ORE 330
Mineral & Energy Resources of the Sea

Oil Supply Problem: The response
FIGURE 1.1 Components of the New Oil Industry
Fossil Fuel Alternatives
- Tar sands, oil shale, unconventional oil.
Unconventional oil

- Conventional oil: "From well to wheels"
- Unconventional oil: "From different kinds of dirt to wheels"
Unconventional oil

According to the ”International Energy Agency”, unconventional oil includes the following sources:

- Oil Shales
- Oil sands-based synthetic crudes and derivative products
- Coal-based liquid supplies
- Biomass-based liquid supplies
- Liquids arising from chemical processing of natural gas
Tar sands
- and extra heavy oil
- Mix of clay, sand, water and BITUMEN → Bituminous sands
- Extremely viscous, high specific gravity
- Mined, extracted, separated, upgraded, refined and fueled

Definition 1 – Canadian Authorities: "petroleum that exists in the semi-solid or solid phase in natural deposits. Bitumen is a thick, sticky form of crude oil, so heavy and viscous (thick) that it will not flow unless heated or diluted with lighter hydrocarbons. At room temperature, it is much like cold molasses"

Definition 2 – World Energy Council: "oil having a viscosity greater than 10,000 centipoises under reservoir conditions and an API gravity of less than 10° API".
Tar sands - Resources

Different sources:

<table>
<thead>
<tr>
<th>Natural Bitumen Reserves WEC 2010</th>
<th>Canadian Association of Petroleum Producers 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Tar sands</td>
</tr>
<tr>
<td>Globally</td>
<td>Total</td>
</tr>
<tr>
<td>Canada</td>
<td>Mining</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>Insitu</td>
</tr>
<tr>
<td>Russia</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
</tr>
</tbody>
</table>

“While tar sands are found in many places worldwide, the largest deposits in the world are found in Canada (Alberta) and Venezuela, and much of the rest is found in various countries in the Middle East. In the United States, tar sands resources are primarily concentrated in Eastern Utah, mostly on public lands. The in-place tar sands oil resources in Utah are estimated at 12 to 19 billion barrels.”

Tar sands – Compared to crude

<table>
<thead>
<tr>
<th>Crude Stream</th>
<th>Country</th>
<th>Degrees API</th>
<th>Sulfur, % by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Slope</td>
<td>United States</td>
<td>27</td>
<td>1.0</td>
</tr>
<tr>
<td>Arabian Light</td>
<td>Saudi Arabia</td>
<td>33</td>
<td>1.8</td>
</tr>
<tr>
<td>Bachequero</td>
<td>Venezuela</td>
<td>17</td>
<td>2.4</td>
</tr>
<tr>
<td>Bonny Light</td>
<td>Nigeria</td>
<td>38</td>
<td>0.1</td>
</tr>
<tr>
<td>Ekofisk</td>
<td>Norway</td>
<td>36</td>
<td>0.2</td>
</tr>
<tr>
<td>Poleng</td>
<td>Indonesia</td>
<td>43</td>
<td>0.2</td>
</tr>
<tr>
<td>Ratawi</td>
<td>Neutral Zone</td>
<td>23</td>
<td>4.1</td>
</tr>
</tbody>
</table>

\[
\rho(g/cm^3) = \frac{141.5}{131.5 + API} \quad \text{API} = \frac{141.5}{\rho(g/cm^3)} - 131.5
\]

API – American Petroleum Institute

<table>
<thead>
<tr>
<th>Crude stream</th>
<th>Country</th>
<th>Degrees API</th>
<th>g/cm³</th>
<th>kg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Slope</td>
<td>USA</td>
<td>27</td>
<td>0.89</td>
<td>893</td>
</tr>
<tr>
<td>Arabian Light</td>
<td>Saudi Arabia</td>
<td>33</td>
<td>0.86</td>
<td>860</td>
</tr>
<tr>
<td>Bachequero</td>
<td>Venezuela</td>
<td>17</td>
<td>0.95</td>
<td>953</td>
</tr>
<tr>
<td>Bonny Light</td>
<td>Nigeria</td>
<td>38</td>
<td>0.83</td>
<td>835</td>
</tr>
<tr>
<td>Ekofisk</td>
<td>Norway</td>
<td>36</td>
<td>0.84</td>
<td>845</td>
</tr>
<tr>
<td>Poleng</td>
<td>Indonesia</td>
<td>43</td>
<td>0.81</td>
<td>811</td>
</tr>
<tr>
<td>Ratawi</td>
<td>Neutral Zone</td>
<td>23</td>
<td>0.92</td>
<td>916</td>
</tr>
<tr>
<td>Freshwater</td>
<td>-</td>
<td>10</td>
<td>1</td>
<td>1000</td>
</tr>
<tr>
<td>BITUMEN</td>
<td>Canada</td>
<td>&lt;10</td>
<td>&gt;1</td>
<td>&gt;1000</td>
</tr>
</tbody>
</table>
Tar sands production

- Extraction: Exsitu or Insitu
- Separation: Hot water, NaOH, Air bubbles, ”Clean Bitumen” skimmed off
- Upgraded with lighter HC to make synthetic crude
- Two tonnes of TS gives 1 barrel of oil
Canadian Tar sands

- Athabasca-Wabiskaw
- Cold Lake
- Peace River

According to CAPP-stats 2010; Approx 54% of oil prod. from tar sands (1.46 million barrels/day) – 44% in 2007 (Wikipedia)
Global Primary Energy Demand (Current Policies scenario)

Source: IEA 2010

Oil sands help supply oil energy needs.
Surface mining 1

Mining shovels dig into sand and load it into trucks.

Trucks take oil sands to crushers, where it is prepared for extraction.

Mining method
Surface mining 2

Hot water is added to the oil sands and then transported via hydrotransport to the extraction plant.

Bitumen is extracted from the oil sands in the separation vessels.

The tailings are pumped to the settling basin, where the water is recycled and reused in the process.
Insitu-extraction

- Buried too deep for surface mining
- Steam injection, solvent injection, firefloods
- Cyclic Steam Stimulation (CSS)
- Steam assisted gravity drainage (SAGD)
- Vapor extraction process (VAPEX)
- Toe to heel air injection (THAI)
- Combustion overhead gravity drainage (COGD)
Oil Shale
-The Rock that burns

- Formed like conventional oil, but the process stopped
- Differs from oil-bearing shales
- Large part of Kerogen is Bitumen
- Shale oil VS Shale gas

Definition 1 – API: *Oil shale is a fine-grained sedimentary rock containing a solid material (kerogen) that converts to liquid oil when heated.*
## Oil Shale - Resources

<table>
<thead>
<tr>
<th>Location</th>
<th>Resource/Reserves</th>
<th>Amount</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Globally</td>
<td>Resource</td>
<td>2.8 - 3.3 Trillion barrels</td>
<td>WEC 2005</td>
</tr>
<tr>
<td>Globally</td>
<td>Reserves</td>
<td>1,3117 Trillion barrels</td>
<td>EIA 2007</td>
</tr>
<tr>
<td>Green River</td>
<td>Resource</td>
<td>1.5 - 1.8 Trillion barrels</td>
<td>RAND 2005</td>
</tr>
<tr>
<td>Green River</td>
<td>Est. Recoverable</td>
<td>800 Billion barrels</td>
<td>RAND 2005</td>
</tr>
</tbody>
</table>

### Location of the Green River Formation Oil Shale and Its Main Basins

![Map of Green River Basins](Map.png)

- **Saudi Arabia**: Proved reserves (267 billion Bbls)
- **Potential recoverable from Western U.S. Oil Shale**: (800 Billion Bbls)
Oil Shale Production

Major Process Steps in Mining and Surface Retorting

1. Mining and crushing
2. Retorting
3. Oil upgrading
4. Oil to refinery
5. Spent shale disposal on-site
6. Reclamation

RAND MG414-3.1
Oil Shale Production

Major Process Steps in Thermally Conductive In-Situ Conversion

1. Drilling and site preparation
2. Heating and production
3. Oil to refinery
4. Postproduction clean-up
In-situ extraction

The Shell In-Situ Conversion Process

SOURCE: Adapted from material provided by Shell Exploration and Production Company.
RAND MG414-3.2
Why so upset?
Energy

EROI - USA
Ratio of Energy Returned on Energy Invested - USA

Hydro
Coal
World oil production
Oil imports 1990
Oil and gas 1970
Oil production
Wind
Oil imports 2005
Oil and gas 2005
Oil imports 2007
Nuclear
Natural gas 2005
Oil discoveries
Photovoltaic
Shale oil
Ethanol sugarcane
Bitumen tar sands
Solar flat plate
Solar collector
Ethanol corn
Biodiesel

Land
Tailing Pond
Advances in offshore oil production

- innovations from pipe to platform design
History of offshore oil production

Blue Water Rig No. 1 (1961)

Aker Spitsbergen (2009)
Offshore drilling

The following main types of drilling rigs are used:

- Onshore rigs
- Drilling barges
- Submersible rigs (drilling platforms)
- Jack-up rigs
- Semi-submersible platforms
- Drill ships

Prof. Anatoly Zolotukhin
Troll A
Conversion to Natural Gas

- Natural Gas is now priced at the equivalent of $15/barrel oil in the US
- Trucking fleets are converting to natural gas (CNG)
- Power plants are converting from coal
- Rail and mining operations are increasingly running on dual fuel CNG/diesel systems
Gas compression on the seabed:

“Gas compression on the seabed represents an important advance in technology, and once again, Statoil is leading the way for development of new technology. This is one of our most important measures for improving recovery from existing fields,” says Siri Espedal Kindem, Statoil’s vice president of technology.
Oil & Gas prod. From shoreline base:

Technology Tunnel
Build dry. Wet or dry drilling/production
L < 30 km, D 6+ m, Cavern 35 m high
Max depth 350 m below sea level
Floater with buoy release:
5 key factors (+1)

1. Source rock
2. Migration path
3. Reservoir rock
4. Trap
5. Seal
6. TIMING
Seismic exploration

Acoustic waves propagate through the earth’s surface layers and are reflected by rock boundaries.
Seismic exploration – 1st gen.

Principle of 2D acquisition:

- **P** = Pressure waves
- **S** = Shear waves

Survey lines often kms apart

Seismic section
Seismic exploration – 2nd gen.
Seismic exploration – 3rd gen.
World record holder

www.pgs.com

Petroleum Geo-Services’s “Ramform Sovereign”

"Live stream"
New drilling technologies

- Complex drilling trajectories – Multibranch wells
- High tech. wells / "Smart wells"
- Rigless exploration drilling – Badger Explorer
Multibranch and horizontal

- First multibranch well, Bashkiria, 1953

Bashkiria

Troll field, Norwegian cont. shelf
Different multibranches
Example: Multilateral well drilled on the Troll field and placed over the Moscow image...
Inflow profile to (a) conventional Well and (b) High Technology Well. In (a) well inflow profile distributed unevenly because of pressure drop along the well. As a result, earlier water and gas breakthrough in the heel region. In case (b) inflow profile is equalized.
What is a high tech. well?
- Multibranch well
- Well with complex profile
- Well equipped with downhole measurement systems
- Well with inflow control systems (passive or active)
Sidetracking through tubing
Vast Arctic Reserves

- Ultra deep water
- Moving into arctic
- Extended life time of old fields

![Arctic resources and technically recoverable reserves, BTOE](image)

**Legend:**
- **First letters:** R – resources; TRR – technically recoverable reserves;
- **Second letters:** A – the whole Arctic; RA – Russian Arctic; RAO – Russian Arctic Offshore
Challenges

Marine spray icing

Drift ice

Prof. Ove Gudmestad
Challenges

87 days in the middle of GOM. What about the north pole?
Challenges

Ice bergs
Hibernia: Caisson island: