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Unconventional Resources in Alberta

- **Extra heavy oil**
  - 177 billion barrels
- **Tight formations**
  - 434 billion barrels of oil
  - 59 billion barrels of NGLs
  - 3,424 Tcf of natural gas
Focus Areas in Alberta

• **Thermal processes**
  – Viscous oil extraction
    • Decreasing footprint
    • Increasing energy efficiency
      – Decreasing carbon intensity
      – Cost of extraction
  
• **Non thermal processes**
  – Tight oil and gas extraction
    • Reducing footprint
      – GHG, water
    • Reducing costs
    • Improving oil recovery

• **Technology development & risk**
  – Staged (de-risking)
  – Revolution => evolution

After Fair et al IPTC 12361

Courtesy of Tom Boone, Imperial Oil
Shales are Very Complex

- **Geological complexity**
  - Locally heterogeneous
  - “design one build many” does not work
- **Economics**
  - Recoverable oil
    - Decline rates?
- **Footprint and Sensitivities**
  - Water use & GHGs
  - Infrastructure, population, receptors
- **Montney Example**
  - 3,500 MSHF wells = confidence in geological characterization
    - Comfort level sufficient to commence optimization

<table>
<thead>
<tr>
<th>Basin</th>
<th>Technically Recoverable oil (bbls)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bakken - USGS 1995</td>
<td>151 million</td>
</tr>
<tr>
<td>Bakken - USGS 2014</td>
<td>7.4 billion</td>
</tr>
<tr>
<td>Monterey Shale (EIA, 2012)</td>
<td>13.7 billion</td>
</tr>
<tr>
<td>Monterey Shale (EIA, 2015)</td>
<td>600 million</td>
</tr>
</tbody>
</table>

Courtesy of the Oil and Gas Journal, 08/13/2014
Recoverability

- **EUR: 3% - 6%**
  - > 90% left in ground
- **Characterizing gas release and production**
  - Storage & release mechanisms?
    - Free gas vs. adsorbed gas
    - Phase trapping and nanopores
  - Flow characteristics?
    - Diffusive transport regime
  - Fundamental science required
- **Optimizing release and flow**
  - Microfractures and pores
  - Sensitivity to contacting fluids
  - Fluid and process selection
  - Timescale and cost

Courtesy of Dr. Maurice Dusseault, 2015

Courtesy of Dr. Chris Clarkson, 2015
Improving Reservoir Models

- **Geology**
  - Gas & liquid storage
  - Natural fracture network
  - Release mechanisms

- **Geomechanics**
  - Stress/strain behavior
  - Flow regime
  - Fracture geometry

- **Elastic/planar models insufficient**
  - Dual porosity systems
  - 3D coupling (geomechanics)
  - Look-back studies, history match, calibration

- **Repeat for each formation**
  - Predictive models

After Gonzalez et al, SPE 159765
Fluid Trends in Alberta

- Trend towards foamed/energized fluids
  - Liquid and gas combinations
  - Stability, phase behavior, proppant transport
  - Familiarity, safety & cost

- N2 and CO2 used as commercial energizers
  - Lots of equipment and expertise
    - Reservoir impacts (?)
  - Flowback is not saleable (cleanup or flare)
Energized (“Foamed”) Fluids

- **Alberta**: energized fluid gas quality 70% - 80%
  - 79% water reduction vs. non-foamed
- **Some energizer benefits**
  - Leak-off reduction by ~ 50%
  - Cold fluid & hot reservoir
    - Expansion & net fracture fluid volume reduction
- **Lifecycle cost/benefit analysis important**
  - Higher upfront costs
  - Increased production and lower lifecycle costs
- **Balance between**
  - EUR, economics, environment

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Comparison of Normalized Fluid Volumes Used for Fracturing in Alberta

After Seifert et al, SPE 178490-MS
Flowback Management

- **Wellsite gas separation technology evolving**
  - First trailer mounted CO2 separation unit: 2014
- **Recompression and reuse**
  - Technology still some years away

Both figures courtesy of Reynolds et al, SPE 167197
Economics => Fluid Selection

- **Some commercial use in Alberta**
  - Gelled propane, butane
  - Natural gas

- **Ideal fracturing fluid**
  - Native reservoir fluid (natural gas)
  - Compatibility with reservoir
  - Flowback pipelinelable

- **Economics**
  - 62% greater per stage cost for gas base fluids
    - High pressure compressed (flammable) gas purchase, equipment, handling costs
  - MSHF volumes are massive
    - Reservoir retention & loss
    - Cost $$$
Waterless Research is Needed

- Few comparative analyses available
  - Economic advantage not apparent
  - Not apples to apples - smaller volumes of NGLs used
- Fundamental understanding will help
  - Need for field scale studies
Summary

- Local innovation and technology adaptation
  - Long lead time to development and commercial application
- Shared data and IP
  - Leverage infrastructure already in place
  - Common knowledge base for reservoir type
  - Iteration and adaptation of technology
- Commercial scale pilots are essential
  - Government has an important role
- Enabling environment important
  - Fiscal and regulatory policies
  - Favorable environment for operator persistence
- Economics are fundamental
  - Lack of alternatives to reserves growth
  - Stable price environment

Figure 2: Cold Lake Development History and Production Growth

After Fair et al IPTC 12361
Backup slides
Evolution of Thermal Processes

- **SAGD**
  - 100% water
  - Solvent Assisted SAGD
    - 80% - 95% saline water (~5% - 20% solvent)
  - Solvent SAGD
    - 100% solvent (no water)

- **CSS**
  - 100% water
  - LASER
    - 85% - 95% saline water (~5% - 15% solvent)
  - Cyclic solvent process
    - 100% solvent (no water)

After Dickson et al., SPE 165485

Courtesy of the Government of Alberta
SAGD – A New Technology Ecosystem

• 2003 – 2010
  – SAGD commercial: 2003
    • Fresh water, 500m long wells
  – No fresh water: 2006
    • WLS & WAC
  – 90% water recycling (2012)
    • Drum boilers, MVR
  – ESPs, fiber optic sensors

• ~ 2010 +
  – SA-SAGD
    • 5% – 20% solvent
    • Assess solvent recovery and cost
  – Longer wells (~1.5 km), ICDs
  – “WedgeWells”
  – Improved geoscience & models

• Waterless SAGD is here
  – Warm Solvent SAGD
  – Solvent EM and resistive heating
Waterless CSS is also here

- **CSS**
  - 1966: steam only
- **LASER (2005)**
  - Add 5% solvent to steam
    - Cost, benefit
  - Solvent loss and geological knowledge/understanding
- **Cyclic Solvent Process (2010)**
  - Waterless - solvent only process
  - First commercial application in 2015
  - Improved process and geology knowledge fundamental to economic success

*Both figures courtesy of Tom Boone, Imperial Oil*
Mechanical Vapor Recompression (MVR)

Figure 3: Simplified Vapour Compression Falling Film Evaporator System

Courtesy of GEWater
300 Degrees Celsius Electrical Submersible Pumps (ESP)

Courtesy of www.schlumberger.com
Inflow Control Device (ICD)

Without EquiFlow® ICDs

With EquiFlow® ICDs controlled steam injection

Courtesy of www.halliburton.com
Electromagnetic Heating (EM)

RFH Gated Path to Develop the Technology

Electromagnetic Property IR&D

Scaled Breadboards

Small Scale Breadboards

Pressure Test (2kW)

Dirt Box I IR&D (10kW)

Dirt Box II IR&D (10kW)

Fall 2009

Fall 2009

Spring 2010

Summer 2010

Winter 2011

Summer 2011

Fall 2011

Winter 2012

Pilot in 2014

Malabar Test Facility (100kW)

CCEMC Mine-face (100kW)

CCEMC 100M Pilot (0.5MW)

We are Here

Courtesy of the Government of Alberta