FACTSHEET FOR PARTNERSHIP FIELD VALIDATION TEST

Partnership Name	West Coast Regional Carbon Sequestration Partnership **(WESTCARB)**		
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Field Test Information: Field Test Name	Kimberlina large-volume CO_2 sequestration test (WESTCARB Phase III)		
Test Location	Kimberlina Test Facility, Kern County, California		
Amount and Source of CO_2	Tons: 1,000,000	Source: Clean Energy System's Oxy-Fuel Combustion (ZEPP-1) Power Plant	
Field Test Partners (Primary Sponsors)	California Energy Commission, Clean Energy Systems, Inc. (CES), Schlumberger		

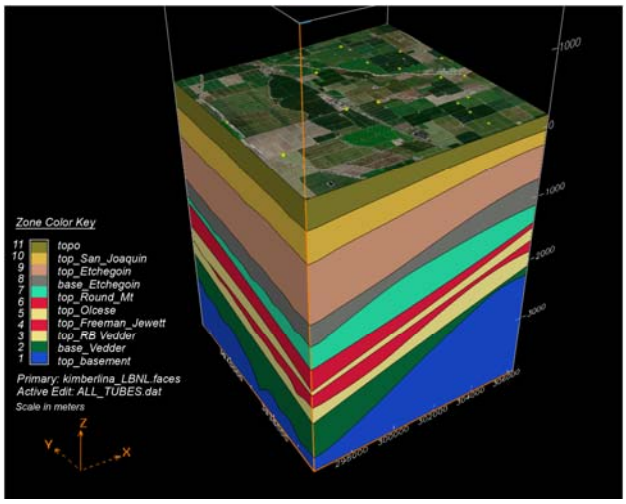
Summary of Field Test Site and Operations:

The WESTCARB Partnership will inject 250,000 tons of CO_2 per year for four years into a San Joaquin Basin saline formation about 7000 feet (2100 meters) beneath a new Clean Energy Systems' oxy-combustion power plant (the CO_2 source) being built at the Kimberlina Test Facility in Kern County, California. The plant site (see photo at right) consists of flat, open terrain surrounded by almond orchards, a fruit processing plant, and California Highway 99. It is currently home to Clean Energy Systems' 5 MW oxy-combustion pilot plant—which has been the host for oxy-combustion R&D sponsored by DOE and the California Energy Commission.

Proposed site of Clean Energy Systems' oxy-combustion power plant and WESTCARB large-volume CO_2 storage test

Current plans call for the new ~50 MW plant (designated "Zero Emission Power Plant 1," or ZEPP-1) and associated CO_2 clean-up, compression, and injection systems to be built alongside the existing pilot plant. The ZEPP-1 unit is projected to come online in mid-2011. In preparation for large-volume injection operations (which will constitute the ZEPP-1 plant's entire exhaust, not a slipstream), WESTCARB will, in 2009-10, inject a small quantity of commercially acquired CO_2 to verify injectivity and other subsurface characteristics important to the design of the large-volume test. For the large-volume injection test itself, short runs of above-grade process piping will transfer CO_2 from the ZEPP-1 plant to the injection wellhead.

The clean-up cycle within the ZEPP-1 plant will result in a gas stream with a CO_2 concentration of 96% or greater. Clean Energy Systems will deliver CO_2 to WESTCARB at commercial-scale pressure, approximately 2000 psi (140 bar). A booster pump will be used, if needed, to achieve injection into the target saline formation. Schlumberger will manage injection operations, and will partner with Lawrence Berkeley National Laboratory (lead science organization) on data acquisition, interpretation, and analysis. Lawrence Livermore National Laboratory has built a preliminary layered geomodel framework for the Kimberlina site as part of WESTCARB Phase II, based on the limited amount of available data. Early in Phase III, WESTCARB will conduct a three-dimensional seismic survey to provide higher confidence data.



Initial geomodel of WESTCARB Phase III large-volume CO_2 storage test site in the San Joaquin Basin below the Kimberlina site in Kern County, California

Two sandstone units are suitable candidates, and the deeper of the two—the Vedder—is the primary injection target. At a depth of 7000 feet (2100 meters), it is regionally continuous. The site is believed to contain a braided stream unit with a thickness up to 500 feet (150 meters).The Vedder formation is a typical example of the marine and coastal marine sediments which fill the Great Central Valley of California. These sediments are a very large storage resource for California, with a capacity initially estimated as 50 to 250 billion tons of CO_2. Thick shale units provide good overlying seals at the site and surrounding areas.

Research Objectives:

1. Gain a more thorough understanding of the science, technology, and operations associated with the injection of a substantial amount of CO_2 into a saline formation, and broaden our knowledge of the storage capacity and the injectivity and storativity of CO_2 in saline formations.

2. Demonstrate secure geologic storage in a saline formation concurrent with CO_2 capture operations at a power plant.

3. Conduct a thorough site characterization to provide useful information, not only for this project but for establishing policy and procedures by which private and public entities may subsequently pursue commercial CO_2 sequestration activities.

4. Demonstrate existing, and field-test new and improved monitoring and modeling techniques and systems to determine the subsurface location of the plume, validate capacity estimates, confirm seal and wellbore integrity, and assure no adverse environmental impacts. Results will be crucial to the development of future measuring and monitoring protocols for assuring public safety and satisfying policy and market

requirements for carbon storage verification.

5. Gain experience in permitting a CO_2 injection and storage operation and interact with appropriate government and regulatory agencies to help define the regulations and policies for geologic carbon sequestration projects.

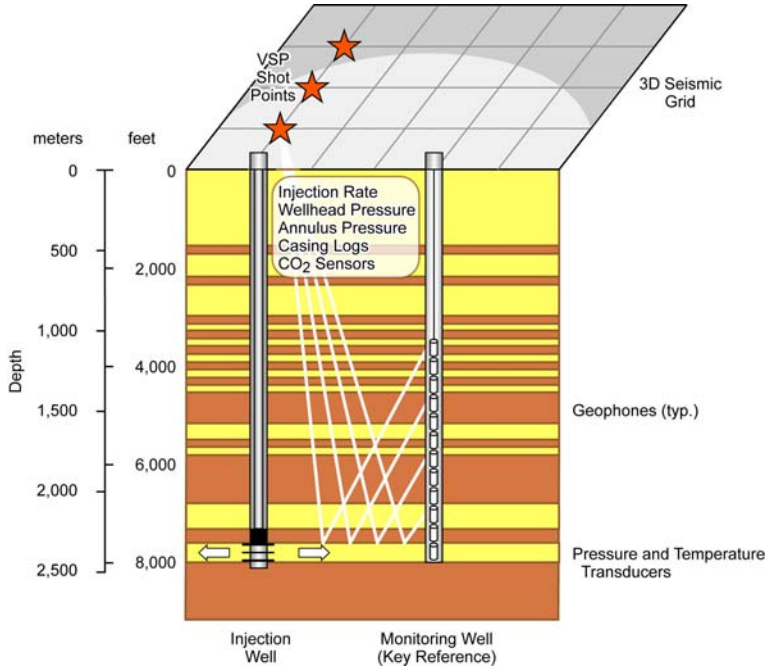
6. Develop outreach and educational tools to engage the public, stakeholders, and policymakers by communicating project results and the benefits of long-term geologic carbon sequestration in helping to curb global climate change.

The complete integrated package of results from the large-volume sequestration test at Kimberlina (modeling, monitoring, validation, evaluation, technology development, permitting, operations and maintenance, and public outreach) will serve as a model for future projects of this kind.

Summary of Modeling and MMV Efforts:

WESTCARB's monitoring program will be carried out in three phases, in conjunction with the characterization and test activities at the site.

The *pre-operational phase* will emphasize support of geologic characterization, baseline data acquisition, and assessment of environmental, health and safety risks. A considerable amount of testing and coring will be conducted as the injection well is drilled. An initial vertical seismic profile (VSP) test will be conducted to optimize placement of transmitters and receivers for the three-dimensional (3D) seismic test. Small-scale injection tests of CO_2 and/or water will be conducted to help gauge injectivity and optimize injection operations.



WESTCARB Phase III proposed approach to surface and subsurface monitoring

During the *operational phase* of the project, CO_2 will be injected into the reservoir (for four years); surface facilities and injection rates will be monitored; the location of the plume will be tracked (via VSP tests); and modeling activities will be conducted.

The *post-injection phase* of the project will be used as a confirmatory period to detect continued movement of the plume (via 3D seismic), detect any potential leakage, and to assess if the storage project is performing as expected.

Computer simulation using the models ECLIPSE, TOUGH2, and TOUGHREACT will be used to predict plume migration and the effectiveness of solubility, residual gas (capillary), and mineral trapping. During operations, comparisons between simulated and monitored plume migration will

be used to refine and calibrate the model and to update forecasts of plume migration. During the post-operational phase, a similar approach will be used to predict post-injection plume behavior—with a primary focus on quantifying the secondary trapping mechanisms that will eventually immobilize the CO_2 plume.

Table 1. Measurement Technologies Evaluated for Potential Use in the LVST

Measurement Technique	Measurement Parameters	Application
Well logs and cores Fluid sampling	Brine salinity Sonic velocity CO_2 saturation	Provide baseline data and estimates of permeability and porosity Track CO_2 movement Track brine migration Check condition of well casing and cement
Formation, wellhead, and annulus pressure	Pressure readings	Verify injection equipment is performing as expected (no leaks) Keep injection rate from going too high
Injection rate monitoring	Flow rate measurements	Accurately account for the mass of CO_2 injected into the storage formation
Seismic Surveys (time-lapse 3D and VSP)	P and S wave velocity Reflection horizons Seismic amplitude attenuation	Detect detailed distribution of CO_2 in the storage formation Detect leakage through any faults and fractures
Atmospheric CO_2 monitoring	CO_2 concentrations measured at wellheads	Detect potentially unsafe conditions during injection
Pressure and water quality above the storage formation	Establish baselines prior to injection. If pressure data indicate leakage, collect formation water samples for additional data and verification.	Detect leakage of CO_2 or brine out of the storage reservoir
PSInSAR	Surface displacement	Areal extent of pressure plume

Accomplishments to Date:

Planning and coordination meetings with project partners have been held to address critical path activities during the first two years, notably the NEPA and California Environmental Quality Act (CEQA) processes; permitting; public outreach; data acquisition for the site characterization, modeling, and simulation; and subcontracting.

Summarize Target Sink Storage Opportunities and Benefits to the Region:

The Great Central Valley province is an elongated topographic valley approximately 450 miles (720 kilometers) long, extending from the Klamath Mountains in the north to the Transverse Ranges in the south, and lying between the Sierra Nevada and the Coast Ranges. The Great Central Valley consists of a large depositional basin that has received sediments almost continuously since the late Jurassic and contains, by some estimates, as much as 40,000 feet (12,000 meters) of mostly marine, sedimentary rocks (Magoon and Valin, 1995). In the subsurface, the Great Central Valley is divided into the Sacramento Basin in the north and the San Joaquin Basin to the south, the point of division being the buried Stockton Arch south of the Stockton city limits.

The San Joaquin Basin extends about 220 miles (350 kilometers) from the Stockton Arch to its southern terminus at the northern Transverse Ranges and averages 50–70 miles (80–110 kilometers) wide. It is bounded on the east by the Sierra Nevada and on the west by the Central Coast Ranges and the San Andreas Fault. The target formation is the Vedder Sandstone. Basin porosities range from 10–40% and permeabilities from 0.2 millidarcies to 10,000 millidarcies. Porosity and permeability decrease with depth. Hydrocarbon traps in this area are partly structural, as a result of mild folding throughout the Great Central Valley, but mostly as a result of large-scale facies variations.

Favorable attributes of the San Joaquin Basin include: (1) geographic diversity; (2) thick sedimentary fill with multiple porous and permeable aquifers and hydrocarbon reservoirs; (3) thick, laterally persistent marine shale seals; (4) locally abundant geological, petrophysical, and fluid data from oil and gas operations; and (5) numerous abandoned or mature oil and gas fields that might be reactivated for CO_2 sequestration or benefit from CO_2-enhanced recovery operations.

Cost:

Total Field Project Cost:
$90,719,100

DOE Share:	**$**65,606,584	72.4**%**
Non-DOE Share:	**$**24,987,515	27.6**%**

Field Project Key Dates: Proposed Schedule

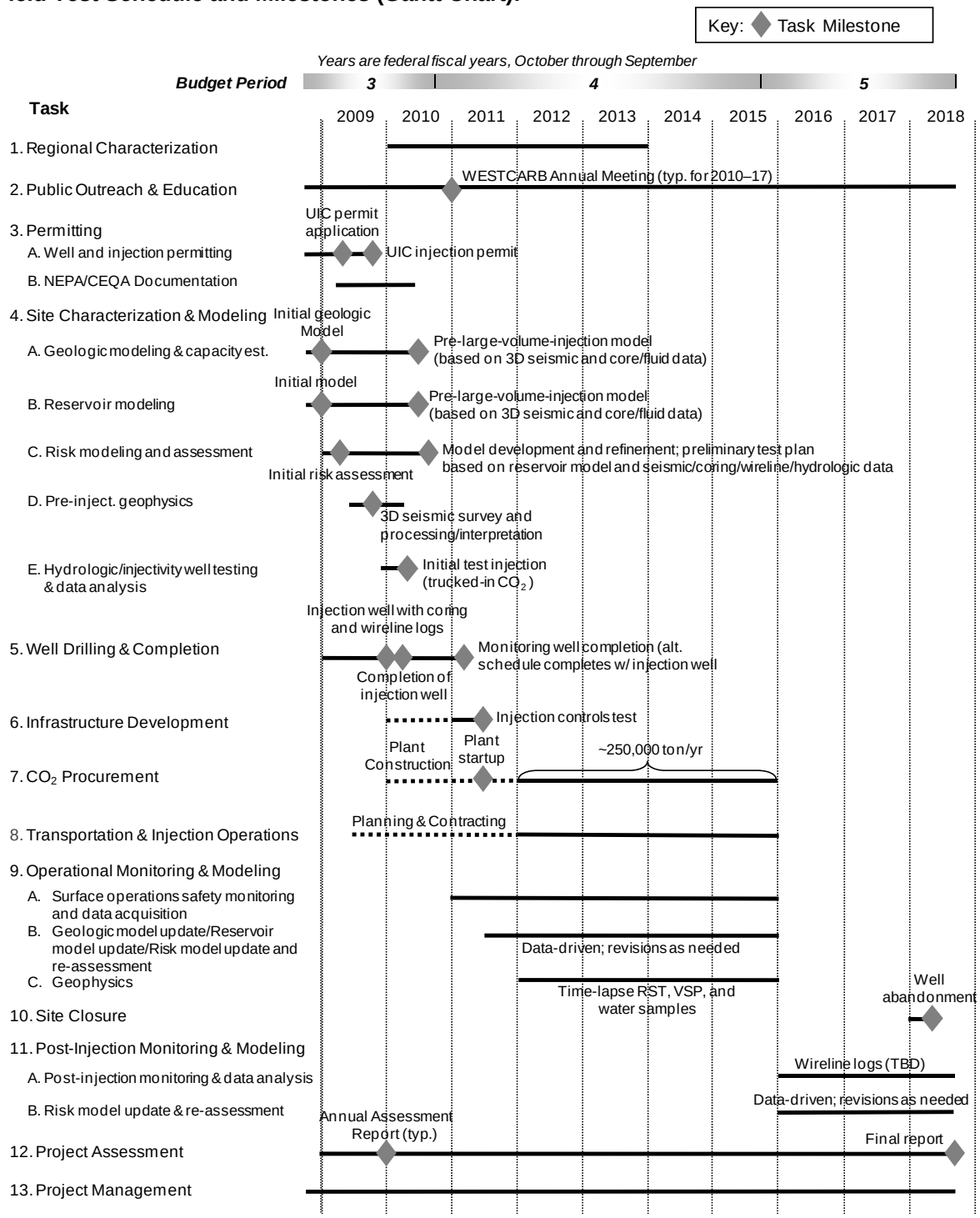
Baseline Completed: 2010 (interim data earlier)

Drilling Operations Begin: Spring 2010

Injection Operations Begin: Fall 2011

MMV Events: 2011-15

Field Test Schedule and Milestones (Gantt Chart):



Additional Information

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