Energy & Environmental Research Center (EERC)

INITIAL ENGINEERING AND DESIGN FOR CO_2 CAPTURE FROM ETHANOL FACILITIES

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PROJECT MANAGEMENT

Jason Laumb
Principal Investigator (PI)
Task 1.0 – Project Management and Planning

Kerryanne Leroux

Task 2.0 – Project Engineering and Design

John Kay

Task 3.0 – Determine Pre-FEED Cost Estimate

AGENDA

- Project Overview
- Red Trail Energy, LLC (RTE) CCS
- Technology and Scope
- Project Status
- Summary and Questions

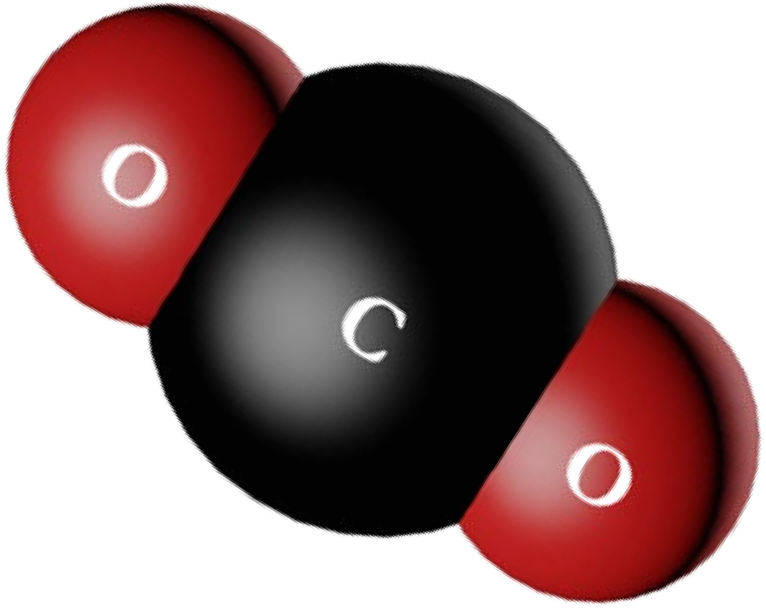
Image Credit: Red Trail Energy

PROJECT OVERVIEW

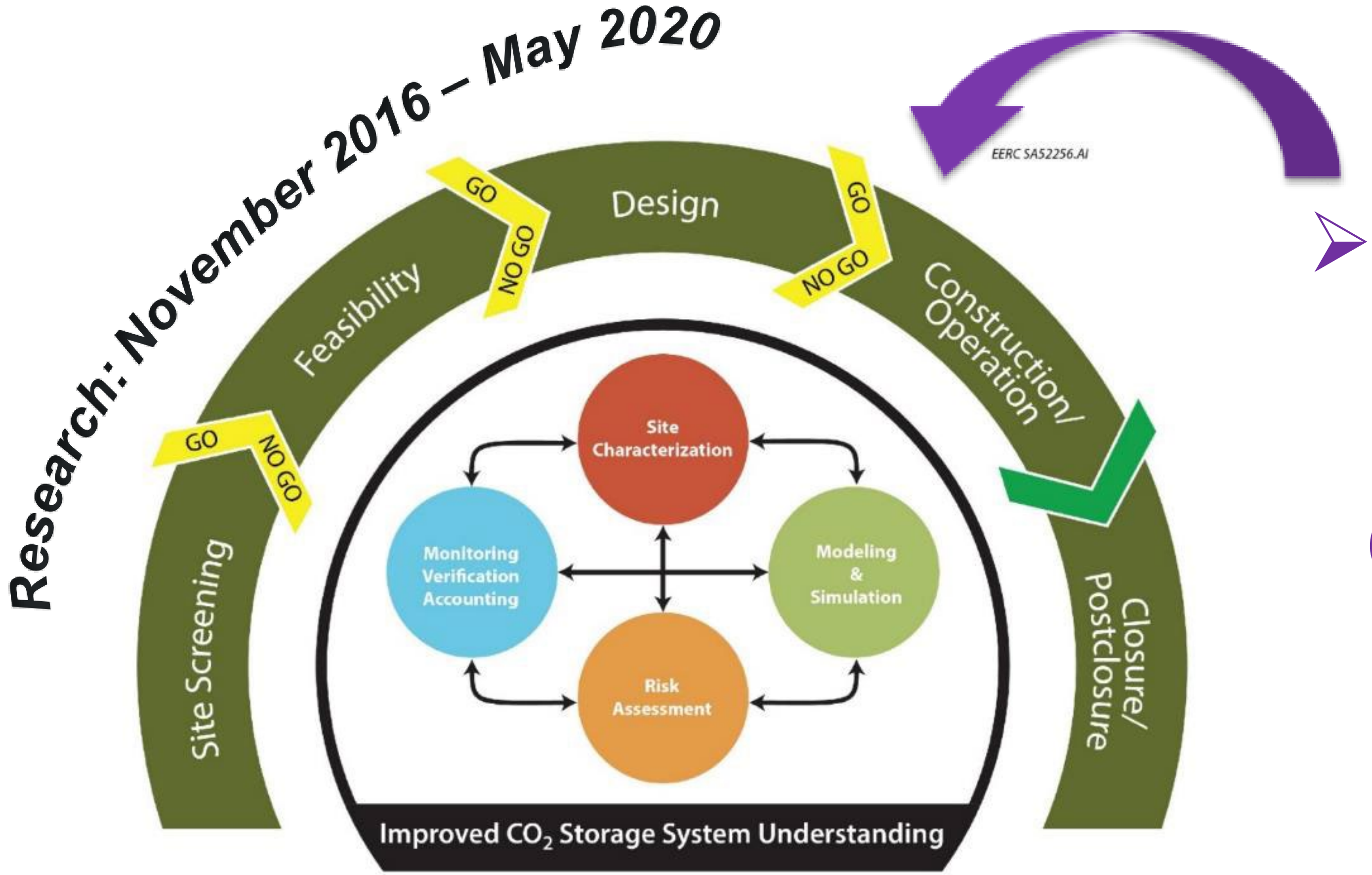
- Project Budget: $1,949,954
  - $1,559,954 DOE funds
  - $390,000 cost share
    - ♦ $375,000 RTE
    - ♦ $15,000 EERC
- Period of Performance (POP): Oct 1, 2020 – Sep 30, 2022
- Goal: Develop an initial engineering design (IED) and estimated cost for capture and compression of CO_2 generated from an operational ethanol production facility

PROJECT OBJECTIVES

- Design a hybrid capture system using CO_2 emissions from both bioprocessing and heat production at the RTE facility.
- Complete a pre-front-end engineering and design (FEED) analysis of the hybrid capture system, which includes environmental health and safety (EH&S), constructability report, identification of permits, and corporate approvals.
- Complete a techno-economic assessment (TEA) in accordance with DOE's methodology, as demonstrated by the bituminous baseline study.

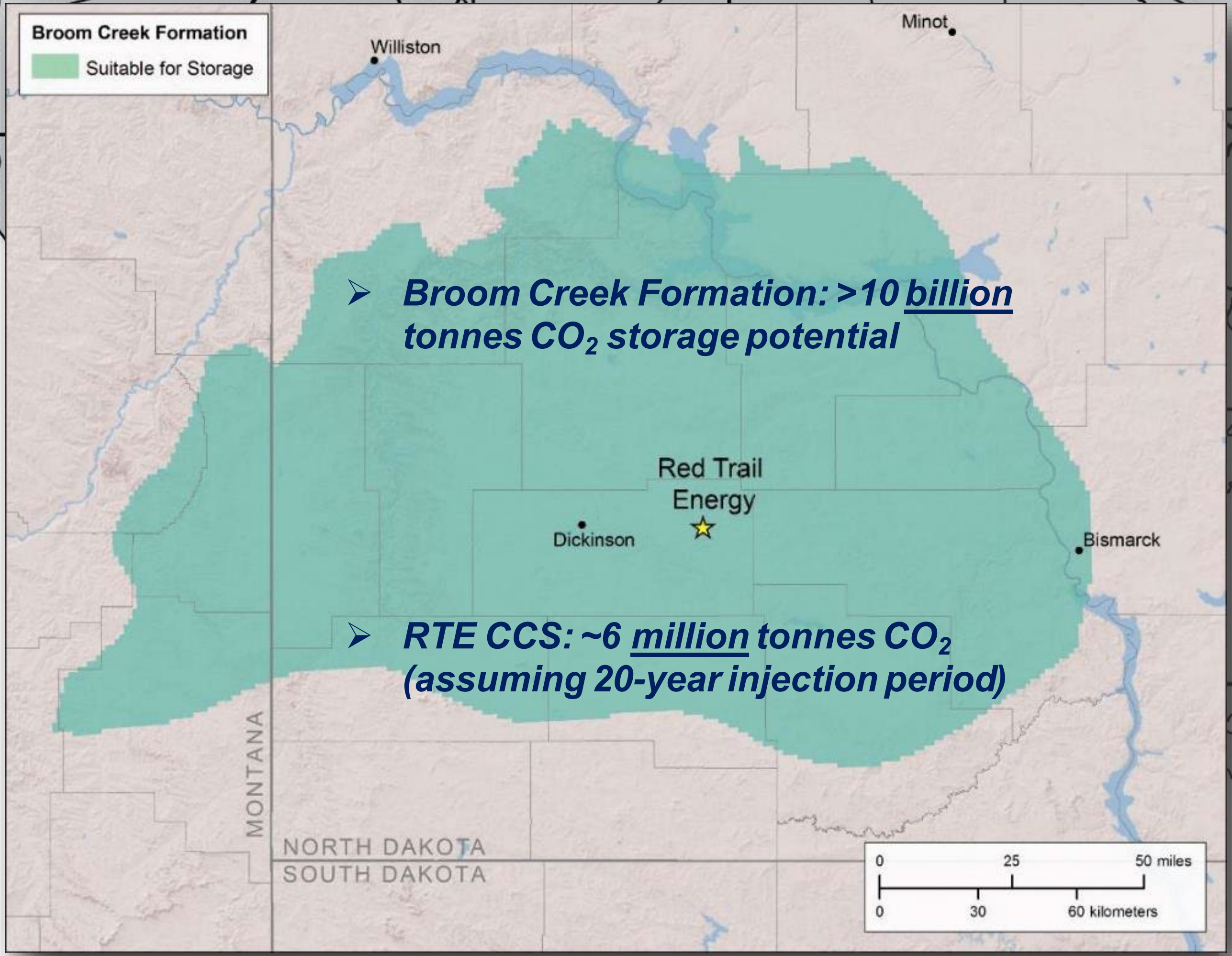


RTE CCS PROJECT



- The first North Dakota Class VI permit *approved* October 19, 2021.

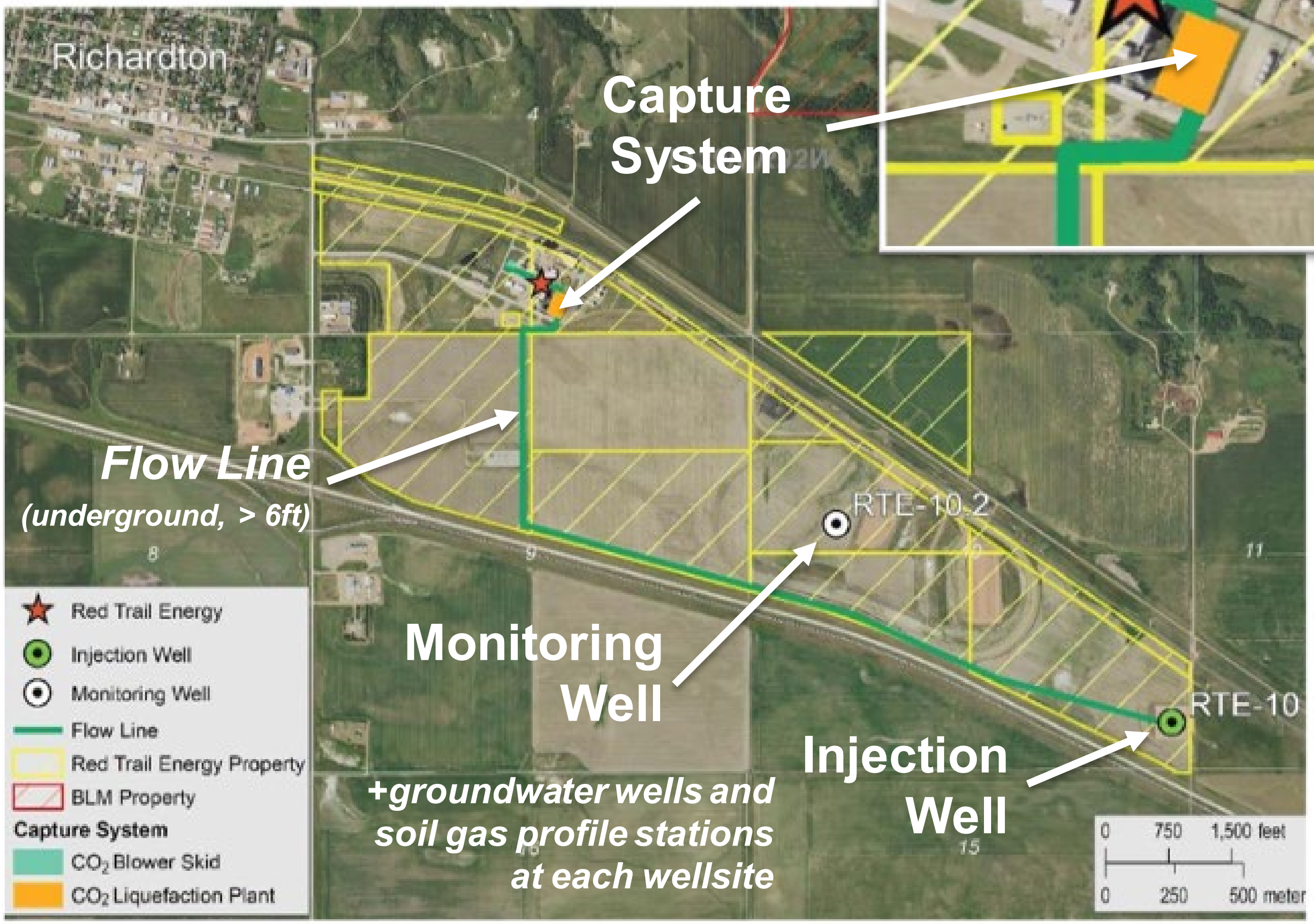
RTE SITE:
Excellent CCS Case Study



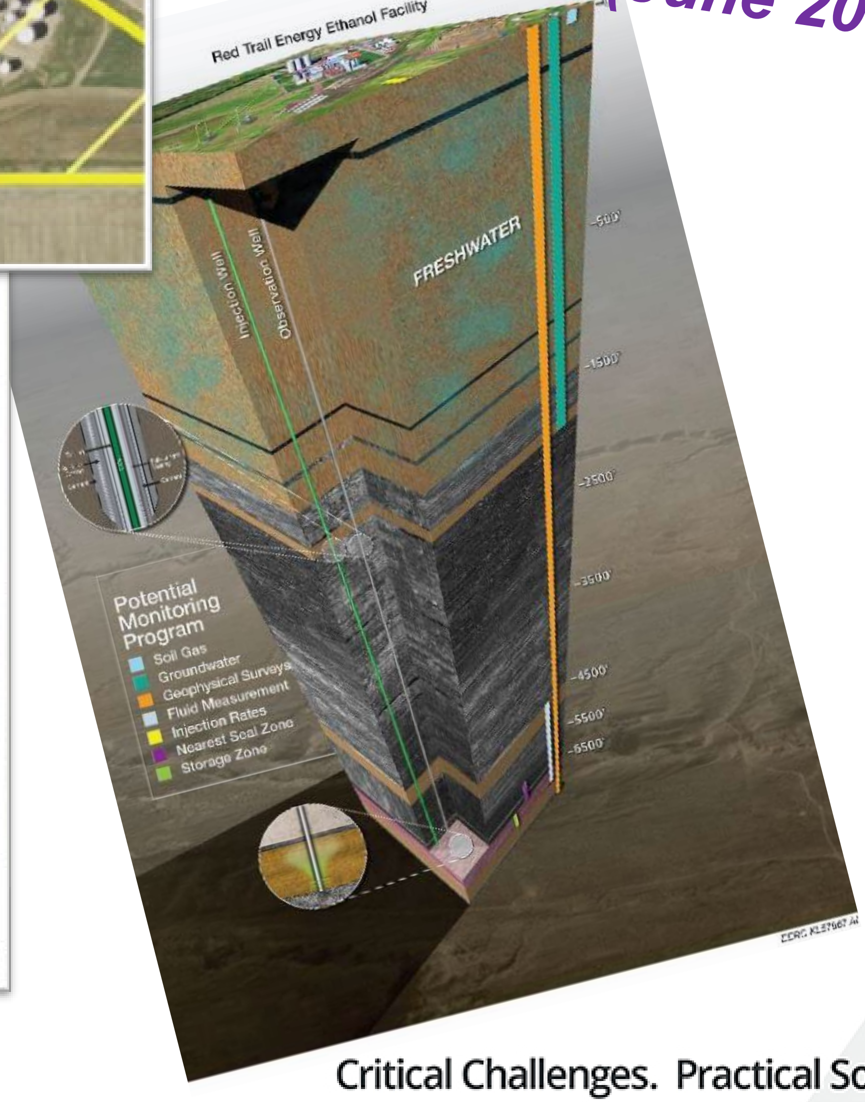
- ***Broom Creek Formation: >10 billion tonnes CO_2 storage potential***
- ***RTE CCS: ~6 million tonnes CO_2 (assuming 20-year injection period)***

- CO_2 capture potential
  - ~310,000 tonnes/yr of CO_2 from bioprocessing, heat production.
  - Bioprocessing CO_2 stream is nearly pure.
- Geologic storage potential:
  - Broom Creek Formation
  - 6400 ft directly underlying RTE facility, ~300 ft thick

RTE CCS IMPLEMENTATION



➢ <u>First</u> commercial-scale CCS operations in North Dakota (June 2022)



PROJECT TECHNOLOGY

CO_2 from Bioprocessing

Steam/Electricity

CO_2 from Heat Production

Hybrid Capture System

Injection for Geologic Storage

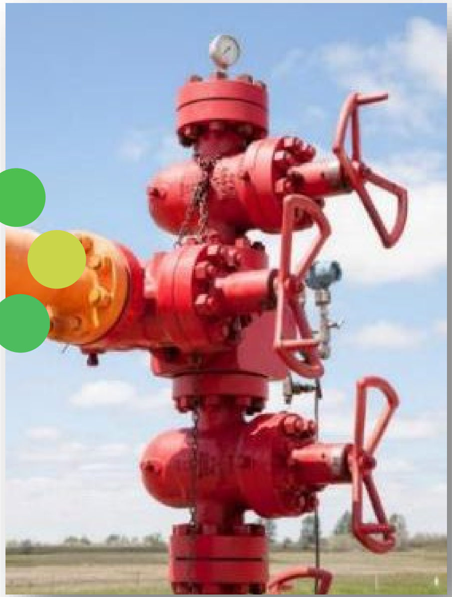
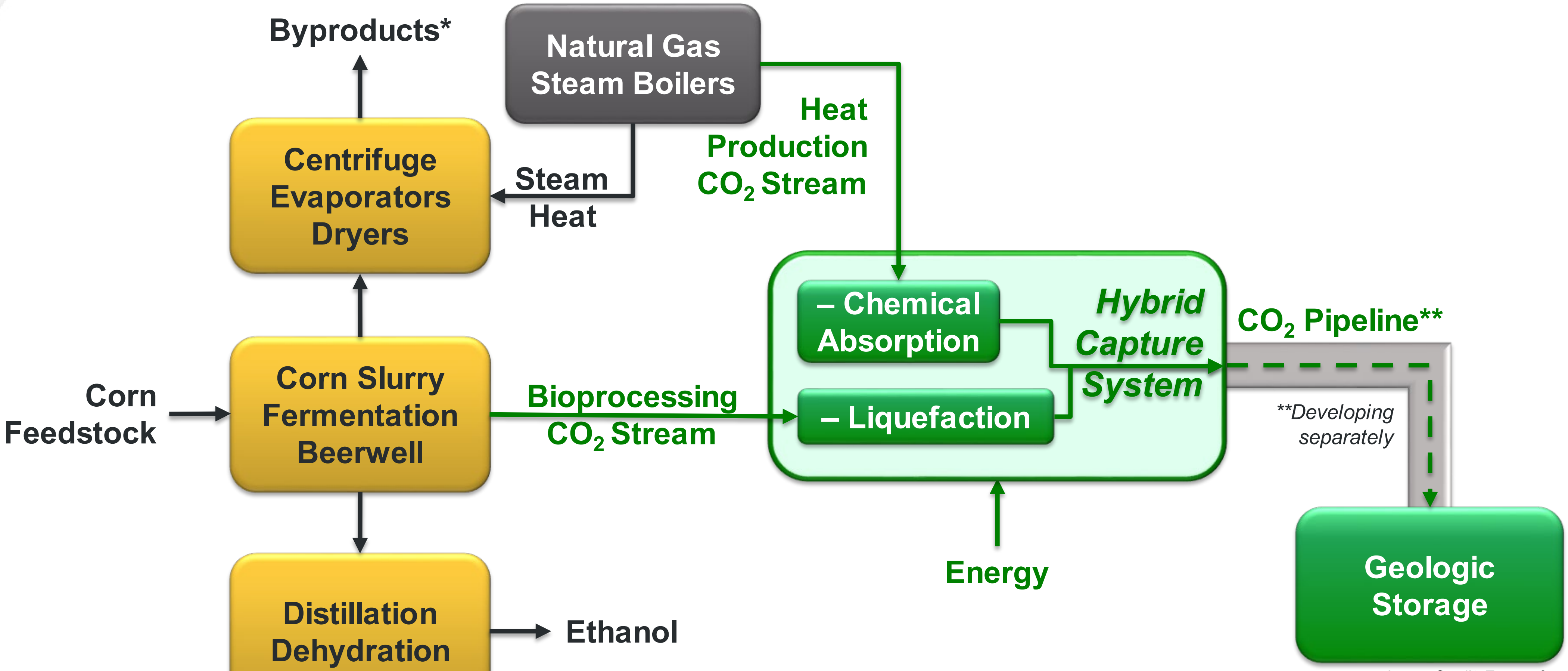


Image Credit: Energy & Environmental Research Center

ETHANOL–CCS PROCESS WITH NOVEL HYBRID CAPTURE SYSTEM



*Includes distillers grains, etc.

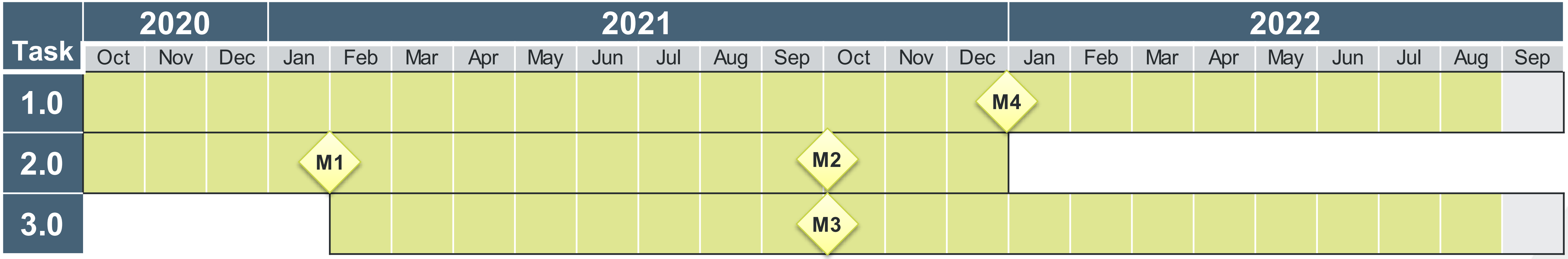
Image Credit: Energy & Environmental Research Center

PROJECT SCOPE

1. Project Management and Planning
2. Project Engineering and Design
3. Determine Pre-FEED Cost Estimate

➢ ***POP: Oct 1, 2020 – Sep 30, 2022***

Milestone Title	Planned Completion Date
M1 – Design Basis Determined	End of Month 4
M2 – Complete Pre-FEED Analysis	End of Month 12
M3 – Complete Design	End of Month 12
M4 – Complete TEA	End of Month 15



SUCCESS CRITERIA

✓Completion of design basis for hybrid capture at RTE.

Photograph by Lars Plougmann

✓Completion of TEA for design basis at RTE.

✓Pre-FEED-level cost estimate for implementation of hybrid capture technology at RTE.

✓Designed capture process that provides negative CO_2 emissions for RTE.

❑RTE management approval of hybrid capture design such that it is considered by the RTE Board.

HYBRID–CCS SCENARIOS:
*Design Basis and Operational Estimates**

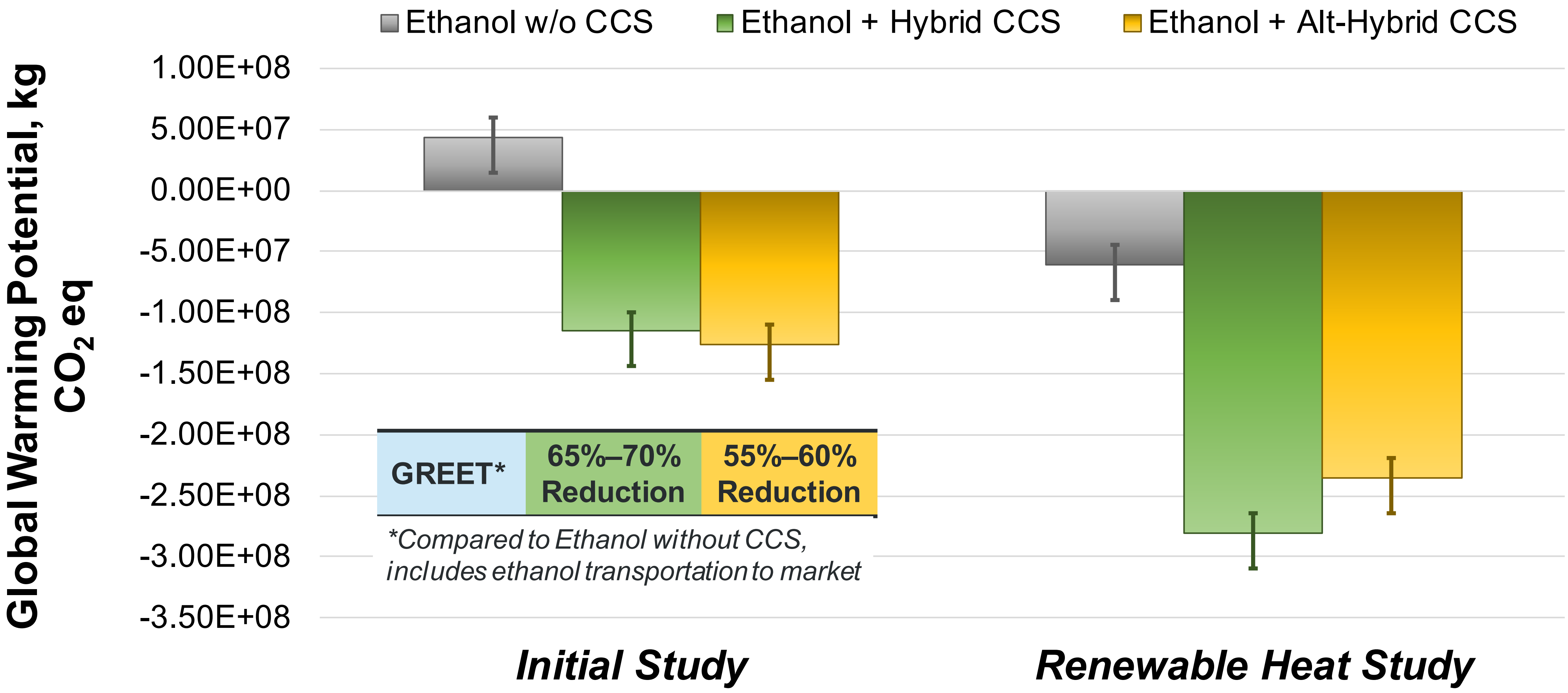
Scenario:	Maximum Amine Capture	Alternative Amine Capture
CO_2 Capture Design	***90% of CO_2 from boiler flue gas***	***45% of CO_2 from boiler flue gas***
Annual CO_2 Rate	~130,000 tonnes (~310,000 tonnes total)	~65,000 tonnes (~245,000 tonnes total)
Equipment Differences	New boiler and flue gas blower; added compression and dehydration	Smaller amine unit
Power	3.3 MW	0.8 MW
Natural Gas	54 MMBtu/hr	27 MMBtu/hr

**In addition to bioprocessing–liquefaction system and existing ethanol-processing operations.*

TASK 1.0 – PROJECT MANAGEMENT AND PLANNING

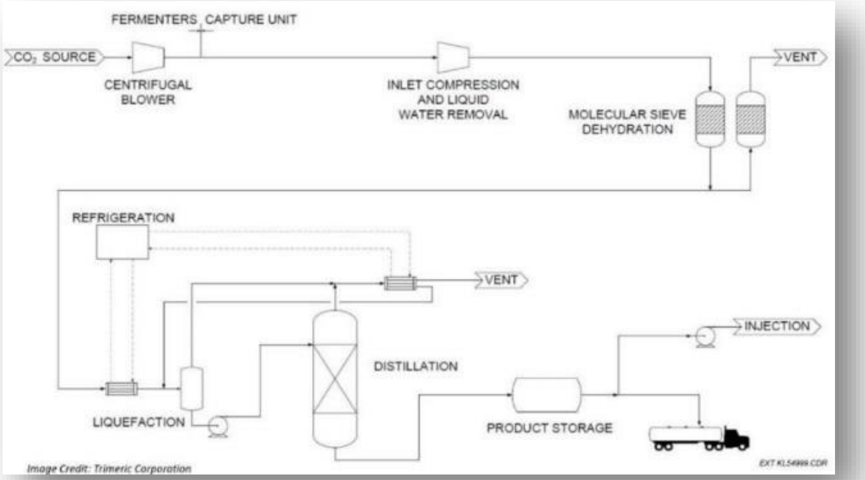
- **Subtask 1.1 – Project Management Plan (PMP)**
- **Subtask 1.2 – Technology Maturation Plan (TMP)**
- **Subtask 1.3 – TEA and Technology EH&S Risk Assessment**
  - ✓ Hazardous Operations (HAZOP) Assessment
- **Subtask 1.4 – State Point Data Table**
- **Subtask 1.5 – Life Cycle Assessment (LCA) Report**
  - ✓ NETL openLCA modeling
  - ✓ **Investigate renewable heat**
    - * *Corn stover gasification for steam generation*
  - ✓ **Compare to low-carbon fuel model**
    - * *GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation)*

NETL LCA MODEL: PRELIMINARY RESULTS



TASK 2.0 – PROJECT ENGINEERING AND DESIGN

- **Subtask 2.1 – Design Basis**
- **Subtask 2.2 – Utility Requirements**
- **Subtask 2.3 – Flow Diagrams**
  - ✓ Existing diagrams updated
  - ✓ Major equipment list



- **Subtask 2.4 – Balance of Plant (BOP)**
  - ✓ Interconnection requirements
  - ✓ Technology island configurations
- **Subtask 2.5 – Develop Permitting Strategy**
- **Subtask 2.6 – Optimization Studies**
  - ✓ Redundancy, materials of construction
  - ✓ Scoping/optimization

DESIGN BASIS SUMMARY

Component	Bioprocessing–Liquefaction	Flue Gas – Chemical Absorption	Hybrid Capture System
CO_2 Capture Design	100% of CO_2 from fermentation	90% of CO_2 from boiler flue gas	**>90% CO_2 capture from emissions**
Annual CO_2 Rate	~180,000 tonnes	~130,000 tonnes	**~310,000 tonnes**
Major Equipment	Blower, compression, dehydration, refrigeration, distillation	Boiler, blower, amine system, compression, dehydration	**[combined equipment]**
Power	3.8 MW	3.0 MW	**6.8 MW**
Natural Gas	4.3 MMBtu/day	1300 MMBtu/day	**1300 MMBtu/day**
Water	82,000 gallons/day	420,000 gallons/day	**500,000 gallons/day**

HYBRID–CCS SCENARIOS INVESTIGATED

Capture Included per Scenario	Bioprocessing–Liquefaction	Flue Gas – Chemical Absorption	Hybrid Capture
Max-Capture	100%	90%	**>90%**
Alt-Capture*	100%	45%	**~80%**

*Alternative design for an amine system within existing RTE boiler and liquefaction capacities.

TASK 3.0 – DETERMINE PRE-FEED COST ESTIMATE

- **Subtask 3.1 – Develop Capture Island Cost Estimate**
  - ✓ Determine pre-FEED-level costs
  - ✓ Estimate postcombustion capture costs
  - ✓ Integrate with compression and liquefaction subsystems
- **Subtask 3.2 – Develop BOP Cost Estimate**
  - ✓ Complete integration of the hybrid capture system with the remainder of the plant
- **Subtask 3.3 – Advanced Solvent Modeling Study**
  - ✓ Model advanced solvent technologies
  - ✓ Investigate potential system sizing and cost improvements
  - ✓ Compare previous estimates

HYBRID–CCS PRELIMINARY RESULTS:
*Cost Estimates**

Item (2019$)	*Bioprocessing – Liquefaction*	*Flue Gas – Chemical Absorption*	*Hybrid Capture System*	*Alternative Amine Scenario*	Alternative Hybrid Scenario
Capital Investment	*$32MM*	*$59MM*	**$91MM**	*$25MM*	**$57MM**
Cost of CO_2 Captured	*$35/tonne*	*$96/tonne*	**$55/tonne**	*$80/tonne*	**$45/tonne**

***Additional Notes**

- Installed equipment cost estimates (i.e., do not include civil engineering).
- Estimate accuracy is about ±30% based on DOE modeling and limited vendor quotes.

HYBRID–CCS PRELIMINARY RESULTS:
Advanced Solvent Comparison

Parameter	*Flue Gas – Chemical Absorption*	Hybrid Capture System	*Advanced Solvent*	Advanced Hybrid
Natural Gas	1300 MMBtu/day	1300 MMBtu/day	950 MMBtu/day	950 MMBtu/day
Cost of CO_2 Captured	*$96/tonne*	**$55/tonne**	*$93/tonne*	**$54/tonne**

***Additional Notes**

- Only natural gas showed significant variation between solvents.
- Estimate accuracy is about ±30% based on DOE modeling and limited vendor quotes.

FUTURE HYBRID CCS PLANS

- **Combined heat and power (CHP) investigations**
  - Fossil and renewable
  - Renewable feedstock logistics
  - Implementation cost estimates
  - ➢ *State Energy Research Center of North Dakota (SERC)*
- **FEED investigations**
  - Refined advanced solvent modeling
  - Refined cost estimates
- **LCA revisions**
  - Following FEED efforts
  - Following in-depth CHP investigations
  - Continued GREET comparisons

Image Credit: Energy & Environmental Research Center

PROJECT SUMMARY: IED COMPLETED

Major Activities Conducted

- Pre-FEED
  - Design basis
  - Processing design
  - Engineered plot plan
  - HAZOP assessment
- TEA modeling
  - Advanced solvent modeling
- LCA modeling
  - Renewable heat
  - GREET comparisons

DOE Deliverables Submitted

- ➢PMP
- ➢TMP
- ➢HAZOP report
- ➢Pre-FEED report
- ➢State point data table
- ➢TEA report
- ➢LCA report

QUESTIONS?

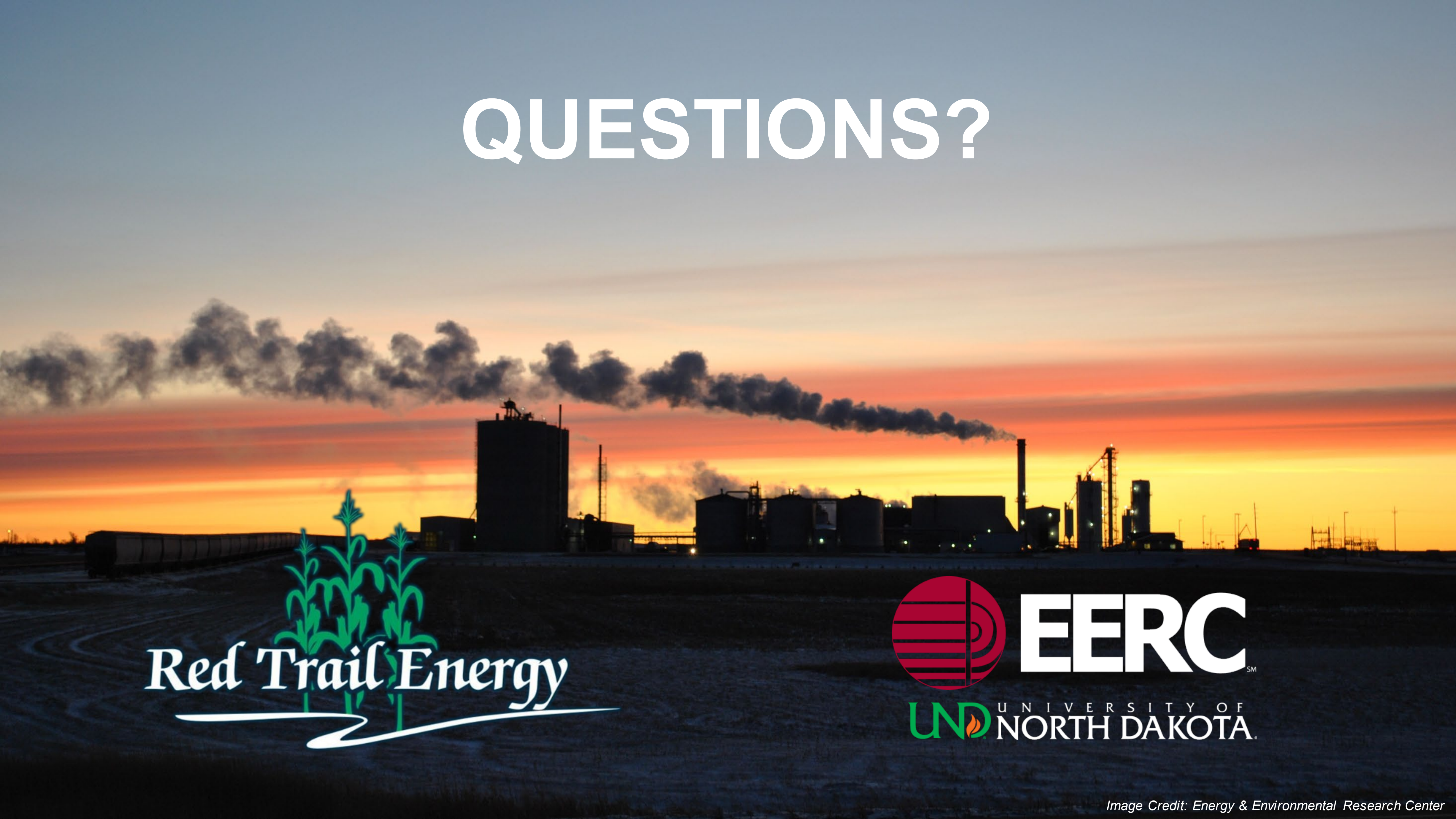


Image Credit: Energy & Environmental Research Center

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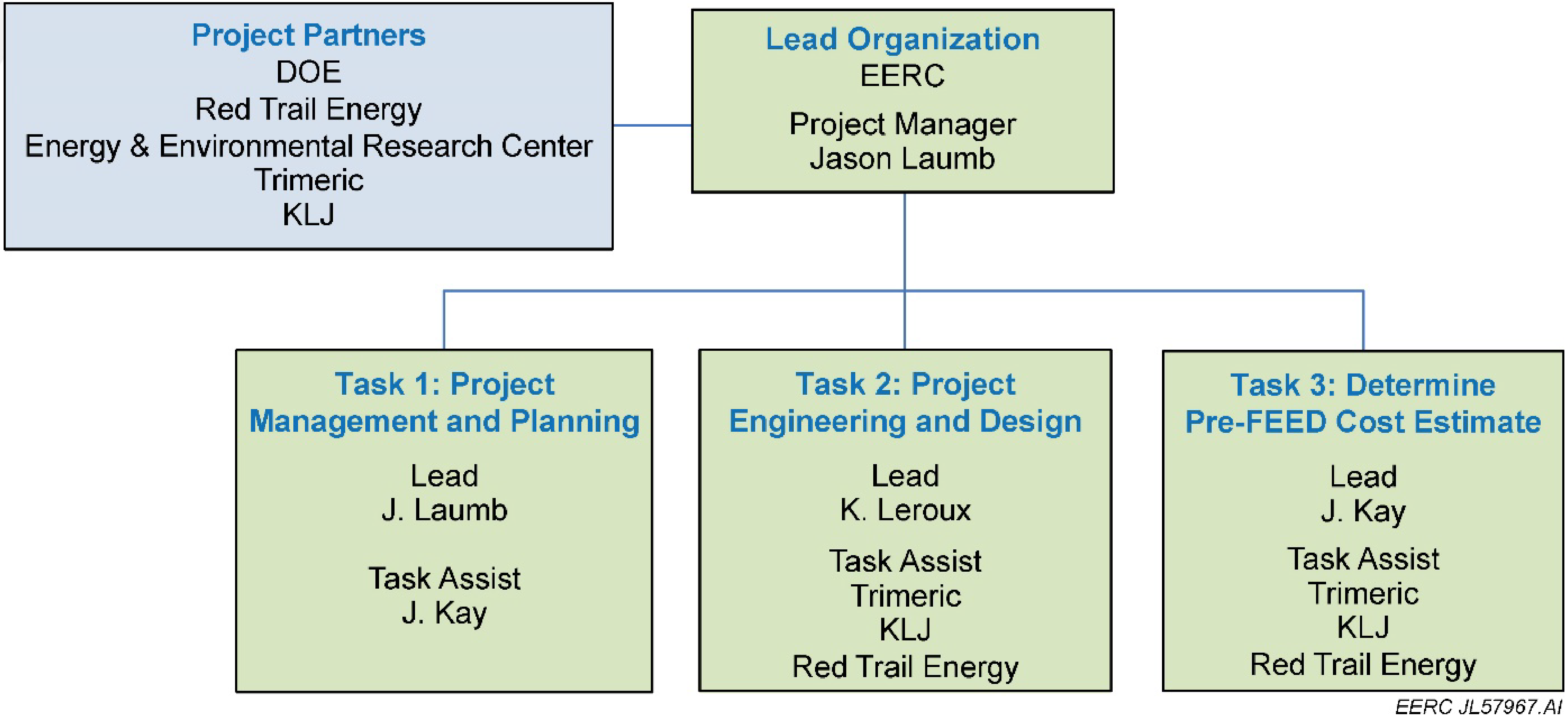
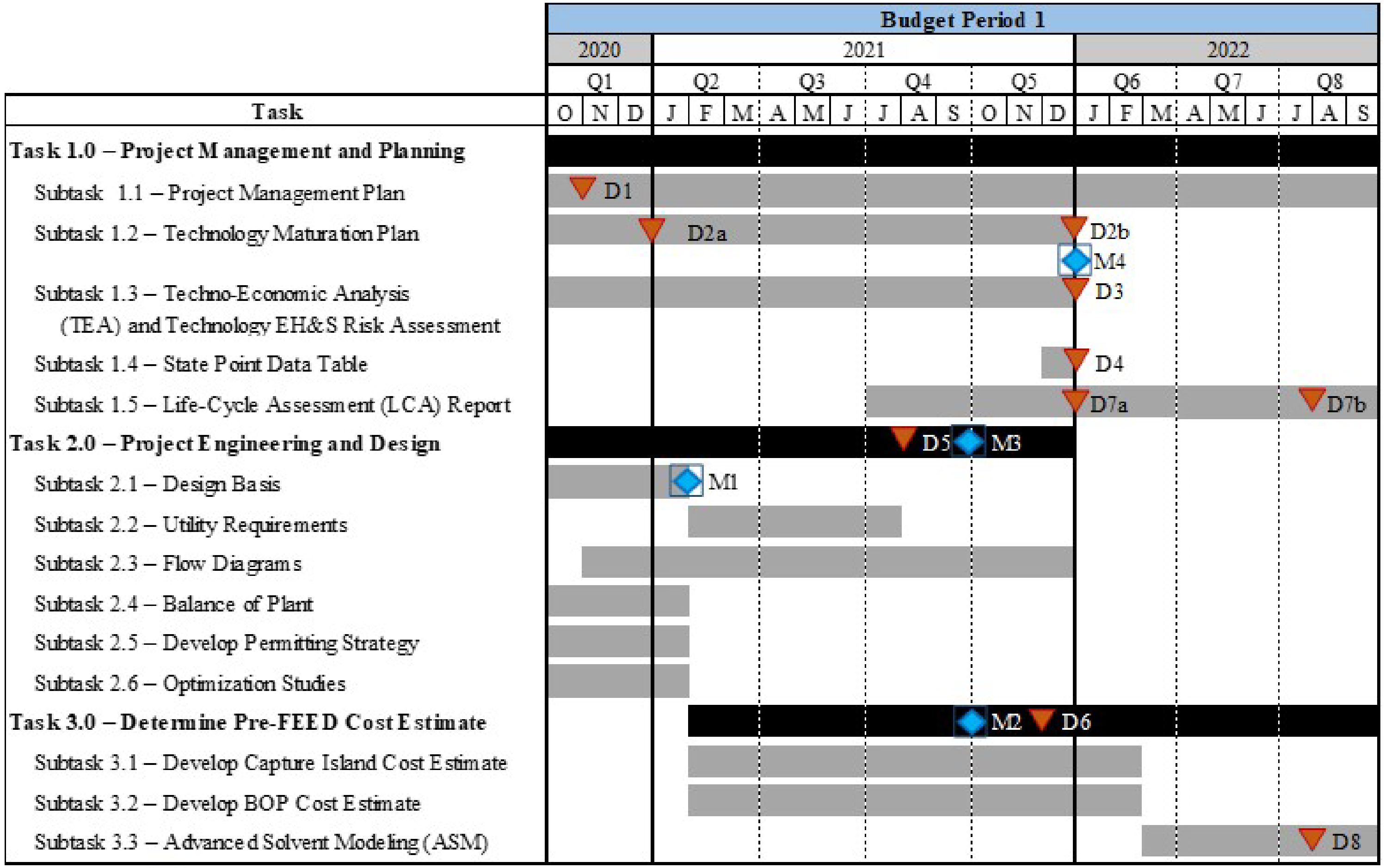
PROJECT ORGANIZATION



PROJECT TIMELINE



Milestone (M)	Deliverables (D)
M1 – Design basis determined.	D1 – Updated Project Management Plan
M2 – Complete pre-FEED analysis.	D2a – Technology Maturation Plan (TMP)
M3 – Complete design.	D2b – TMP Final
M4 – Complete TEA.	D3 – TEA and Technology EH&S Risk Assessment
	D4 – State Point Data Table
	D5 – HAZOP Review
	D6 – Pre-FEED Report
	D7a – LCA Report
	D7b – LCA Addendum
	D8 – Advanced Solvent Modeling Addendum

5.2.22 hmv