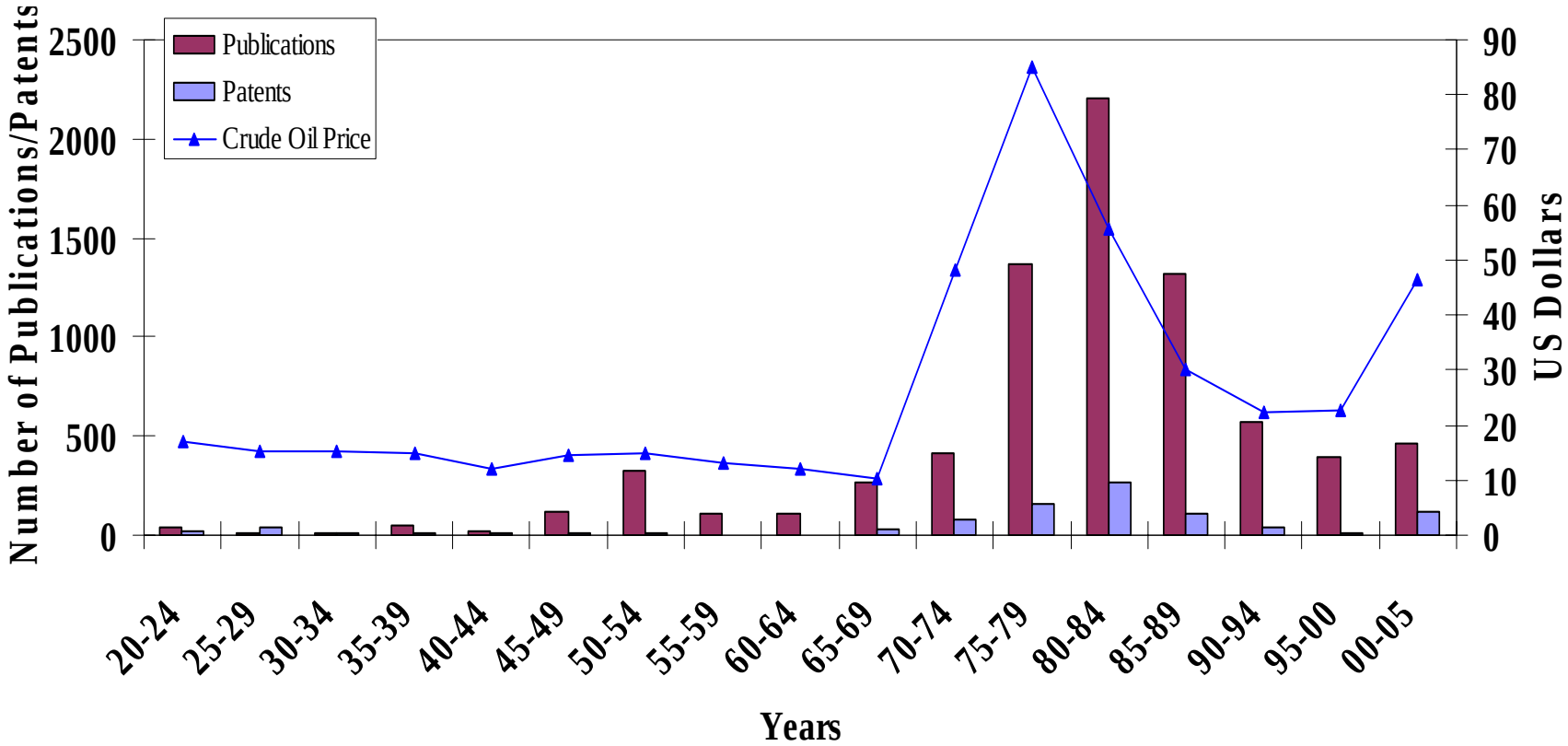
UOR Repository cont'd

Source	Entries
Journal Articles (Web of Science)	7800
Government Funded Reports (ECD & Information Bridge)	3200
NETL Microfiche (LETC)	2800
Patents (US, CAN, & EUR)	2500
Eastern & Western Oil Shale Symposia	1000

UOR Repository cont'd.



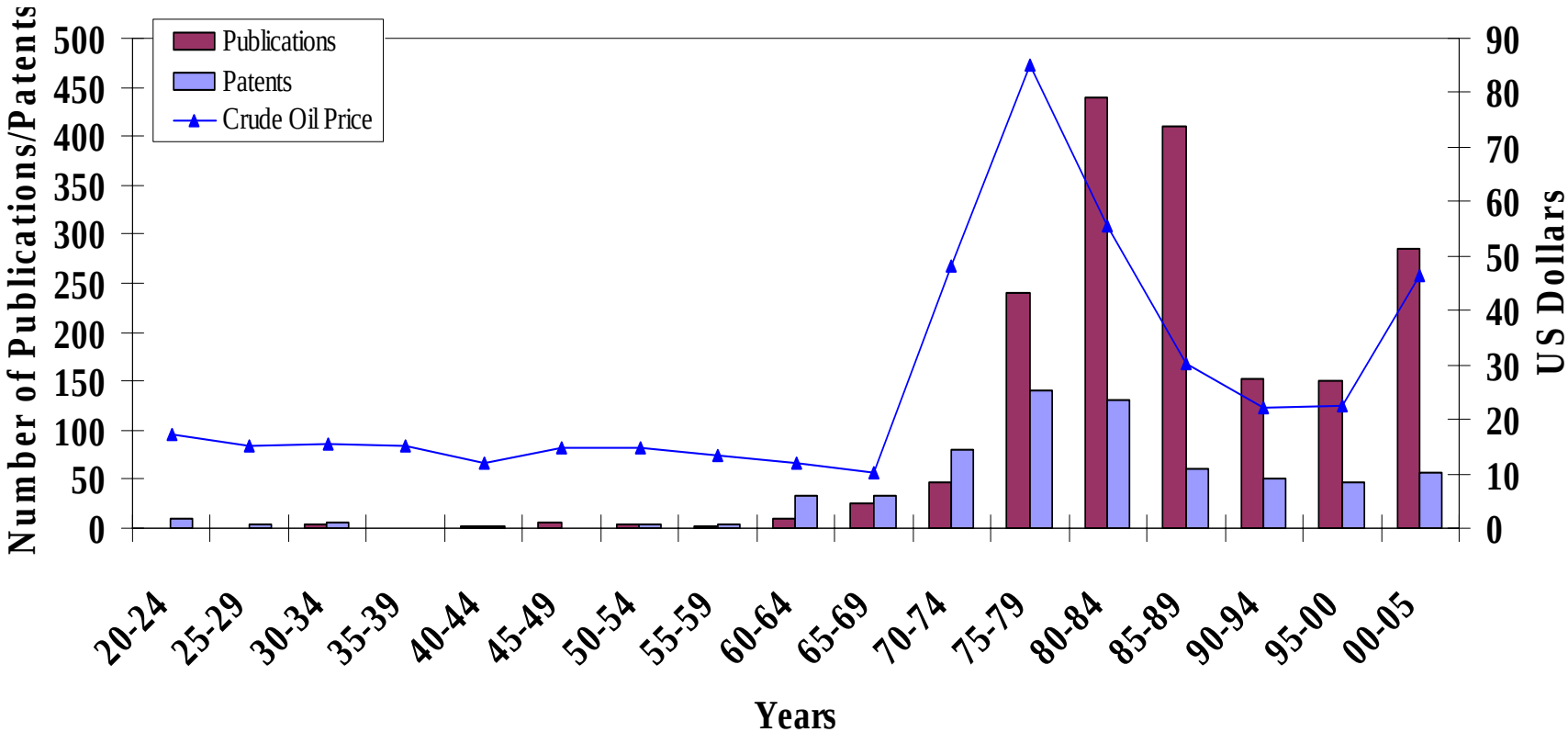
UOR Repository – Oil Shale Patents and Publications



Source for Crude Prices (adjusted for 2006 at 3.49% ROI): http://www.forbes.com/static_html/oil/2004/oil.shtml

Source for Publications and Patents numbers: Department of Energy's Unconventional Oil Resources Repository

UOR Repository – Oil Sands Patents and Publications



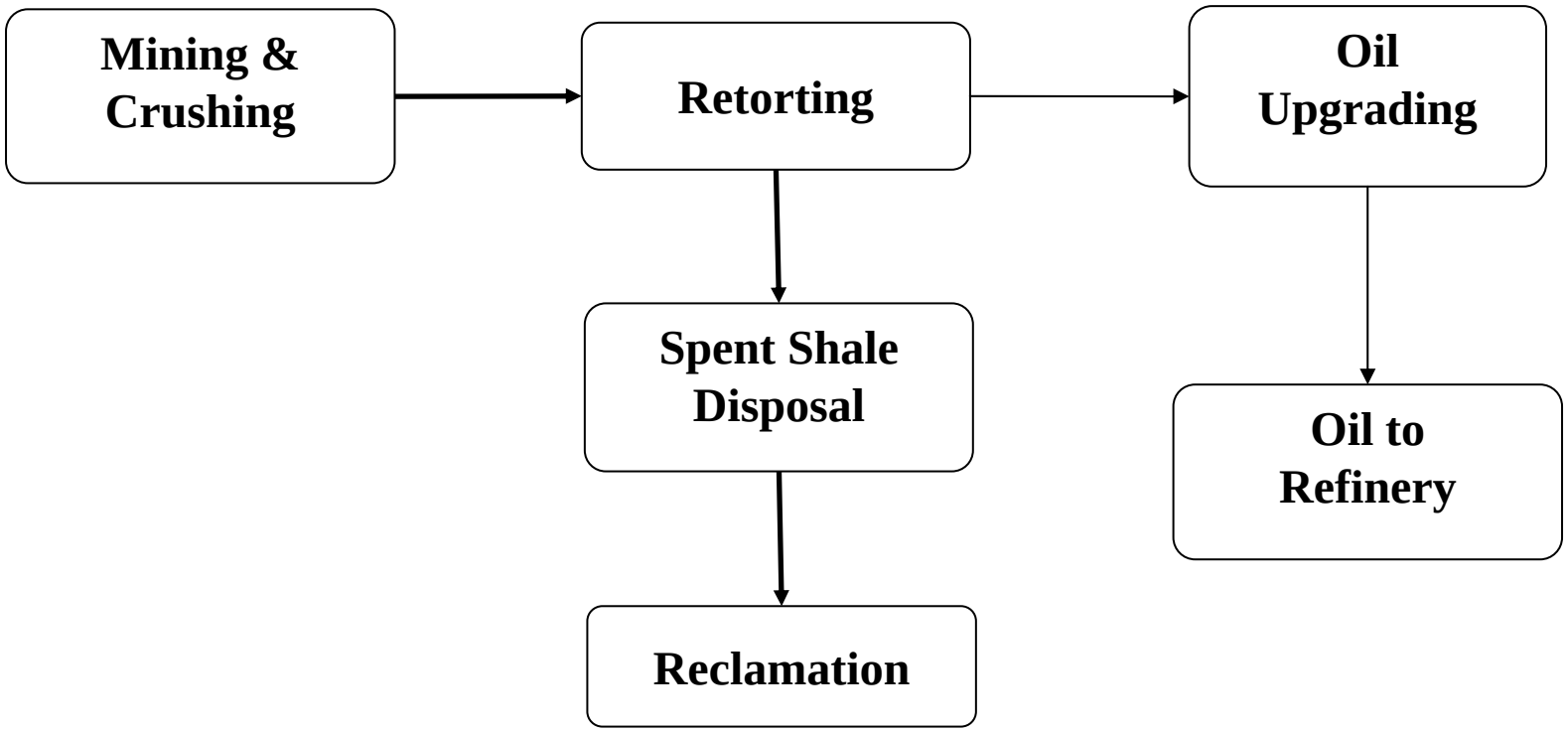
Source for Crude Prices (adjusted for 2006 at 3.49% ROI): http://www.forbes.com/static_html/oil/2004/oil.shtml

Source for Publications and Patents numbers: Department of Energy's Unconventional Oil Resources Repository

“Boom-Bust” Cycle of Oil Shale Development

- Influencing Factors
  - Crude oil price fluctuations (capital investment)
  - Infrastructure
  - Land access
  - Environmental permitting
- Measured Future Approach
  - EPACT 2005
    - Multi-agency “Task Force”
    - Mineral lease regulations
  - Well defined permitting process
  - Large scale technology demonstrations

Oil Shale Technology – Above Ground (Surface) Retorting



Summary of AGR – Direct Heat Efforts

Entity/ Process	Dates	Location	Description of Effort
NTU [168]	1920s, 1947-51, 1969	Anvil Points, CO; Laramie, WY	Batch, internal combustion retort; CO-Two 40-ton NTU retorts; 20,000 barrels shale oil produced; WY-150-ton retort
Union "A" [39]	1940s - 1950s	Near Grand Valley, CO	Vertical kiln retort; "rock-pump" feed; 2, 50, and 350-ton retorts; 75% Fischer Assay; 800bpd for 6 weeks in 1200-ton retort
USBM [85]	1950-1956	Anvil Points, CO	Gas Combustion retorting process – 6, 25, and 150-ton retorts; low pressure and temperature – low capital investment; low oil recovery 85-90% Fischer Assay
Paraho [131]	1972-1982	Anvil Points, CO	Similar to Gas Combustion retort process – 30 and 300-ton retorts; low pressure and temperature; 80% Fischer Assay; 109,000 barrels shale oil

Summary of AGR – Indirect Heat Efforts

Entity/ Process	Dates	Location	Description of Effort
Petrosix [12]	1950s-1970s	Brazil	Similar to Paraho except mechanical feed and spent shale handling; pilot plant constructed by Foster Wheeler Corp.(1950); demonstration near Curitaba, Brazil let to 43,000bpd design (1972)
Soviet Kiviter [6]	1920s -1941 1960s-1970s	USSR	Vertical kiln, cross- and counter-current gas heat transfer; two 1000 ton/day plants that co-featured the Kiviter process and the Galoter (fines); 75-80% Fischer Assay
Phillips & IGT [10]	1960s-1970s	Kentucky	Hydrogen Retorting – IGT operation of a Process Development Unit (PDU) to produce high BTU gas or middle distillates oil (1976); no large scale demonstrations reported
Paraho [131]	1975-1976	Anvil Points, CO	Demos at same facility used for Direct Retorting mode; 10,000 ton/day plant designed for US DOE
Superior [15]	1977	Cleveland, OH	Traveling grate system (doughnut shaped) – 250-ton pilot plant; designs based on Piceance Basin deposits
Union “B” [39]	Late 1970s	Near Grand Valley, CO	Similar to NTU but continuous with shale and gas flow countercurrently; Union A retort run in an indirect mode; 100% Fischer Assay; 69% thermal efficiency; 13,000 ton/day constructed only reached 50% of capacity

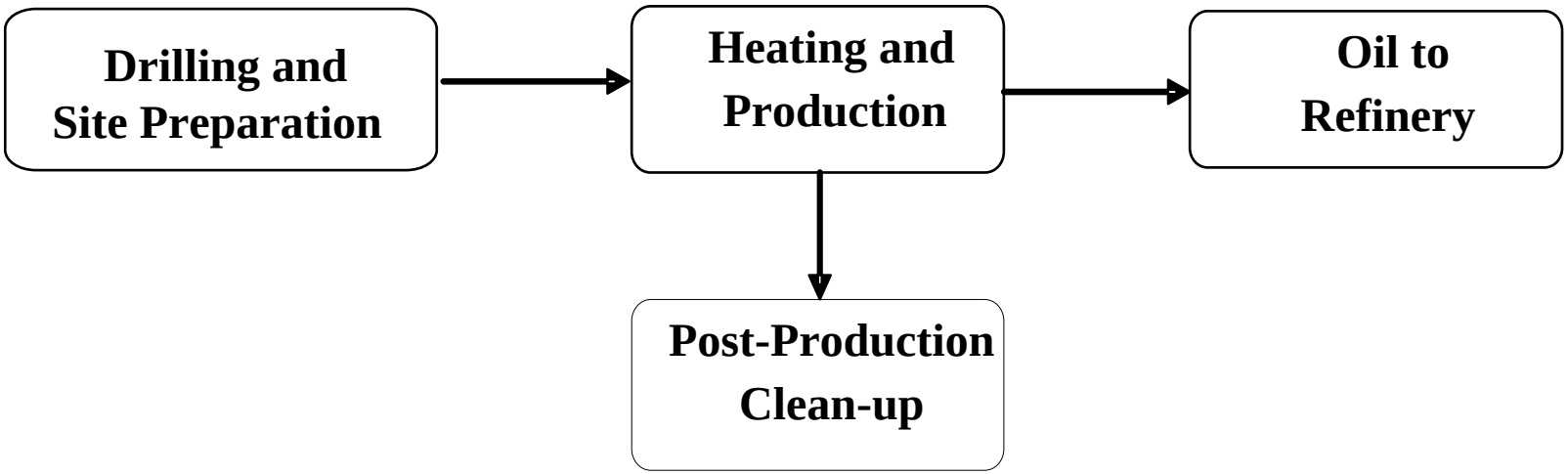
Summary of AGR – Solids Heat Transfer

Entity/ Process	Dates	Location	Description of Effort
TOSCO II [32]	1950s-1970s	Denver & Grand Valley, CO	Ceramic balls (¾ in) – 25-ton pilot plant, 1000-ton semi-works plant; >100% Fischer Assay; low thermal efficiencies, high crushing costs; 180,000 barrels of shale oil produced
Lurgi-Ruhrgas [25]	1950s-1960s	Europe & Asia	Ceramic balls replaced with fine-grained retort residual; feed stock included oil shale, oil sand, coal, and liquid hydrocarbons; 4000-ton plants built; 110% Fischer Assay; high crushing costs and shale dust problems encountered
Galoter [6]	1950s-1970s	USSR	Hot spent shale used as heat carrier – 1000-ton demonstration plant; 85-90% Fischer Assay; 1-1.3KBtu/scf product gases, lower electricity and steam than Kiviter; fine dust problems
Chevron [7]	1970s-1980s	Richmond, CA	Staged Turbulent Bed process – 10-ton pilot plant; high shale through-put, high thermal efficiency, wide range of shales; high crushing costs, pollution/control
Alberta Taciuk [8]	1970s-1980s	Calgary, Alberta, Canada	Rotary kiln process – two concentric horizontal vessels; hot spent shale utilized for preheating and mixed with raw shale feed; 120-ton pilot plant

R&D Needs
Above Ground Retorting

- Data from previous R&D cycles accessible to potential developers
- Process research to improve design, scale-up, and control of candidate retort technologies
- Mine design and solids disposal/reclamation to reduce environmental and water/land impacts while maximizing oil shale resource recovery
- Incorporate technical advances since the mid-1980s (gas separations, computers, microbiology, etc…)
- Testing of existing technology to meet new emissions and environmental targets such as Hg, CO_2 and NO_x

Oil Shale Technology – *In-Situ* Retorting



Summary of True *In-situ* Retorting Efforts

Entity/ Process	Dates	Location	Description of Effort
Sinclair Oil	1953 - 1966	Mahogany Zone, Piceance Basin	Field experiments; small amount of shale oil recovered; difficult but successful ignition; small fractures reseal as formation swells with retort.
USBM [97]	1960 - 1974	Rock Springs, Wyoming	Laboratory experiments, computer simulations, pilot plant and field fracture tests; low yields and recoveries, incomplete retort or large blocks of shale; inadequate and irregular fracturing allows heat carrier fluids to bypass large blocks of unretorted shale
Equity Oil Company [38]	1961 - 1977	Piceance Creek basin, Colorado	Field tests: heated methane/ nat.gas injected 547days; steam injected 4 months; small quantity of oil recovered w/ hot gas injection; no recovery w/ steam injection because of insufficient injection capacity; natural gas trapped in fractures and pores; improvement of steam injection capacity and operating cost needed
LERC [24]	1966 - 1977	Rock Springs, Wyoming	Fracture tests at 12 sites; burn tests at 5 sites: Site No. 2-One gallon recovered, Site No. 4-30,000gal produced, 8000 recovered, Site No. 6-no recovery, Site No. 7-Ignition test only – successful, Site No. 9-1080bbl retorted, 60bbl recovered; large energy losses in ignition – small amount of shale reached retort temperature; mechanical problems in production wells
Geokinetics (Sandia) [87]	1973 - 1982	Uintah County, Utah	Phase III & IV: commercial scale of 2000bpd; computer models developed; over 20 retorts burned in Utah; largest retort in 1979 130' x 180' x 30' thick; difficult to model extent of fracturing and retort with available field experiment data; challenges in scale-up of pilot studies
Talley Energy Systems	1977	Green River, Wyoming	Phase I: Multiple explosion fracturing; computer model; Phase II: Pilot demo; fracture tests under contract w/ LERC; multiple detonation fracturing methods unsuccessful; project terminated after initial testing

Summary of Modified *In-situ* Retorting Efforts

Entity/ Process	Dates	Location	Description of Effort
DOW Chemical [129]	1950's-1970's	Midland, MI	Hydraulic fracturing, sand propping, chemical explosives; acid leaching, chemical explosives; Explosive under-reaming, well bore cleaning
Occidental [96]	1970's-1980's	Debeque, CO	20-25% of shale mined; ANFO used for detonation; air injected after ignition; 8 retorts varying from 32ft on a side by 70ft to 120ft on a side by 270ft in Piceance Creek basin
LLNL [80]	1970's-1980's	Livermore, CA	Rubble *In-situ* Extraction (RISE) – computer simulation and pilot scale retorts; AGR – hot recycled-solid retorting (HRS)

R&D Needs
In-Situ Retorting

- Data from previous R&D cycles accessible to potential developers
- Improved surface and subsurface monitoring to assess process and environmental performance
- Additional laboratory testing to evaluate potential operational and post-operation impacts
- Mathematical modeling to understand process impact on underground product flows and geo-mechanics
- Testing of technologies to meet new emissions and environmental targets

Current Oil Shale Activity in the U.S.

- Above Ground Retorting
  - Oil Shale Exploration Company (OSEC)
  - Chattanooga Process
  - OilTech
- *In-situ* Processes
  - Shell Oil Co. (ICP)
  - Chevron
  - EGL Resources, Inc.

UOR Repository – Future Efforts

- Assessment of future R&D considerations
  - Technology evaluation
  - Summarize recent patent literature in oil shale
- Continue to update/complete records, abstracts, and full documents
- Collaboration with University of Utah Unconventional Oil Research Program
- Resource made available to researchers, industry and general public via web site

Comments/Suggestions