

Comprehensive and Quantitative Risk Assessment of CO₂ Geologic Sequestration DE-FE0001112

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Project Team

- **Headwaters Clean Carbon Services LLC**
 - Headwaters Resources Inc.
 - University of Utah
- **Marsh Risk Consulting**
- **Los Alamos National Laboratory**

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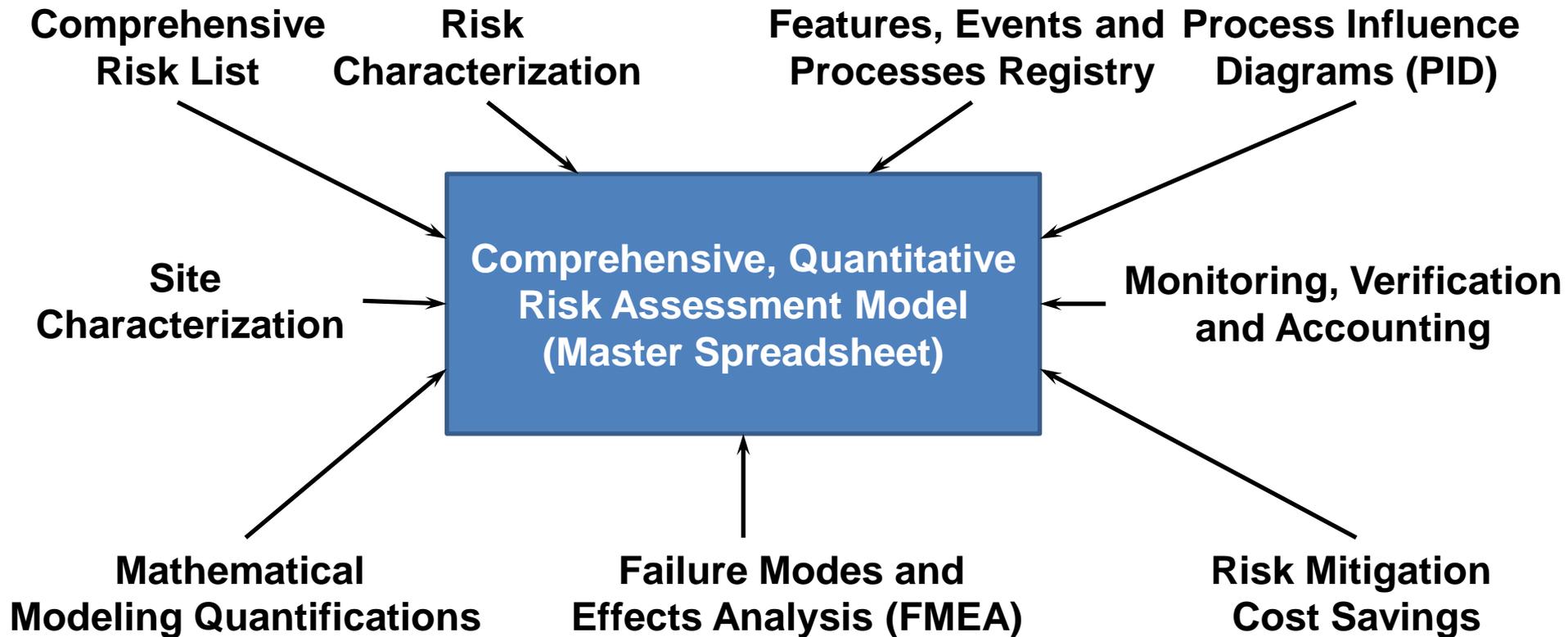
Project Objective

- **Develop and apply an innovative, advanced, process-based risk model and protocol to determine quantitative risks and predict quantitative impacts for CO₂ geologic sequestration project sites.**
- **The model shall be capable of integration with advanced simulation models and MVA technologies.**

Tasks

- 1. Project Management Planning and Reporting**
- 2. Identify and Characterize Risks**
- 3. Risk Quantification by Mathematical Modeling**
- 4. Failure Modes and Effects Analysis**
- 5. Risk Mitigation Cost Savings**
- 6. Application of Risk Assessment Model**

Risk Assessment Model



Task 2. Identify and Characterize Risks

- **Risk Identification**
 - Programmatic and technical risks
 - Expanding Quintessa FEPs registry* into a comprehensive list of risks
- **Risk Characterization**
 - Description of risk area
 - Relevance to CO₂ geologic storage
 - Interdependencies
 - Risk Ranking (probability, severity, difficulty to pre-detect)
 - FEPs Type (feature, event, process)
 - CO₂ Storage Type (DSA, EOR, ECBM)
 - Project Phase(s) Impacted

* Taken from Quintessa's on-line CO₂ FEP database, which is freely accessible at: <http://www.quintessa.org/co2fepdb/>

Risk Areas

Geologic Sequestration Technical Risks

- 0. Assessment Basis**
- 1. External Factors**
- 2. CO₂ Storage**
- 3. CO₂ Properties, Interactions & Transportation**
- 4. Geosphere**
- 5. Boreholes**
- 6. Near-Surface Environment**
- 7. Impacts**

Risk Areas

Surface and Programmatic Risks

8. Economic Risks

9. Permitting Risks

10. External Risks

11. Project Management Risks

12. Engineering Risks

13. Procurement Risks

14. Construction Risks

15. Commissioning & Startup Risks

16. Field Safety Risks

17. Legislation & Regulatory Risks

18. Liability Risks

19. CO₂ Capture Risks

20. CO₂ Dehydration Risks

21. CO₂ Compression Risks

22. CO₂ Pipeline Risks

23. Wellhead Risks

24. Other On-Site Facilities Risks

25. Monitoring Risks

Task 3. Risk Quantification by Mathematical Modeling

- **Experimental design and probabilistic calculations**
 - Very little data available
 - Monte Carlo or similar approach
 - Used to quantify probability and severity of specific process characteristics
- **Process-level models (Generalized reservoir, seal and surface models)**
 - Medium level of data available (e.g., data normally available in the public domain)
 - Used to quantify generalized values of probability and severity of specific process interactions or interdependencies
 - Results may reduce the number of system-level simulations (goal)
- **System-level models (Site-specific reservoir, seal and surface models)**
 - Large amount of data available
 - CO₂-PENS model and/or other systems-analysis packages
 - Used to quantify probability and severity of CO₂ leakage from a reservoir, seal veracity, and surface risk FEPs
 - Best suited for site specific conditions

Risk Ranking

Risk Priority Number = P x S x D (1-125)

P = Probability of Failure (1-5)

S = Severity of Failure (1-5)

D = Difficulty of pre-detecting failure (1-5)

Tentative Ranking Factors

Ranking Factor	Probability of Failure Occurring	Severity of Failure Effect	Difficulty of Pre-Detecting Failure
5	Probable – Greater than 75% chance of failure occurring*	Catastrophic – Multiple fatalities. Damages exceeding \$50M. Project shut down.	Almost Impossible – No known control(s) available to detect failure mode.
4	Likely – 51 to 75% chance of failure occurring*	Serious – Isolated fatality. Damages \$5M-\$50M. Project lost time greater than 1 year.	Low – Low likelihood current control(s) will detect failure mode
3	Possible – 11 to 50% chance of failure occurring*	Significant – Injury causing permanent disability, Damages exceeding \$500k to \$5M. Project lost time greater than 1 month. Permit suspension. Area evacuation.	Moderate - Moderate likelihood current control(s) will detect failure mode
2	Unlikely – 1 to 10% chance of failure occurring*	Moderate – Injury causing temporary disability. Damages \$50k to \$500k. Project lost time greater than 1 week. Regulatory notice.	High – High likelihood current control(s) will detect failure mode
1	Improbable – Less than 1% chance of failure occurring*	Light – Minor injury or illness. Damages <\$50k. Project lost time >1 day. Moving vehicle situation.	Almost Certain – Current control(s) almost certain to detect the failure mode. Reliable detection controls are known with similar processes.

Task 4. Failure Modes and Effects Analysis

- **Potential failure mode**
- **Cause of failure**
- **Potential failure effect**
- **Method of pre-detecting failure**
- **Method of mitigating risk of failure**
- **Revised probability of failure**
- **Revised severity of failure**
- **Revised difficulty of pre-detecting failure**
- **Revised risk priority number**

Task 5. Risk Mitigation Cost Savings

- A. Damage recovery cost without mitigation (\$)
- B. Damage recovery cost with mitigation (\$)
- C. Cost of mitigation (\$)
- D. Savings with risk mitigation (\$)

$$D = A - B - C$$

Task 6. Application of Risk Assessment Model

- **Conduct risk assessment on CO₂ geologic storage sites to evaluate the efficacy of the model**
- **Site selection**
 - Up to three specific sites
 - Multiple types of CO₂ storage reservoirs
 - Based on availability of sufficient field data
 - Mutual agreement between DoE and HCCS
- **Results to be reviewed by cross-functional team of experts for completeness and accuracy**

Benefits of the Risk Assessment Model

- **Converts input from multiple sources into a common format**
- **Incorporates inputs from best practices manuals**
- **Easily customized for site specific conditions**
- **Easily expanded as new information becomes available**
- **Easily searched by key words or phrases**
- **Easily sorted by index number, risk area, risk ranking, FEPs type, CO₂ storage type, project phase type, etc.**
- **Quantifies and prioritizes risks**
- **Identifies and evaluates risk mitigation steps**
- **Quantifies risk mitigation cost savings**
- **Communicates and displays results in a straightforward, user-friendly format suitable for a wide range of stakeholders**

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