Next Generation SAGD Produced Water Treatment Technology Development
Energy and water are co-dependent

Energy is required for making water and water is required in the production of energy.
Water & energy needs are interlinked

- **Power production**: 90% for once through cooling
- **Oil Sands**: 90% water recycle
- **Unconventional Gas**: 30%+ process water reuse
- **Mining**: >70% in water scarce regions

**Energy production is thirsty**
Upstream oil sands value chain

- **Synthetic Crude Oil for Refining**
- **Bitumen Upgrader**
- **Extraction Facility**
- **SAGD Well Pads**
- **Mine Sites**
- **Exploitation Methods**
- **Oil Sands Reservoir**
It has only been 24 years since SAGD came off the paper and 12 years at commercial scale in the field.
Optimizing SAGD Facilities

SAGD Facility Efficiency and Reliability

• Downtime
• Energy Use
• Water Use
• Carbon Intensity
• CAPEX
• OPEX

30 years to commercialize SAGD technology

Today’s Process Designs

Step Change Improvement

6 – 8 year project cycles

Incremental Improvement

Facilities of the Future
Key SAGD Produced Water Issues

Discharge Composition & Quality
Water to meet 1B wells, reduced pH and silica concentration

Evaporator capex & opex
Energy usage, CO₂ emissions, capital cost

Water usage...recycle, discharge, intake
Minimize discharge volume, site make-up volume, increase recycle

Deoiling efficiency
Oil-Water separation, plant operability, boiler reliability

Installation cost and time
Minimize on-site construction thru modularization
SAGD facility unit processes

“Water Side”

Crystalizer → Evaporator

Softened, brackish make-up water

Thermal Water Recycle

Steam Generation

BFW Tank

OTSG

Separator

Blowdown to disposal

Conventional De-oiling

WSF → IGF → Skim Tank

De-oiled Water 5 ppm oil

Slop Oil Tank

Oily Water 1 – 5 k ppm

Reservoir

Production from well pads 80:20 water/oil emulsion

FWKO

Treater

Diluent Tank

99% steam quality to well pads

“Oil Side”

Sludge to disposal

Dilbit Sales $/Bbl

8
Program objectives

1. **Deoiling field pilot - 6 months @ 20 gpm**
   - deliver treated water with no more than ~1ppm oil-in-water @ 90°C
   - establish optimum system design, recovery rate and operating conditions for deoiling system across a broad range of SAGD produced water inlet conditions
   - determine options available for control and monitoring the efficiency of oil separation
   - validate total lifecycle cost model and value proposition for existing and nextgen SAGD deoiling unit operations
   - identify most promising pathways for future technology development

2. **Pre-concentration field pilot - 4 months @ 20 gpm**
   - deliver boiler feed water quality and concentrate stream compatible with evaporator treatment @ 90°C and pH >10
   - design and build robust, high temp/high pH tolerant RO membrane
   - establish optimum system design, recovery rate and operating conditions for pre-concentration system
   - determine options available for control and monitoring the pre-concentration process
   - validate total lifecycle cost model and value proposition for combined deoiling & pre-concentration system
   - identify most promising pathways for future technology development

3. **Demonstration plant with best technology - 6 months @ 100 gpm**
   - Demonstrate the achievement of the above criteria at a scale sufficient to support commercialization
   - Validate total lifecycle cost model and value proposition for best combined deoiling & preconcentration system
Field testing – “erector set” approach

Phase 1: De-oiling Pilot
- Coarse Treatment
  - Physical Separator A
  - Physical Separator B
  - Physical Separator C
- Polishing
- Sorbent
- Heat Exchange

Phase 2: Pre-concentration Pilot
- Advanced Treatment
  - Ceramic A
  - Ceramic B
  - Polymeric
- Silica Removal A
- Silica Removal B
- TOC Analyzer
- HT Reverse Osmosis

Phase 3 – Scale up best performing technologies to 100 gpm demo plant

Operation
- Chemical Pre-treatment
- Physical Separation
- Sorbent
- Ceramic/Spiral Membrane
- Silica Removal
- TDS Removal

Goal
- Break oil for subsequent removal in a physical separator
- Remove oil/solids from process fluids
- Remove dissolved and other organic components
- Provide absolute barrier to emulsified oils
- Remove silica at pH <10, 90°C
- Provide high purity boiler feed water
Deoiling pilot layout

- Deoiled
- Membranes
- Filtrate
- CIP
- Reject
- Chemical Addition
- Physical Separators
- Controls
- Sump
Value proposition

- **Water Recycle Unit**
  - Smaller evap system to remove salt from brine:
    - Lower CAPEX
    - Lower OPEX
    - Lower CO₂ emissions

- **De-oiling Unit**
  - More effective de-oiling + pre-concentration system to remove oil and salt:
    - Higher CAPEX
    - Higher OPEX

- **O/W Separation**
  - BFW < 3 ppm
  - Concentrated Brine
  - Deoiled Water

- **Steam Generation**
  - Protect OTSG/Boiler from oil/fouling:
    - Increase up-time
    - Lower OPEX
    - Increase boiler efficiency

- **Diluent**
  - Oily Water 1000 - 5000 ppm

**Increase plant availability and decrease overall CAPEX/OPEX**
Value proposition

Establishment of an efficient deoiling process offers the potential for RO systems to be used in conjunction w/ thermal evaporators to reduce total energy and cost required for SAGD produced water recycling.

Direct Benefits:
- 40% smaller evaporator required
- 26% lower capital cost
- 29% lower annual operating cost
- 30% lower CO$_2$ emissions

Indirect Benefits:
- Reduced risk of boiler issues/tube failures – barrier to oil
- Smaller areal footprint
- Improved plant availability - down time costs ~ $2.4M/day

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<th>Equip.</th>
<th>CAPEX</th>
<th>OPEX/yr</th>
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<td>Total</td>
<td>64.4</td>
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* Estimates based on 30,000 BOPD SAGD facility
Finding the saddle point

Further improvements in water quality have marginal affect on cost reduction

Produced Water Treatment

Total Life-cycle Costs

Steem Generation

Water Treatment

Increasing Boiler Feed Water Quality

What is the optimum combination for lowest overall life-cycle cost?