Critical Challenges. Practical Solutions.

Energy & Environmental Research Center (EERC)

Improving EOR Performance Through Data Analytics and Next-Generation Controllable Completions (DE-FE0031790)

U.S. Department of Energy National Energy Technology Laboratory

Oil & Natural Gas

2020 Integrated Review Webinar

October 13, 2020

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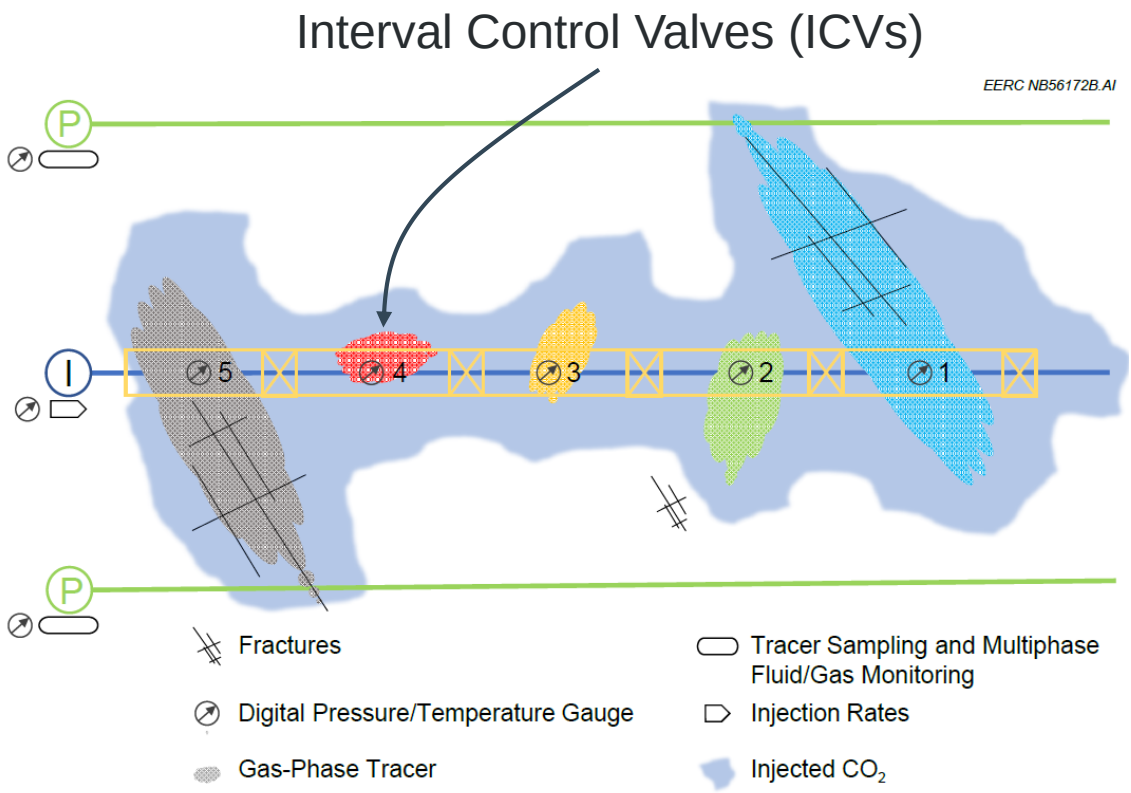
Conceptual Pilot Test Design

- Field-test controllable completion for active well control during carbon dioxide (CO_2) enhanced oil recovery (EOR).
- One lateral injection well with ICV system.
- Two offset lateral production wells with openhole completion.
- Rigorously monitored field test.
- Use offset patterns as a reference case to assess performance.
- Combine field and simulation data to develop business case scenarios.



Red River Fm. Cedar Creek Anticline

Project Partners

Lead Organization

- Energy & Environmental Research Center

Project Partners

- U.S. Department of Energy
- North Dakota Oil & Gas Research Program
- Denbury Onshore LLC
- NCS Multistage LLC
- North Dakota Geological Survey
- Schlumberger
- Computer Modelling Group Ltd.

Funding and Project Performance Dates

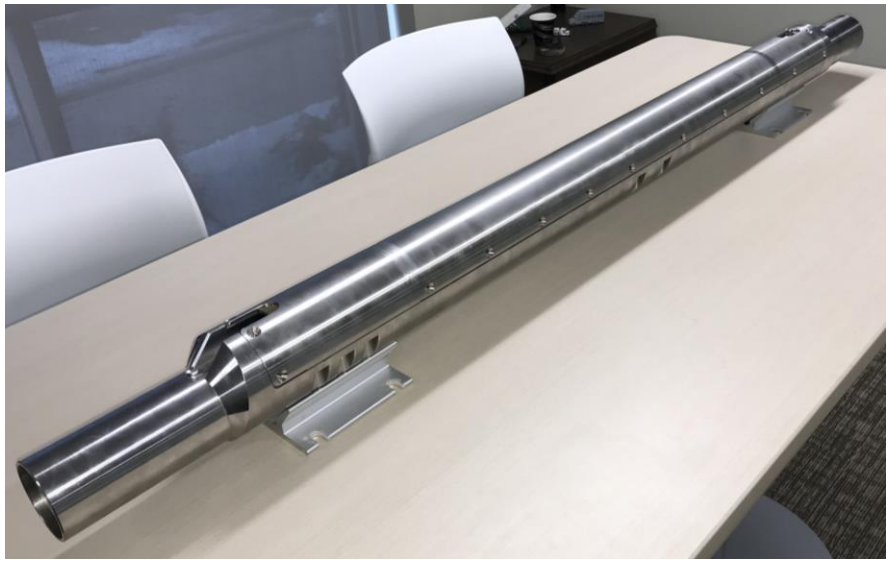
Funding Profile by Budget Period (BP) (October 1, 2019 – September 30, 2024)

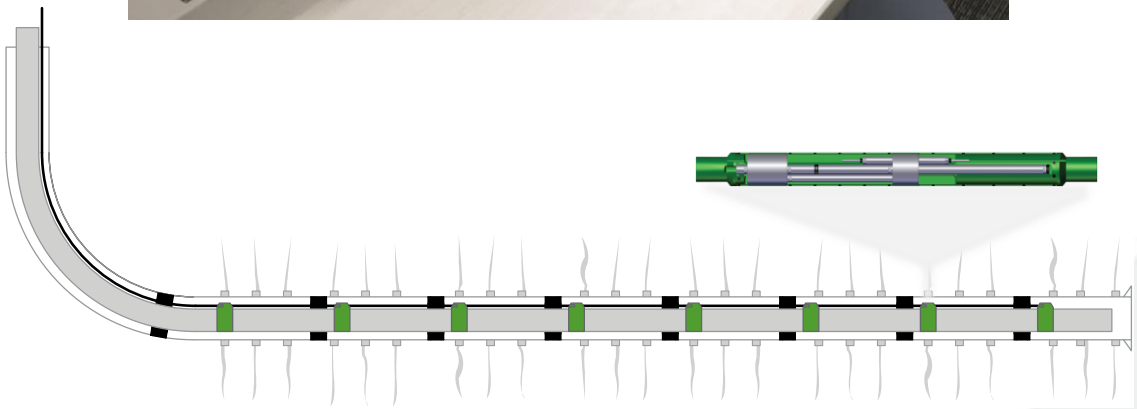
	BP1 ($) (10/01/2019 - 01/31/2021)			BP2 ($) (02/01/2021 - 01/31/2023)			BP3 ($) (02/01/2023 - 09/30/2024)			Total ($)		
	Federal	**Nonfederal**	**Total**	**Federal**	**Nonfederal**	**Total**	**Federal**	**Nonfederal**	**Total**	**Federal**	**Nonfederal**	**Total**
DOE	2,671,594	–	2,671,594	3,297,845	–	3,297,845	2,027,638	–	2,027,638	7,997,077	–	7,997,077
NDIC OGRP	–	133,000	133,000	–	200,000	200,000	–	167,000	167,000	–	500,000	500,000
Schlumberger	–	475,580	475,580	–	128,810	128,810	–	128,914	128,914	–	733,304	733,304
CMG	–	508,350	508,350	–	137,691	137,691	–	120,602	120,602	–	766,643	766,643
Total	**2,671,594**	**1,116,930**	**3,788,524**	**3,297,845**	**466,501**	**3,764,346**	**2,027,638**	**416,516**	**2,444,154**	**7,997,077**	**1,999,947**	**9,997,024**
Total Cost Share %	70.5%	29.5%		87.6%	12.4%		83.0%	17.0%		80.0%	20.0%	

*Note: **Denbury** is providing additional contributions in the form of field support, infrastructure development, CO_2 supply, and injection/production operations. **NCS Multistage** is providing additional contributions in the form of field activities: multizone completions and injection well tracer testing.*

Technology Background: Qumulus™ Ultimate Recovery System

- Packers provide isolation between zones.
- Injection valve control at each zone.
- Pressure and temperature at each zone.
- Single wire for all valves and gauges.
- Operate from anywhere using a cloud-based supervisory control and data acquisition (SCADA) system.
- Slim dimensions, suitable for common onshore wells.





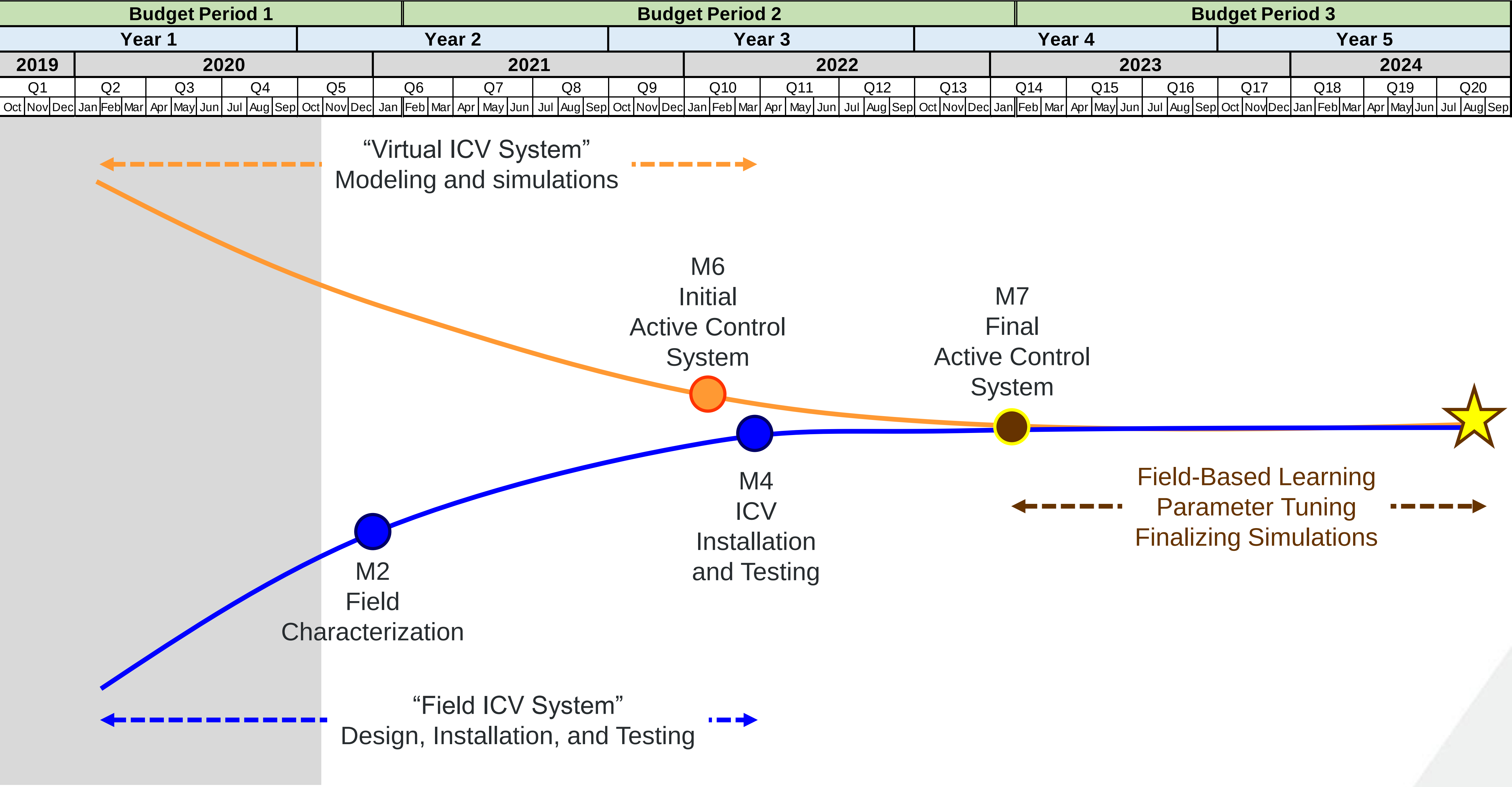
Technical Approach/Project Scope

- **Task 1.0 – Project Management and Planning**
- **Task 2.0 – ICV Pilot Systems Design**
  - 2.1 – Screening and Selection of Test Pattern
  - 2.2 – Characterization ← *DP1: Go/no-go decision for the candidate injection well 12/31/20*
  - 2.3 – Baseline Modeling
  - 2.4 – Pilot Design
- **Task 3.0 – Operation and Monitoring**
  - 3.1 – Install and Test Systems

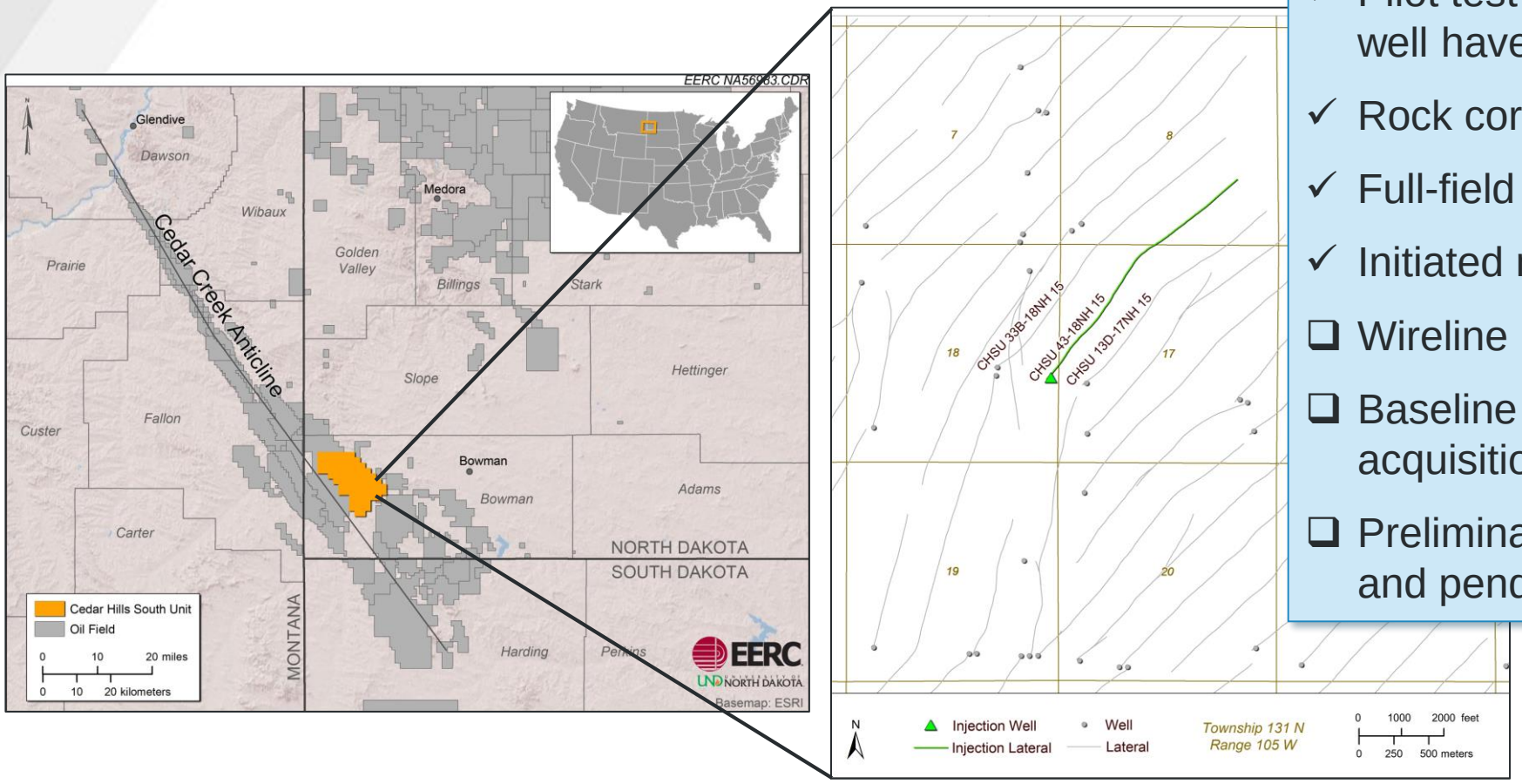
DP2: Go/no-go decision for successful ICV system in the injection well 3/31/22

Technical Approach/Project Scope (cont.)

- **Task 3.0 – Operation and Monitoring (cont.)**
  - 3.2 – System Operation and Monitoring
- **Task 4.0 – Active Control System Development**
  - 4.1 – Database and User Interface Development
  - 4.2 – Active Control System Development, Testing, and Optimization
- **Task 5.0 – Business Case Development**
  - 5.1 – Long-Term Pilot Test Pattern Performance Simulation
  - 5.2 – Business Case Development


Budget Period 1
Budget Period 2
Budget Period 3
Year 1
Year 2
Year 3
Year 4
Year 5
2019
2020
2021
2022
2023
2024
Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17 Q18 Q19 Q20
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
“Virtual ICV System”
Modeling and simulations
M6
Initial
Active Control
System
M7
Final
Active Control
System
M4
ICV
Installation
and Testing
M2
Field
Characterization
Field-Based Learning
Parameter Tuning
Finalizing Simulations
“Field ICV System”
Design, Installation, and Testing

Progress and Current Project Status



- ✓ Pilot test pattern and candidate injection well have been selected.
- ✓ Rock core laboratory analyses complete.
- ✓ Full-field geologic model complete.
- ✓ Initiated numerical reservoir simulations.
- ❑ Wireline logging in early October 2020.
- ❑ Baseline three-component, 3D seismic acquisition planned for November 2020.
- ❑ Preliminary ICV system design complete and pending field data.

Expected Results

- Demonstrate performance and reliability of ICV deployment for CO_2 EOR in horizontal injection and production wells (*first application*).
- Evaluate perceived risks of deploying ICVs in horizontal wells. Inform ICV system design, installation practices, and operational practices.
- Develop/improve active control systems for ICV operation.
- Quantify performance metrics: 1) net CO_2 utilization, 2) oil recovery and sweep efficiency, and 3) operating costs.
- Evaluate business cases for the implementation of ICVs for improving EOR performance for a range of reservoirs, fields, and operational scenarios (including potential application for conformance control for Bakken EOR).

Benefits

- Demonstrate the reliability and performance to enable broad adoption of controllable completions in horizontal wells.
  - Current state: Limited demonstration of reliability and performance.
  - Path forward: Validate a potential pillar technology for unlocking EOR in unconventional tight oil plays, where conformance is a known challenge.
- Techno-economic assessments indicate horizontal wells are a key to enabling economical EOR in conventional fields.
- Controllable completions may allow horizontal wells to be managed like a series of vertical wells and drive efficiency, reduce CO_2 net utilization rates, and increase oil recovery with fewer wells.

[1]"Techno-Economic Assessment of Implementing Lignite Based CO_2 EOR in North Dakota" Final Report, submitted to North Dakota Department of Commerce, Grant Agreement No. 1867.

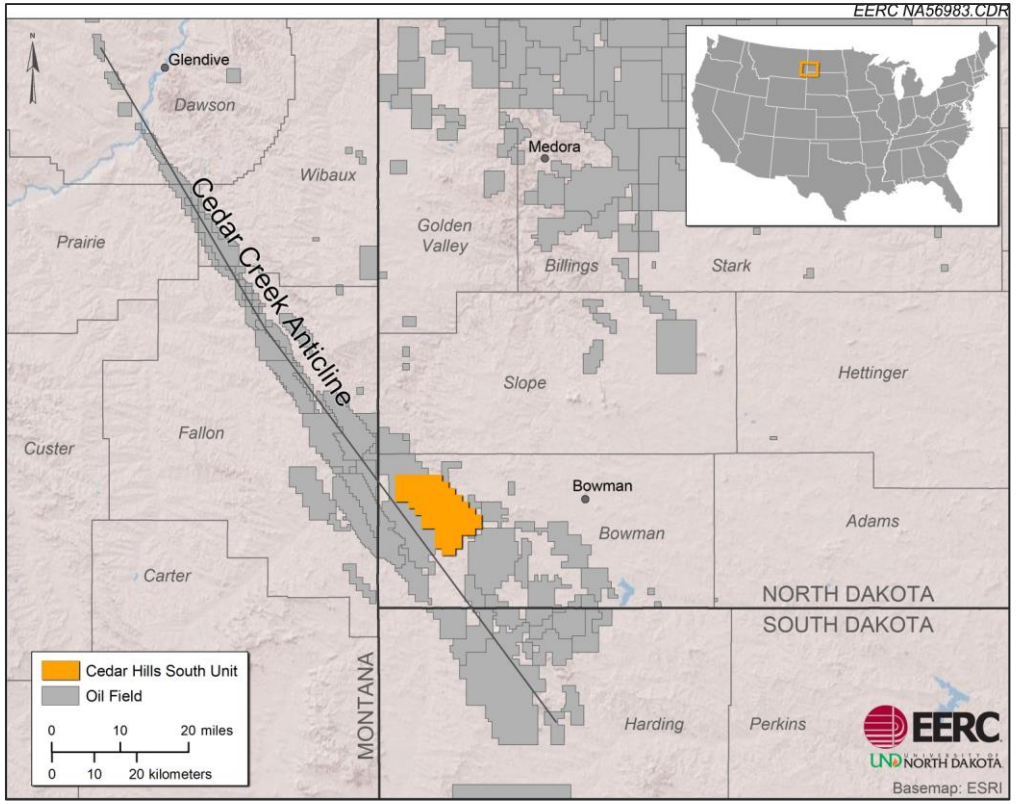
Denbury Statement Regarding Benefits

- Piloting next-generation controllable completions offers an attractive value proposition to Denbury.
- This pilot test will provide new insights on reservoir performance prior to and during CO_2 EOR. Additionally, it will give us operational experience deploying advanced completions in horizontal wells. Furthermore, this pilot will allow us to leverage data analytics to optimize well and reservoir performance.
- The pilot's well-thought-out design will streamline our ability to interpret results. Our findings will be used to evaluate the business case for applying this technology at Cedar Creek Anticline and in other fields.

Denbury

Summary

- This project has adapted to the 2019–2020 operating conditions and is on track to complete the modified scope of work and project timeline.
- Field work is under way, which will inform the ICV design and reservoir simulations.
- The expected installation date for the ICV system is Q3-2021.



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THANK YOU

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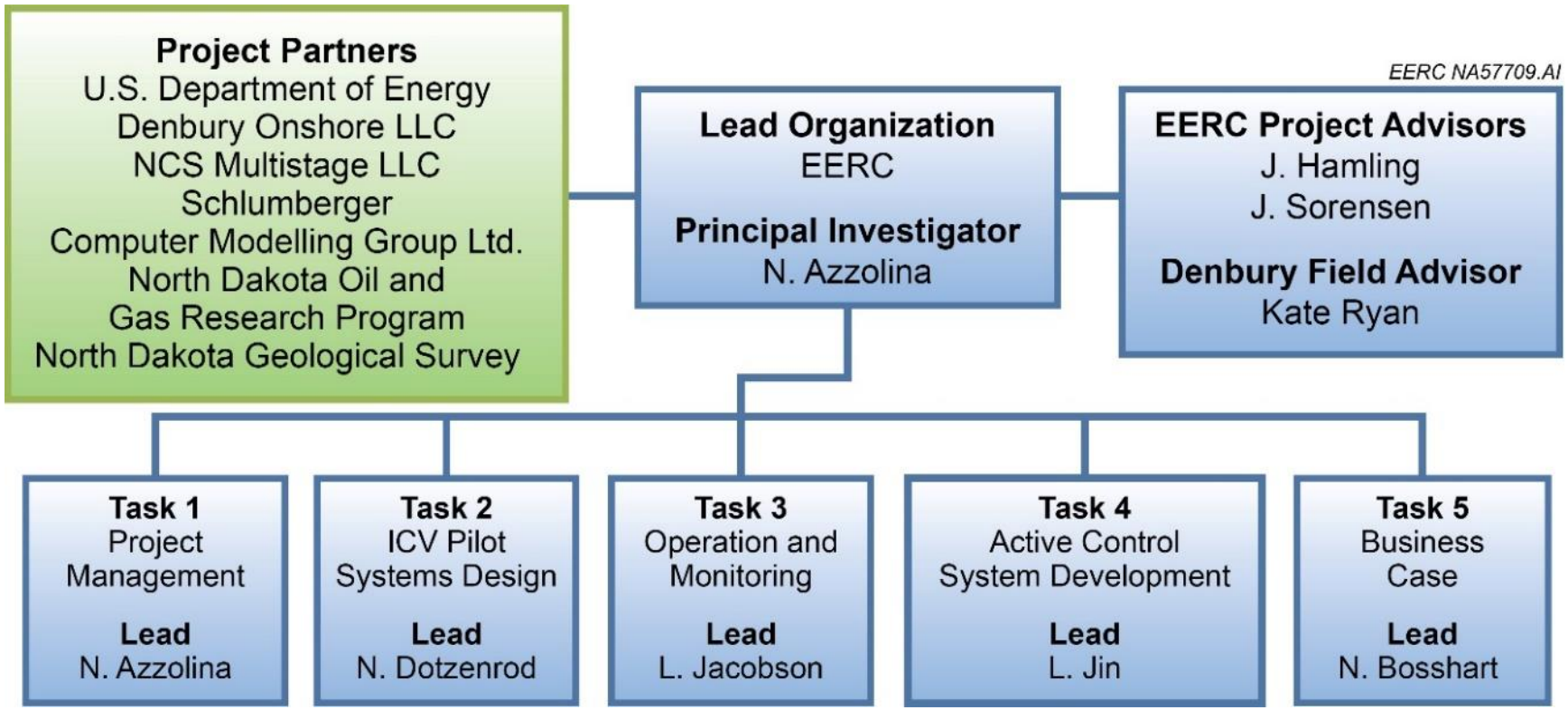
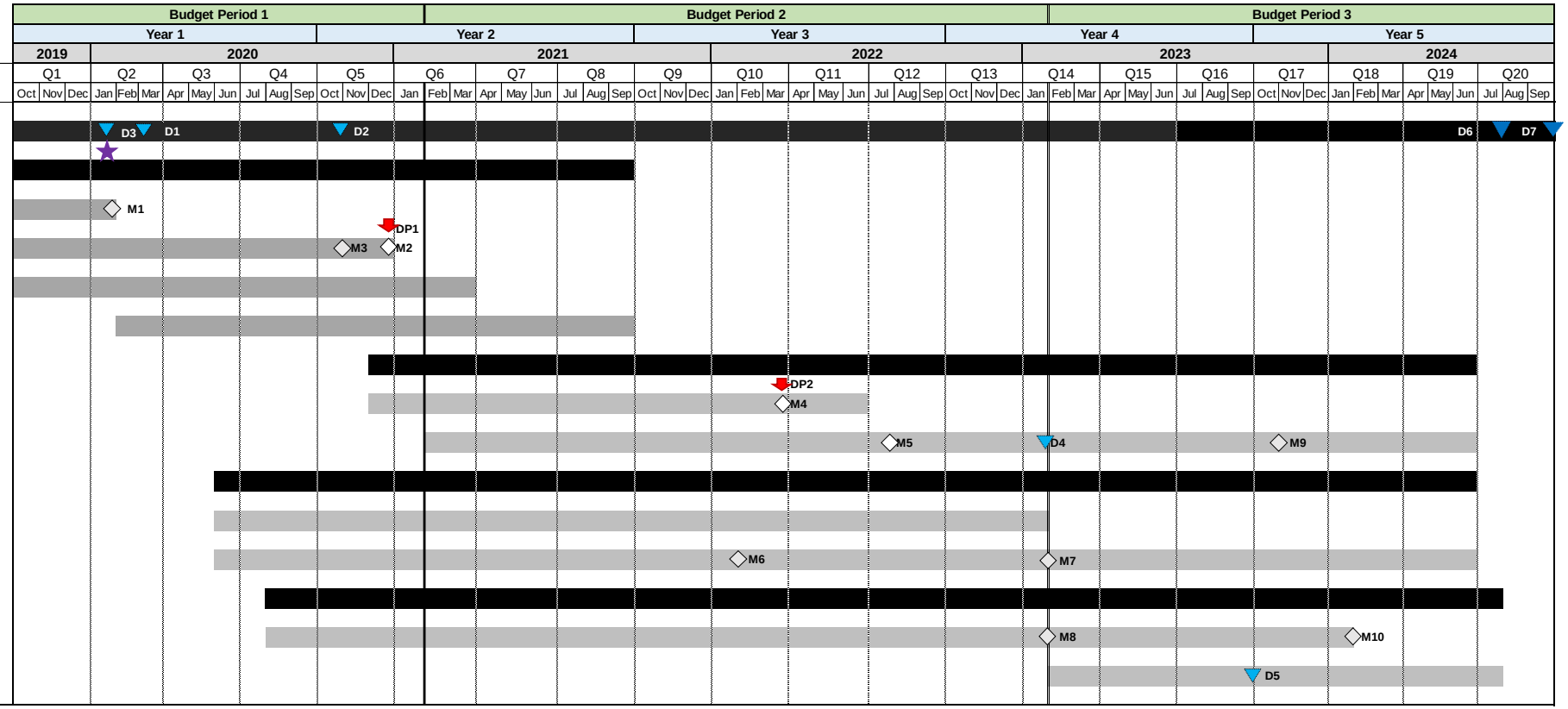
APPENDIX

Project Organizational Chart



Project Gantt Chart

Task	Start Date	End Date
Task 1.0. Project Management and Planning	**10/1/19**	**9/30/24**
Task 2.0. ICV Pilot Systems Design	**10/1/19**	**9/30/21**
2.1. Screening and Selection of Test Pattern	10/1/19	1/31/20
2.2. Characterization	10/1/19	12/31/20
2.3. Baseline Modeling	10/1/19	3/31/21
2.4. Pilot Design	2/1/20	9/30/21
Task 3.0. Operation and Monitoring	**12/1/20**	**6/30/24**
3.1. Install and Test Systems (Injection Well)	12/1/20	6/30/22
3.2. System Operation and Monitoring (Injection Well)	2/1/21	6/30/24
Task 4.0. Active Control System Development	**2/1/21**	**6/30/24**
4.1. Database and User Interface Development	2/1/21	1/31/23
4.2. Active Control System Development, Testing, and Optimization	2/1/21	6/30/24
Task 5.0. Business Case Development	**8/1/20**	**7/31/24**
5.1. Long-Term Pilot Test Pattern Performance Simulation	8/1/20	1/31/24
5.2. Business Case Development	2/1/23	7/31/24



★ Definitized Amendment Finalized (1/27/20)

Milestones (M) ◇	Deliverables (D) ▽	Decision Points (DPs)
M1 – Screening and Selection of Pilot Test Pattern Complete (1/31/20)	D1 – Project Management Plan (2/26/20)	DP1 – Go/No-Go decision for the candidate injection well (12/31/20).
M2 – Field Characterization Activities Complete (12/31/20)	D2 – Workforce Readiness Plan (11/1/20)	DP2 – Go/No-Go decision for successful ICV system in the injection well (3/31/22).
M3 – Laboratory Characterization Activities Complete (10/31/20)	D3 – Data Management Plan (1/27/20): Revised for Definitized Agreement	
M4 – ICV Installation and Initial Testing Complete (3/31/22)	D4 – Interim Field Performance Summary Report (1/31/23)	
M5 – Tracer Study Initiated (8/1/22)	D5 – Business Cases for Commercial Deployment of ICV Systems for Managing EOR Performance (9/30/23)	
M6 – Initial Active Control System Design Complete (1/31/22)	D6 – Development Strategy Plan (7/31/24)	
M7 – Active Control System Design Complete (1/31/23)	D7 – Data Submitted to NETL EDX (9/30/24)	
M8 – Geologic Model Complete (1/31/23)		
M9 – Transfer of Operational Ownership of ICV Pilot to Field Operator Initiated (11/1/23)		
M10 – Numerical Simulation Complete (1/31/24)		

06.03.20 naa

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