Management of Water from CCS

Project Number 49607

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National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Developing the Technologies and Building the
Infrastructure for CO_2 Storage

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Benefit to the Program

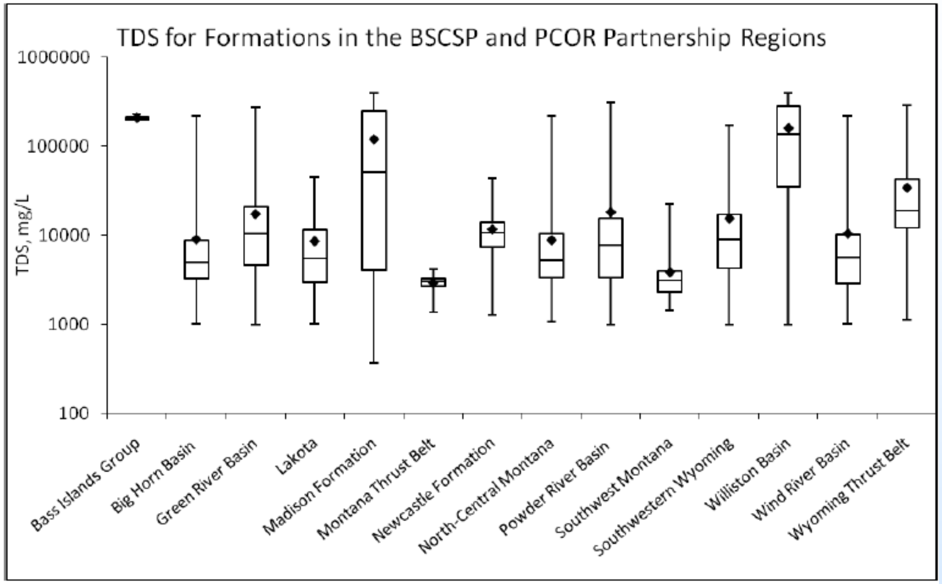
- Program goals being addressed.
  - Increased control of reservoir pressure, reduced risk of CO2 migration, and expanded formation storage capacity.
- Project benefits statement.
  - This work supports the development of active reservoir management approaches by identifying cost effective and environmentally benign strategies for managing extracted brines (Tasks 1 + 2).
  - This work will help identify water related constraints on CCS deployment and provide insight into technology choices that can help reduce these constraints (Task 3)

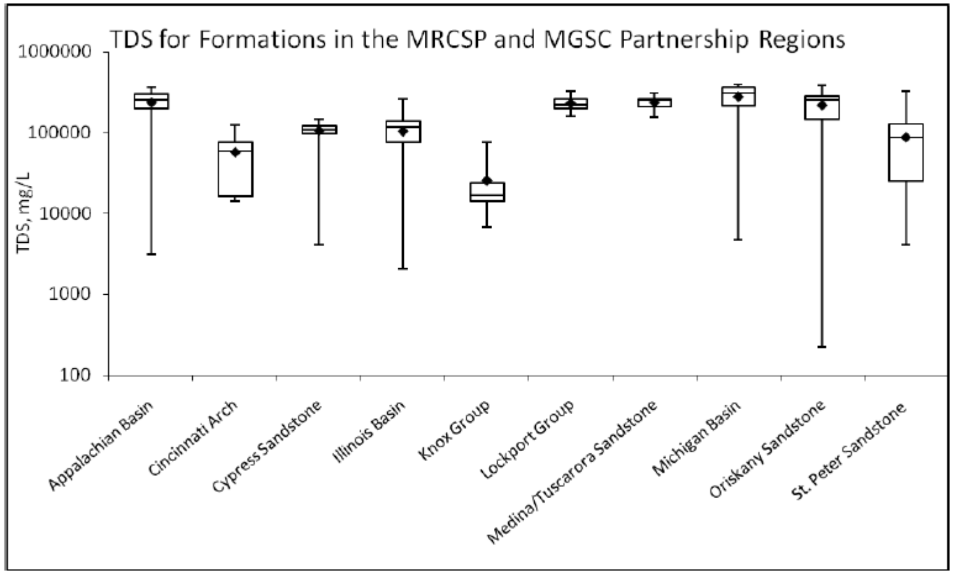
Project Overview: Goals and Objectives

- **Task 1 (FY10/11)** – Analyze geochemical composition of deep saline aquifers, identify viable options for managing extracted water, estimate management costs, and evaluate options for beneficial reuse. (**Completed)**
- **Task 2 (FY11/12)** – Quantify the environmental costs and benefits of a range of viable extracted water management practices to identify those with the potential to manage extracted brines with the lowest impact. **(Draft Final Report Submitted July 2012)**
- **Task 3 (FY12/13)** – Quantify the life cycle water consumption from coal electricity production with carbon capture and geological carbon sequestration. The analysis will consider a range of scenarios with different capture and sequestration technologies to assess their relative impact on water resources. **(In Progress)**

Task 1 – Key Findings: Geochemcial Composition

- Composition analyzed for 61 basins or formations identified with potential for geological sequestration
- Wide variation in composition both within formations and between formations
- Variability in composition presents challenges for selecting appropriate management practices





Task 1 – Key Findings: Management Practices

- Reuse
  - Injection for enhanced oil recovery
  - Hydraulic fracturing or drilling fluid
  - Enhanced geothermal systems makeup water
  - Injection for hydrological purposes
  - Cooling water
- Treatment
  - Reverse Osmosis
  - Thermal Treatment
- Disposal
  - Underground Injection
  - Evaporation

Task 1 – Key Findings: Costs

Management Practice	Cost Range ($/bbl)*	Cost to CCS ($/ton CO_2)
Reverse Osmosis	$1.00-$3.50	$8.80-$31.00
Thermal Distillation	$6.00-$8.50	$53.00-$75.00
UIC Injection	$0.05-$4.00	$0.45-$35.00
Evaporation	$0.40-$4.00	$3.50-$35.00

**Quoted costs for produced water management and do not include transportation*

- In some cases transportation can make up 50-75% of total management costs
- Cost to load and unload truck ~$1.00/bbl

Task 2 - Methodology

- Hybrid life cycle assessment (LCA) approach used to compare
  - Energy consumption
  - GHG emissions
  - Net water savings
- Hybrid LCA combines process based LCA approach with economic input-output LCA approach (EIOLCA).
- Process approach (used for direct inputs)
  - Ideal for well characterized processes
  - Requires lots of specific data
  - Suffers from cut-off error
- EIOLCA approach (used for capital equipment)
  - Suitable for more general processes
  - Only requires costs
  - Suffers from aggregation error

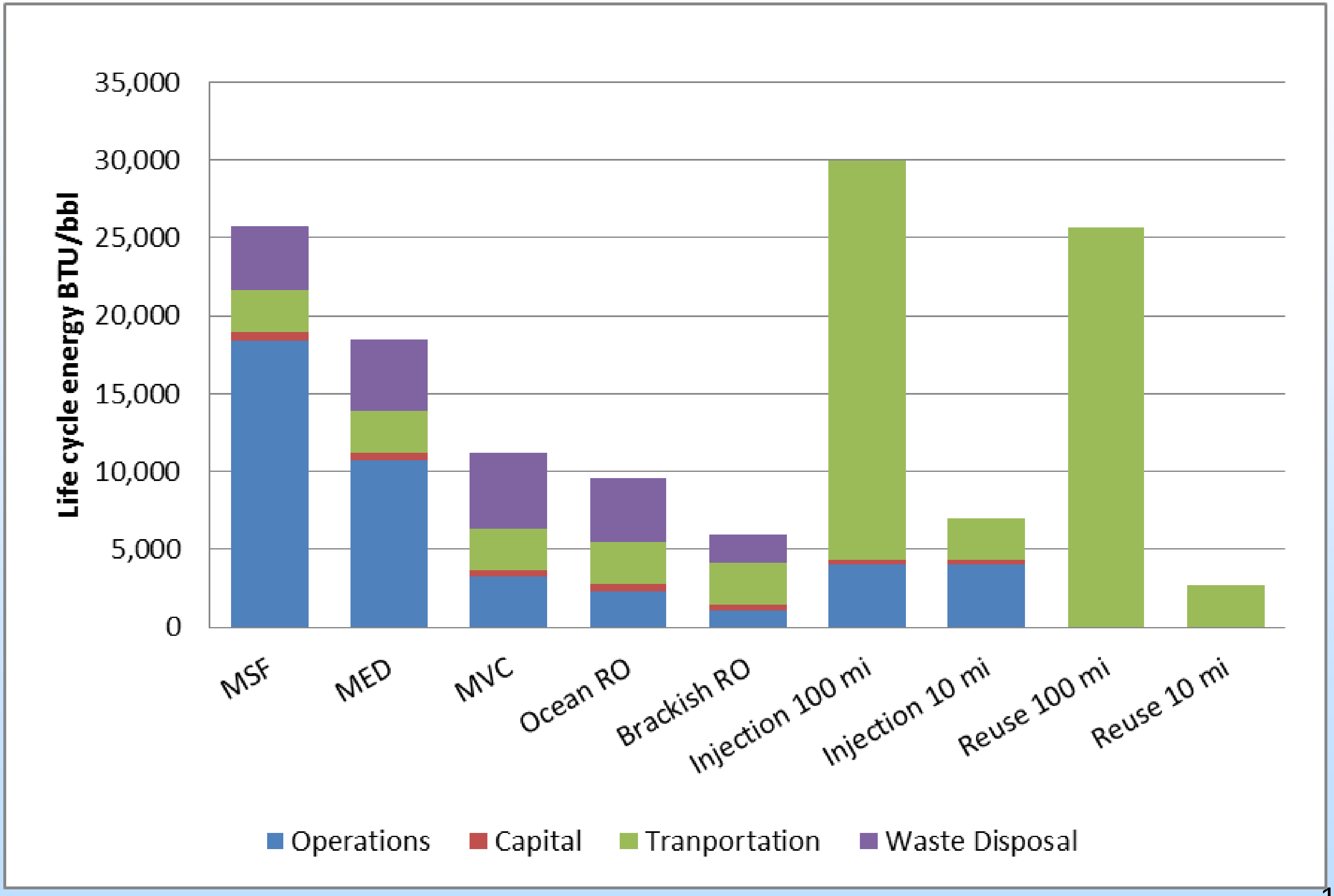
Factor	Seawater Desalination	Produced Water Treatment	CCS Extracted Water Management
Primary Goal	Clean water delivery	Waste elimination	Waste elimination
Water Source	Ocean	Multiple wells, possibly multiple fields	Multiple wells from a single or multiple CCS projects
Input Water Quantity	As demanded	Highly variable	Depends on operational conditions, but likely low variability
Input Water Quality	Low variability	High variability	Unknown, possibly moderate to high variability
Operational Considerations	Near ambient temperature, low concentration of scale or precipitate forming ions	Variable temperature, organic contaminants, scale forming compounds, divalent ions, possible NORM	Variable temperature, scale forming compounds, divalent ions, possible NORM
Transportation	Located at source, minimal transportation	Typically located in a producing area drawing from multiple wells, transport costs very important	Depends if dedicated to specific project or draws from multiple projects
Concentrate Disposal	Minimal concern, returned to source	Disposal in evaporation or injection well, major cost consideration	Disposal in evaporation or injection well, major cost consideration

LCA Scenario Parameters

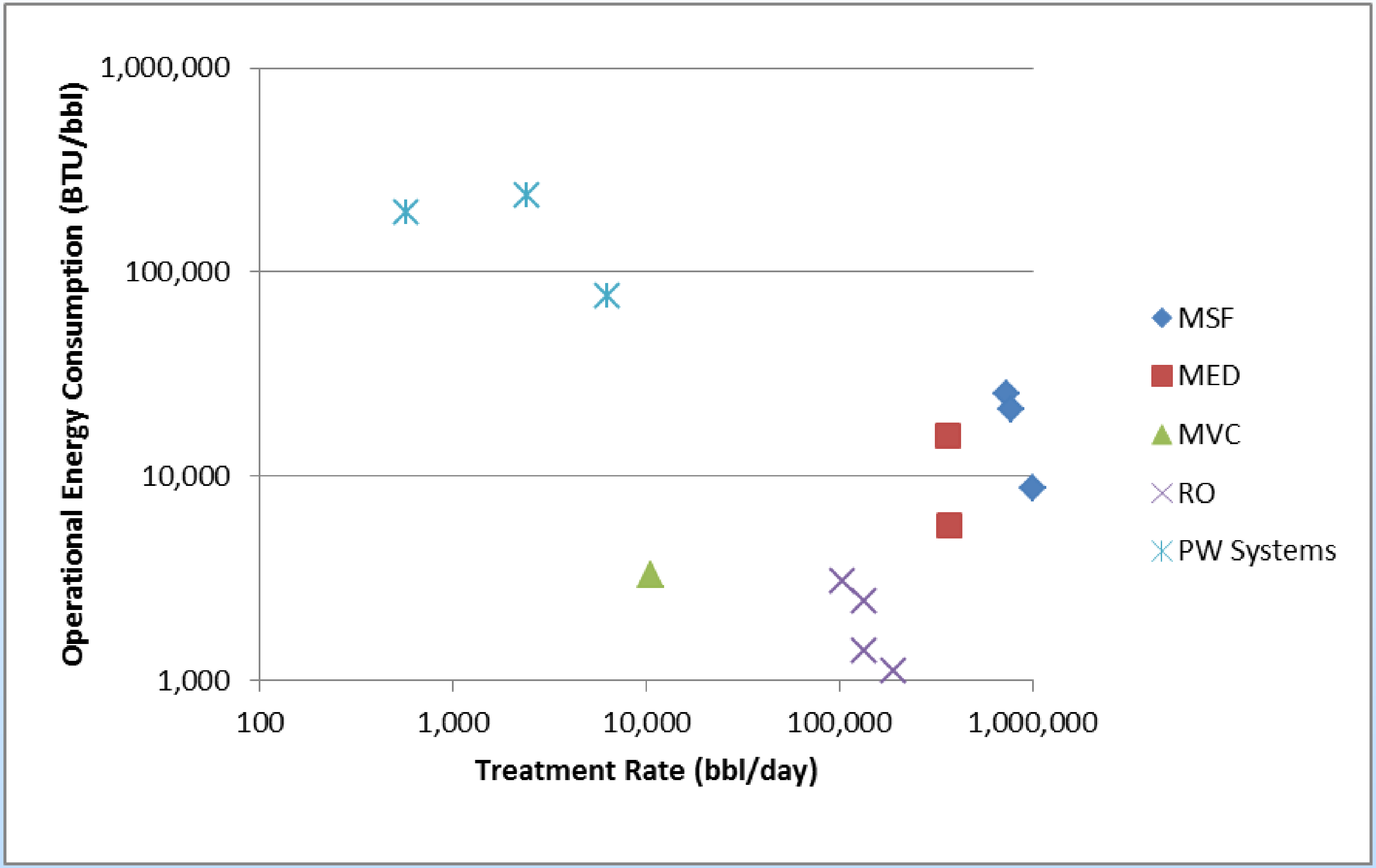
Scenario	**Technology**	**Water Source**	**Transport Distance ***	**Number of Data Points Averaged**
MSF	Multi-Stage Flash	Seawater	10 miles	3
MED	Multi-Effect Distillation	Seawater	10 miles	2
MVC	Mechanical Vapor Compression	Seawater	10 miles	1
Ocean RO	Reverse Osmosis	Seawater	10 miles	4
Brackish RO	Reverse Osmosis	Brackish Groundwater	10 miles	1
Injection 100 mi	Underground Injection	Any	100 miles	137
Injection 10 mi	Underground Injection	Any	10 miles	137
Reuse 100 mi	Reuse (No Treatment)	Any	100 miles	1
Reuse 10 mi	Reuse (No Treatment)	Any	10 miles	1

*All transport by 100,000 bpd pipeline = ~ 4 Million ton/year storage site

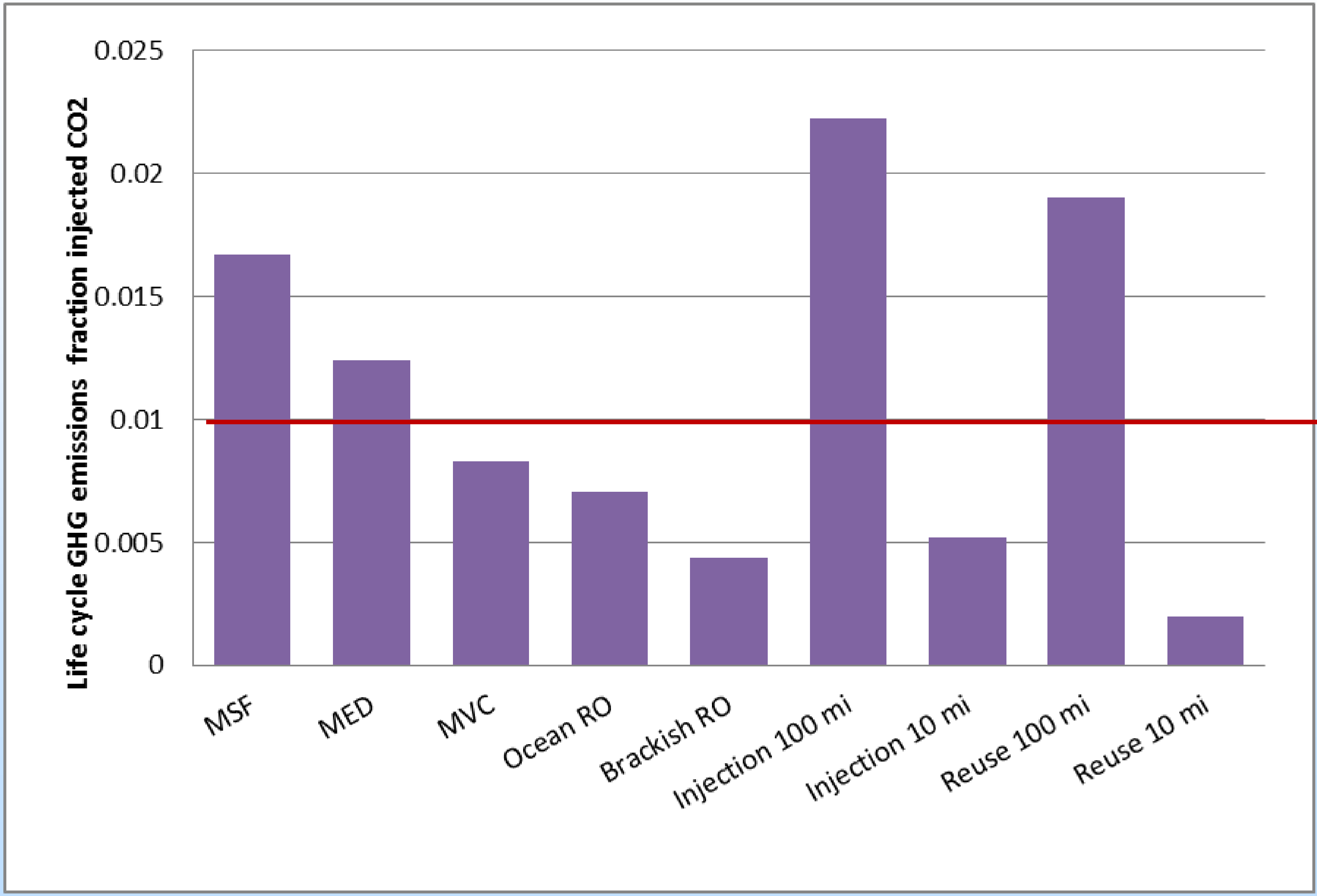
Task 2 – Key Findings: Energy Consumption



Task 2 – Key Findings: Energy Consumption



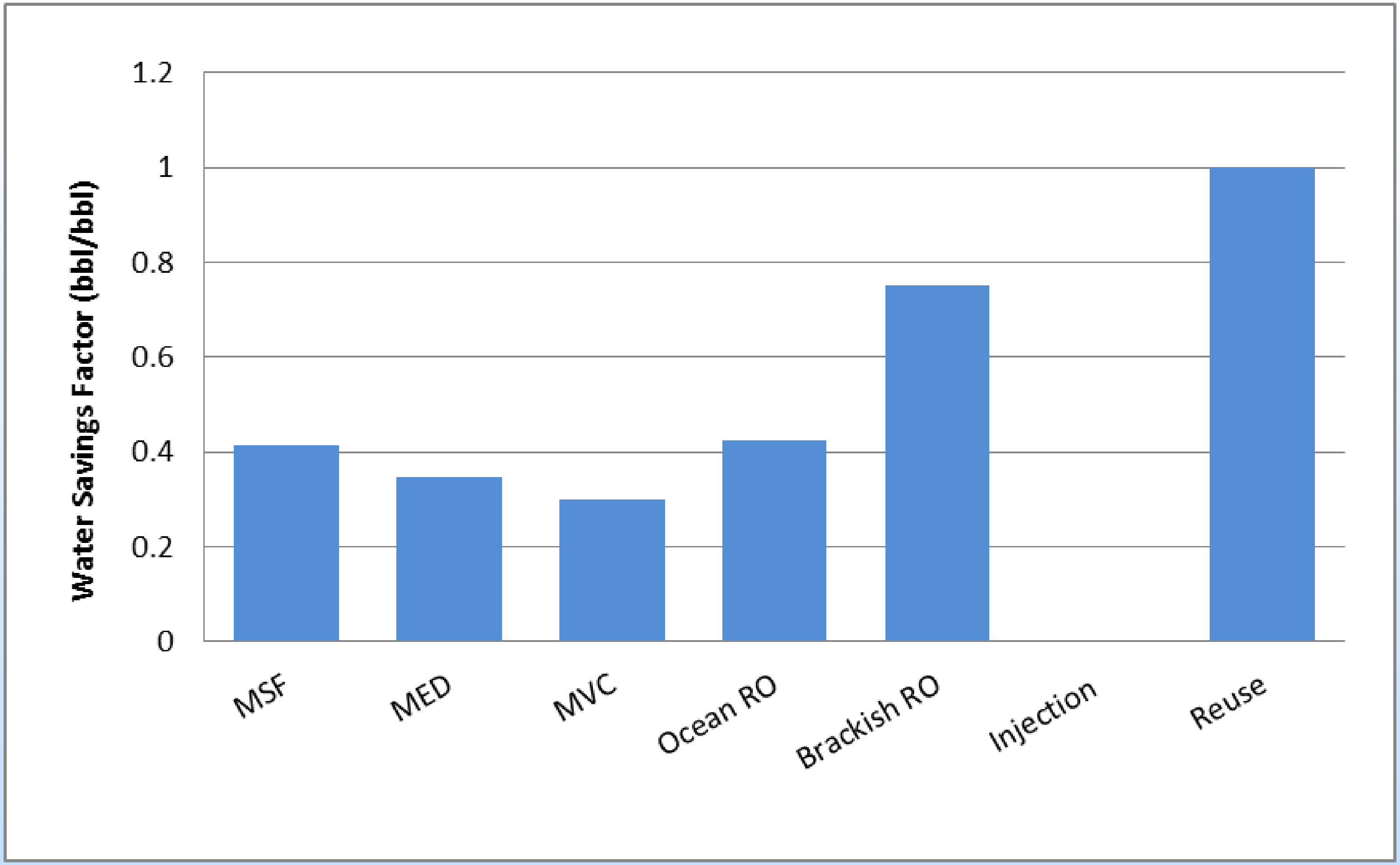
Task 2 – Key Findings: GHG Emissions



1% of injected CO_2

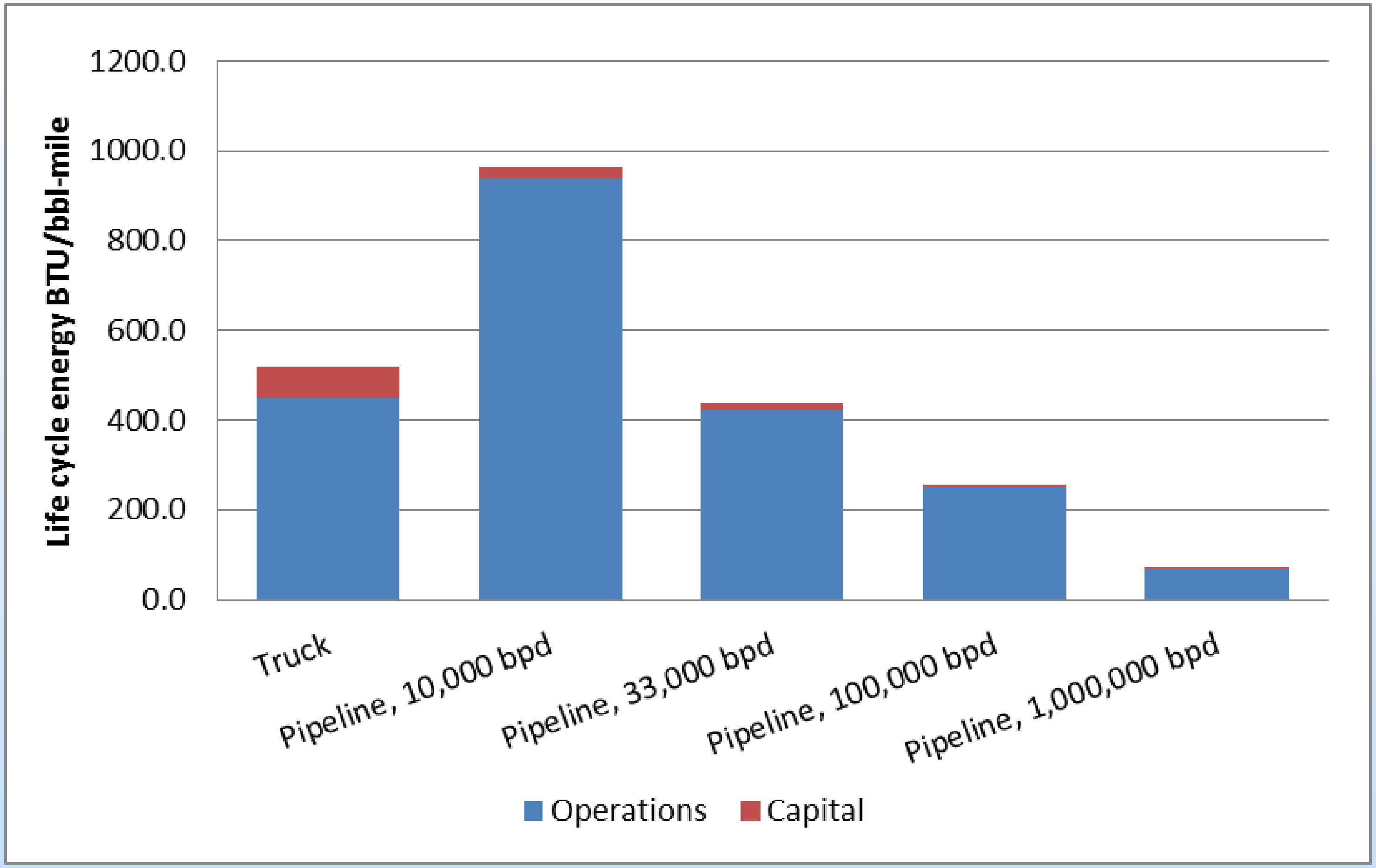
Assumes 1 to 1 volume displacement of water by injected CO_2

Task 2 – Key Findings: Water Savings



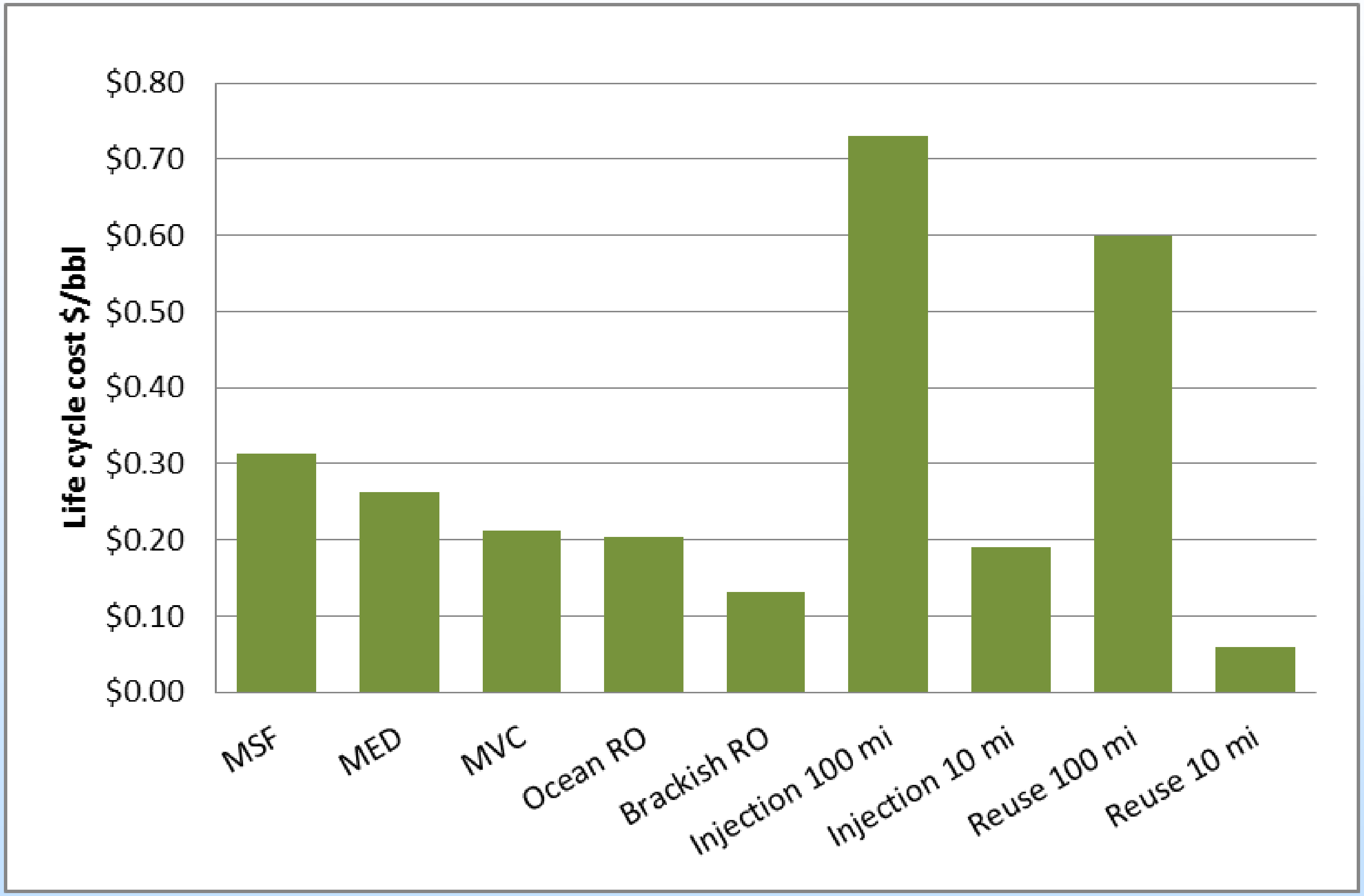
Note: based upon ocean desalination systems optimized to minimize fresh water production costs. Tradeoffs exist between energy consumption and water savings.

Task 2 – Key Findings: Transportation



Minimal impact of length of pipeline on per mile energy costs, but significant impact of flow rate on per mile energy costs.

Task 2 – Key Findings: Estimated Costs



Key assumptions: Only capital and energy costs included, 8% interest rate over 20 years, $0.10/kwh electricity, $6 MCF natural gas

Task 2 – Additional Considerations

- Important additional factors in selecting brine management practices:
  - Fluctuations in brine composition and/or flow rate
  - Matching brine production volume and composition with beneficial re-use demand
  - Scaling and membrane fouling potential and the effectiveness of pretreatment
  - Availability of suitable formations for brine or concentrate injection

Task 2 - Conclusions

- The extraction of brines from many formations can likely be done with acceptable environmental costs (There is still uncertainty over financial costs).
- The extraction and management of brines is unlikely to add significantly to the full life cycle carbon footprint.
- Reverse Osmosis appears to be the preferred treatment method, however it's applicability is limited to low TDS brines.
- Further study is recommended to evaluate the efficacy of RO in treating extracted brines from different formations and to improve understanding of pretreatment requirements and costs.
- Transportation distance should be a major factor in the decision making process and should be minimized to the extent possible.

Task 3 - Status

- Initial literature review in progress
- Previous ANL Aspen models of Amine and Oxy-combustion capture systems have been explored to extract process water consumption and cooling loads

Summary

- Key Findings
  - Management of extracted water is not likely to be a major barrier to the deployment of active reservoir management assuming sufficient operational benefits can be demonstrated from extracting brine.
- Future Plans
  - Finalize Task 2 final report
  - Continue Task 3
    - Complete literature review
    - Define system configurations and scenarios
    - Continue data collection and begin analysis

Appendix

– These slides will not be discussed during the presentation, but are mandatory

Organization Chart

- PI:
  - Christopher Harto
- Other Researchers
  - John Veil, *Retired* (Task 1 only)
  - Richard Doctor, *Retired* (Task 3 only)
  - David Murphy (Task 3 only)
  - Robert Horner (Task 3 only)

Gantt Chart

Task	Milestone Description	FY10				FY11				FY12				FY13			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1 - Extracted Water from CCS	Qualitative assessment of options for managing extracted water based upon produced water mangament practices																
Task 2 - Extracted Water from CCS: Environmental Cost/Benefit Analysis	Quantification of the life cycle envirionmental costs and benefits of different extracted water management scenarios.																
Task 3 - Extracted Water from CCS: Water LCA	Quantification of the life cycle water consumption for electricity production from coal generation with carbon sequestration																

Bibliography

– Technical Reports

- Harto, C.B., and J.A. Veil, 2011, “Management of Water Extracted from Carbon Sequestration Projects,” Prepared for the US DOE National Energy Technology Laboratory Carbon Sequestration Program by Argonne National Laboratory, ANL/EVS/R-11/1, January.
- Harto, C.B., 2012, “Life Cycle Assessment of Water Management Options used for Managing Brines Extracted from Deep Saline Aquifers used for Carbon Storage,” DRAFT.

– Conference Papers

- Veil, J.A., Harto, C.B., and A.T. McNemar, 2011, “Management of Water Extracted From Carbon Sequestration Projects: Parallels to Produced Water Management,” SPE 140994, Presented at SPE Americas E&P Health, Safety, Security and Environmental Conference, Houston, Texas, 21–23 March 2011.

– Conference Presentations

- Harto, C.B., 2011, “Environmental Costs of Managing Geological Brines Produced or Extracted During Energy Development,” presented at the International Petroleum and Biofuels Environmental Conference, Houston, TX, November 8-10.
- Harto, C.B., 2011, “Environmental Costs of Managing Geological Brines Produced or Extracted During Energy Development,” presented at the Groundwater Protection Council Annual Forum, Atlanta, GA, September 25-28.
- Harto, C.B., Veil, J.A., and McNemar, A., 2011, “Extracting Water from Carbon Sequestration Projects: Quantities, Costs, and Environmental Considerations”, presented at the 10th Annual Conference on Carbon Capture & Sequestration, Pittsburgh, PA, May 2-5.
- Harto, C.B., Veil, J.A., and McNemar, A., 2010, “Managing Water from CCS Programs”, presented at the Groundwater Protection Council Water Energy Sustainability Symposium, Pittsburgh, PA, September 26-29.