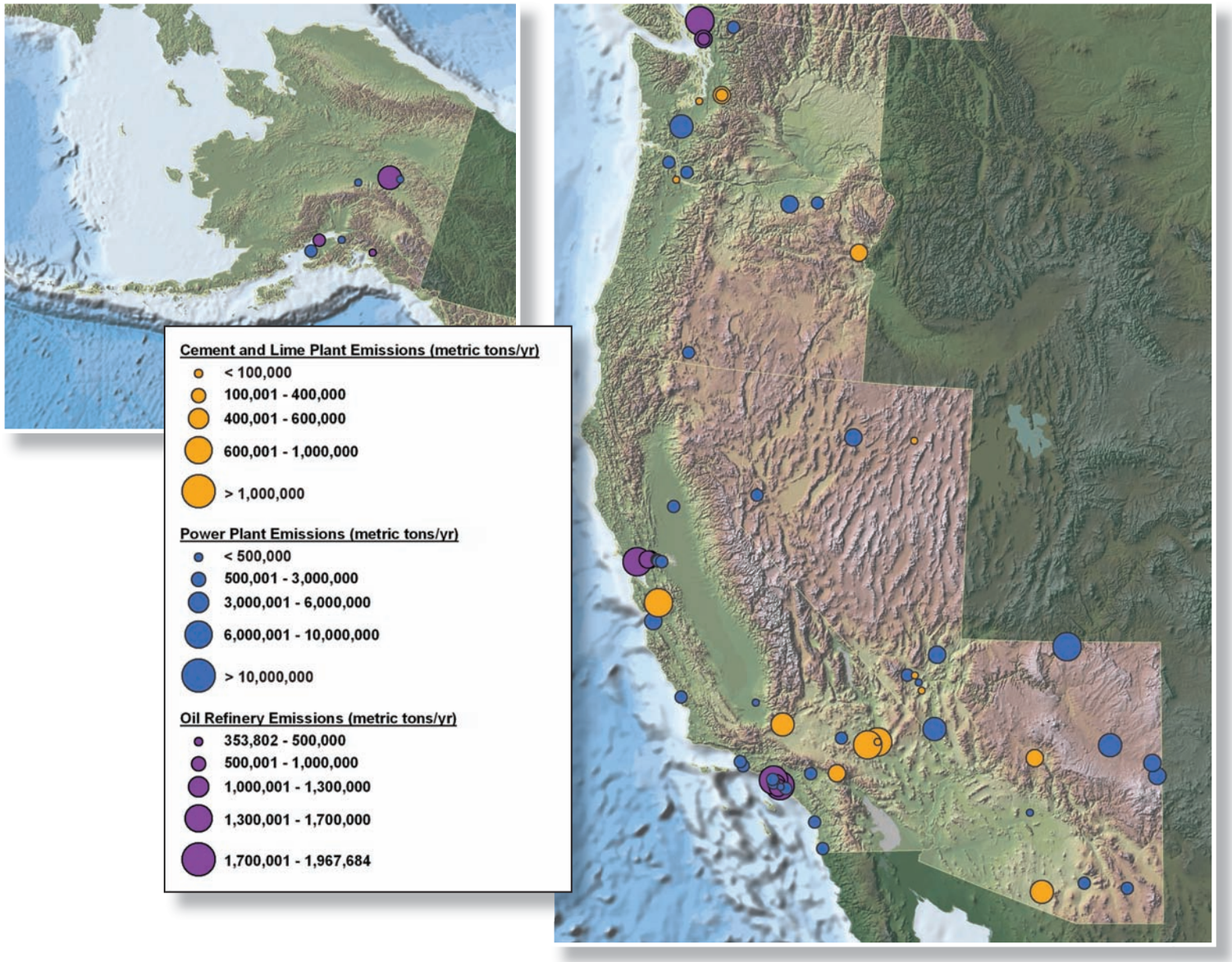
West Coast Regional Carbon Sequestration Partnership

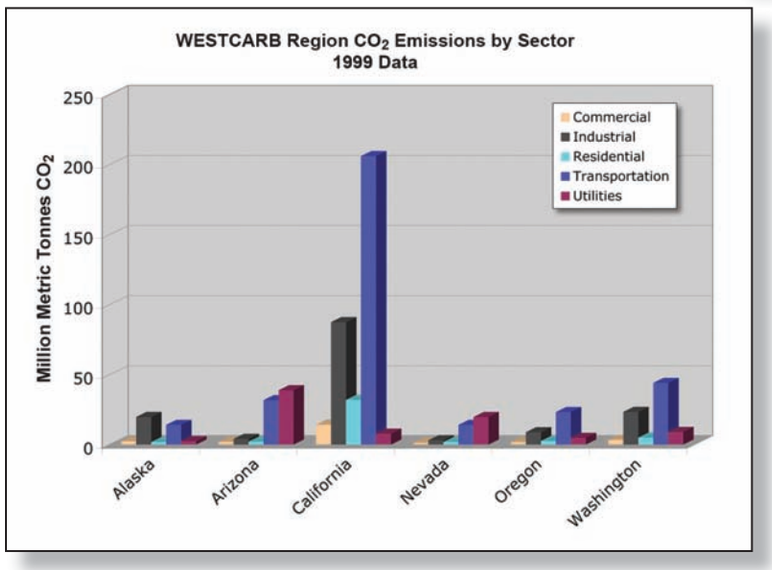
Western North America is characterized by picturesque natural beauty, an entrepreneurial spirit, and a large and growing population. Featuring cultural and economic diversity to match its geographic superlatives, the West Coast Region has one of North America's broadest mixes of CO_2 sources and an equally broad array of opportunities to curb atmospheric CO_2 buildup through carbon sequestration.

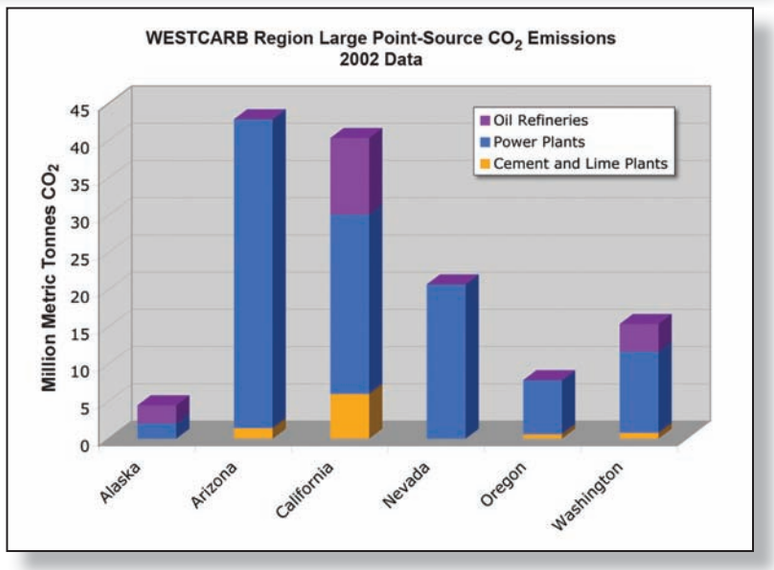
The West Coast Regional Carbon Sequestration Partnership (WESTCARB), led by the California Energy Commission, comprises researchers from more than 70 public agencies, private companies, and nonprofits in the U.S. and Canada. WESTCARB's goal is to identify and map the regional opportunities for geologic and terrestrial carbon sequestration. WESTCARB also seeks to validate the feasibility, safety, and efficacy of some of the best regional opportunities through pilot-scale field tests.

Results of WESTCARB characterization studies to date show excellent carbon sequestration potential throughout the Region. Numerous EOR and enhanced gas recovery opportunities, as well as ECBM, offer the potential for geologic sequestration to get an economic foothold. In addition, large, broadly distributed saline formations have the capacity to store hundreds of years of the Region's industrial emissions, if needed. Terrestrial sequestration opportunities are among the best in North America and provide a viable approach to offsetting the Region's relatively large transportation-related CO_2 emissions.

With policymakers seeking to both preserve cherished vestiges of the Old West and to lead the innovation-based 21st century economy, WESTCARB researchers feel carbon sequestration can play an important role in state and provincial efforts to address climate change issues.







WESTCARB CO_2 Emission Sources

The WESTCARB Region accounts for approximately 11 percent of U.S. CO_2 emissions. The chart illustrating CO_2 emissions by sector, based on the 1999 EPA emission inventories from fuel combustion for the WESTCARB Region, shows that transportation accounts for 53 percent, and industry and utilities 36 percent of the emissions within the Region. Emissions from the transportation sector are somewhat higher than the national average, while those of the utility sector are lower. California ranks second among all states in CO_2 emissions, with the transportation sector accounting for the majority of the state's total. The large percentage of emissions from mobile sources is one justification for evaluating terrestrial sequestration options. The significant percentage from industrial sources motivates analysis of industrial stationary sources along with power plants in assessing geologic sequestration options. The largest stationary sources in the Region are power plants, oil refineries, and cement and lime plants.

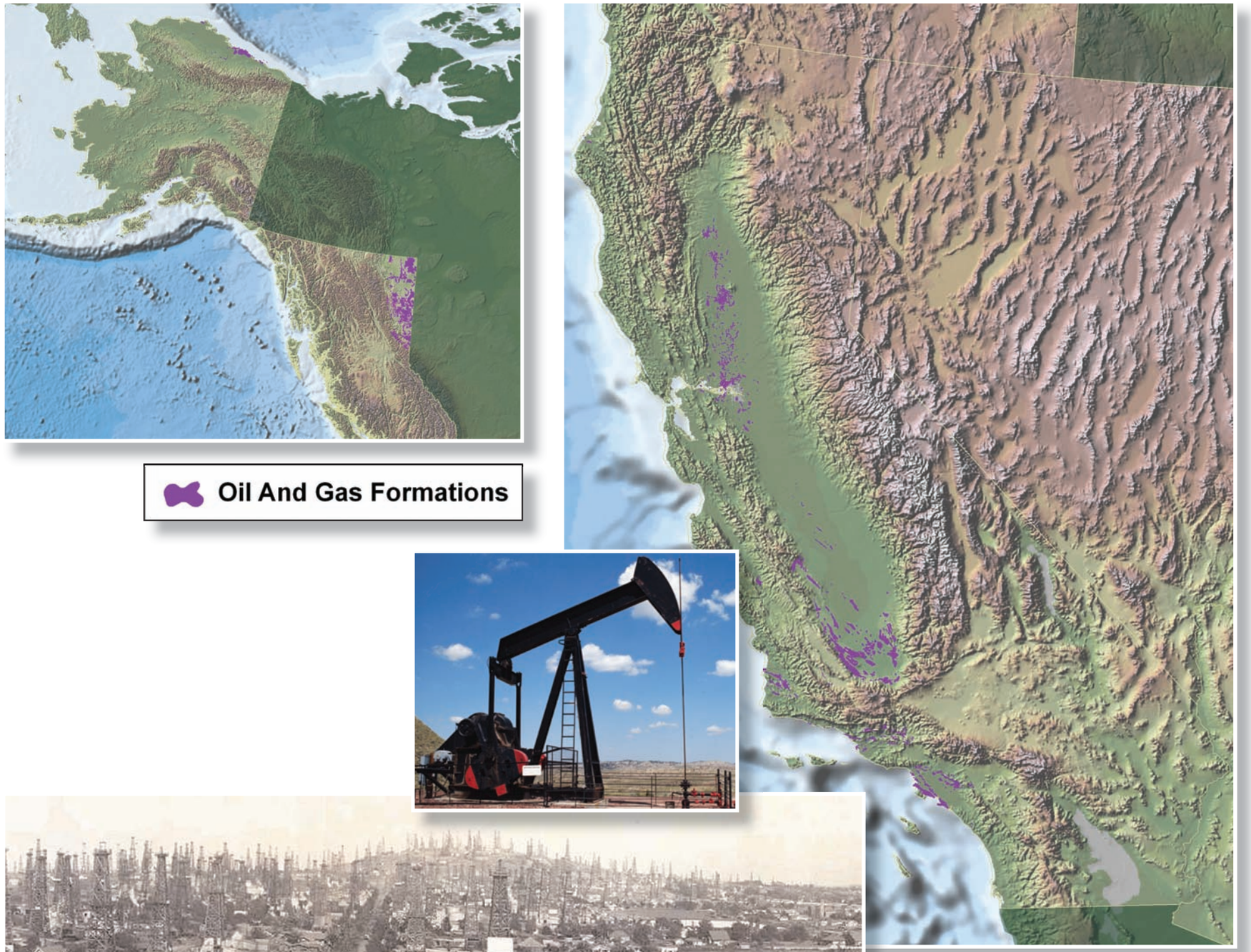
The WESTCARB CO_2 sources database includes information for 77 facilities from three categories with total annual CO_2 large point-source emissions over 130 million metric tons (140 million tons) as seen in the chart summarizing the CO_2 emissions from major stationary sources in the WESTCARB Region by facility type and by state. The CO_2 emissions from power plants are actual 2002 CO_2 emissions from EPA's eGRID database, and annual CO_2 emissions from cement plants and oil refineries are estimates based on production capacities. Power plants are the single largest point source of CO_2 emissions, accounting for more than 80 percent of the emissions from the Region's largest stationary sources in the database. Arizona has the highest annual CO_2 large stationary source emissions in the Region, representing over one-third of the regional total emissions, followed closely by California.

WESTCARB Region Oil and Gas Fields

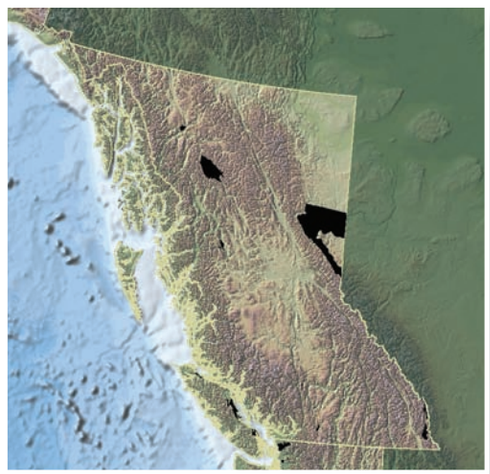
In the WESTCARB Region, major oil and gas fields represent both sequestration targets and EOR/EGR opportunities—especially in both California and Alaska.

In California, most oil reservoirs are found in the southern San Joaquin Basin, Los Angeles Basin, and southern coastal basins. Estimates made by WESTCARB investigators suggest a potential CO_2 EOR storage of 3.4 billion metric tons (3.7 billion tons), based on a screening of reservoirs using depth, an American Petroleum Institute (API) gravity cutoff, and cumulative oil produced. A study of CO_2 EOR potential in California recently completed by Advanced Resources International concluded that technically recoverable reserves are over 0.3 million m^3 (5.6 billion barrels). There are abundant gas reservoirs in the Sacramento River Delta, including the Rio Vista gas field which has produced over 99 million m^3 (3.5 trillion ft^3) of gas since the 1930s. To estimate the CO_2 sequestration potential in California gas reservoirs, the cumulative production from reservoirs screened by depth to assure proper storage pressure was used to find a storage capacity of 1.7 billion metric tons (1.9 billion tons).

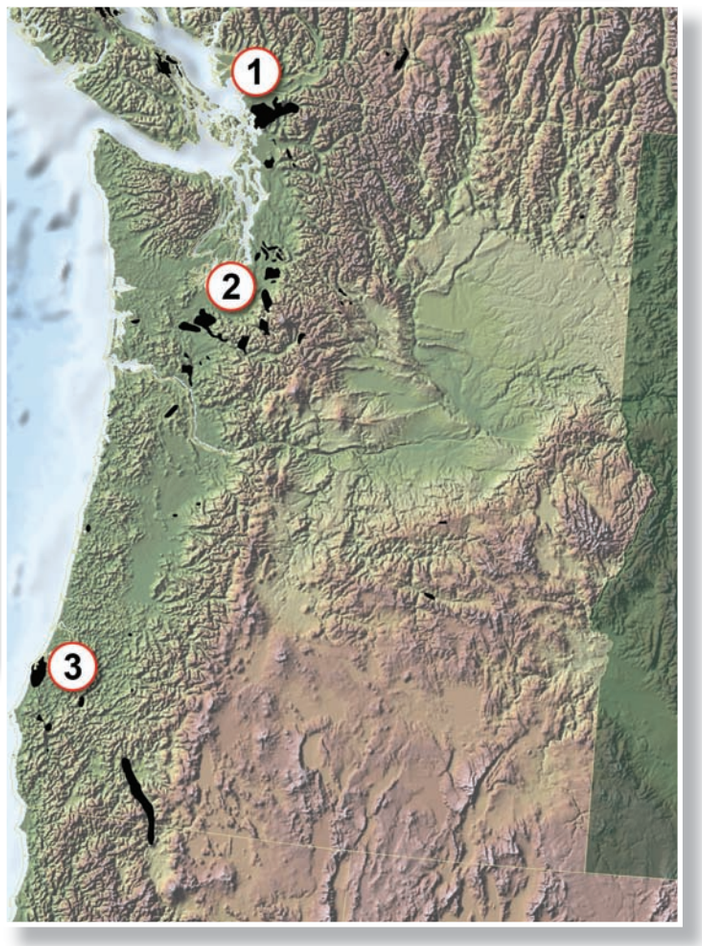
In Alaska, the oil and gas fields on the North Slope are of prime interest because of the large potential for CO_2 EOR. Assessment of oil and gas fields suitable for CO_2 sequestration in Alaska and Nevada are ongoing.



This historical photograph of Signal Hill in Long Beach, California, dates from 1923, when wells were drilled on townlots. At that time, approximately 41,000 m^3 (260,000 barrels) of crude oil was produced daily from about 300 wells, making Signal Hill the most productive field per acre worldwide, and making California the nation's top oil-producing state. Signal Hill may take on new historical significance in the 21st century as a site for geologic CO_2 storage.



Coal Basins



TransAlta's 1400MW coal-fired power plant in Centralia, Washington.

WESTCARB Coal Basins

Opportunities for geologic CO_2 storage in coal basins within the WESTCARB Region are found predominantly in the Pacific Northwest and Alaska. In the Pacific Northwest, three deep coal bed locations offer promise: (1) the Bellingham Basin in northwestern Washington; (2) the coals of the upper Puget Sound Region, south and east of the Seattle-Tacoma metropolitan area; and (3) small, deep coal deposits in southwestern Oregon.

Puget Sound coals have been extensively tested by CBM exploration companies and WESTCARB investigators are characterizing their CO_2 sequestration potential. Preliminary results show the subsurface extent of the coal basins in an area of greater than 2,500 km^2 (950 mi^2). Initial analysis indicates prospective coal seam reservoir properties of 30 m (100 ft) coal thickness, a CO_2 sorption capacity of 20–24 m^3 (700–850 ft^3) CO_2 per ton coal, and approximately 5 millidarcies permeability. The Puget Region offers encouraging prospects for testing CO_2 storage in unmineable coal seams. The estimated CO_2 storage potential in this area is 2.8 billion metric tons (3.1 billion tons), and the estimated recoverable CBM is 57–570 billion m^3 (2–20 trillion ft^3).

Although coal mining in Alaska has been very limited, the state contains major coal deposits that range from shallow deposits to deposits over 2,000 m (6,500 ft) deep. Three major geologic provinces account for nearly 90 percent of Alaska's coal resources: (a) the North Slope Region in Northern Alaska, (b) the Nenana Region in Central Alaska, and (c) the Cook Inlet Region in Southern Alaska. Most estimates of coal resources date back to the early 1980s and tend to be biased towards shallow, mineable coal deposits, and frequently do not consider coals encountered in deep oil and gas wells that are prime targets for CBM development and CO_2 storage. Preliminary estimates of geologic CO_2 storage capacity in Alaska suggest that 84 billion metric tons of CO_2 could be stored in deep coal seams. Alaska's methane resources are estimated to be approximately 22 trillion m^3 (776 trillion ft^3), which is comparable to CBM resources in all of the lower 48 U.S. states. Essentially all of the CO_2 storage potential and CBM potential is located in the North Slope and Cook Inlet regions, which have thick coals of suitable thickness, depth, rank, and quality. It is likely that only a portion of the 84 billion metric tons (93 billion tons) would be considered favorable for CO_2 sequestration, due to permeability, seam geometry, surface access, faulting, and other site-specific but currently unknown conditions. WESTCARB is continuing its analysis and expects to develop more rigorous estimates as studies progress.

WESTCARB Saline Formations

Sedimentary basins containing saline formations are broadly distributed throughout the WESTCARB Region.

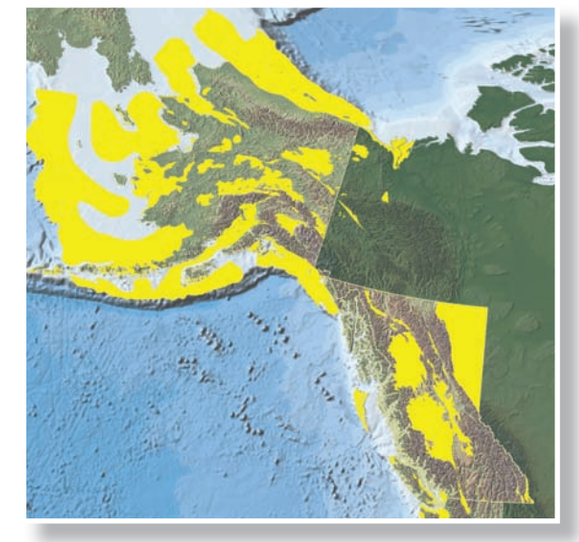
Initial WESTCARB assessments indicate that California's Cenozoic marine sedimentary possess the most potential for geologic sequestration. As a group, these basins exhibit a wide areal distribution, thick sedimentary sections containing multiple widespread saline-saturated sandstones, thick and laterally persistent shale seals, and petrophysical data available through oil and gas development. The most promising basins include the San Joaquin, Sacramento, Ventura, Los Angeles, and Eel River basins. Smaller marine basins, including the Salinas, La Honda, Cuyama, Livermore, Orinda, and Sonoma basins, are also promising but more restricted in terms of size and available geological information. The total storage capacity of the 10 most promising basins is approximately 75–300 billion metric tons (83–330 billion tons) CO_2. Most of California's nonmarine basins are too shallow for carbon sequestration, however, the large Salton Trough and several smaller nonmarine basins may offer some opportunities.

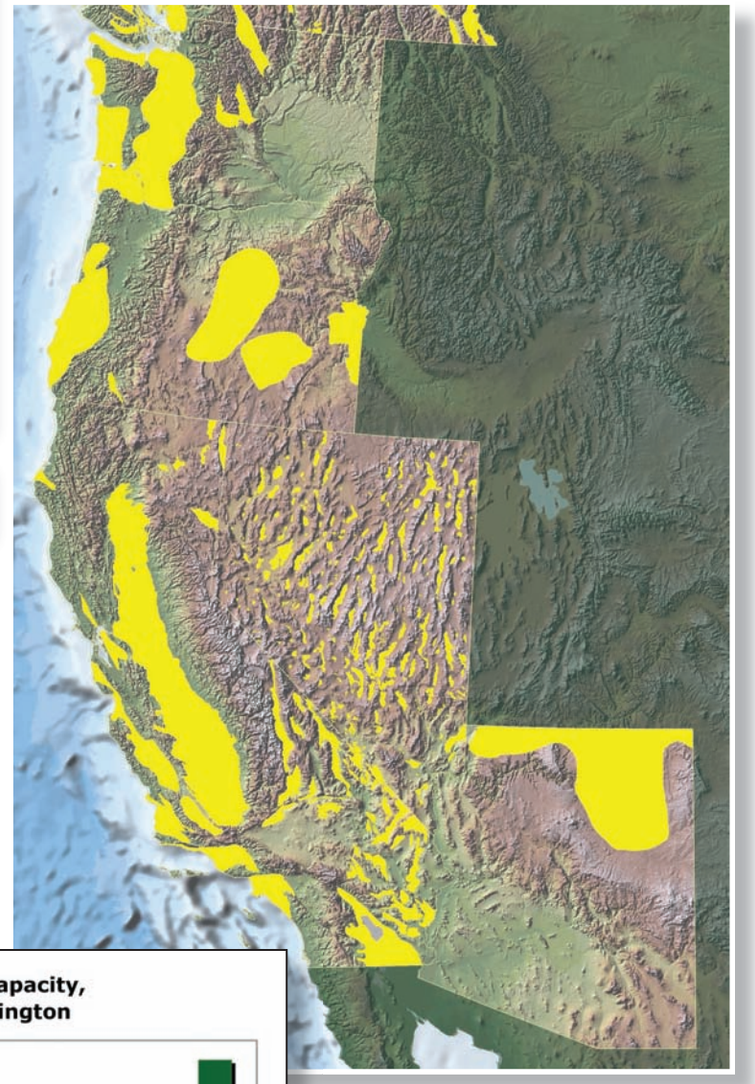
In Oregon and Washington, western coastal basins offer potential sequestration opportunities. These basins are associated with a major Tertiary sedimentary belt of basins formed in a regional fore-arc environment. Promising basins include the Puget Trough, Tofina-Fuca Basin, West Olympic Basin, Whatcom Basin, and Willapa Hills Basin in Washington, and the Astoria-Nehalem Basin and Tyee-Umpqua Basin in Oregon. These basins contain sandstone/shale sequences that are up to 9,000 m (30,000 feet) thick. The total storage capacity for all 7 of these sedimentary basins is approximately 20–85 billion metric tons (22–94 billion tons) of CO_2.

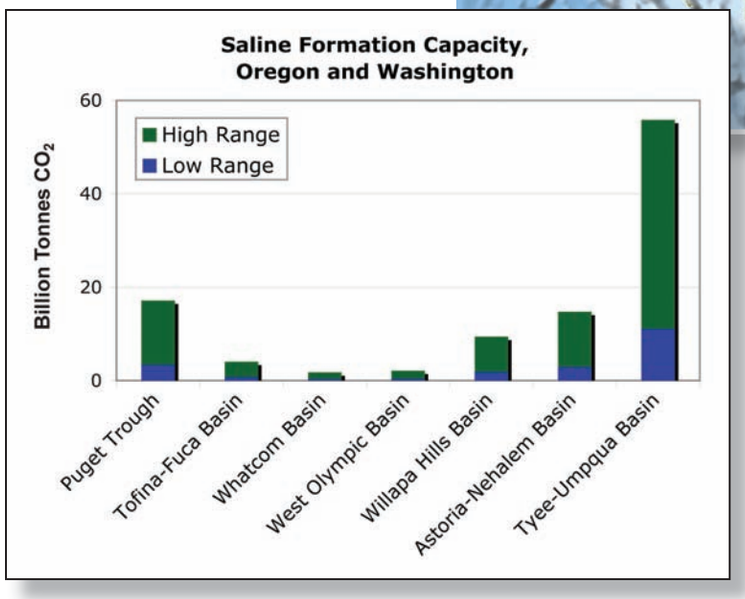
Although basins east of the Cascade Mountains have characteristics that are favorable for potential sequestration, very few data are available to characterize their potential.

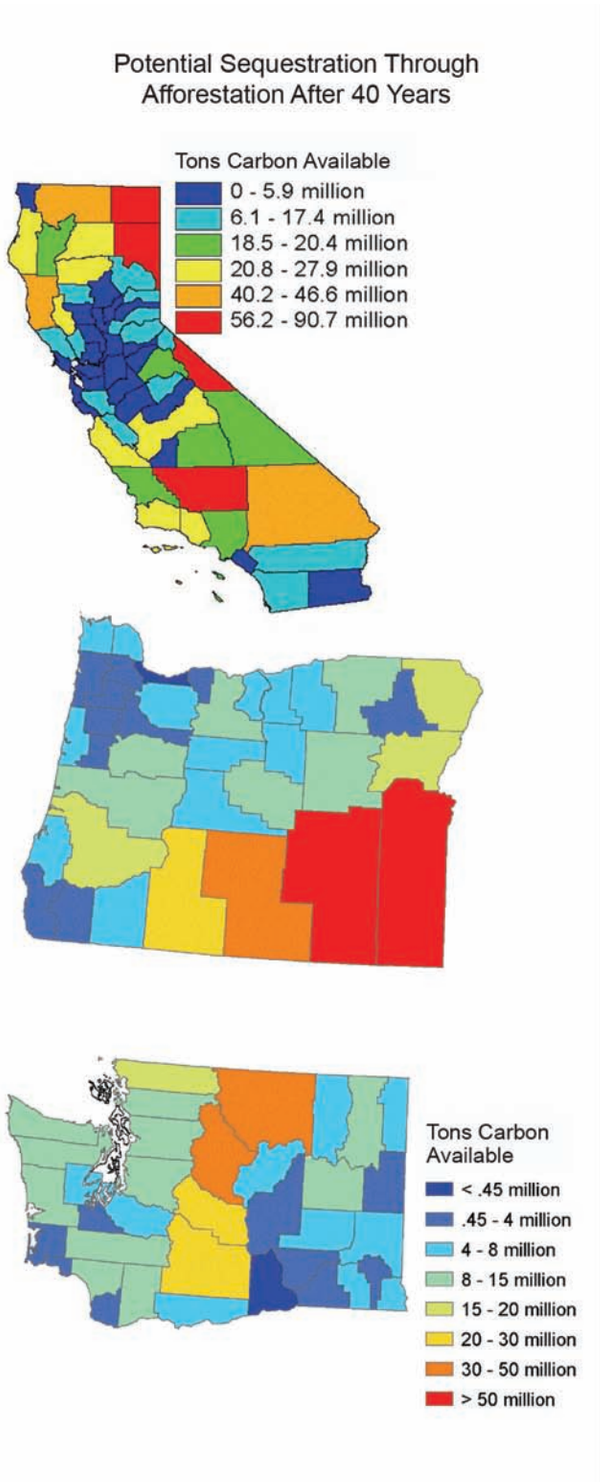
In Alaska, six basins contain sediments of sufficient thickness to be considered as potential sequestration targets.

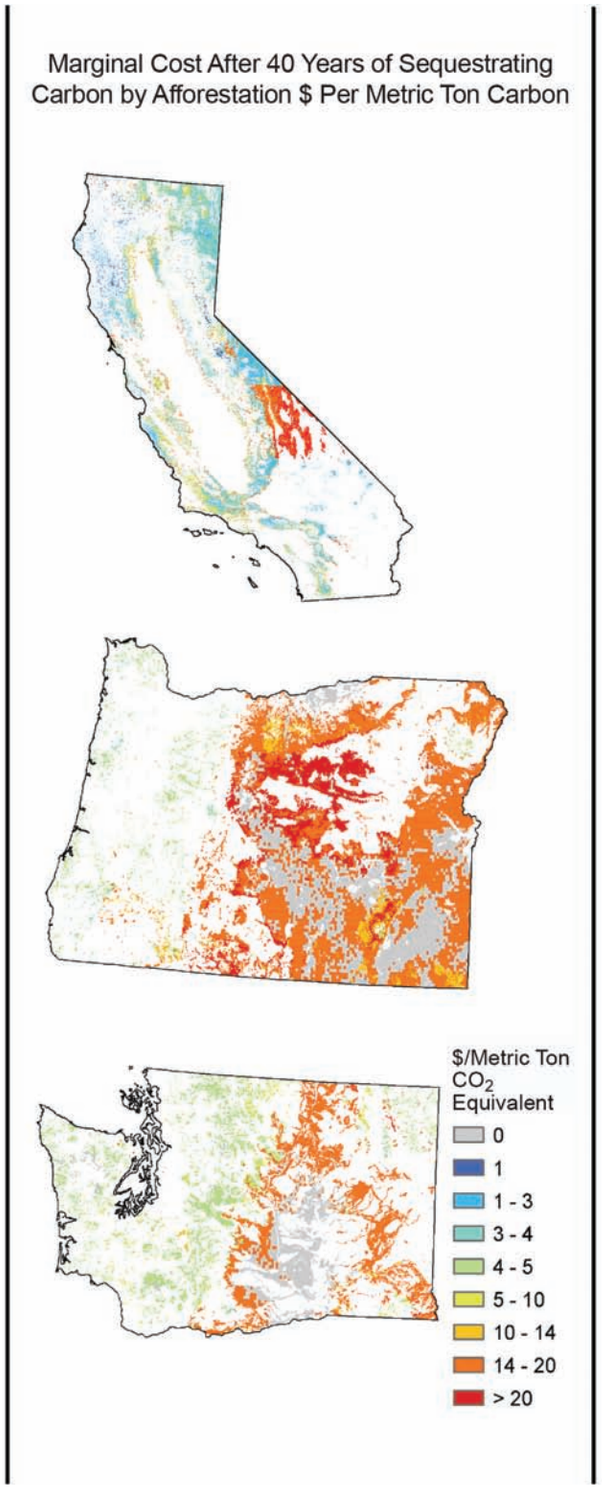
Finally, in Arizona, sediments underlying the Colorado Plateau represent the initial target for sequestration opportunities. The primary storage targets are the Naco Formation, Martin Formation, Coconino Sandstone, and the Schnebly Hill Formation. Potential reservoir seals include the Supai Formation, Chinle Formation, and the Moenkopi Formation. Both the potential storage targets and potential seals are laterally extensive and up to hundreds of feet thick.

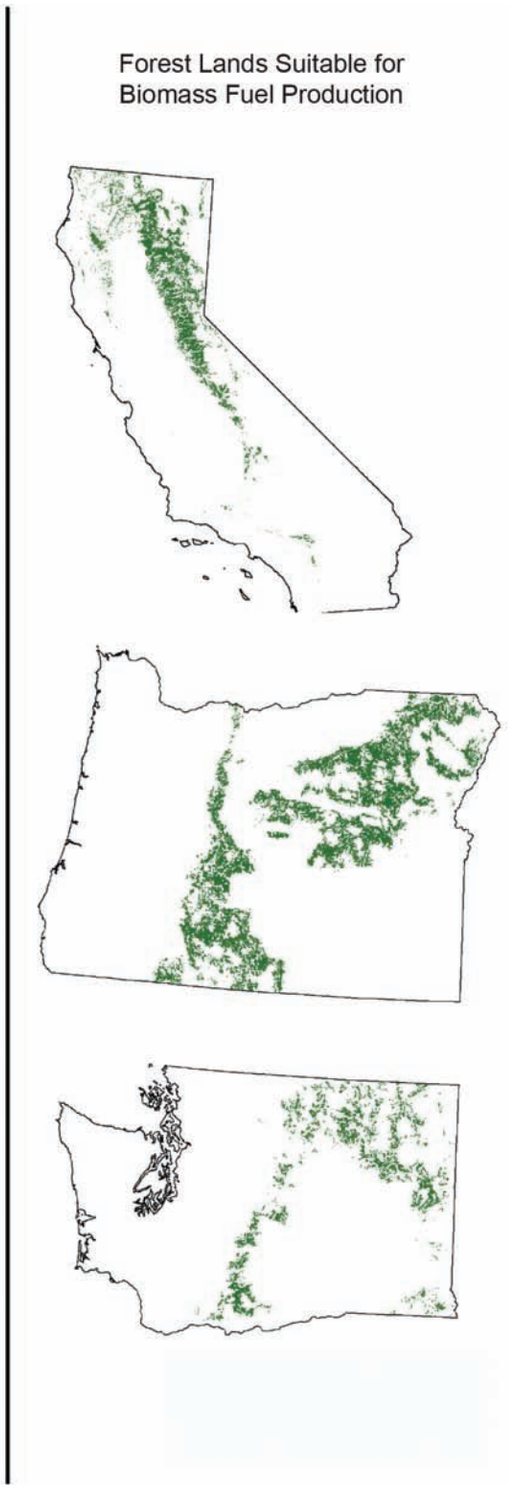












WESTCARB Terrestrial Sequestration Opportunities

Terrestrial carbon sequestration opportunities analyzed for the WESTCARB Region included afforestation of rangelands and agricultural lands, changes in forest management to increase carbon stocks, and improved management of forest fuels to reduce GHG emissions from wildfires, and the use of these fuels in biomass energy facilities.

Afforestation of rangelands was examined for California, Oregon, and Washington on 20-, 40-, and 80-year time periods, including analysis of forest suitability of candidate lands; total costs including opportunity, conversion, maintenance, measurement, and monitoring costs; potential rates of carbon sequestration; and at different prices per metric ton CO_2, the total area and geographic distribution of lands that might be afforested and quantity of carbon thus sequestered.

On agricultural lands, afforestation was analyzed for 20-, 40-, and 80-year projects on hay and wheat lands in Oregon and Washington, and conservation tillage was analyzed for California. Forest management options included widening riparian buffer zones, lengthening harvest rotations in commercial forests, and (for California only) variable retention techniques in commercial forestry operations. Also analyzed was the feasibility of cutting, skidding, chipping, and hauling fuels from wildfire-prone forests to biomass energy plants, including suitability of lands for fuel reduction, treatable area, and biomass yield under typical treatment constraints.

WESTCARB Field Validation Tests

WESTCARB will perform three geologic sequestration pilot tests, two terrestrial sequestration pilot tests, and two CO_2 storage investigations within its region.

Two geologic CO_2 sequestration pilot tests, collectively referred to as the Rosetta Resources CO_2 Storage Project, will be performed in the southern part of the Sacramento River Basin in the Central Valley of California. The Central Valley, composed of the Sacramento River Basin in the north and the San Joaquin River Basin in the south, contains numerous saline formations and oil and gas reservoirs that could be used for geologic storage of CO_2. These Central Valley saline formations are estimated to have a storage capacity of 50–200 billion metric tons (55–220 billion tons) of CO_2, representing a potential reservoir of thousands of years of emissions within the southern Sacramento River Basin near the proposed pilot site. The first pilot test will inject up to 1,000 metric tons (1,100 tons) of CO_2 into a saline formation below the Thornton Gas Field. The second test will inject about 500 metric tons (550 tons) of CO_2 into a depleting compartment of the Thornton Gas Field and assess the extent to which gas recovery can be enhanced due to reservoir pressurization and displacement of methane by CO_2.

The Northern Arizona Saline Formation pilot will investigate CO_2 storage in saline formations in the Colorado Plateau Region in northern Arizona. The occurrence of natural CO_2 accumulations in the Colorado Plateau attests to its potential to store CO_2. Storage capacity within the basin is estimated to be large because of the thickness—more than 100 m (330 ft)—of the potential storage formations and the presence of good seals. Although less studied than California's Central Valley, available well data suggest suitable saline and seal formations may be found in the vicinity of the state's coal-fired power plants. Proximity to these large sources of CO_2 could establish much of the infrastructure needed for a future "integrated" project involving both CO_2 capture and sequestration.

Terrestrial carbon sequestration pilots are initially taking place in Shasta County, California, and Lake County, Oregon. Opportunities for future terrestrial pilots in Washington and Arizona are also being identified. Pilot activities include afforestation (in Shasta County, of rangelands), improved management of forest fuels to reduce emissions from wildfires (and potentially fuel biomass power plants), and conservation-based forest management. Overall objectives are to quantify emission reductions/sequestration attributable to each activity; gather information on costs and benefits to landowners; design measurement, monitoring, and verification methods; evaluate the practicality of existing reporting protocols to capture verifiable reductions at reasonable cost to landowners and carbon credit buyers; explore questions of market validation for terrestrial activities; and evaluate environmental co-benefits.