CMC Research Institutes, Inc. and the University of Calgary are developing a joint project to build a field research station for containment and monitoring technologies. The field research station is a platform for development and performance validation of technologies intended for measurement, monitoring and containment of subsurface fluids including carbon dioxide. CMCRI is investing $10 million in capital funding into this project. We are seeking expressions of support and inviting industry to join in this collaborative development exercise with participation offered via sponsorship, contract research and development projects, facility rental and through technology company creation and support. The facility will also be used for public outreach and engagement activities.

Introduction

Carbon Management Canada (CMC) has established CMC Research Institutes, Inc. with a mission to accelerate the commercial uptake and widespread implementation of industrial ghg mitigation technologies through establishment of a series of research institutes. The first of these, the Containment and Monitoring Institute (CaMI), is developing a comprehensive Field Research Station (FRS) to facilitate and accelerate research and development leading to improved understandings and technologies for geological containment and storage of CO$_2$ and monitoring of fossil fuel production and environmental mitigation. Unconventional fossil fuel extraction (e.g. shale gas and in-situ oil sands) and carbon capture and storage (CCS) require radical new approaches and innovative technologies to be developed for sampling, measurement and monitoring methodologies in order to provide comprehensive models of the subsurface and to ensure containment and operational and environmental conformance. Subsurface research has never been more important than it is today, and new sensing and sampling technologies are
required. New businesses and technologies will be needed not only for regulatory compliance (verification) but also for leak detection mitigation, source identification and crucial performance validation to drive the improvement of processes and to alleviate public concerns about technical safety.

To address these challenges, CaMI is establishing the FRS to undertake research into the efficacy and evaluation of monitoring technologies in a realistic field setting. The facility will be used to test new measurement, monitoring and verification (MMV) technologies as they are developed and commercialized (e.g. fibre optic devices, slim wells, new analytical instruments for air and water analyses) as well as new approaches to the integration of low-resolution volume-based datasets (3D seismic volumes) with high resolution point measurements (wells).

**Containment monitoring technology drivers**

There is an urgent need to better characterize containment risks in both natural and engineered systems. Loss of containment impacts the environment whether this is on the surface or in the subsurface, and it may lead to delays in resource production or loss of efficacy of fluid disposal. Effective monitoring technologies and integrated monitoring systems are thus becoming critically important to many sectors in the petroleum industry and the FRS will be a unique opportunity to develop, refine and calibrate these systems.

Applications include:

- Secure carbon storage (CCS)
- Steam chamber containment and effectiveness
- Tertiary/Enhanced petroleum recovery
- Characterization of hydraulic or natural fractures
- Groundwater protection
- New or legacy well construction /abandonment issues and fugitive emissions
- Acid gas or other fluid disposal
- Induced seismicity risk analysis and mitigation
CCS is a CO₂ emissions reduction strategy that is an integral part of climate change action plans at both the federal and Alberta government levels. A specific goal for the FRS related to CCS is to develop and refine monitoring technologies to determine the detection threshold of gas-phase CO₂ in the subsurface, as an analogue for early-detection of CO₂ leakage from a deeper, large-scale CO₂ storage site. Of paramount importance to CCS is the ability to track and quantify the injected CO₂ plume in the storage formation and to detect any migration through the overlying cap rock into shallower aquifers, or release into the atmosphere. Cap rock assessment procedures need development as cap rock facies may vary laterally and fluid migration pathways (e.g. fault injectites) may intersect cap rock sequences. Alternate strategies for assessment of cap rocks are required and these will be developed at FRS. Advanced monitoring technologies for monitoring subsurface fluids are equally important for shale gas and oil sands production through early detection of loss of fluid containment or stray leakage during operations, due either to loss of well integrity or failure of cap rock seals. Of particular concern is the potential leakage of petroleum or other subsurface fluids into overlying formations, shallow aquifers containing potable water, or into the atmosphere.

Monitoring and verification of containment and injected CO₂ conformance are vital not only for public acceptance of CCS but also for the ultimate transfer of environmental liability from the operator to the government. For unconventional fossil fuel exploitation, surveillance of the overburden from the ground surface to the reservoir is needed to verify containment of process fluids (e.g. hydraulic fracturing fluids or produced fluids), and to monitor well integrity. Comprehensive monitoring technologies and protocols thus need to be established, using a wide range of existing and next-generation technologies.

A further key aspect of research into monitoring and reservoir surveillance leading to technology deployment and commercialization is having appropriately trained and qualified personnel. CaMI will partner with the University of Calgary and others to develop training programs at the FRS for undergraduate and graduate students as well as commercial training for industry scientists, engineers and technologists.
Technology programs

The FRS program will be designed around small tonnages (up to 1000 tonnes per year) of CO\textsubscript{2} (possibly with small amounts of impurities such as CH\textsubscript{4} or other tracers) to be injected into the subsurface at depths of approximately 300 m and 500 m. The injection targets are water filled sandstones within Upper Cretaceous clastic reservoir formations, with overlying shales or mixed sand/shale sequences forming the cap rocks. The target formations are the Basal Belly River Sandstones (300 m deep) and the Medicine Hat Formation (500 m deep).

A physical site location has been selected and agreements for surface and subsurface access have been negotiated with Cenovus Energy, who own the surface rights at this location. A public outreach phase was completed in March, 2014. Development of the FRS will be in accordance with Directives of the Alberta Energy Regular, including exemptions that are being discussed with the Alberta Department of Energy with respect to pore space access and injection of CO\textsubscript{2} at depths less than 1 km.

Initially CO\textsubscript{2} for the injection project will be obtained from industrial sources, but once established, a stream of CO\textsubscript{2} for the project will be produced by a fuel cell will be located on site that will also produce clean heat and power for site operations. The FRS will build towards a green-field energy research station and hub. CO\textsubscript{2} streams from fuel cells can be designed to contain some unused fuel (methane) and the monitoring program will also address detection and fate of methane in the injection zone and overlying formations.

The technologies that will be implemented and further developed at the site include:

- Innovative, data linked geophysical and geochemical surface, aerial and subsurface surveillance systems.
- Novel cap rock assessment procedures
- Analytical and Measurement methods will include:
  - 3D surface seismic surveys
  - time-lapse seismic data analysis
  - borehole seismic measurements, including 3D vertical seismic profiles (VSP)
- cross-well seismic measurements and analysis
- high-resolution Global Positioning System (GPS) and Interferometric synthetic aperture radar (InSAR) geodetic surveys
- comprehensive well logging and analysis
- microseismic monitoring programs
- electrical and electromagnetic borehole surveys
- surface electrical resistivity tomography
- microgravity surveys
- rock mechanics
- time-lapse downhole pressure and temperature monitoring and analysis
- on-site surface and subsurface geochemical sampling and analysis capabilities
- time-lapse geochemical data analysis
- reservoir fluid residence time analysis for cap-rock assessment
- nanosensor technology development for cap rock surveillance
- hydrologic techniques and near-surface geophysical methods
- hydrostratigraphic characterization
- advanced aquifer testing and analysis, including tracers
  - solid oxide fuel cell technology
  - other technologies as they become available for validation or development

**FRS Site Development**

Figure 1 illustrates the schematic layout of infrastructure at the site, which will be established on slightly less than one section of land (approximately 1 km x 1 km in accessible area).

Schlumberger Carbon Services has been contracted to develop and construct the FRS infrastructure. The final well design and layout will be determined after initial reservoir modelling has been undertaken. Separate injector wells will be drilled for the two target depths (300 m and 500 m) and cap rock and reservoir horizons for both levels will be cored for geomechanical analysis, mineralogy and cap rock studies. Full log suites will also be run in both wells. Observation wells will be fully instrumented with both permanent and
retrieval sensors. The periodic injection of small volumes of CO$_2$ will be tracked by these
down-hole monitoring technologies as well as by various surface surveys.

Site activities will focus on research and technology development as well as training in
monitoring technologies. Geophysical, geochemical, geomechanical and geodetic
monitoring of the subsurface gas plume (both CO$_2$ and methane) will be complemented by
near-surface hydrogeological studies to better understand shallow groundwater systems,
near-surface subsurface fluid flow, and to establish the fate of both CO$_2$ and CH$_4$ in an
aquifer below ~225 m depth, which is the local base of groundwater protection.
Researchers from industry, the University of Calgary and from the CMC Network of researchers across Canada and internationally will be able to take part in research at the site with various access protocols. We are inviting partners to join in this collaborative development exercise with partnership offered via sponsorship; contract R&D arrangements and by other collaboration mechanisms. The facility can also be used for public outreach and engagement activities.

**Infrastructure**

The FRS infrastructure will initially consist of:

- A 3D seismic array (either permanent or deployable) for research and training in time-lapse surface seismic methods for CO₂ monitoring, particularly 3D data acquisition schools.
- Two injection wells (300 m and 550 m deep) with appropriate well-head apparatus for injecting small volumes (< 1000 tonnes/year) of CO₂ into the target formations.
- Up to two 300 m deep and two 550 m deep vertical observation wells, fully deployed with geophones and other instruments, for research and training in 3D VSP survey design and data analysis. Geophones will be placed behind casing to enable retrievable tools to be used in the cased wellbore. The observation wells will also include fluid sampling tubes for geochemical analyses of subsurface fluids and training in sampling protocols as well as fibre-based pressure and temperature sensors.
- A mobile, truck-mounted geochemistry laboratory for in-field real time analyses.
- Broad-band seismometer and a passive seismic array for research and training in microseismic monitoring.
- Downhole electrical resistivity tomography systems.
- Permanent GPS monuments and a near-surface tiltmeter array for monitoring ground surface deformation associated with fluid injection or retrieval.
- InSAR reflectors for monitoring ground surface dilation and integrated training between surface and downhole monitoring technologies.
• Shallow multi-level groundwater monitoring and sampling wells (between 4 and 8 to penetrate shallow aquifers).
• Permanent monuments for time-lapse microgravity surveys to monitor subsurface density changes due to fluid substitution.
• A solid oxide fuel cell and associated \( \text{CO}_2 \) capture unit.

This infrastructure will enable a full spectrum of research and training programs to be undertaken, from individual technologies to integrated monitoring system design and implementation.

**Site Characterization**

The full characterization of a selected site has been completed, based on available well data from the region as well as 3D seismic data made available to the project from Cenovus. This includes regional and local geological models from available well data, and a high-resolution 3D seismic survey of the site that was completed in May, 2014. Sampling shallow potable aquifers from existing water wells within 3 km of the site is currently being undertaken.

**Outcomes**

The FRS will provide tremendous opportunities for industry and university personnel to participate in leading edge research about surface and subsurface characterization and monitoring that are of critical importance to Alberta and Canada. It will provide a platform to validate current and novel monitoring, detection and measurement technologies, as well as support for equipment and services companies developing new products and methods for the industry. The site will also serve an important role to educate the public about subsurface containment issues and how to de-risk injection schemes. In particular, it will excite students of all ages about career opportunities in these fields and inform the public about both carbon capture and storage (CCS) as well as measurement, monitoring and verification (MMV) practices which can be applied to other resource developments, such as shale gas and oil sands production.
Funding

CMC currently has $9.8 M allocated to this project, and is inviting industry and government participation to cover operating costs for a 10 year period.