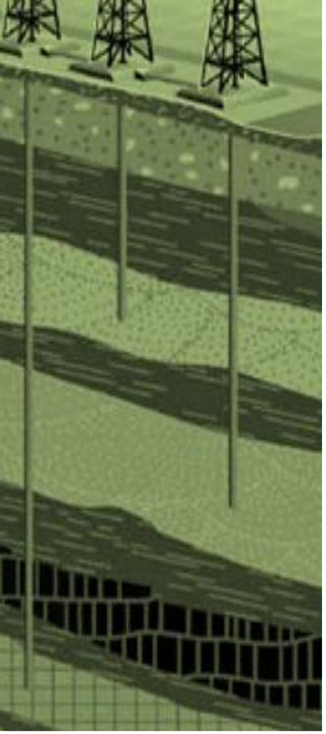


MEXICAN CCS+EOR DEMONSTRATION PROJECT

Environmental Impact and Risk Analysis

Monitoring

Rodolfo Lacy

Mario Molina Center

IIE-UNAM Workshop

CO_2 Geological Storage and EOR

March 2012

Centro Mario Molina

INSTITUTO DE INVESTIGACIONES ELECTRICAS

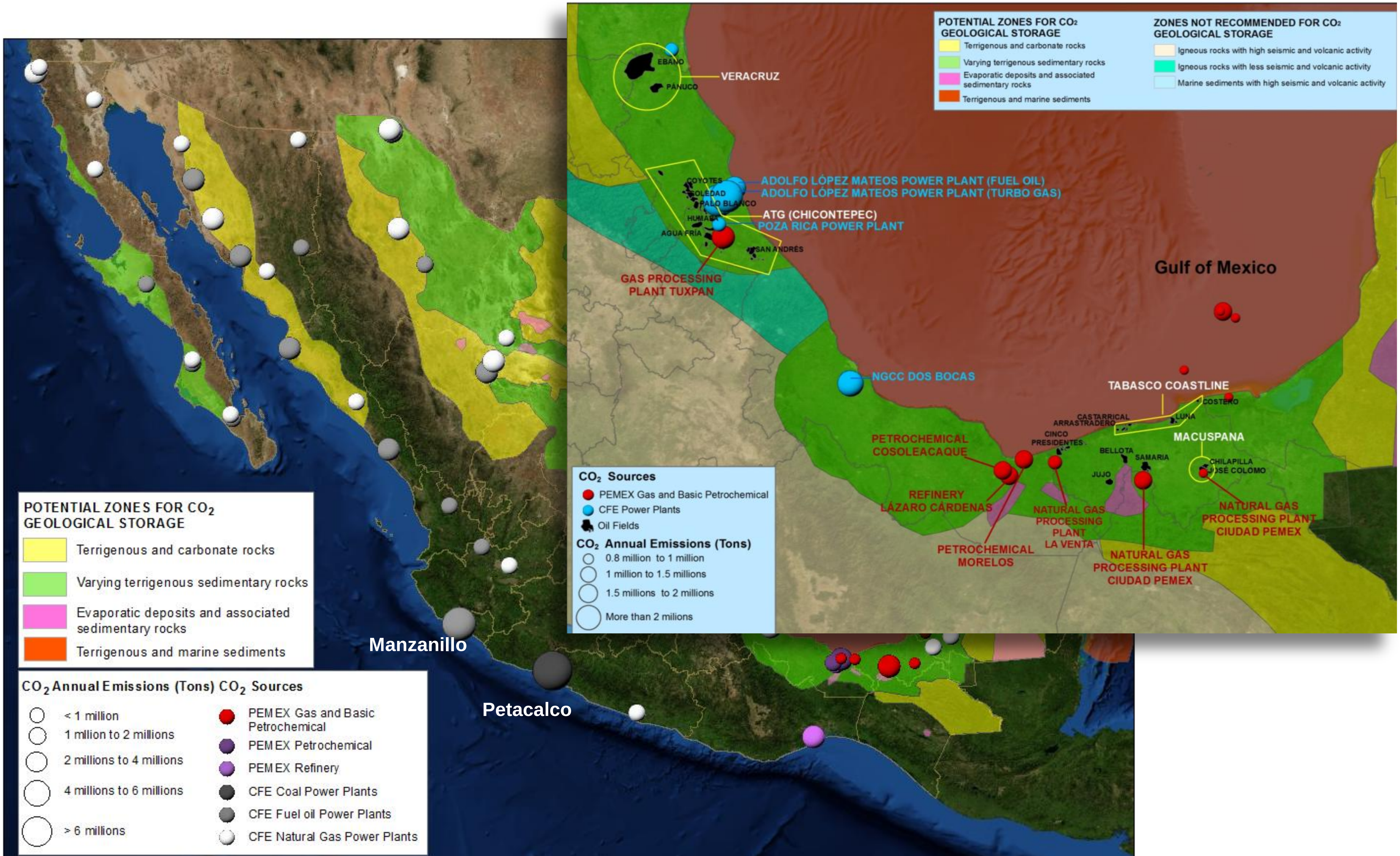
PEMEX

CFE

IMP INSTITUTO MEXICANO DEL PETRÓLEO

CO_2 Sources in Mexico

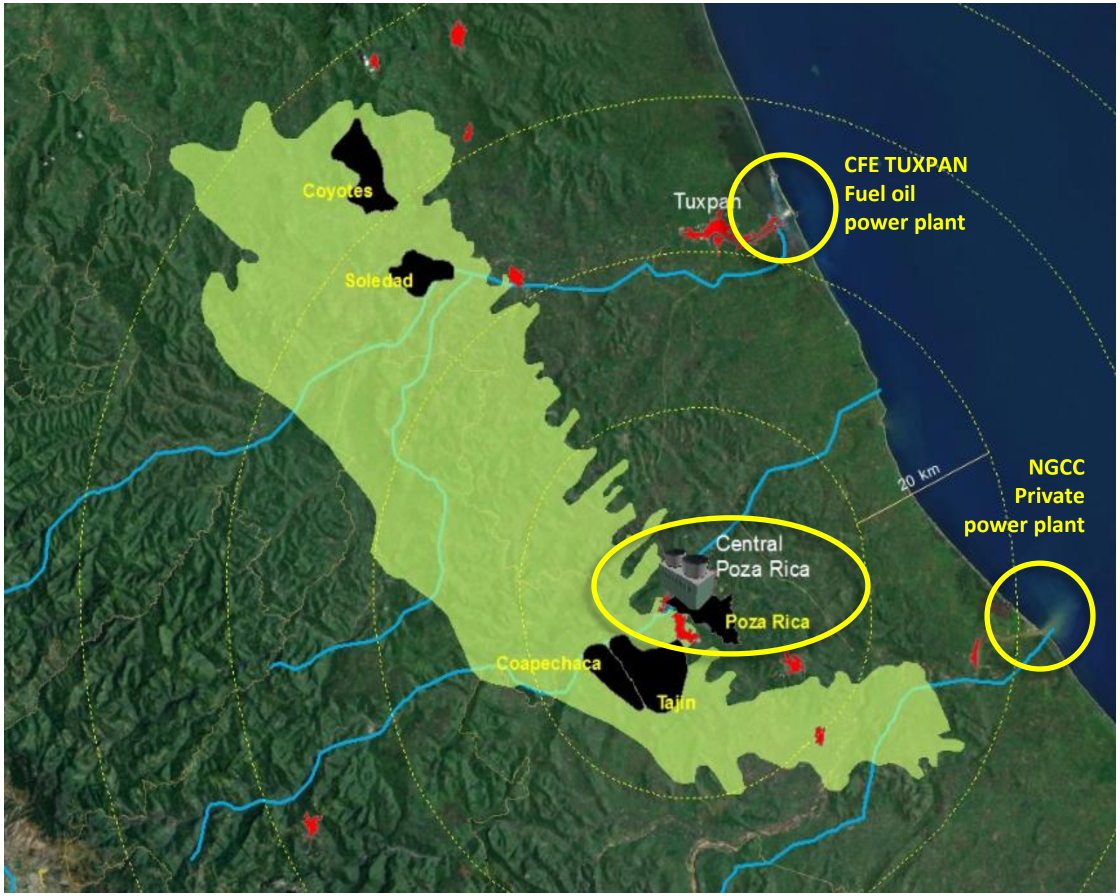
2009



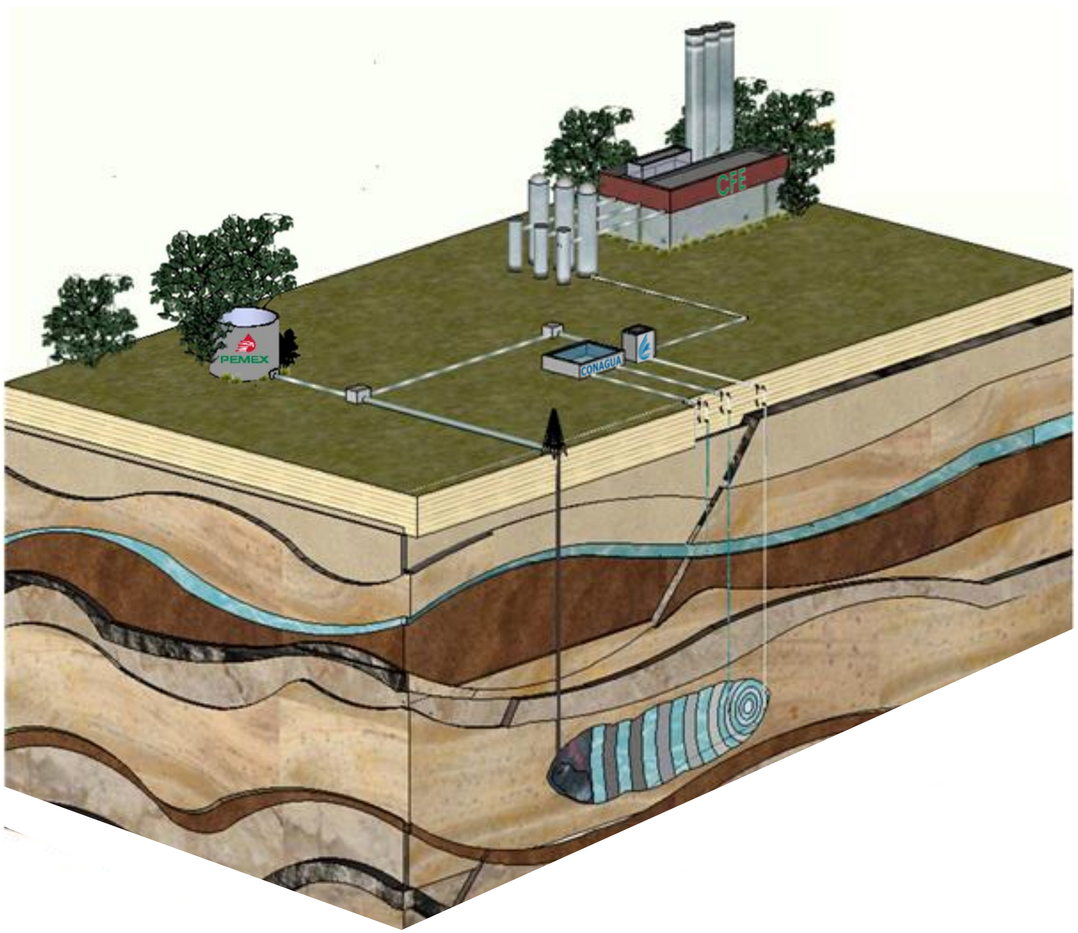
EOR sites in the Chicontepec Region

The initial proposal was to run the demonstration project in the Tuxpan Power Plant that would be refitted to use coal as their primary source

However, due to CFE strategic decisions, it was decided to have the CCS project in the NGCC Power Plant located at Poza Rica. The first stage is the implementation of the Pilot Plant where the first arrangements for EOR will be implemented



CCS+EOR Proposal



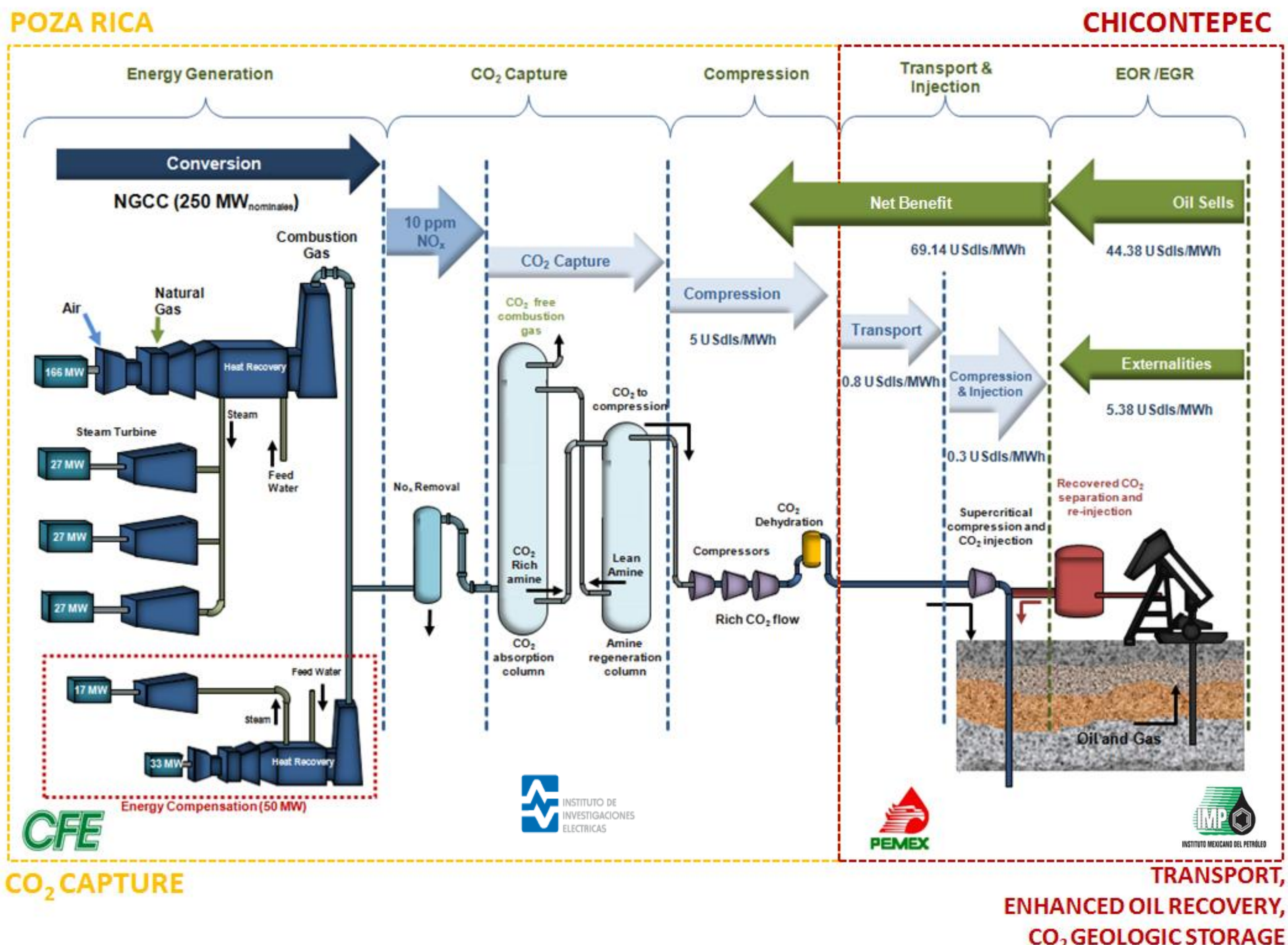
It is planned that the first carbon capture project that will take place in Mexico must be a **CCS+EOR** form. This strategy will enable Mexico to start utilizing this low-carbon emission technology

One of the main factors that support such a project is that the CFE, PEMEX, and geological reservoirs are state-own industries and assets

*CCS+EOR. *Carbon Capture and Storage + Enhance Oil Recovery*

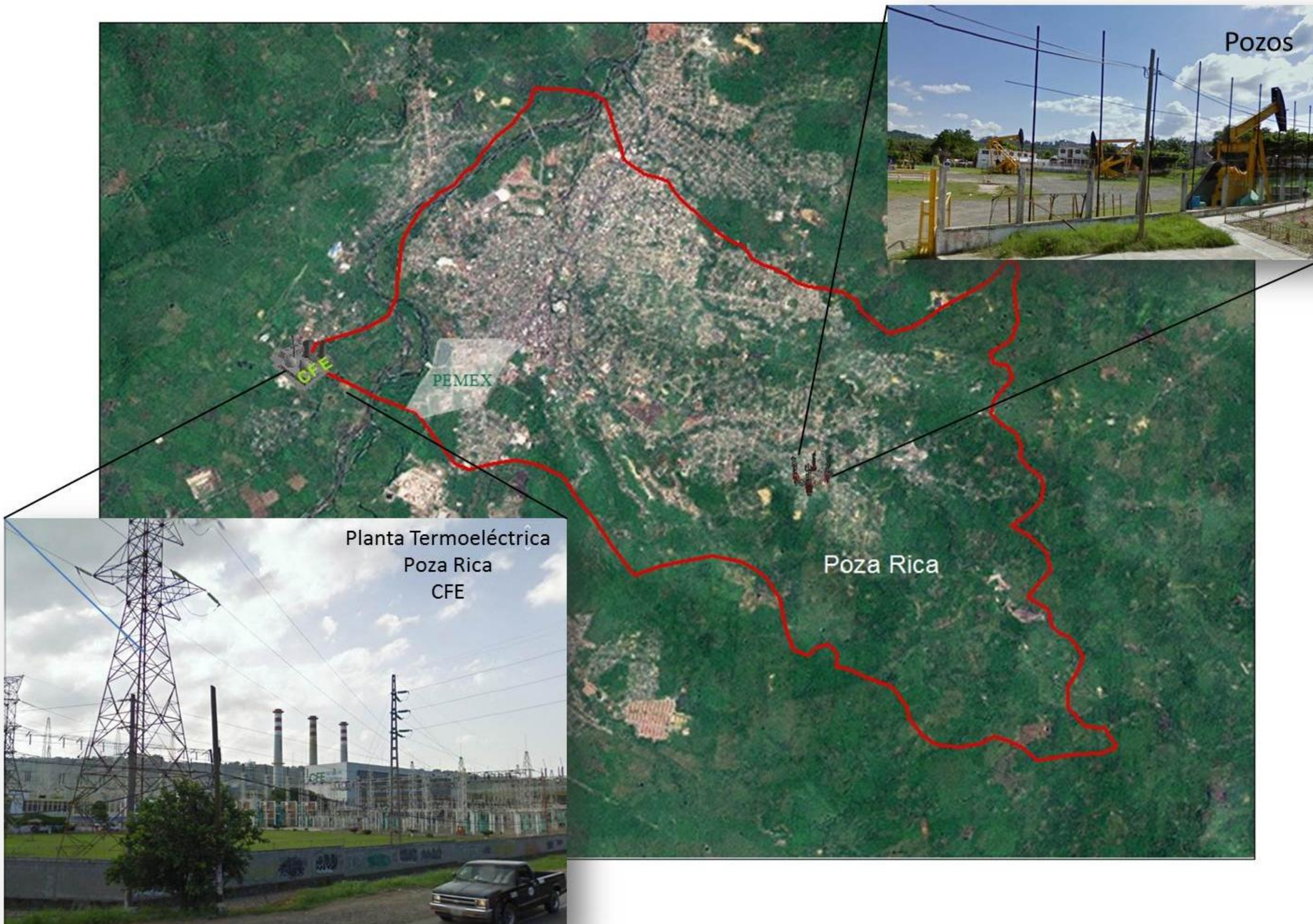
Demonstration Project

General scheme for the CCS+EOR demonstration project between CFE and PEMEX



Source: Mario Molina Center

CFE Power Plant and Poza Rica oil field



Environmental Impact and Risk Assessment

In Mexico, the Ministry of Environment and Natural Resources (SEMARNAT) requires an Environmental Impact and Risk Assessment (EIA/ERA) for the approval of any project from the oil and electricity sectors that may cause a significant environmental or public health problem

Taking into account that a broad regulatory framework for CCS-EOR would not be ready in the next years an early EIA/ERA for the demonstration project shall provide:

HUMAN HEALTH PROTECTION
ENVIRONMENTAL PROTECTION


SEMARNAT
SECRETARÍA DE MEDIO AMBIENTE Y RECURSOS NATURALES

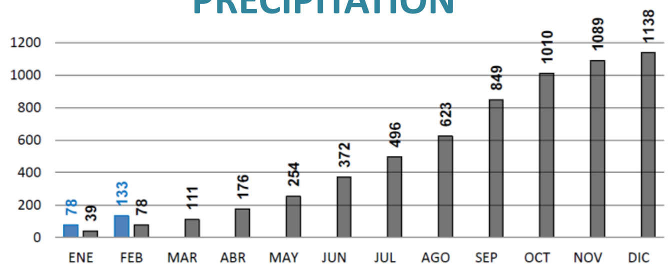
GUÍA PARA LA PRESENTACIÓN DE LA MANIFESTACIÓN DE IMPACTO AMBIENTAL

Poza Rica

Tropical Weather

2010 population: 193,311 people

PRECIPITATION

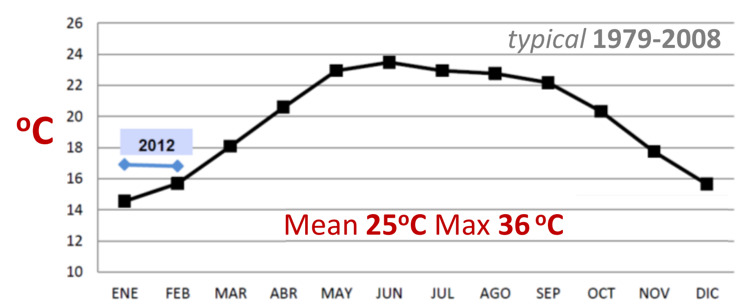


Normal year 1979-2008

Mean 1,186 mm

Acumulated 2012

mean minimum **TEMPERATURE**



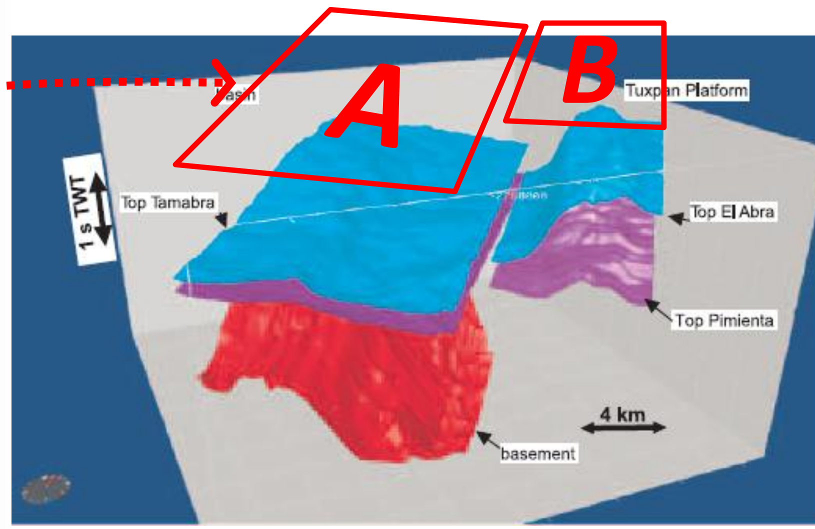
INFORMATION TO BE INCLUDED IN AN EIA/ERA FOR CCS+EOR

EIA Current general structure	CCS-EOR Specifics
1. Project description	• Site selection methodology • Site characteristics and safety proves
2. Environmental system description	• Geological data of storage and confining zones • Wells integrity • Seismicity • Surface and groundwater quality • CO_2 concentrations in soil
3. Environmental impacts	• Delimitation of the area that could be affected by CCS-EOR operations, modeling of CO_2 plume and behavior is necessary.
4. Mitigation strategies	• CO_2 monitoring plan • Corrective strategies
5. Environmental projections	

Information gathered by monitoring for the EIA should cover at least one year of records…

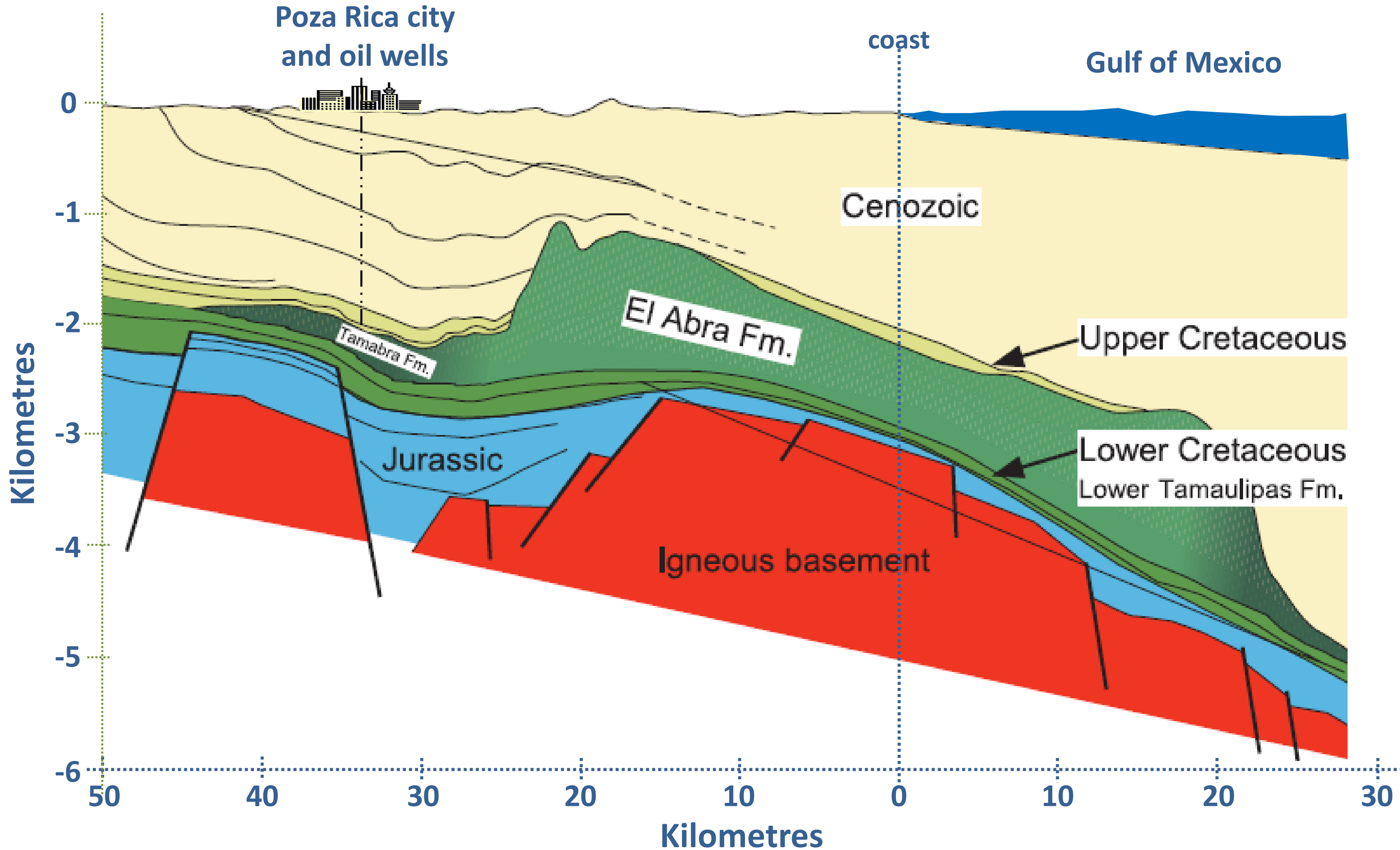
Poza Rica's Geology

The Golden Lane platform and its associated debris apron in the Poza Rica field area are well known and have the potential to host significant volumes of hydrocarbon



Source: X. Janson, C. Kerans, R. Loucks, A. Marhx, C. Reyes, and F. Murguia, 2011. Seismic architecture of a Lower Cretaceous platform-to-slope system, Santa Agueda and Poza Rica fields, Mexico. AAPG Bulletin, V. 95, No. 1.

Poza Rica's Geology

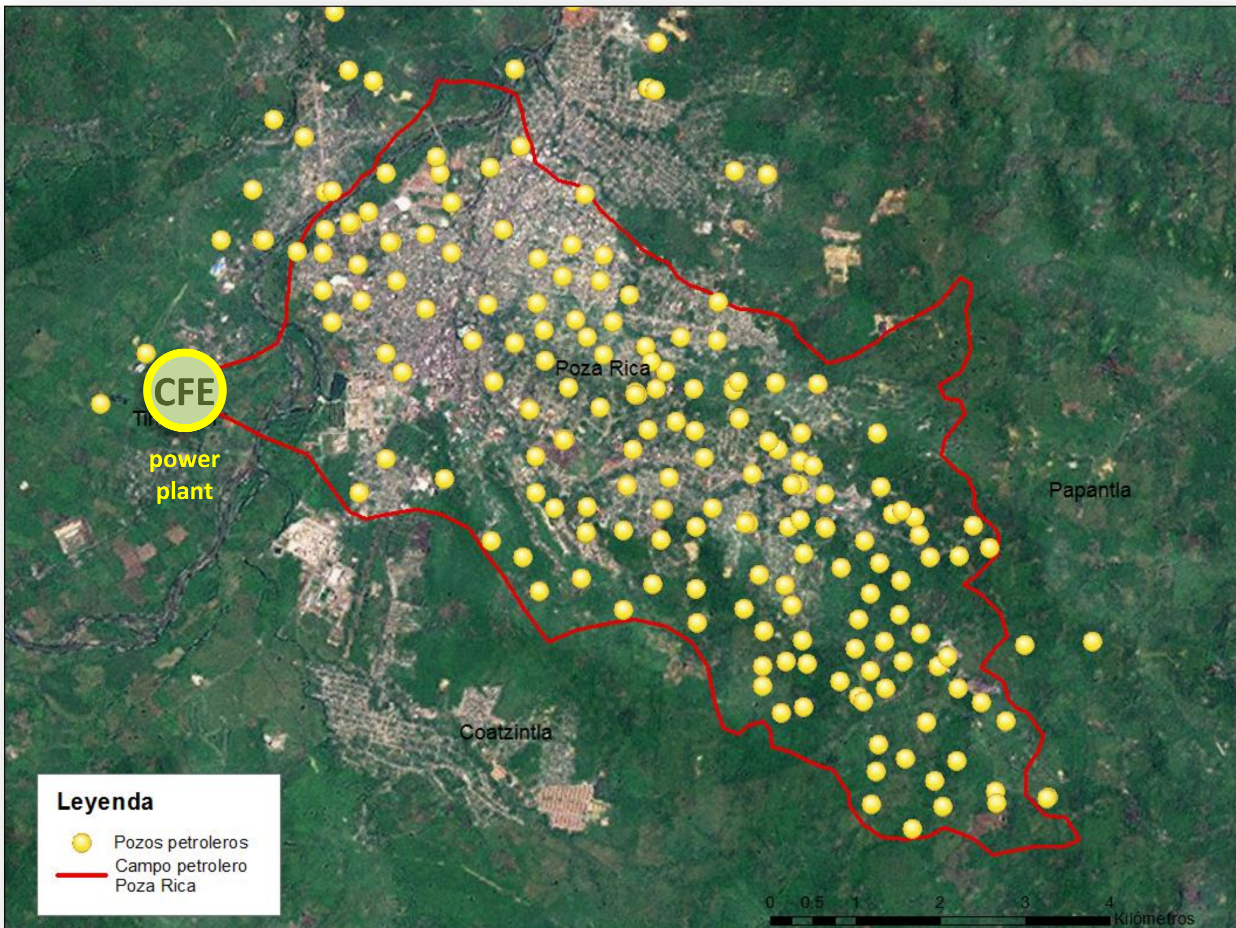


Source: X. Janson, *et al.*

Poza Rica

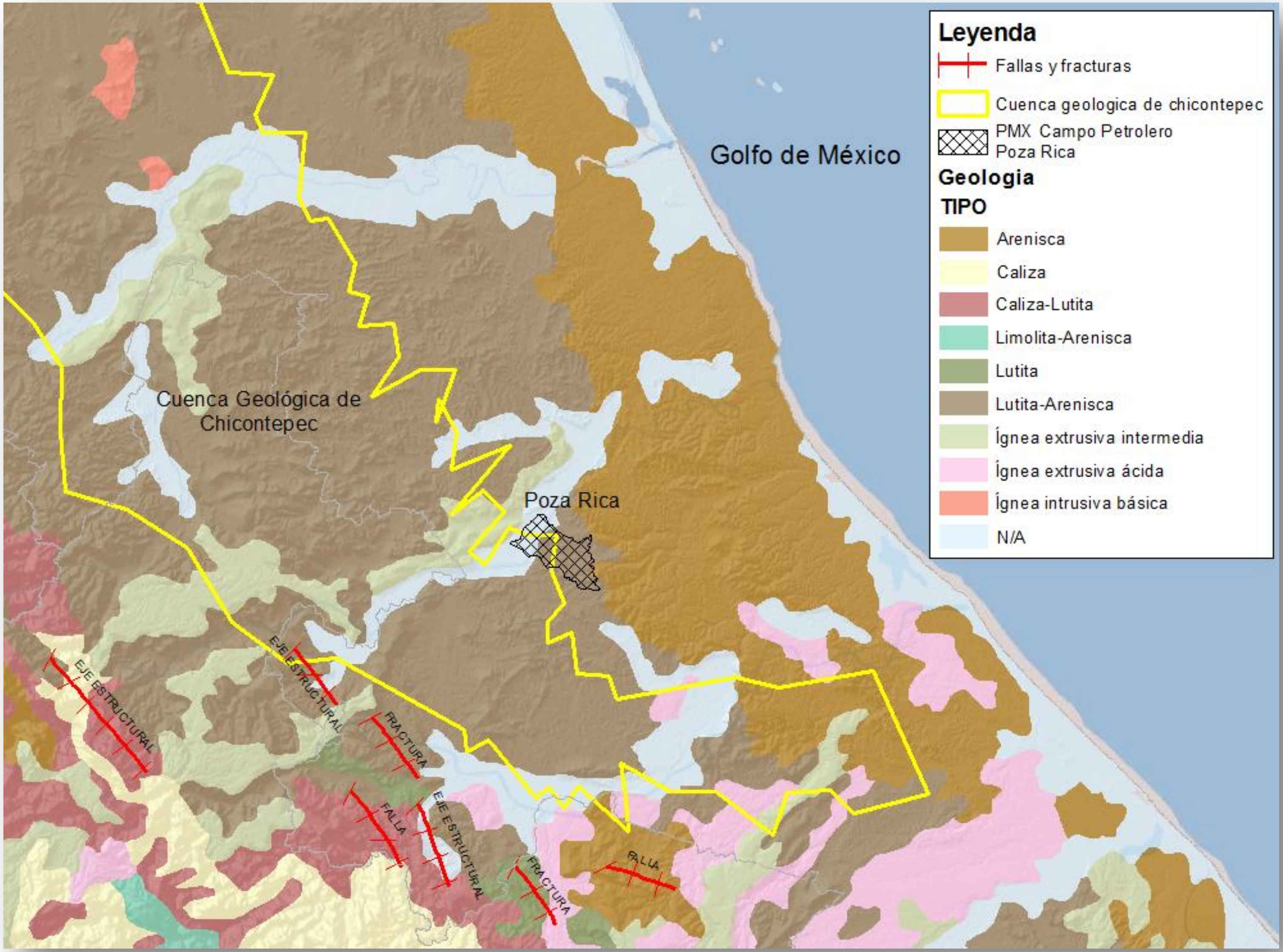
Oil field and wells

PEMEX has several well sites located at Poza Rica that are relatively close to the CFE Power Plant, facilitating CO_2 transport



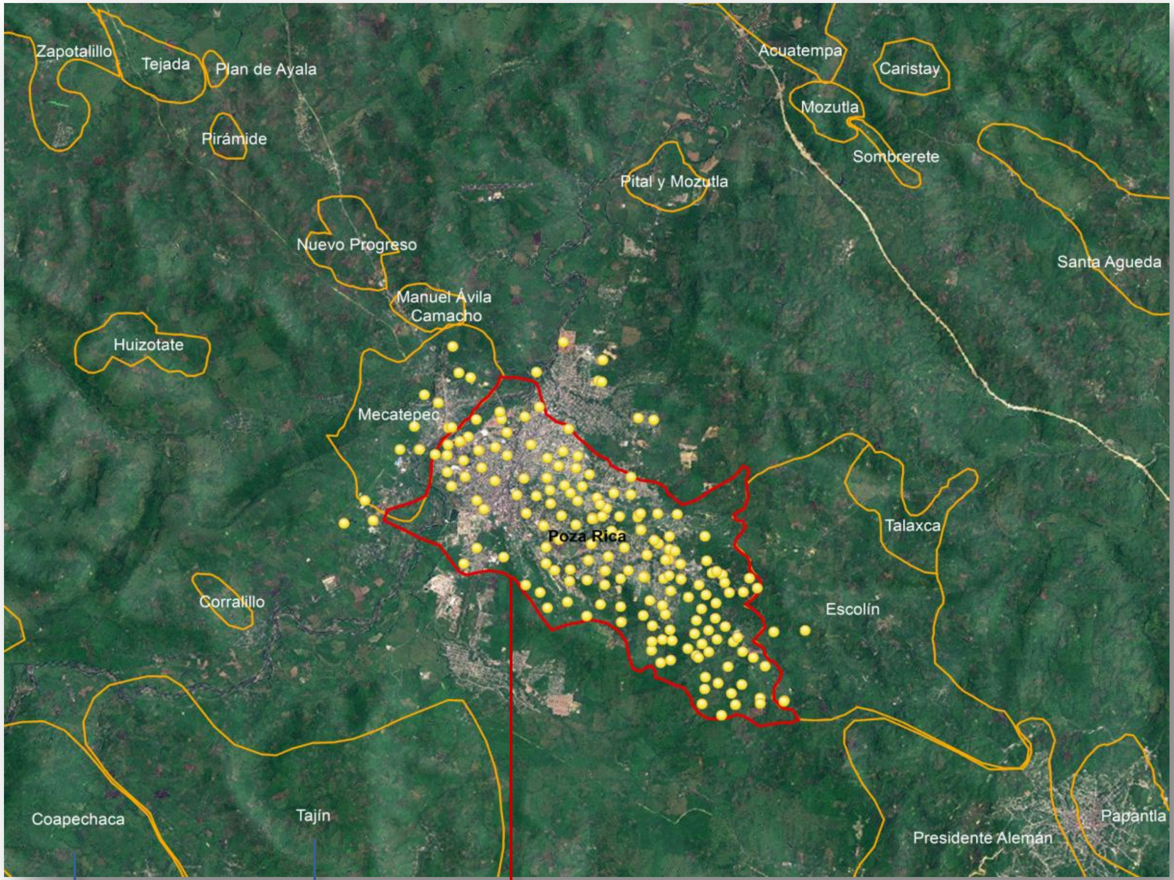
Poza Rica Region

Faults and Fractures



Poza Rica Region

Oil Fields for CO_2 EOR

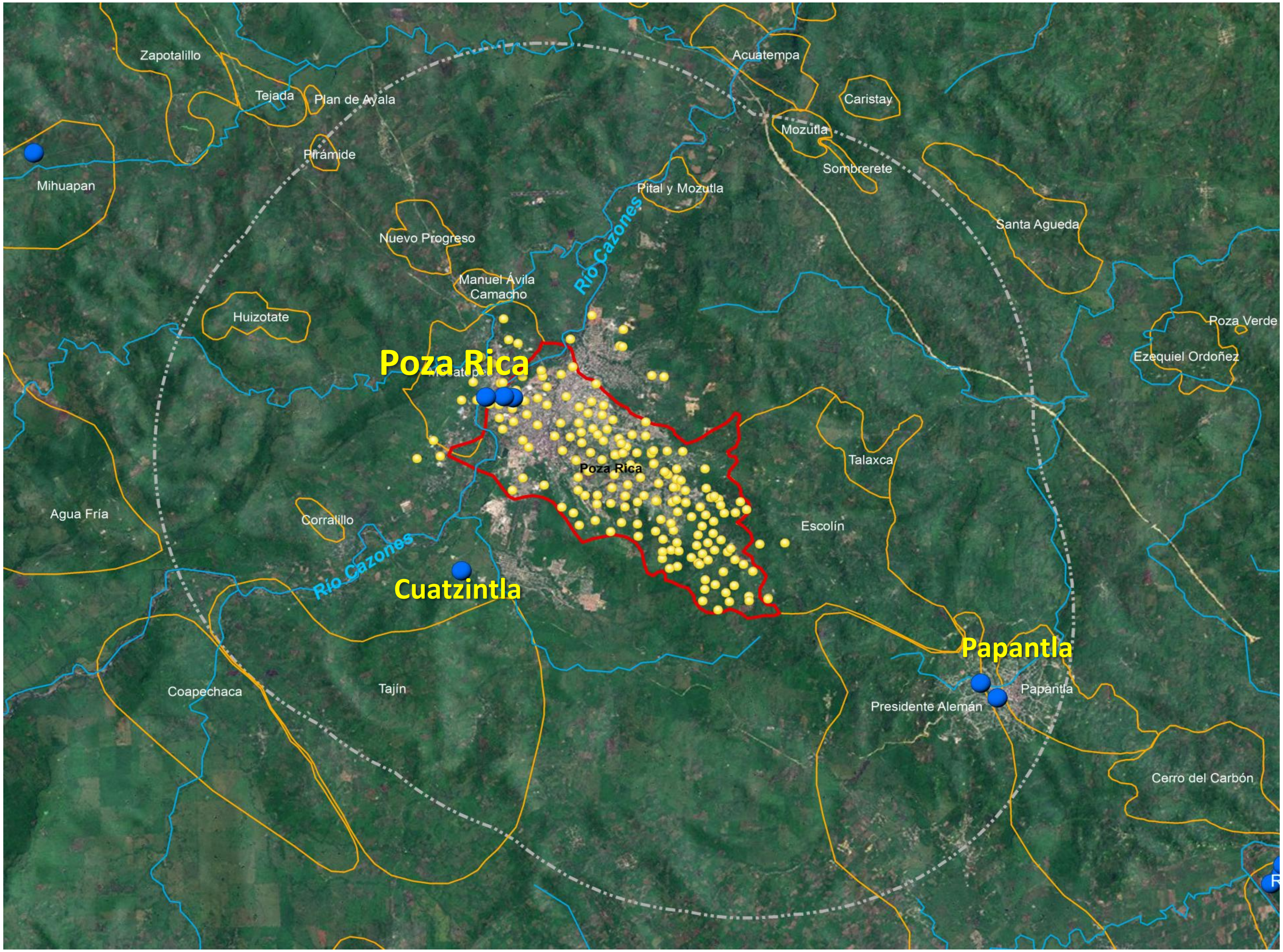


Oil well
Poza Rica oil field
Oil fields

OIL FIELD	POSSIBLE OIL RECOVERY MMbbl	CO_2 DEMAND	
		MMCFD	MMtons/y
Poza Rica	150-**390**	200-530	4.1-**10.8**
Tajin	160-430	220-590	4.5-12
Coapechaca	100-260	130-360	2.6-7.3

Poza Rica Area

Cities, Oil fields, Rivers, and Meteorological Stations



Simbología

Pozos Petroleros

Estaciones Meteorológicas

Campo petrolero Poza Rica

Campos Petroleros

Radio de Influencia 10 km de Campo Poza Rica

KEY RISK AND MONITORING TECHNOLOGIES

In Salah, Algeria
BP & Statoil CCS project

Near-surface seismic survey with geophones MASW technics photo: USGS

KEY RISK	MONITORING TECHNOLOGIES
Injection Well Problems	Ongoing pressure monitoring, continuous wellhead and annual down-hole or trough casing logging
Early CO_2 Breaktrough	Modelling, tracers, seismic imaging, observation wells, fluid sampling, wellhead and annulus monitoring
Vertical leakage	**Seismic imaging**, microseismic, shallow aquifer monitoring, soil gas sampling, surface flux, gravity, tiltmeters, satellite imagery
Wellbore leakage	Annulus monitoring, soil gas sampling, through case logging
Old wellbore integrity	Annulus pressure monitoring and **CO_2 surface flux monitoring**

Anemometer and open path CO_2/H_20 analyzer photo: Biospherica

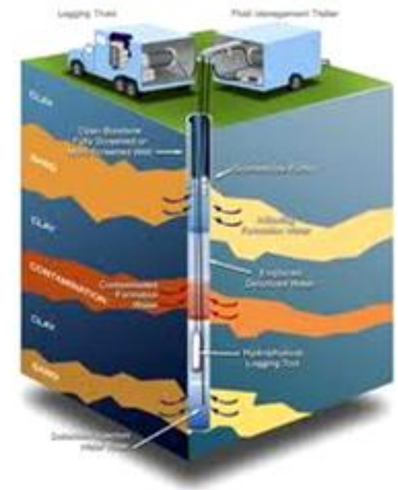
Source: A. Mathieson, J. Midgley, I. Wright, N. Saoula and P. Ringrose, 2010. *In Salah CO_2 Storage JIP: CO_2 sequestration monitoring and verification technologies applied at Krechba, Algeria*. Energy Procedia 00(2010) 1063-00.

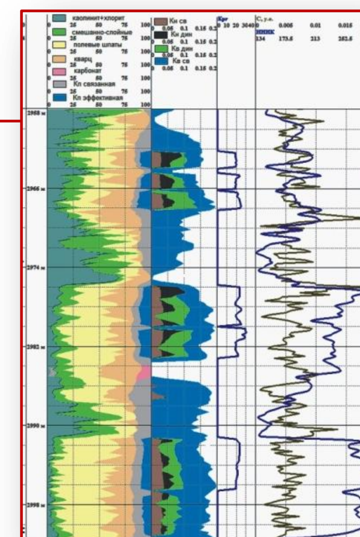
Environmental Impact Assessment

MVA-Monitoring, Verification, and Accounting CO_2

Summary of MVA Program to be Implemented at Large-Scale Injection Sites.

Monitoring Technique	Monitoring Period		
Pre-CO_2 Injection	During Injection		Post-CO_2 Injection
Air quality monitoring Measure CO_2 concentrations at injection well Measure CO_2 fluxes using Eddy Covariance	 X X	 X X	 X X
3-D seismic surveys, Vertical Seismic Profiles (VSP)	X	X	X
Injection well logging	X		X
Measure pressure, gas content and isotopic signature in injection well	X	X	X
Monitor formation pressure, temperature, gas content, and formation fluid chemistry	X	X	X
Conduct High Resolution. Electrical Resistivity surveys	X	X	X
Measure CO_2 concentrations and isotopic signature in vadose zone	X	X	X
Determine shallow groundwater flow direction, install monitoring wells, geophysical logs, measure water quality	X	X	X
Measure water quality from potential residential and other potable water wells	X	X	X
Aerial imaging of injection site using satellite imagery	X		X
Measure CO_2 injection rates and volumes		X	
Isotropic characterization of injected CO_2		X	
Model potential geochemical reactions and CO_2 migration in injection formation, cap rock, and land surface	X	X	X
Add perflourocarbon tracer to injected CO_2 and monitor for tracer in vadose zone soil gases and groundwater.	X	X	X
Measure CO_2 surface fluxes using accumulation chambers	X	X	X
Monitor microseismic activity near injection well	X	X	X
Wireline logs to assess subsurface characteristics	X	X	X





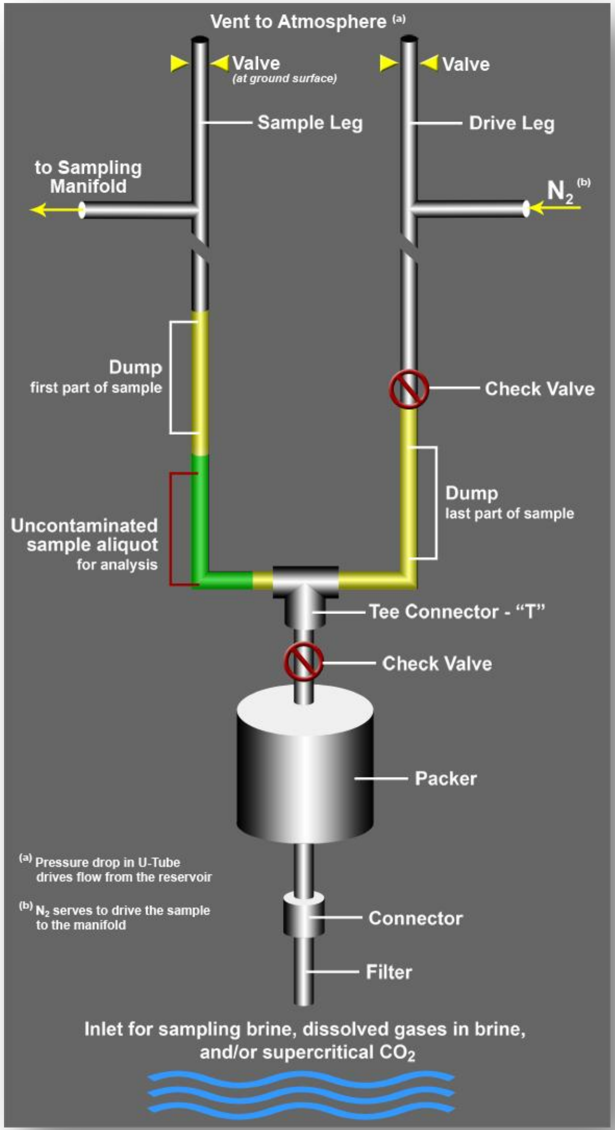
Source: NETL-DOE, 2009. Monitoring, Verification, and Accounting of CO_2 Stored in Deep Geologic Formations.

U-tube

for CO_2 measurements at the injection well

"The U-tube sampler was originally designed by Barry Freifeld and fabricated by Paul Cook, both of Lawrence Berkeley National Laboratory for use in the CO2 sequestration pilot studies at the Frio test site in east Texas in 2004.

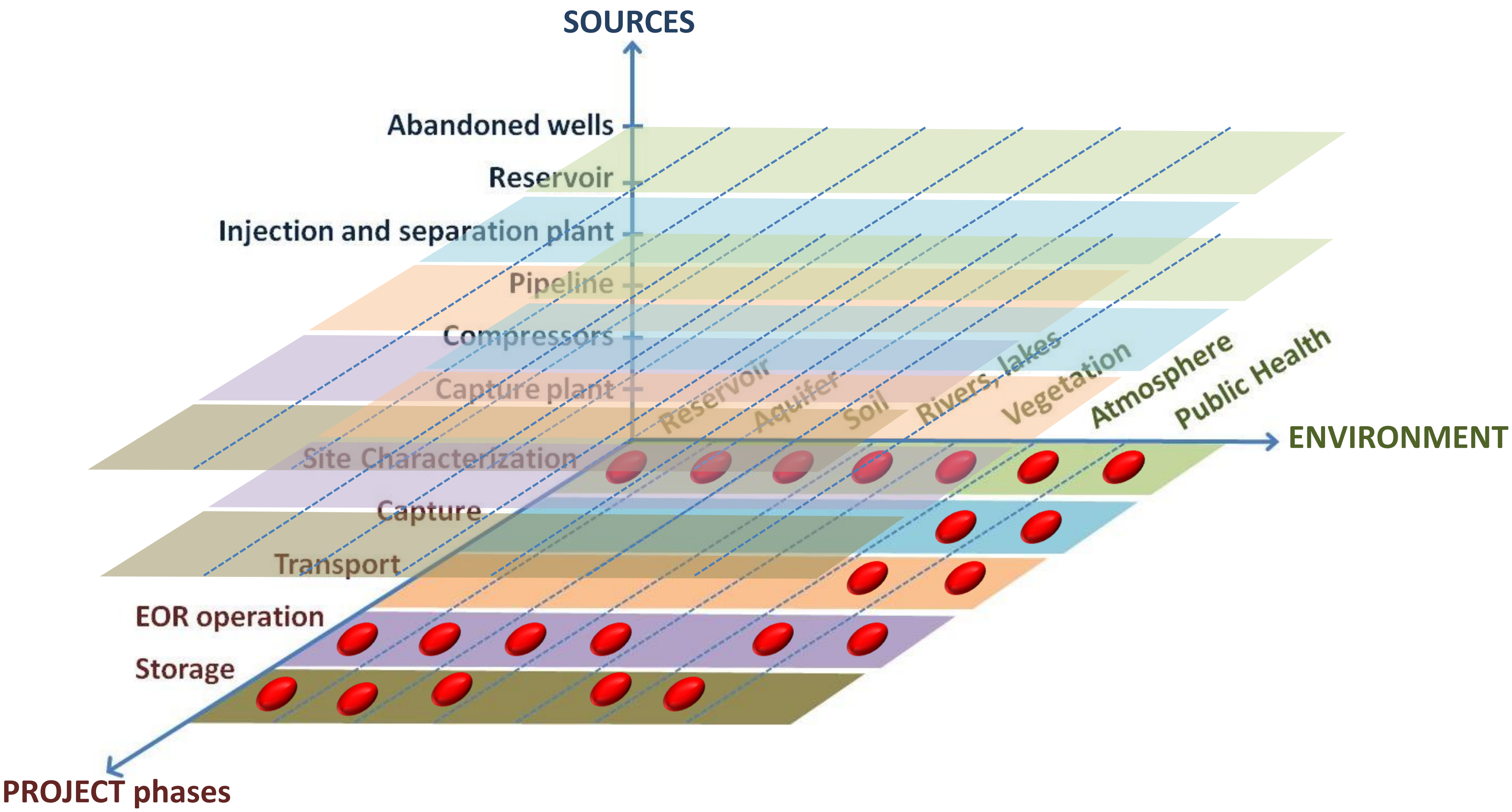
The apparatus is able to collect continuous samples of reservoir fluids near in-situ temperatures and pressures and has now been used for CO2 pilot studies at Cranfield, Mississippi (Southwest Carbon Partnership Phase 3) and Otway in Australia."



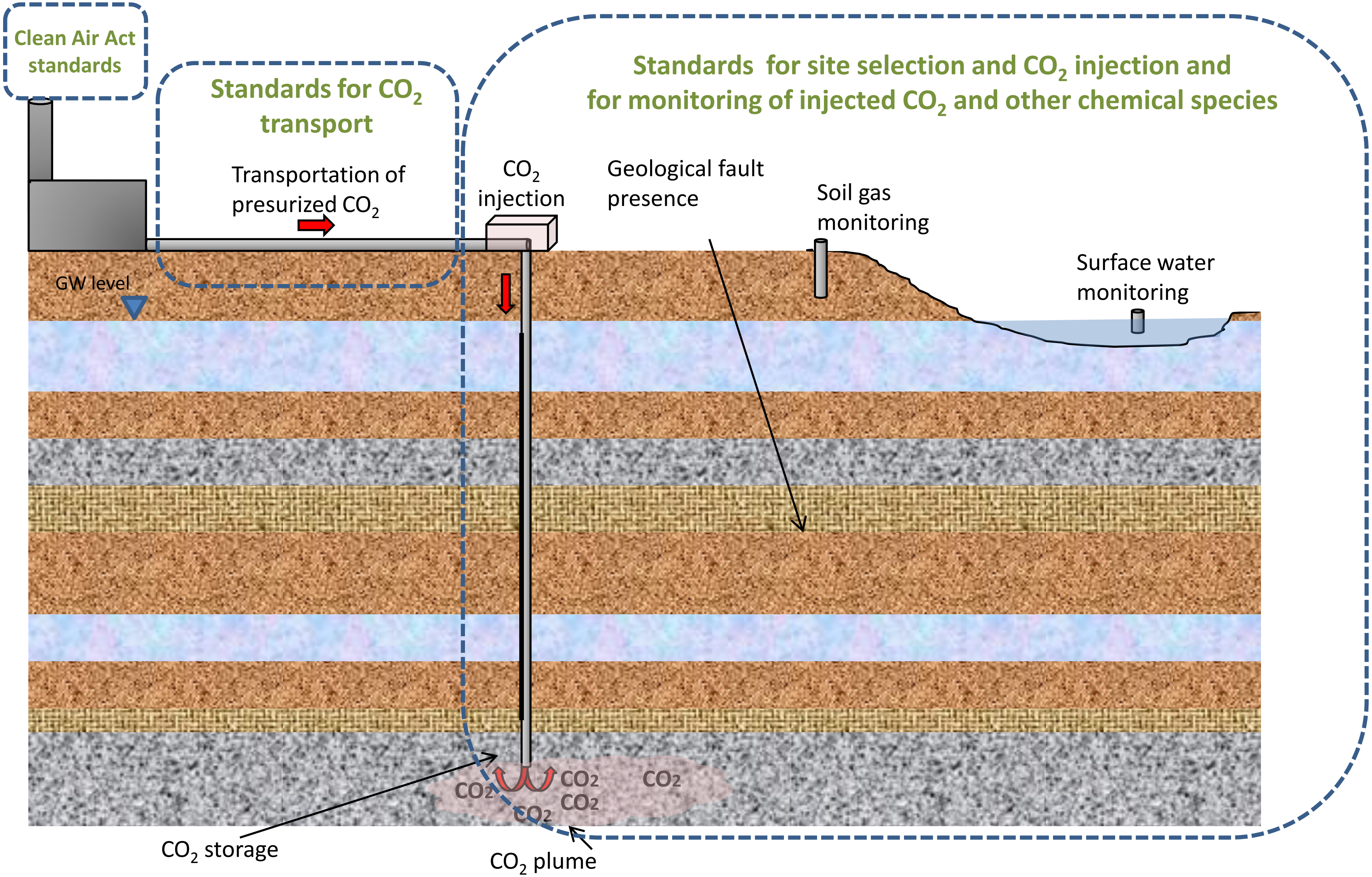
Source: Freifeld, Barry M., Trautz, Robert C., Kharaka, Yousif K., Phelps, Tommy J., Myer, Larry R., Hovorka, Susan D., et al.(2005). The U-Tube: A Novel System for Acquiring Borehole Fluid Samples from a Deep Geologic CO2 Sequestration Experiment. Lawrence Berkeley National Laboratory: Lawrence Berkeley National Laboratory. LBNL Paper LBNL-57317.

Retrieved from: http://escholarship.org/uc/item/5j43009c

Monitoring, Verification, and Accounting Dimensions



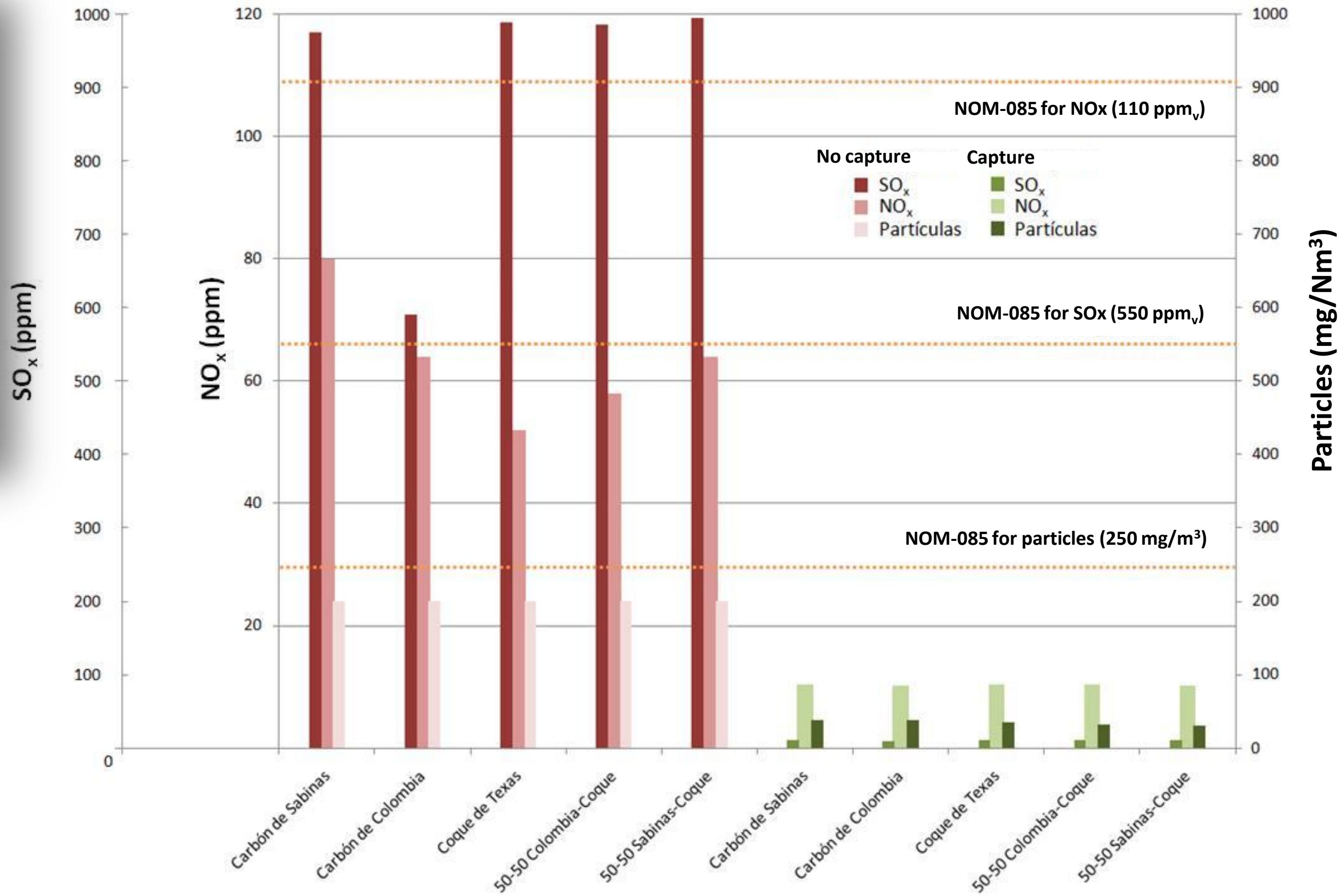
Environmental Impact and Risk Assessment



FUENTE: Centro Mario Molina, 2010

CFE
air emissions from the stack

Levels of pollutant emissions expected from one unit at a coal or petcoke power generation plant WITH and WITHOUT CO_2 capture system*



*The CO_2 capture system requires an influent with NOx and SOx concentrations within the 10-20 ppm range

Environmental Impact and Risk Assessment

Mexico has stringent pipeline regulations for the oil and petrochemical industry, nevertheless, its construction and safety operation are the main public concern

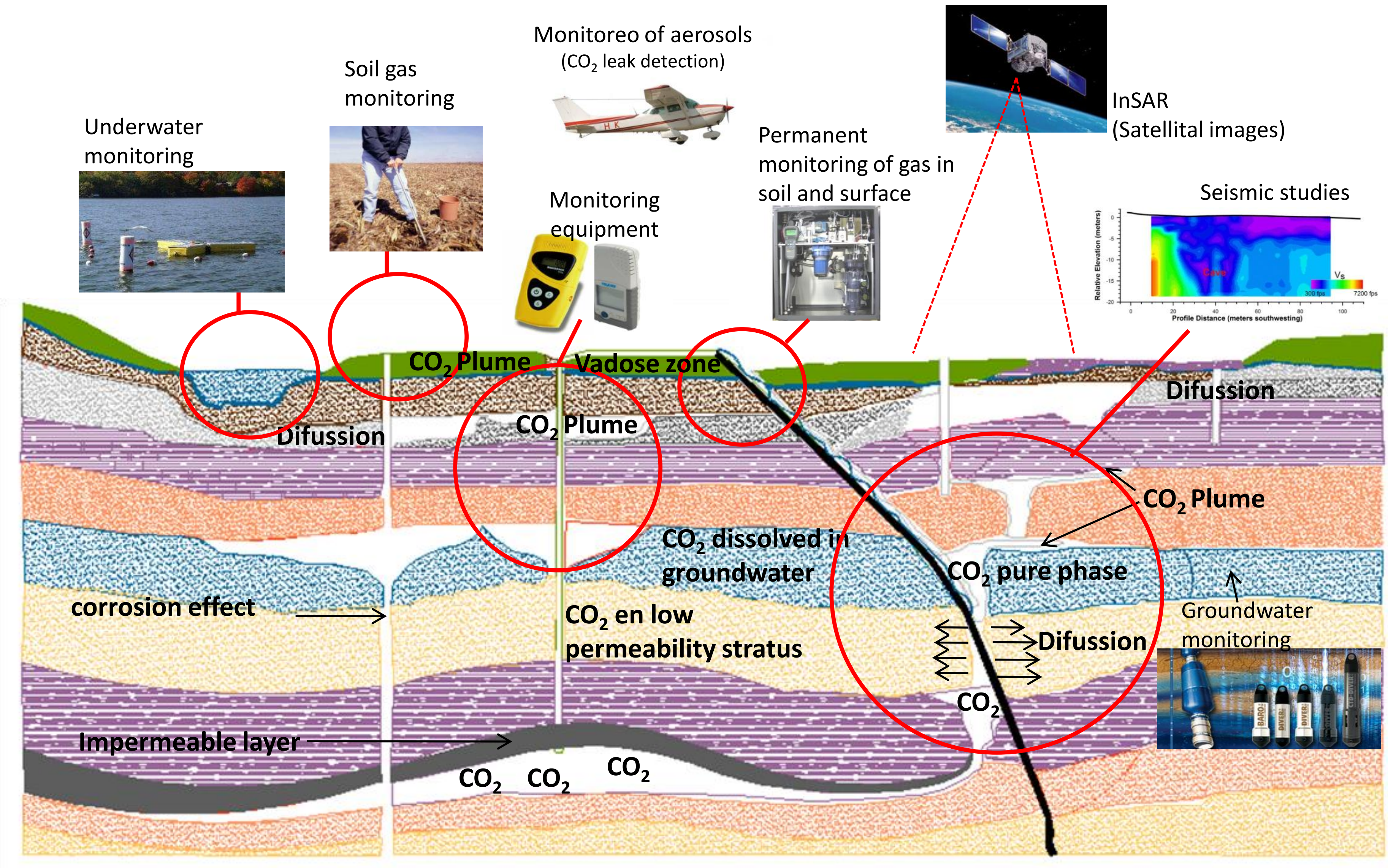
Pipelines in Midale
Photo: R. Lacy

Pipeline explosion in Puebla, Mexico 2010

Cows killed by a 1986 natural carbon dioxide leak at Lake Nyos, Camerum

ENVIRONMENTAL

MAV for CO_2 stored



SOURCE: Ellaborated with ilustrations from British Geological Survey & Schlumberger Water Services

Radar Remote Sensing for CO_2 monitoring

Figure 1: Satellite interferometry data from In Salah, Algeria. Left: Displacement from baseline over the injection period. Uplifted areas are yellow, areas of subsidence are blue. Right: Displacement history around three injection wells (KB-501 to 503) and a gas producing well (KB-CC). Locations are marked on the map (left) (courtesy of Onuma et al, 2009).

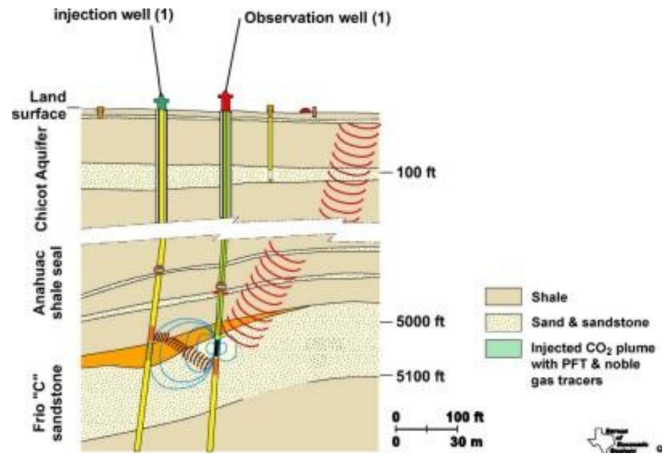
Environmental Impact Assessment

***MVA**-Monitoring, Verification, and Accounting CO_2*

Summary of MVA Plans for Gulf Coast Mississippi Strandplain Deep Sandstone Test

Measurement Technique	Measurement Parameters	Application
Introduced—noble gasses/ partitioning tracers	Dissolution of CO_2 into brine	Significant uncertainties in pressure response is the amount of CO_2 dissolved. The SECARB Early Test will deploy the U-tube to reservoir depths to obtain tracer chromatography to assess dissolution via chromatography. This is a follow-on to Frio with a larger volume and longer flow-path using the same techniques. The SECARB team recognizes that laboratory measurements of fractionation into relevant fluids and rocks is key to quantifying this test.
Produced fluid composition	CO_2 via mass, DIC, DOC; Selected major and minor cations, organics	Validation of well log and cross-well CO_2 detection, index of rock-water reaction.
Bottom-hole pressure	Pressure transducers on wireline with real-time readout	Key measurement assessing relationship between pressure field and multiphase field.
Distributed down hole temperature	Measure zones of fluid movement	Additional data to constrain flow units, especially to determine flow-unit thicknesses under relevant conditions. Also indicates well integrity.
Pulsed neutron reservoir saturation; Cased hole sonic if modeling predicts sensitive	CO_2 saturation	Distribution of CO_2 at measurements points, model match, validation and quantification of CASSM and cross-well ERT. Key input to capacity calculation term "E."
Time-lapse 3-D seismic imaging (surface deployed)	Change from baseline, only if baseline assessment shows reasonable sensitivity to the expected CO_2 saturation change	Extent of CO_2 plume: especially down-dip. May substitute VSP if sensitivity is higher.
Continuous Active Source Seismic Monitoring (CASSM); Cross-well seismic tomography	Detect timing of CO_2 movement cross the plane of measurement	History match model, with high frequency temporal records with pressure signal
Passive seismic monitoring	Assess stress distribution	Development of stress in formation
Above-zone pressure and fluid monitoring	Assess leakage signal (possible through well completions-poor cement bond)	Continuation from Phase II to obtain long record (if Phase II results justify)
Cross-well electrical resistance tomography (ERT)	Improve measurement of saturation; will be used if proves feasible and economic	Tool development will extend tie range of cross-well measurement of saturation and improve the rigor of history match and seismic inversion.
Subsurface deformation	Tilt; Measurements at surface to assess depth-effectiveness of tool under high injection rates	Quantify geomechanical effects on storage formation as part of pressure-field assessment.
CO_2 land surface-soil gas assessment	Measure natural CO_2 fluxes—aquifer-vadose zone-soil-land-surface and atmosphere in depth over time.	Determine sensitivity of these techniques under regional conditions. Possible follow-on-tracer test to validate hypothesis.
Aquifer monitoring	Alkalinity, DIC, DOC, isotopes, chloride selected cations and anions.	Assessment of method in compact possibly contaminated setting, directly regulated recourse. Possible follow-on-tracer test to validate hypothesis.

Preparing fluorescine solution to be injected in the Frio Brine research project, Texas USA



Source: NETL-DOE, 2009. Monitoring, Verification, and Accounting of CO_2 Stored in Deep Geologic Formations.

Information gathered in the EIA and ERA is a useful tool to generate baseline data…

Subsoil:

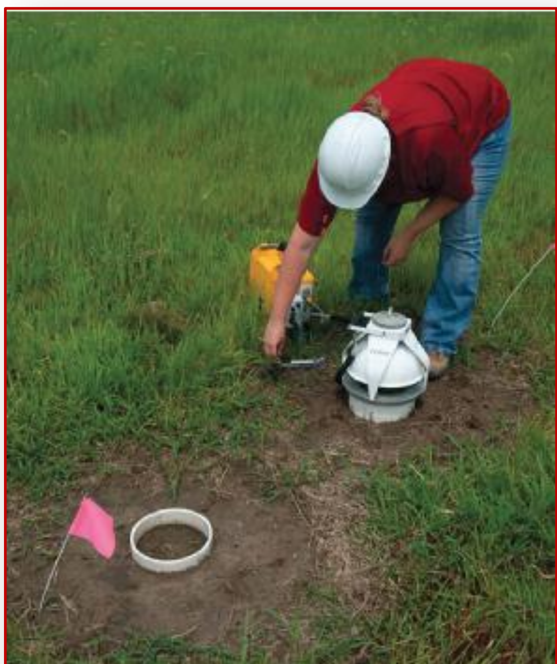
Storage and confining zones
Wells integrity
Gravimetry
Seismicity

This data will support monitoring and analysis of CO_2 plume migration

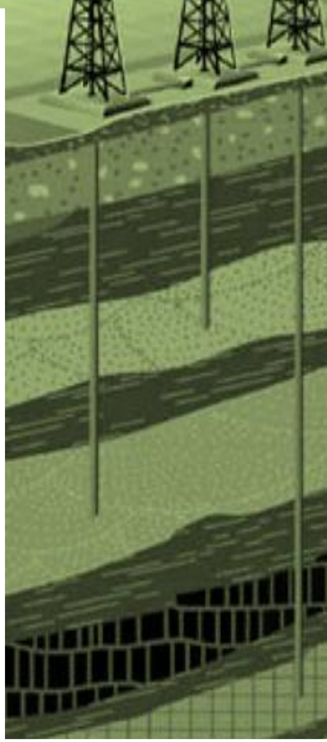
Surface and near-surface:

CO_2 concentrations in soil
Water quality (rivers, lakes, etc.)

Data that provides warning signals in case of CO_2 leakage and also is a reference for remediation actions



Measuring soil CO2 fluxes with a chamber–based method



THANK YOU

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