Environmental Costs of Managing Geological Brines Produced or Extracted During Energy Development

Christopher B. Harto

Argonne National Laboratory

18th IPEC Conference

Houston, TX

November 8-10, 2011

Acknowledgments

- DOE/NETL provided funding to support the work
- Andrea McNemar - NETL
- John Veil – Veil Environmental

Topics Addressed

- Energy systems that produce brines
- Composition of typical brines
- Water management options
- Environmental costs of water management

Sources of Geological Brines

- Produced and Flowback Water from Oil and Gas Operations
- Water Extracted from Deep Saline Aquifers used for Carbon Sequestration
- Spent Geofluid from Geopressured Geothermal Systems

Photo by John Veil

Photo by Corrie Clark

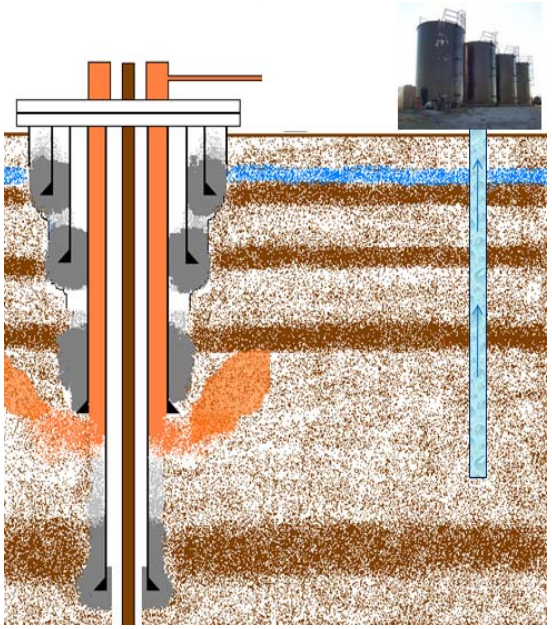
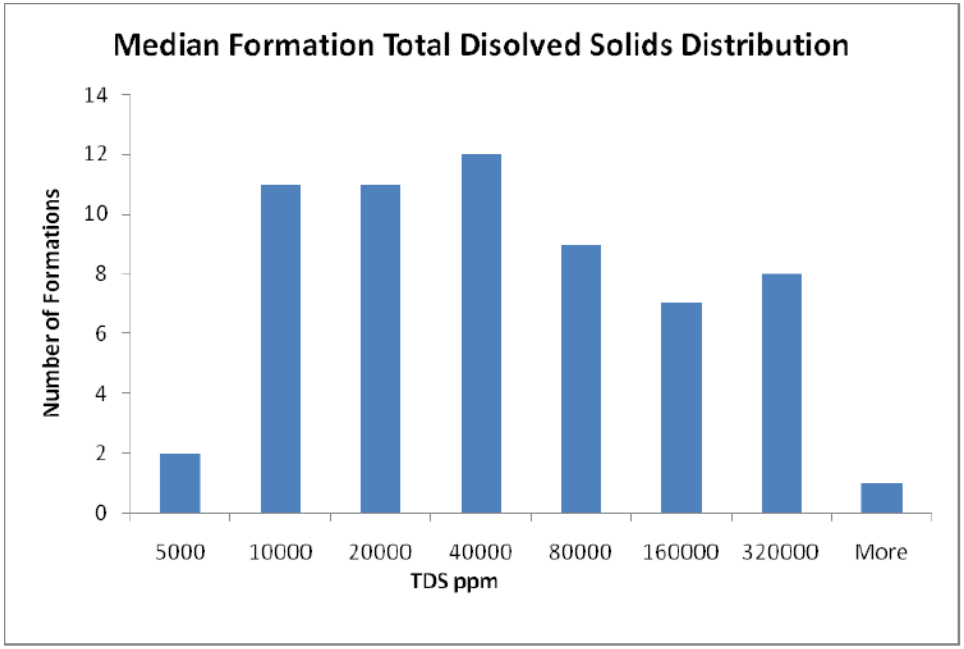
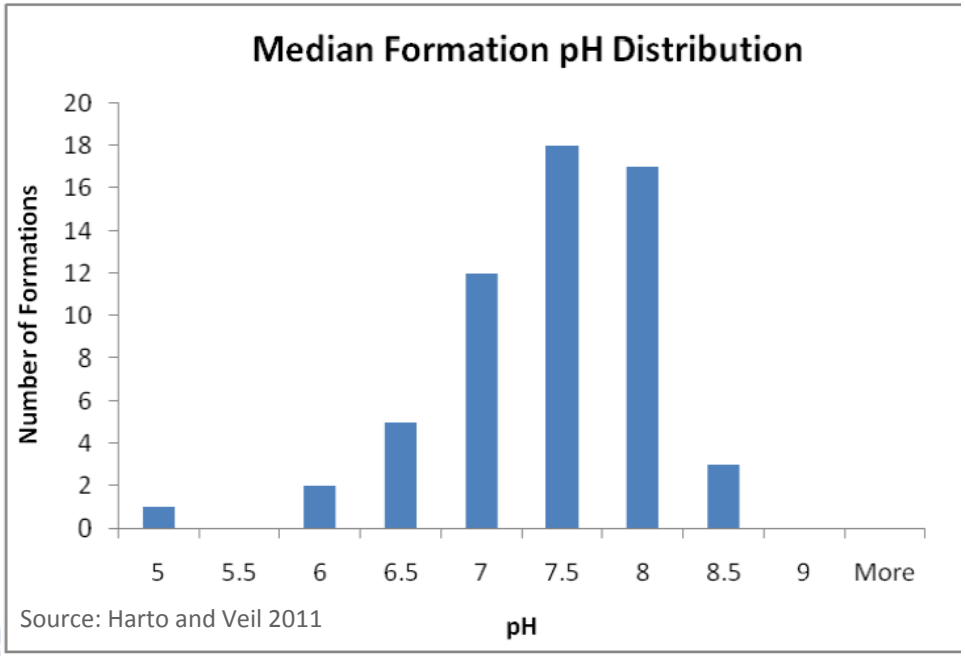


Diagram by John Veil

Water Composition

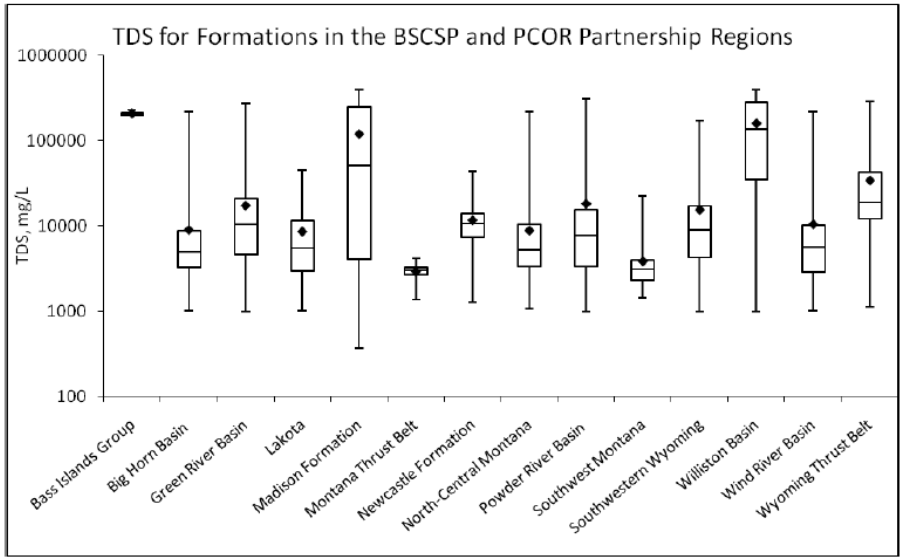
- Examples of the geochemical data
  - Formation TDS varies significantly by location
  - Formation pH ranges from slightly acidic to slightly basic
- Management solution must be targeted to unique local brine chemistry
- Note: data for geological formations of interest for carbon sequestration

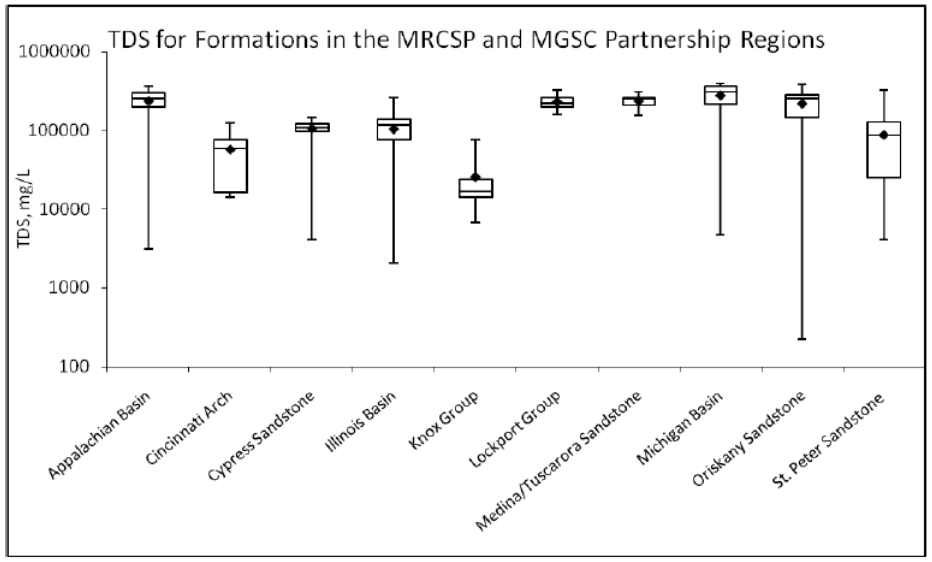


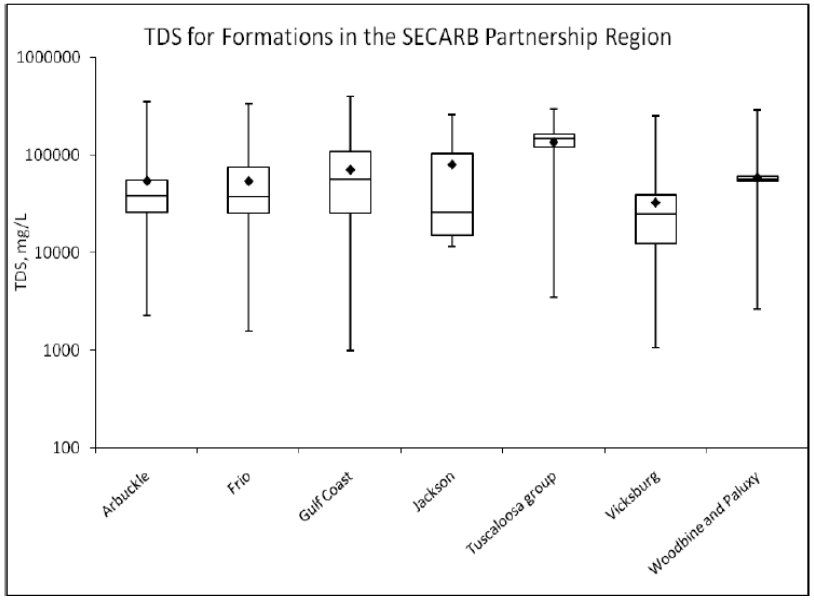


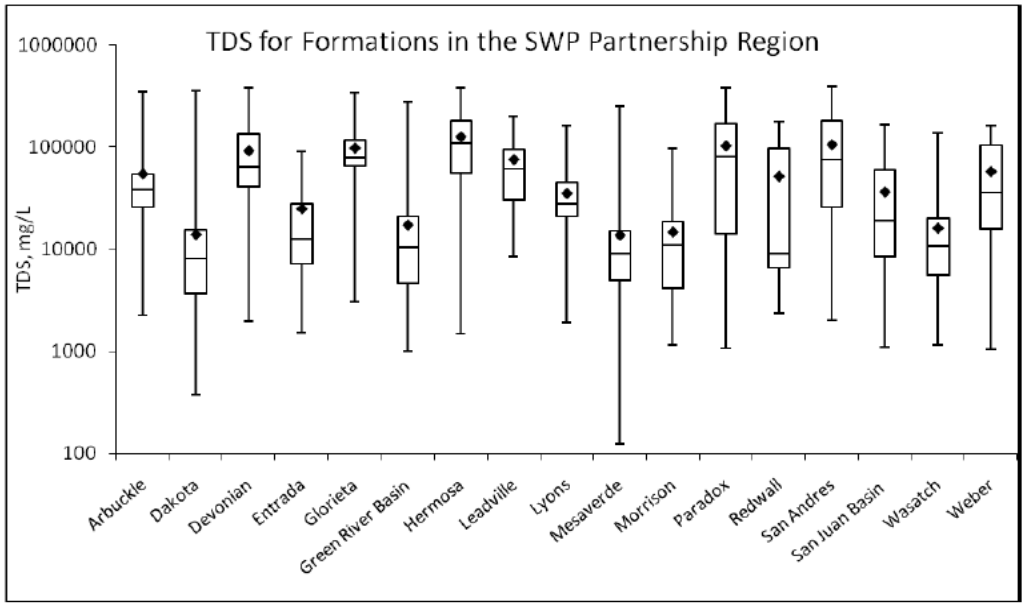
Source: Harto and Veil 2011

Variation in TDS Between Regions









Source: Harto and Veil 2011

Veil Hierarchy of Produced Water Management

Reuse

Treatment

Disposal

Water Management Options

- Reuse
  - Use as is
    - Injection for recovering more oil
    - Hydraulic fracturing or drilling fluid
    - Enhanced geothermal systems makeup water
    - Injection for hydrological purposes
  - Use after treatment
    - Industrial
      - Cooling water
      - Dust control
    - Agricultural
      - Irrigation
      - Livestock
    - Drinking

Source: USFWS

Water Management Options

Treatment Technologies for TDS/Salt Removal

Photo by John Veil

Membrane Processes

Photo by Chris Harto

Thermal Treatment

Photo by John Veil

Water Management Options

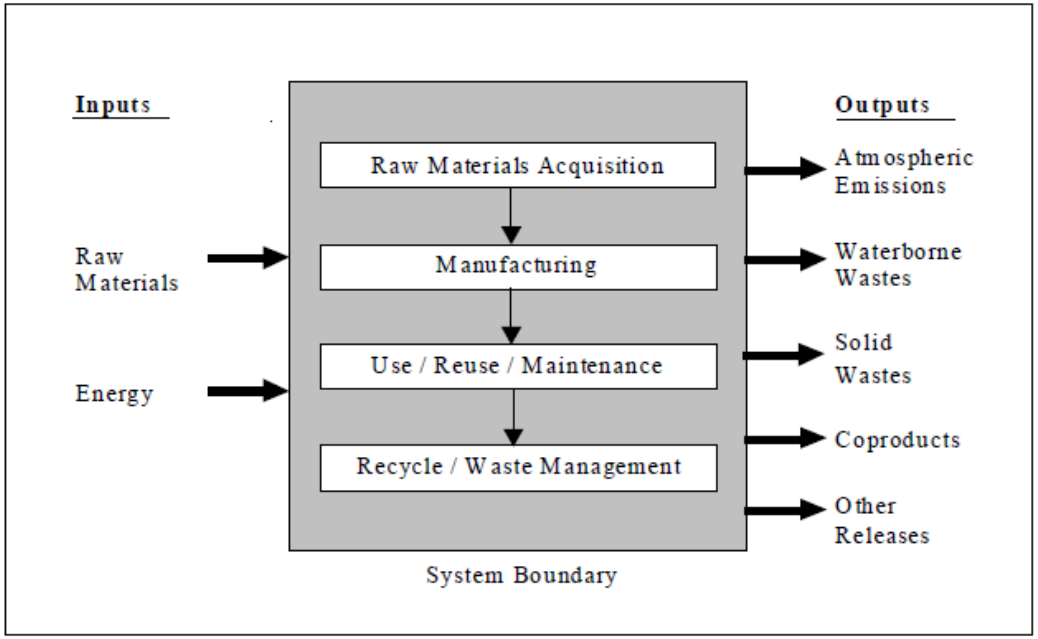
- Disposal of Extracted Water
  - Injection to non-hydrocarbon producing formation (UIC class II)
  - Evaporation

Photo by John Veil

Photo by John Veil

Balancing Environmental Costs and Benefits

- When selecting a water management you must weight the costs and benefits of the alternatives
- Hybrid life cycle assessment (LCA) approach used to compare
  - Energy consumption
  - GHG emissions
  - Net water savings



Source: EPA 2006

Hybrid Life Cycle Assessment

- Combines process based LCA approach with economic input-output LCA approach (EIOLCA).
- Process approach
  - Ideal for well characterized processes
  - Requires lots of specific data
  - Suffers from cut-off error
- EIOLCA approach
  - Suitable for more general processes
  - Only requires capital costs
  - Suffers from aggregation error
- Process approach utilized for direct process inputs
- EIOLCA approach used to consider capital equipment impacts

Data Sources

- Quality of LCA studies highly dependent upon quality of data
- Data sources:
  - Direct data from industry contacts
    - Advantages – direct, real world, operational data
    - Disadvantages – sometimes proprietary, challenging to obtain
  - Peer reviewed literature
    - Advantages – high credibility
    - Disadvantages – typically theoretical calculations
  - Grey Literature (conference papers, industry literature)
    - Advantages – can help fill gaps in LCA inventory
    - Disadvantages – low credibility
  - GREET Model
    - Argonne greenhouse gas LCA model
    - Used to provide impact factors for common material inputs

Produced Water Treatment vs. Desalination

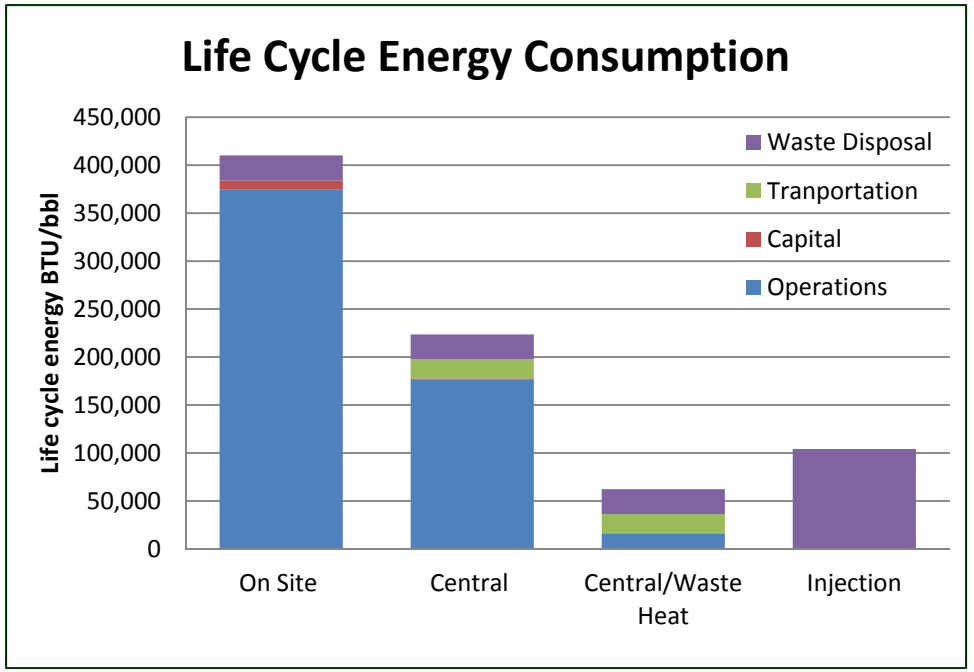
- Produced Water Treatment
  - Key objective: eliminate waste stream
  - Smaller volumes from lots of sources
  - High variability in source water quality and quantity
  - Transportation costs matter
  - Concentrate disposal of significant concern
- Desalination
  - Key objective: produce fresh water
  - Large volume from single feed water source
  - Low variability in source water quality and quantity
  - Transportation is minimal
  - Concentrate disposal of minimal concern (discharge to ocean)

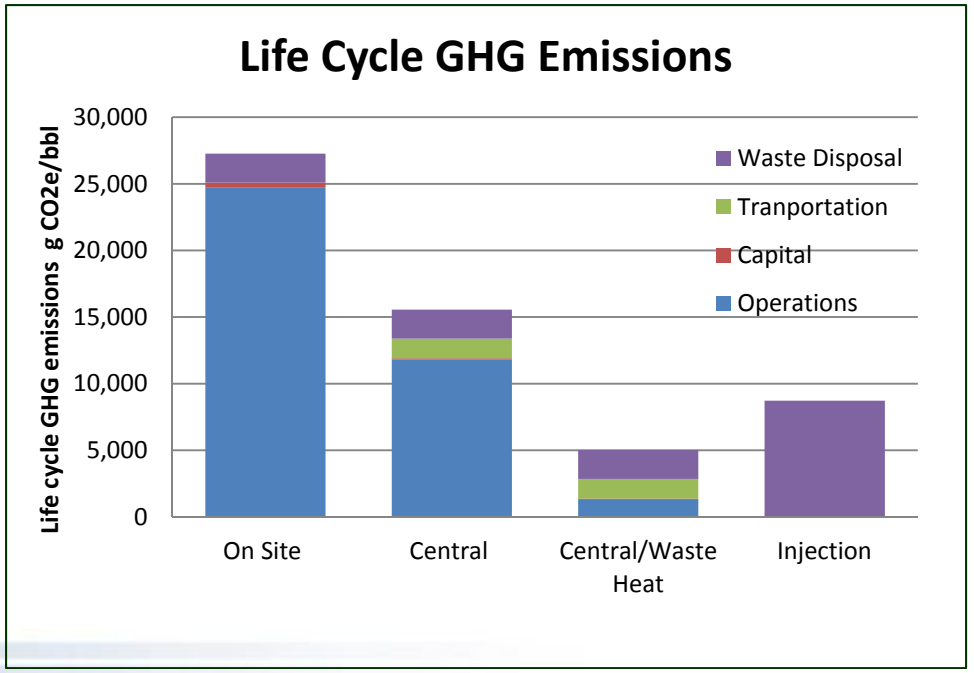
Example Scenario: Marcellus Shale Well

- Analysis for a single well in Marcellus Shale
- 4 options considered
  - Thermal treatment on site
  - Thermal treatment at centralized facility
  - Thermal treatment at centralized facility utilizing waste heat
  - Transport to UIC injection well
- Key Scenario Parameters
  - Transportation distance (0, 30, 150 miles for on site, centralized facility, injection)
  - All transportation by truck
  - Concentrate disposed of through UIC class II injection in Ohio

Results

- Higher efficiency of central location outweighs the energy for transportation for energy and GHG
- Thermal treatment more energy intensive than injection unless waste heat used
- Net water savings
  - Treatment system returns 0.66 bbl of clean water for every 1 bbl treated
- Other considerations
  - Availability
  - # of truck trips
  - costs

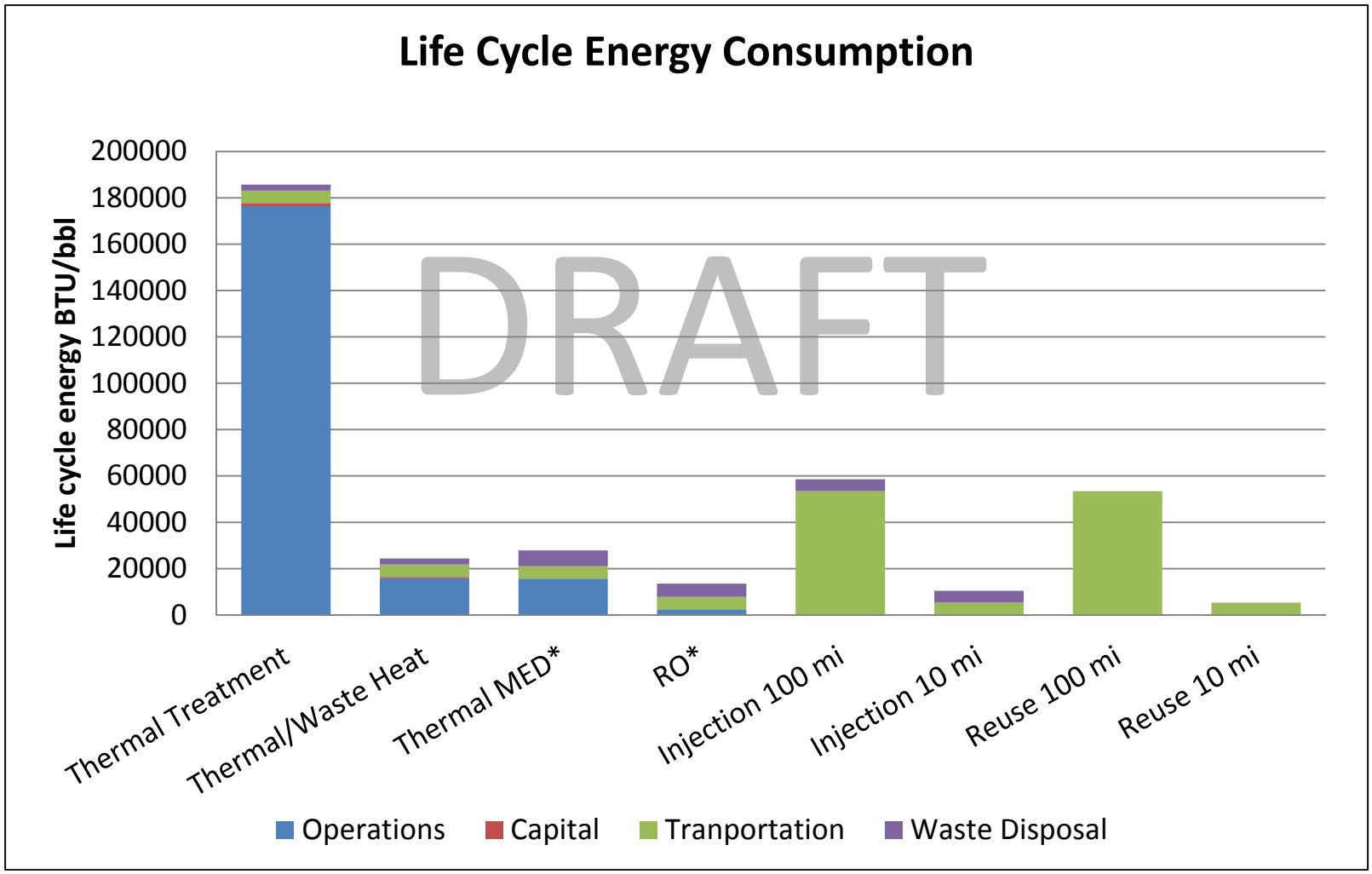




Further study in progress

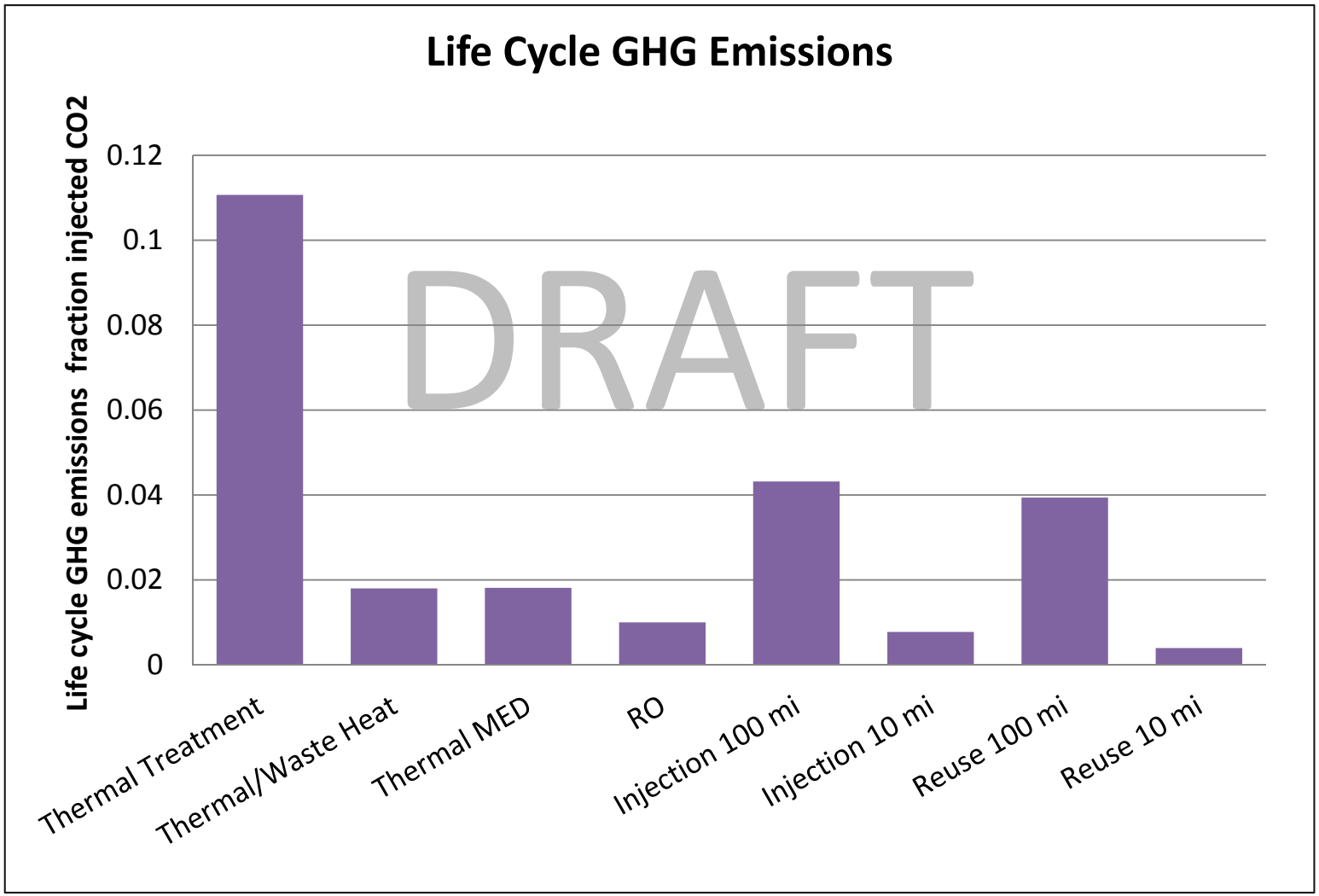
- Focus of further study management of extracted water from geological formations used for carbon capture and storage
- Management options will be included in CCS study
  - Reuse without treatment for TDS
  - Treatment to remove TDS
    - At least one reverse osmosis system
    - At least two thermal treatment systems
  - Disposal
    - Deep well injection
    - Evaporation
- Consider alternative transportation parameters
  - Truck vs. Pipeline
  - Transportation distance
- Explore impact of water quality (TDS)

Preliminary Results - Energy



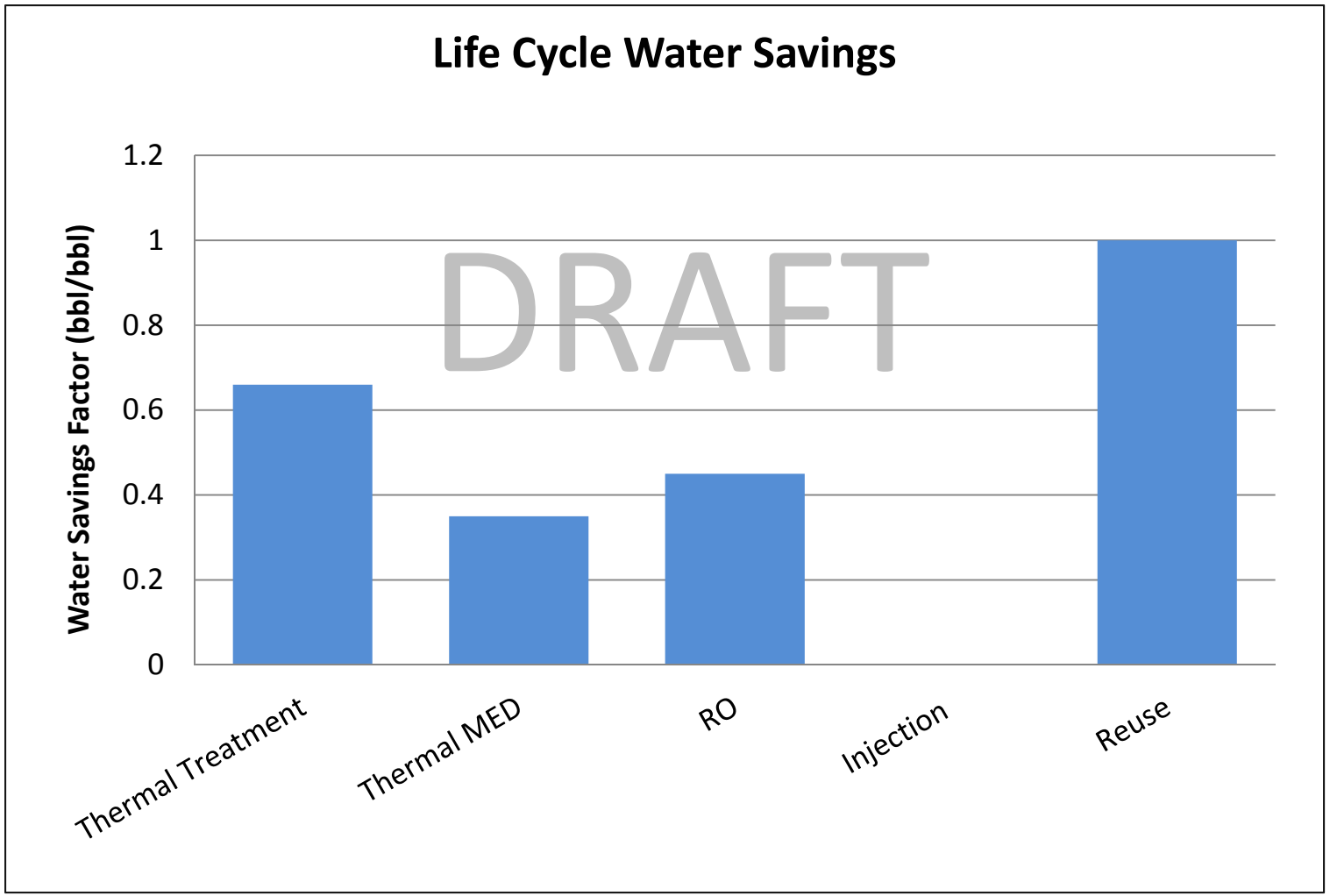
Note: MED and RO based upon seawater desalination designs, capital not included

Preliminary Results – GHG emissions



Assumes volume of water extracted equal to volume of 1 ton of CO2 at formation pressure (8.8 bbl/ton)

Preliminary Results – Water Savings



Final Thoughts

- A number of energy development activities can result in the production of large quantities of salty water.
- Managing these brines can be a challenging, but must be done in environmentally responsible manner.
- When selecting the best management practices a number of factors should be considered in addition to cost.
- LCA is one useful tool for comparing the environmental footprint of competing options.