WESTCARB Phase II Overview

Larry Myer
Technical Director
West Coast Regional Carbon Sequestration Partnership

Sally Benson
Lawrence Berkeley National Laboratory

Richard Rhudy
Electric Power Research Institute

John Kadyszewski
Winrock International

Regional Partnership Review Meeting
October 13, 2005

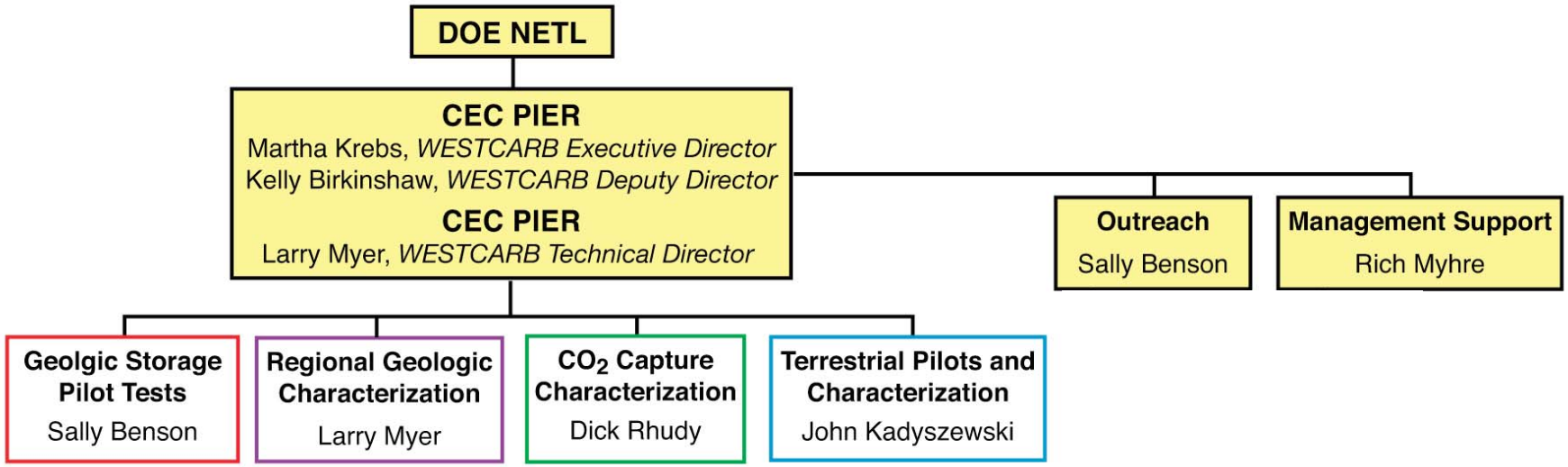
Outline

- **Project overview**
- Geologic storage pilot tests
- CO_2 capture characterization
- Terrestrial pilots and characterization

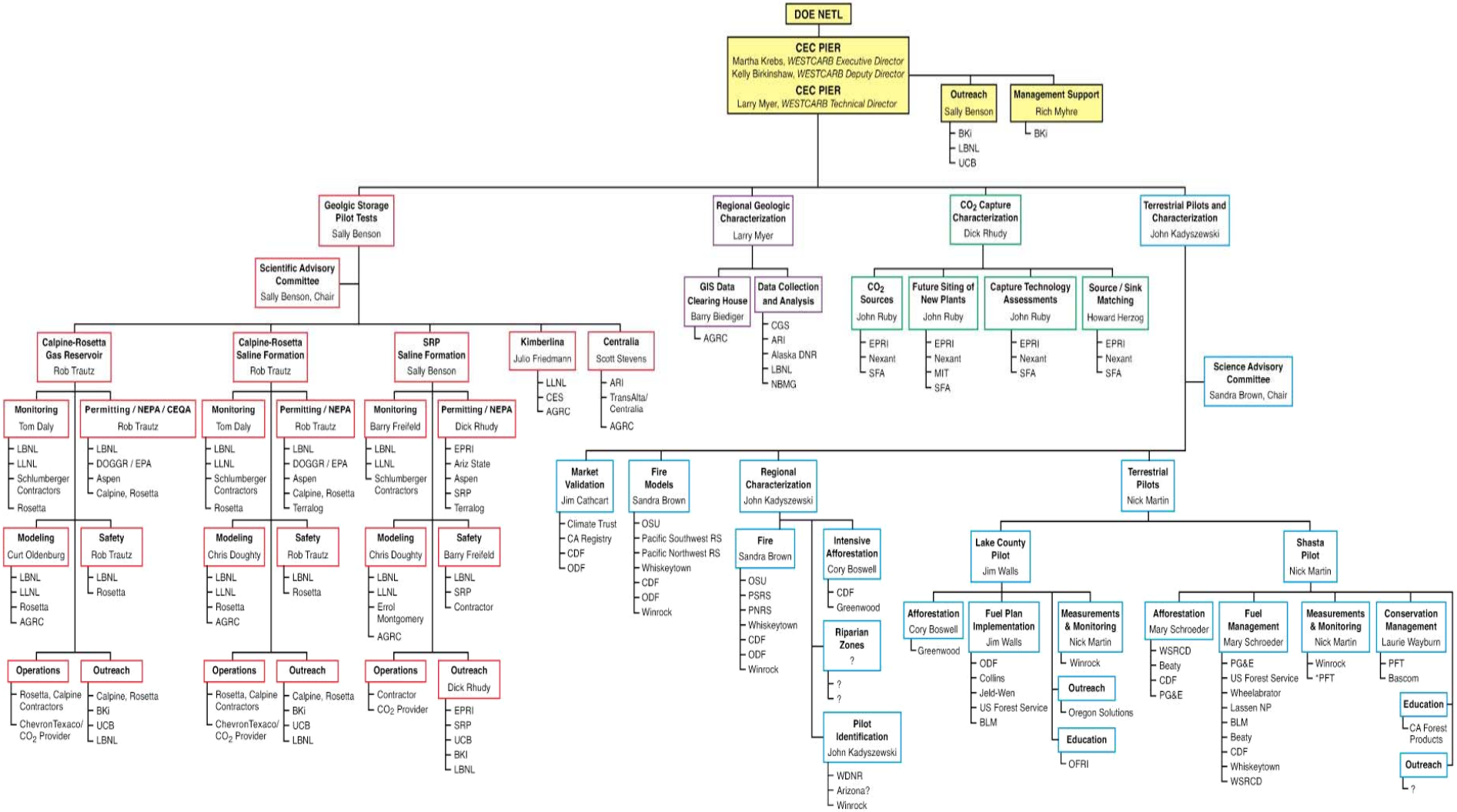
WESTCARB Phase II Participation

- New WESTCARB partners boost membership to 70: Air Liquide, Alaska Department of Natural Resources, Bascom Pacific LLC, California Forest Products Commission, Calpine, Collins Company, DNV Research—Det Norske Veritas, Greenwood Resources, Jeld-Wen Timber and Ranch, Lake County Resources Initiative, Oregon Forest Resources Institute, Oregon State University, Pacific Gas & Electric, Portland General Electric, Rosetta Resources Inc., Schlumberger, USDA Forest Service, US National Park Service, University. of California–Berkeley, Western Shasta Resource Conservation District, Wheelabrator Shasta Energy Company, W.M. Beaty and Associates
- 14 organizations providing cash and in-kind cost share of >$11.5M

WESTCARB Phase II Management Team

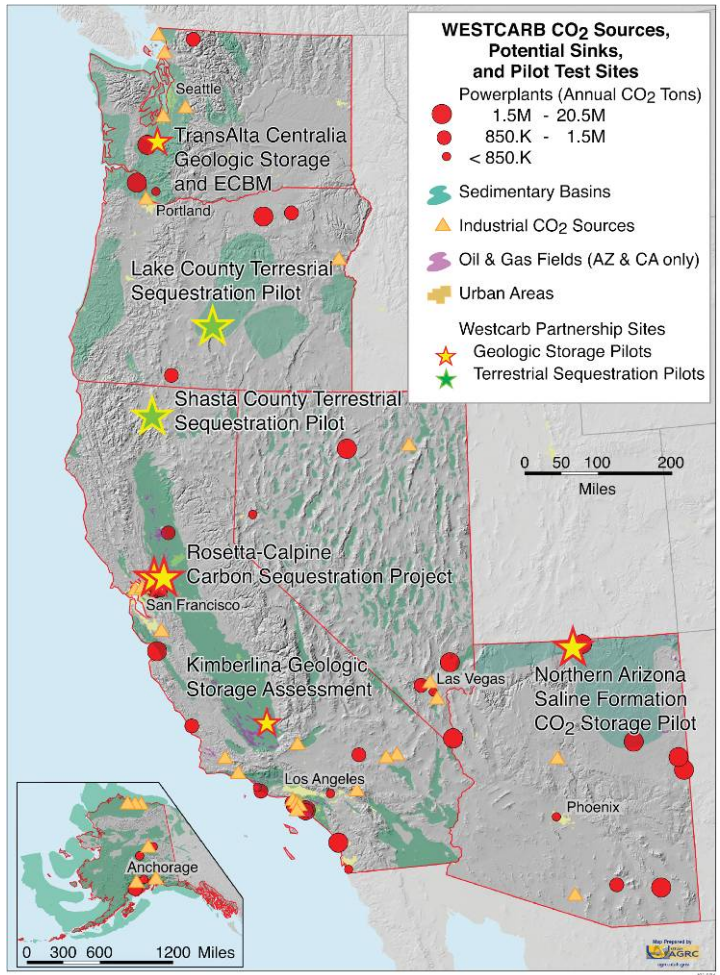


Technical Task Management Structure



Pilots Planned in Arizona, California, Oregon, and Washington

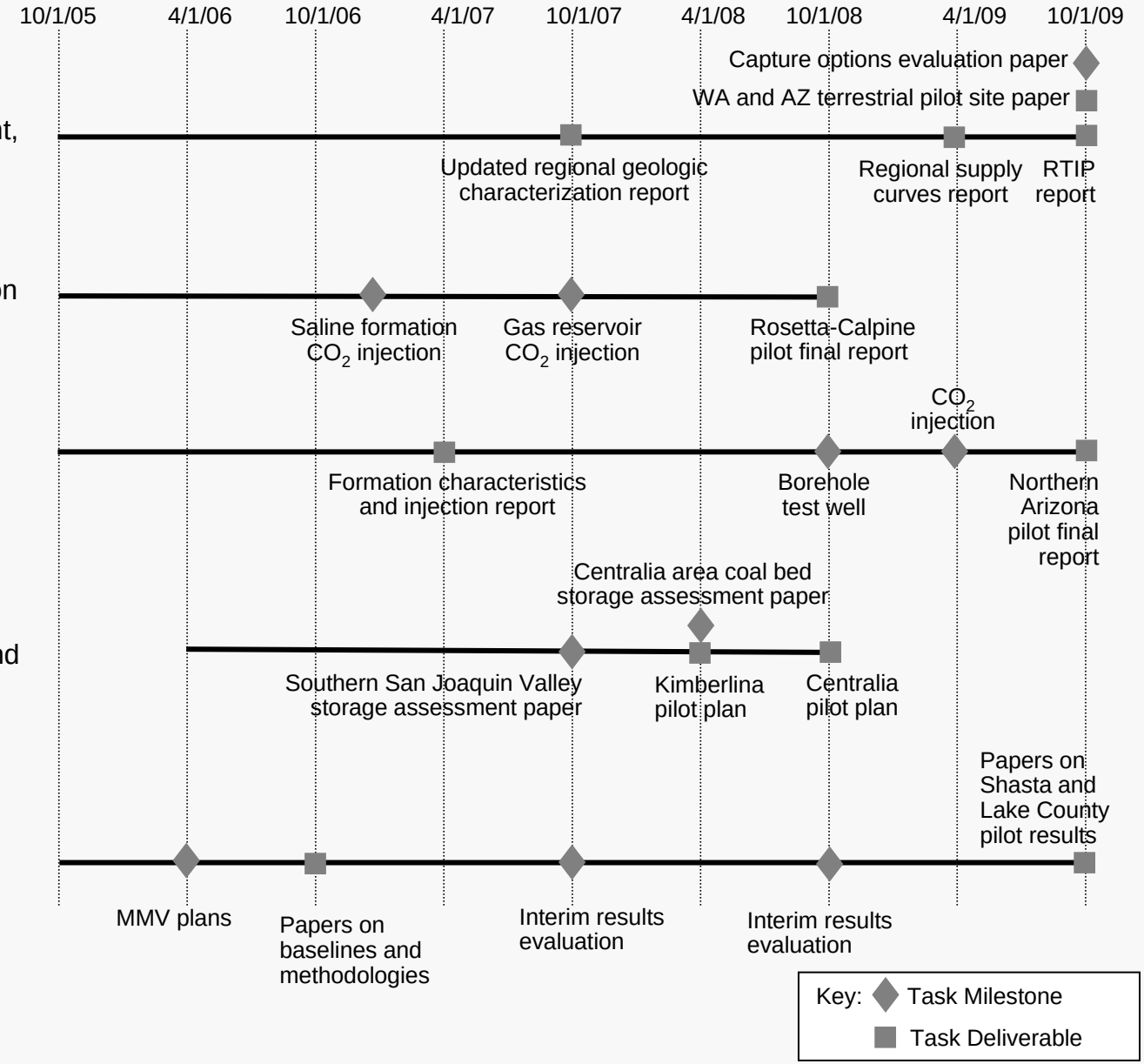
- Pilots are representative of best sequestration options, unique technologies and approaches, in region
- Pilots involve site-specific focus for
  - Testing technologies
  - Assessing capacity
  - Defining costs
  - Assessing leakage risks
  - Gauging public acceptance
  - Testing regulatory requirements
  - Validating monitoring methods



WESTCARB PHASE II SCHEDULE

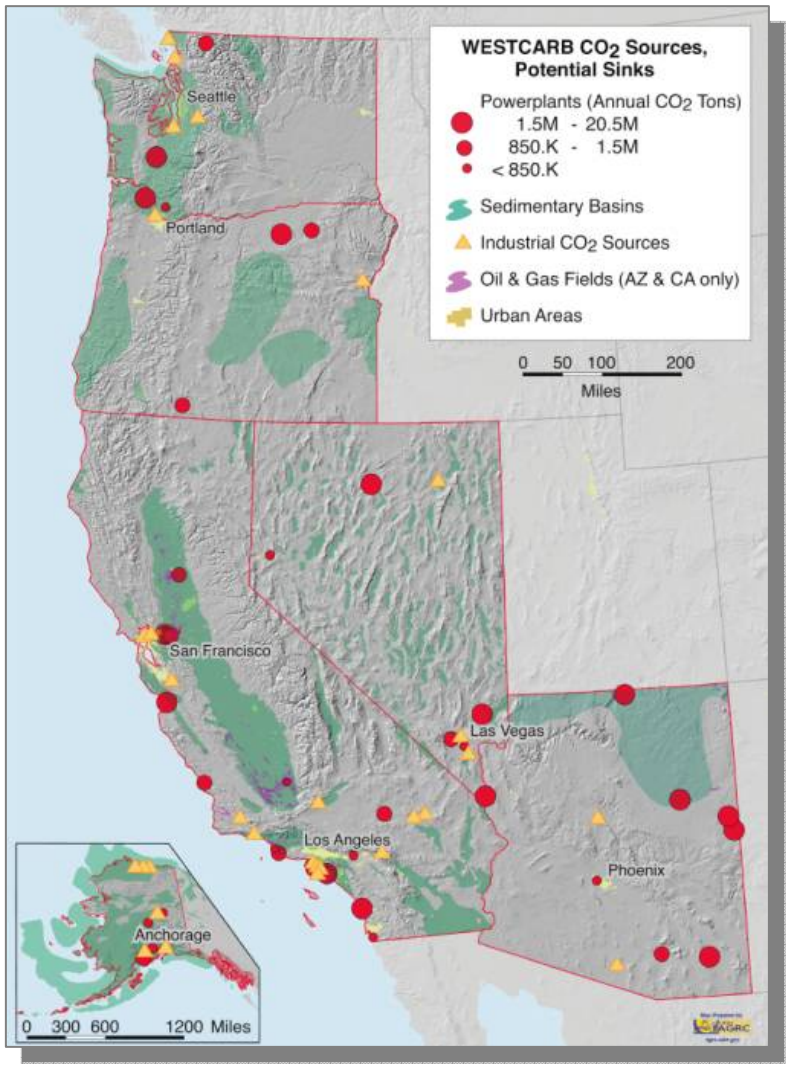
Tasks

1. Continued Regional Characterization, CO_2 Capture Technology Assessment, and Regional Technology Implementation Plan (RTIP)
2. Rosetta-Calpine Carbon Sequestration Saline Formation and Gas Reservoir Pilots
3. Northern Arizona Saline Formation CO_2 Storage Pilot
4. Investigations for Additional CO_2 Storage Pilots (Centralia Coal Bed and Kimberlina Saline Formation/Oilfield)
5. Terrestrial Sequestration Pilots



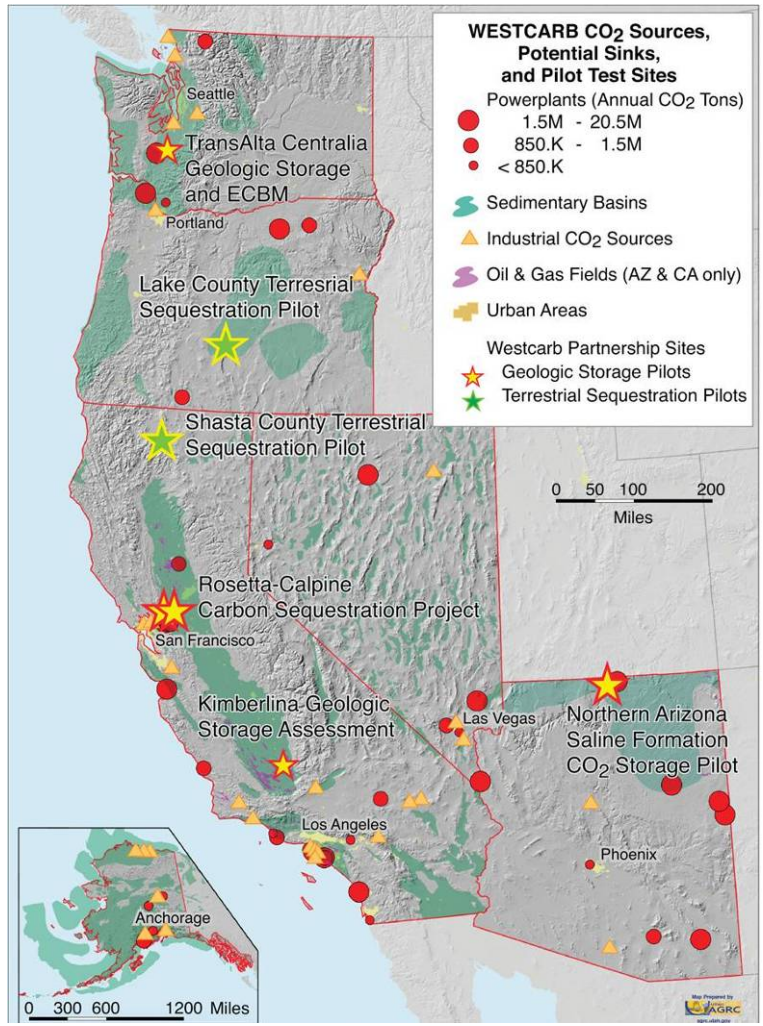
Regional Geologic Characterization Will Be Enhanced

- Additional geologic characterization of sedimentary basins
- Calculation of storage capacity
- GIS data made available through Utah AGRC and NATCARB



WESTCARB Geologic Storage Pilots

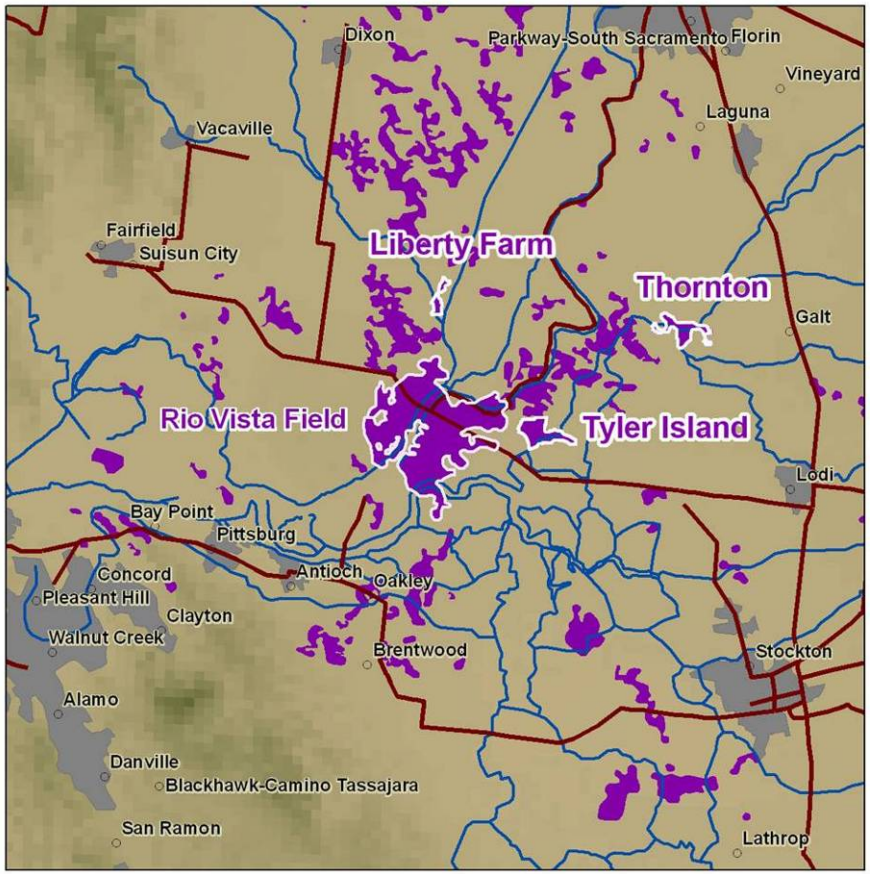
- Rosetta-Calpine Carbon Sequestration Project
- Northern Arizona Saline Formation CO_2 Storage Pilot
- Kimberlina Geologic Storage Assessment
- TransAlta Centralia Geologic Storage and ECBM Assessment



Outline

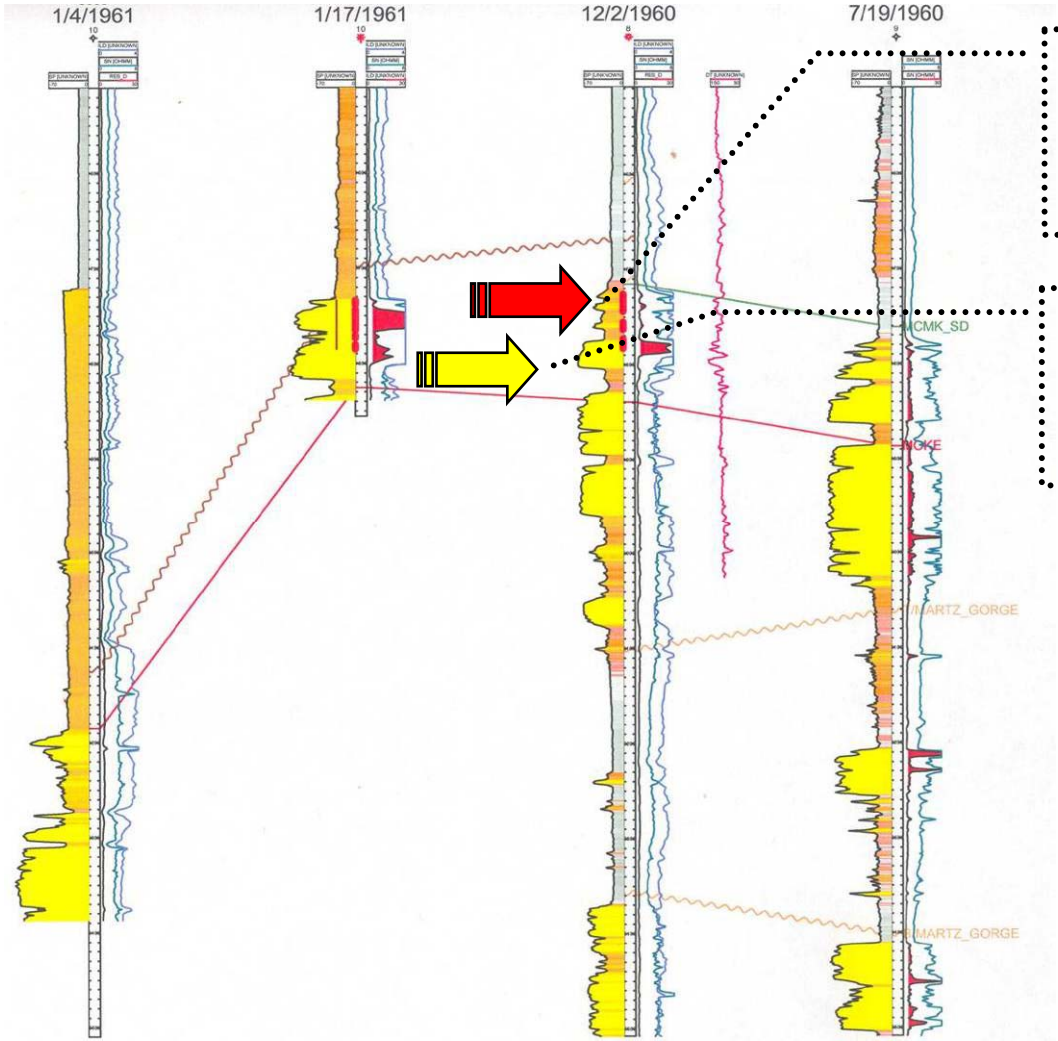
- Project overview
- **Geologic storage pilot tests**
- CO_2 capture characterization
- Terrestrial pilots and characterization

Rosetta-Calpine Carbon Sequestration Project



- Preliminary estimate of 1.8 $GtCO_2$ storage capacity in depleted gas fields in Sacramento Valley (128 fields)
- Preliminary estimate of 140-840 $GtCO_2$ storage capacity in saline formations in California, based on ten largest basins

Rosetta-Calpine: Geological Cross-Section



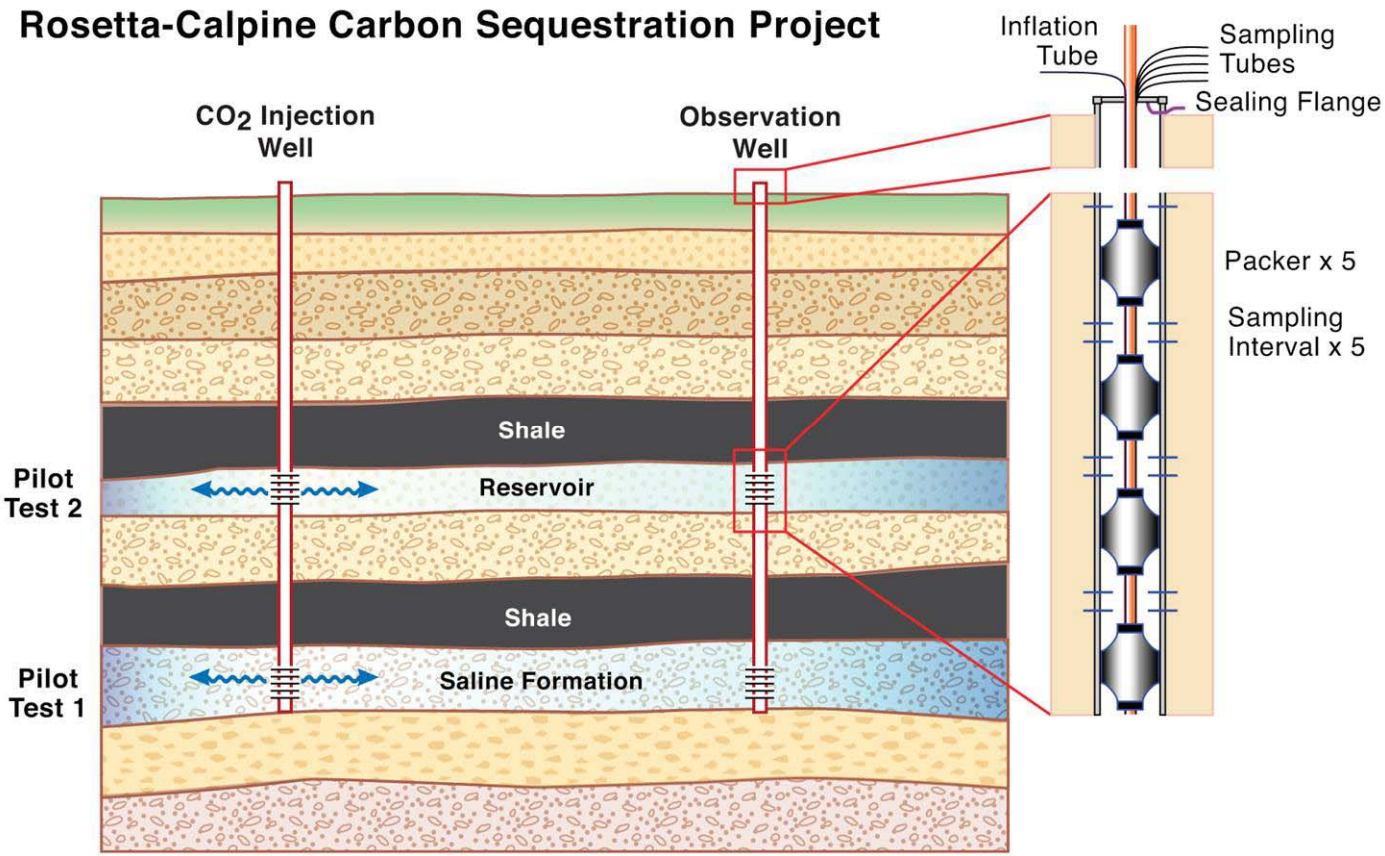
Depleted gas and EGR pilot test (~2000 tonnes CO_2 injection)

Saline formation pilot test (~2000 tonnes CO_2 injection)

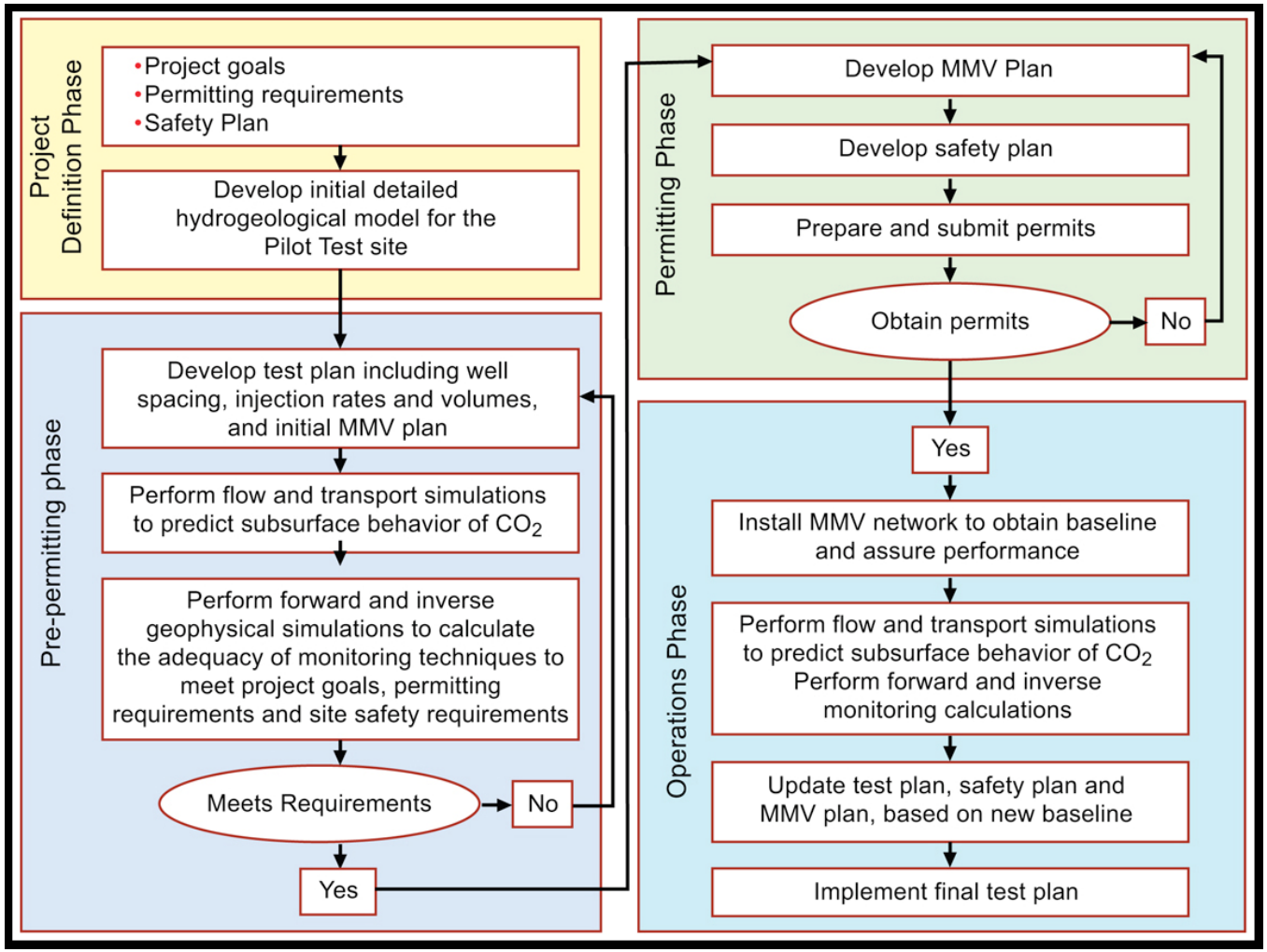
Compliments of Rob Trautz, LBNL

Rosetta-Calpine: Two-Well Pilots

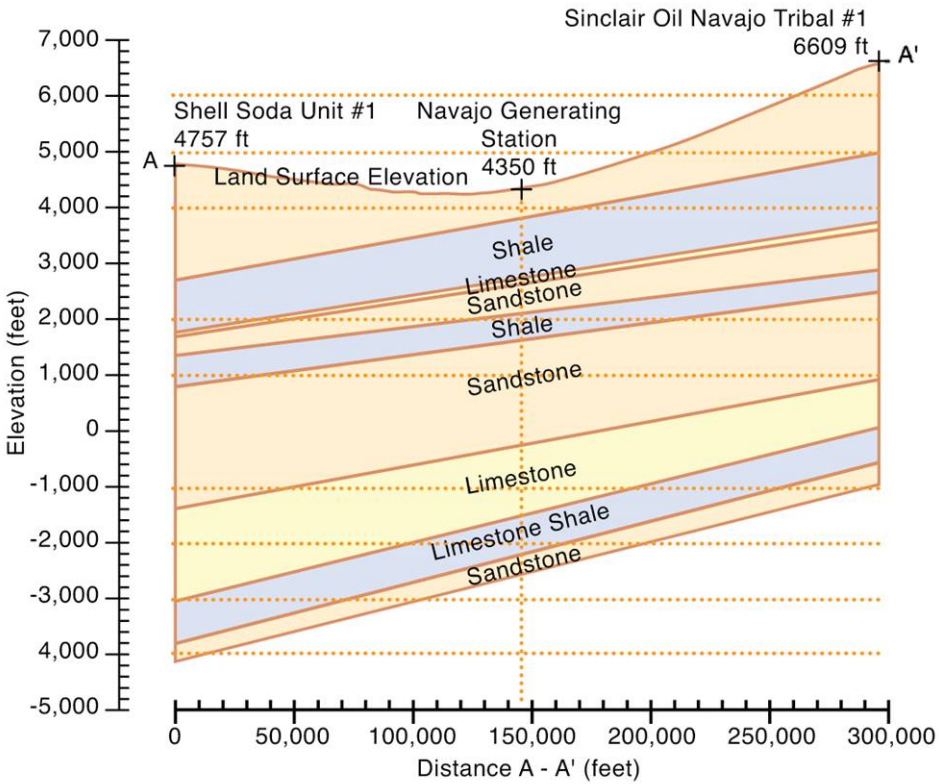
- Fluid and gas sampling
- Cross-well seismic
- VSP
- Reservoir pressure and temperature
- Well logs, including possible RST



Rosetta-Calpine: Project Plan



Northern Arizona Saline Formation CO_2 Storage Pilot

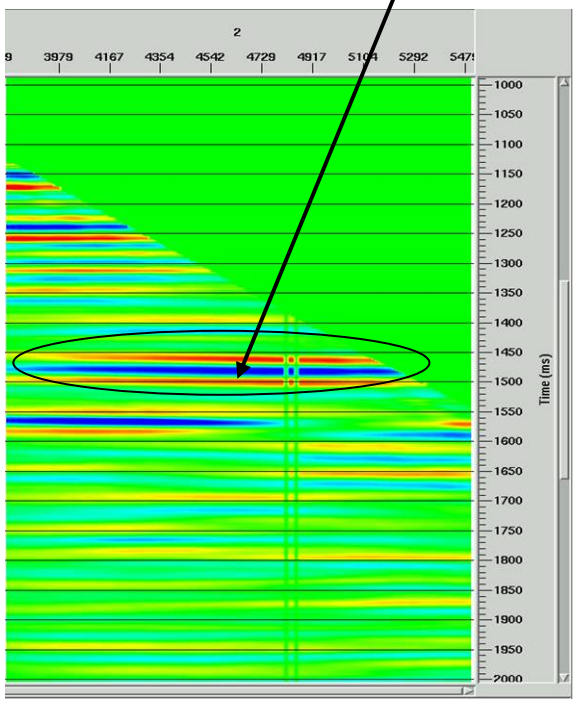


Large but uncharacterized storage capacity in the Colorado Plateau and basins of northern Arizona

Northeastern Arizona

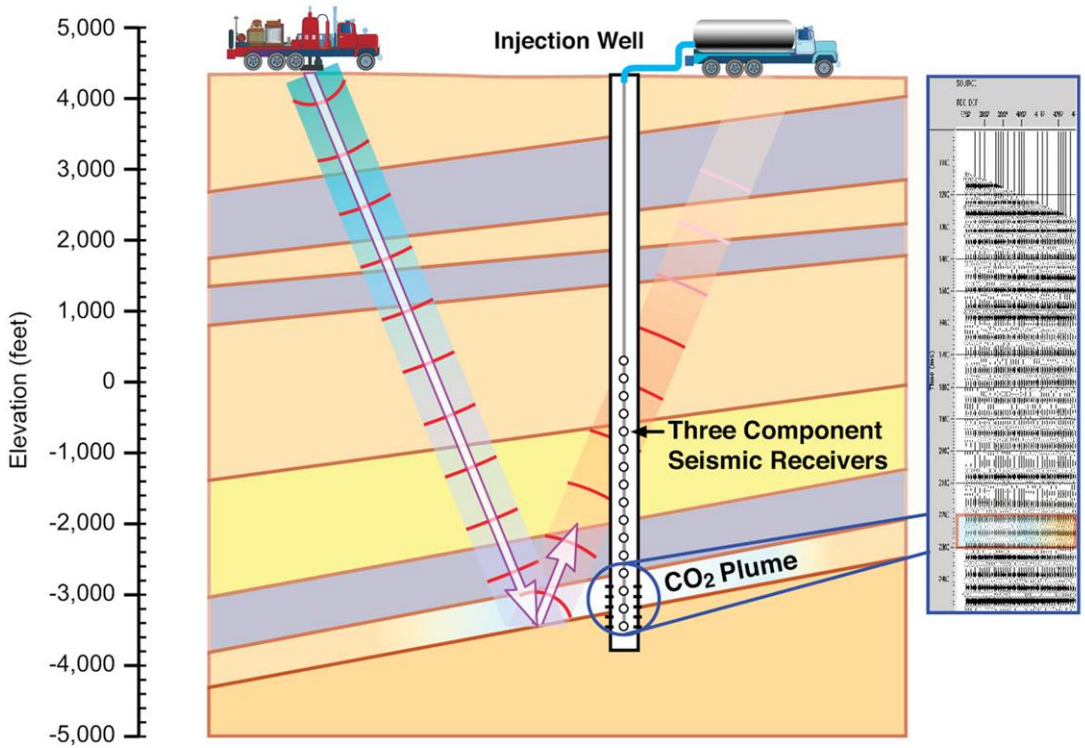
Northern Arizona Saline Formation CO_2 Storage Pilot (cont'd)

Reflection from 1600 tonne CO_2 plume



VSP Results from Frio Formation

Single-well test plan



2000 tonne CO_2 injection

TransAlta Centralia Geologic Storage and ECBM Assessment

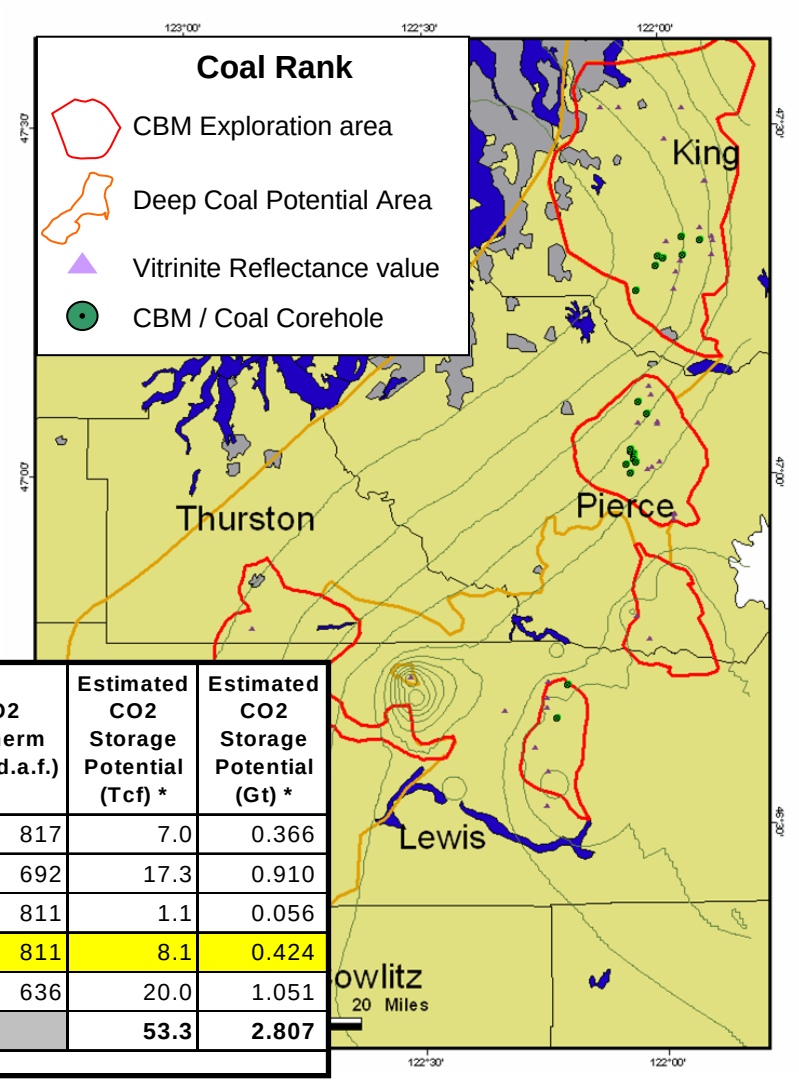
Centralia Generating Station

Assess ECBM and storage potential

Coal bed

Puget, WA Deep Coals Could be Sink for Centralia Plant

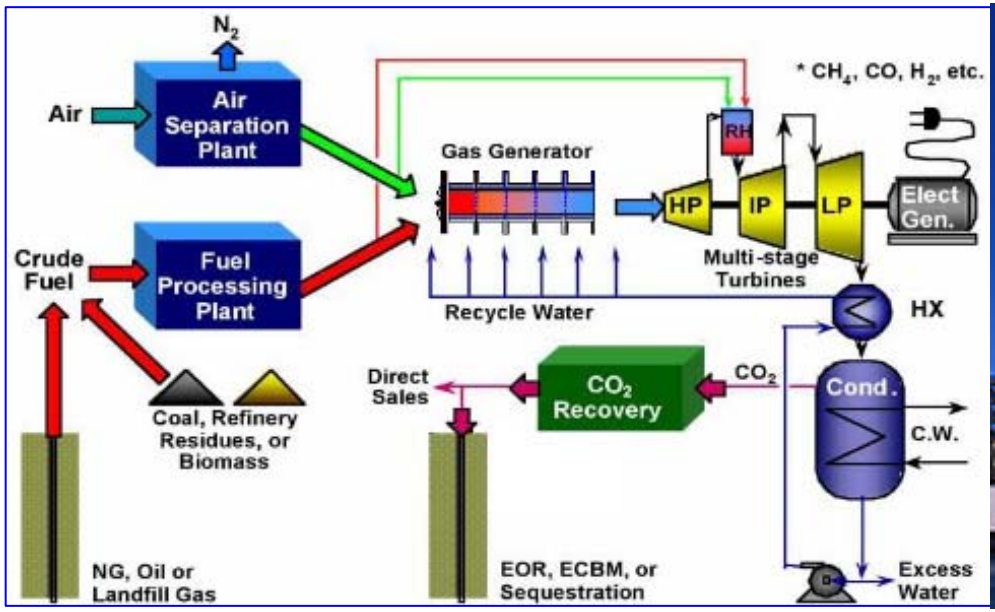
- Favorable coal rank: subbituminous in the W to anthracite in E
- El Paso Production pilot tested 5 md permeability in coals



Sub-Basin	Area (sq mi)	Avg Coal Thickness (ft)	Ash + Moisture (%)	Net Coal Tonnage (million tonnes)	Avg Depth (ft)	CO2 Isotherm (scf/t d.a.f.)	Estimated CO2 Storage Potential (Tcf) *	Estimated CO2 Storage Potential (Gt) *
Carbonado	125	130	57%	8,513	1,691	817	7.0	0.366
Black Diamond	466	110	60%	24,979	1,550	692	17.3	0.910
Storm King	57	65	71%	1,309	1,860	811	1.1	0.056
Centralia	209	100	61%	9,930	1,860	811	8.1	0.424
Rest of Puget Region	1,777	50	71%	31,391	1,500	636	20.0	1.051
Totals	2,634			76,122			53.3	2.807

* Represents TOTAL available potential for each region; actual Stored volume would be significantly less (~15-50%)

Kimberlina Geologic Storage Assessment



CES power plant

Images from Clean Energy Systems, Inc.
http://www.cleanenergysystems.com/

Kimberlina: Assess Storage and EOR Opportunities

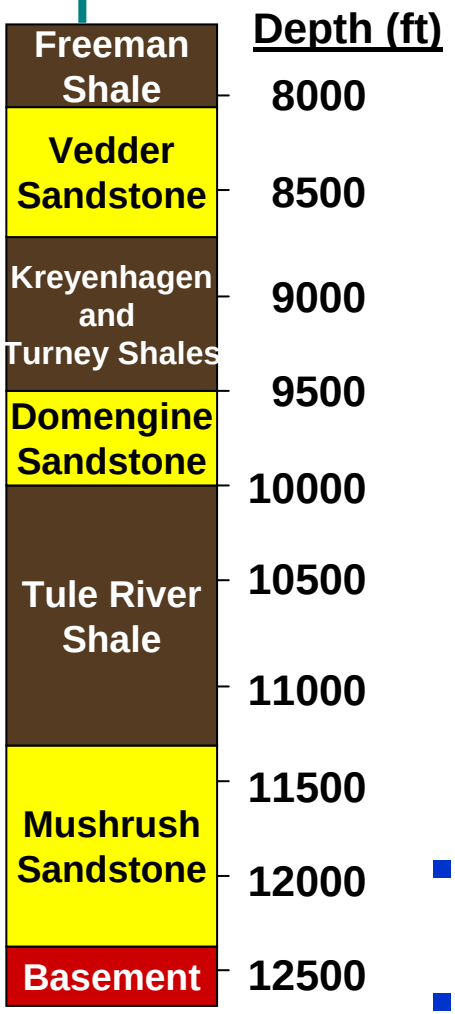
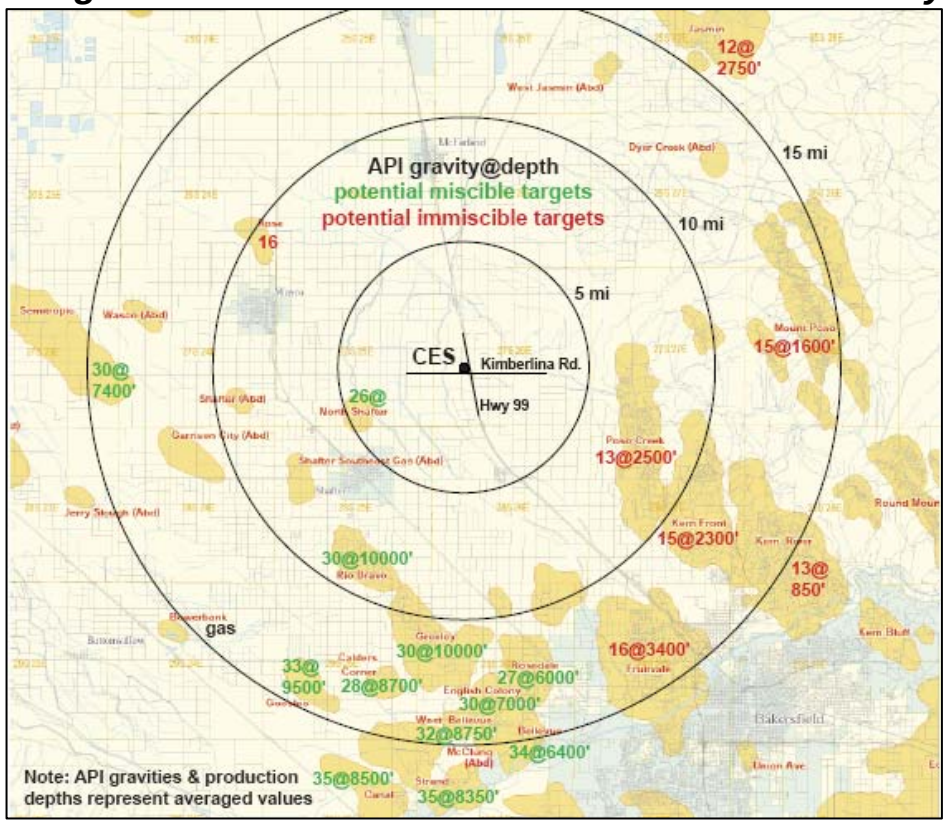


Image from Lawrence Livermore National Laboratory



- Preliminary estimate of 3.4 $GtCO_2$ storage capacity in 121 oil fields in California
- Potential for 5.4 billion barrels of oil production with CO_2-EOR in California

DOE Roadmap Goals for Geological Storage of CO_2 and WESTCARB Contributions

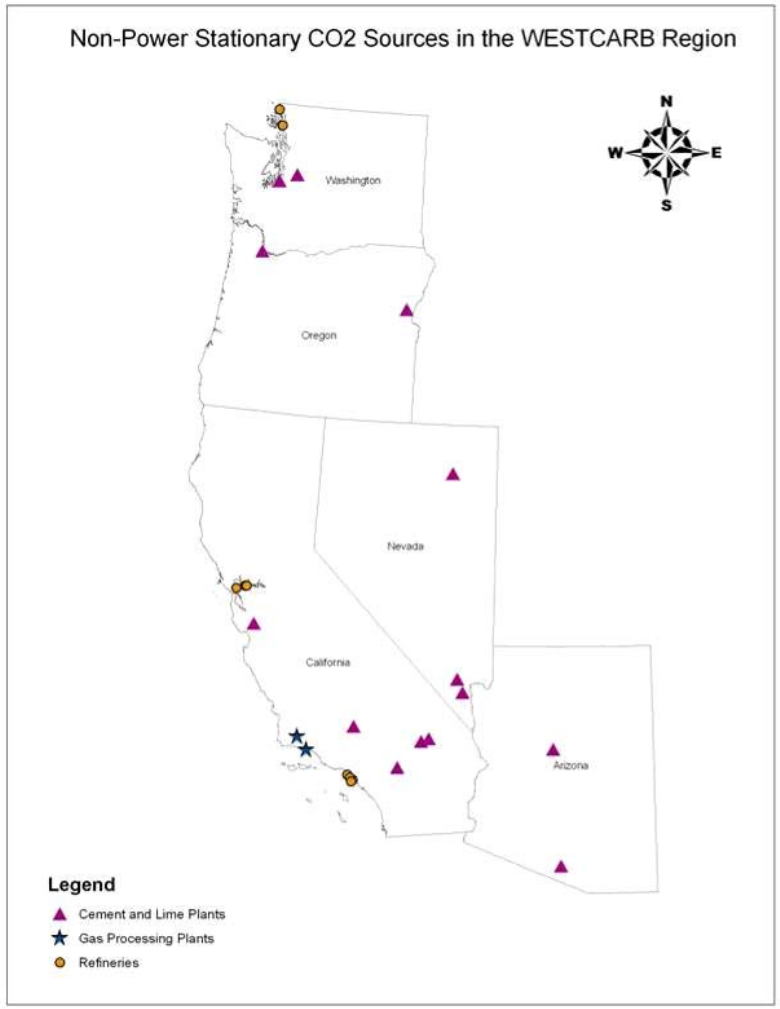
Storage Security and Permanence	Storage Capacity and Optimization	Measurement Mitigation and Verification
▪ Demonstrate safe and secure storage in a depleting gas reservoir ▪ Demonstrate safe and secure injection into 2 saline formations ▪ Improve understanding and modeling of multi-phase flow and residual gas trapping in a saline formation ▪ Improve understanding and modeling of solubility trapping ▪ Predict mineral trapping rates and quantities in two different geologic settings	▪ Perform the first ever test of CO_2-EGR in a natural gas reservoir ▪ Improve understanding and modeling of CO_2 storage capacity in heterogeneous high permeability sandstones ▪ Improve understanding and modeling of storage capacity in lower permeability, highly consolidated sandstones ▪ Develop methods for predicting storage capacity in depleting gas reservoirs ▪ Improve capacity estimation methodology by history matching the injection pilots	▪ Develop methods for monitoring CO_2 storage in gas reservoirs ▪ Test methods for monitoring permeability changes due to CO_2 injection ▪ Enhance and demonstrate the utility of VSP for monitoring CO_2 mitigation from single-well pilot tests ▪ Demonstrate and refine the use of cross-well seismic monitoring to achieve high resolution images of CO_2 migration ▪ Demonstrate and expand the utility of down-hole pressure measurements for monitoring CO_2 injection operations

Outline

- Project overview
- Geologic storage pilot tests
- **CO_2 capture characterization**
- Terrestrial pilots and characterization

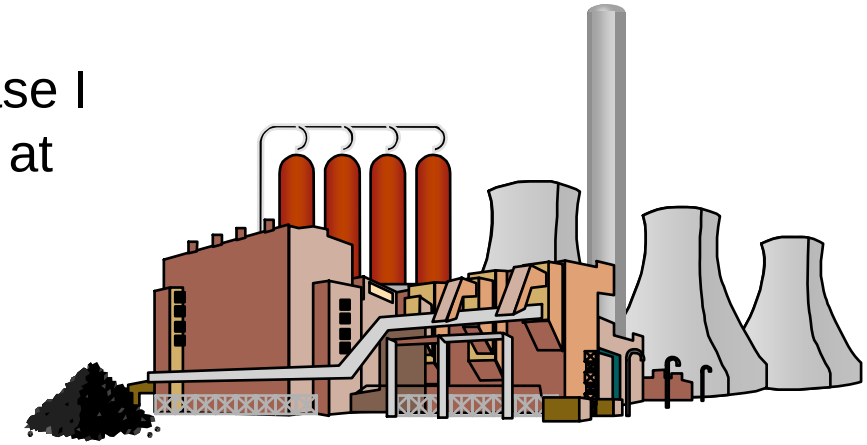
Phase II Activities—Sources

- Power generation data will be updated and expanded to include new and planned facilities
- Non-power-generation industry sources will be asked to provide data for CO_2 and other emissions
- If the industries are reluctant to provide data, as was the case in Phase I, several plants will be selected and examined individually



Phase II Activities—Sources (cont'd)

- Our current assumptions in Phase I are that new plants will be sited at existing plant locations
- To test this assumption, a study will be initiated on future siting of new plants



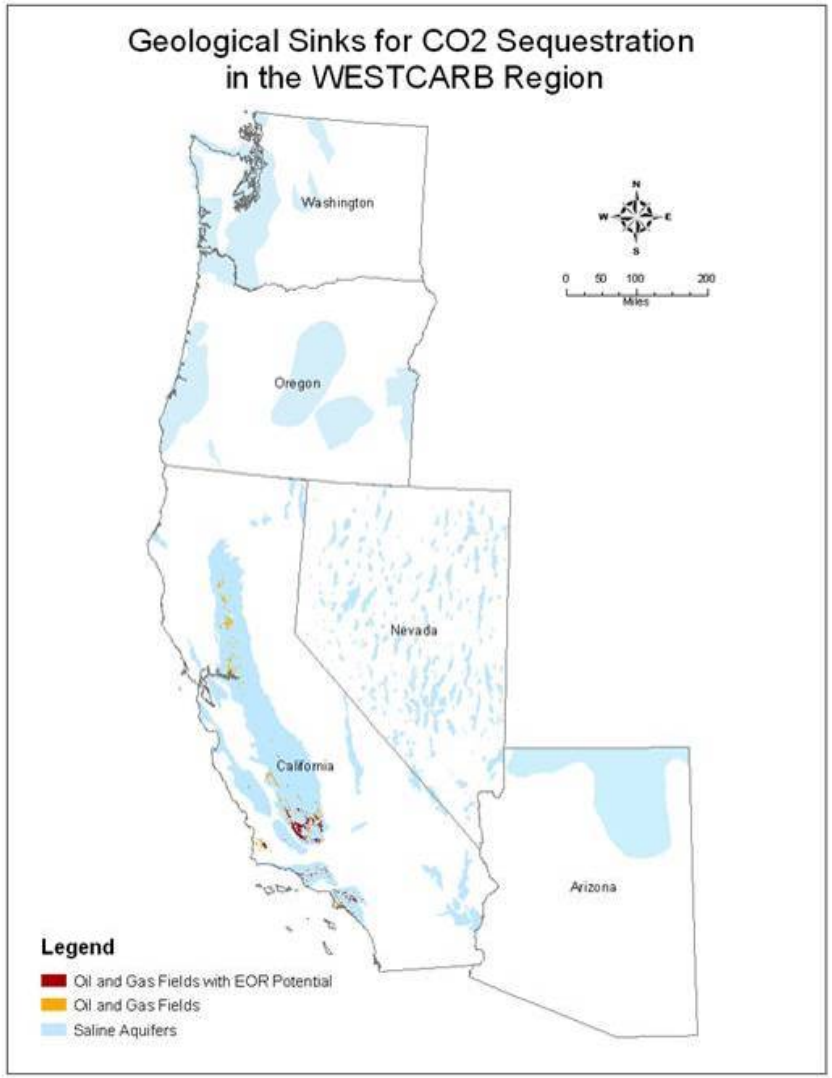
- Consideration will be given to the tradeoffs between fuel, power load location, and CO_2 storage location in siting new plants
- Three types of plants will be evaluated—natural gas, coal, and a refinery producing coke as fuel
- Sites for consideration will be near the CO_2 validation test locations

Phase II Activities—Site-Specific Studies of Capture

- To gain a better understanding of how the options at a specific plant differ from the generic evaluation used for the regional options study, several site-specific studies will be undertaken
- Currently planned for plant sites being considered for the CO_2 storage validation projects
- Each evaluation will examine the appropriate separation and capture technologies and estimate the impacts of their installation on the performance and costs of existing plants
- Separation and capture technology developers will be contacted to update estimates of performance, costs, and commercial readiness of their processes
- Engineering documents to be produced include process energy and material balances, major equipment lists, cost estimates, and drawings to show how separation and capture facilities will be arranged on-site
- Results will be compared to the generic evaluations to help determine the uncertainty in results from the regional options work

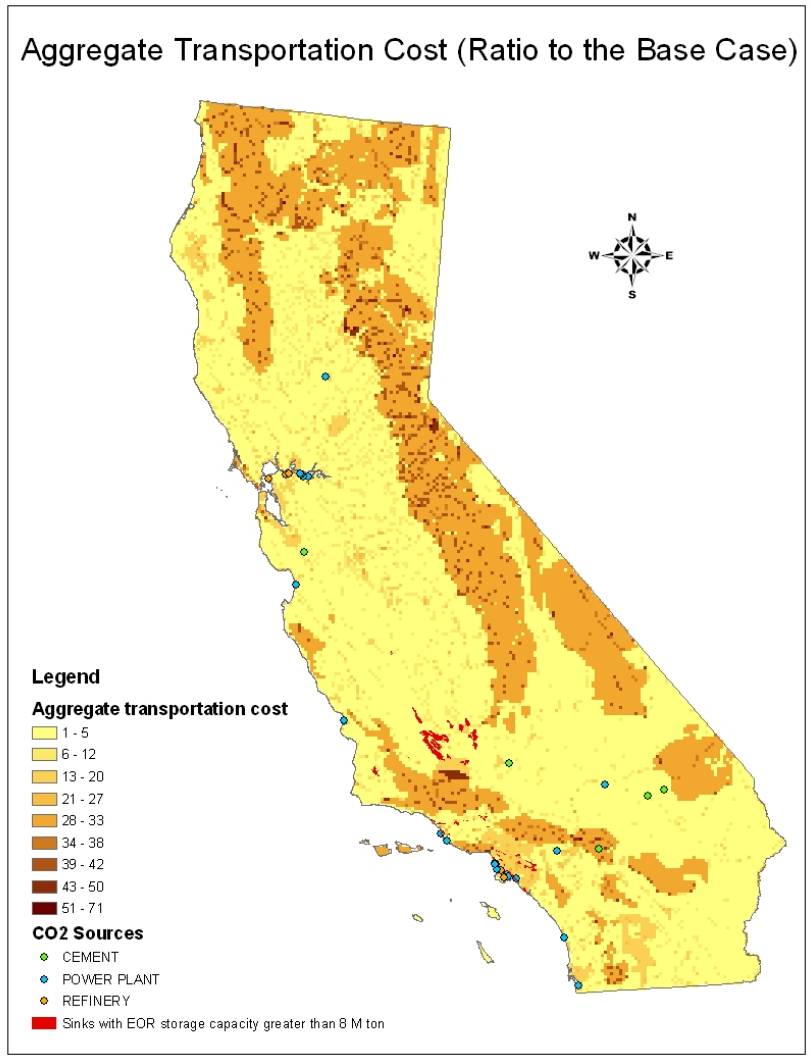
Phase II Activities—Source-Sink Matching

- Improved screening criteria (to determine best prospective reservoirs)
  - Phase I: limited to EOR and ECBM
  - Phase II: expand to gas reservoirs, saline formations, and coal beds
- Improved data for reservoirs (spatial extent, thickness, porosity)
- Improved methodology to determine fraction of pore space accessible for storage



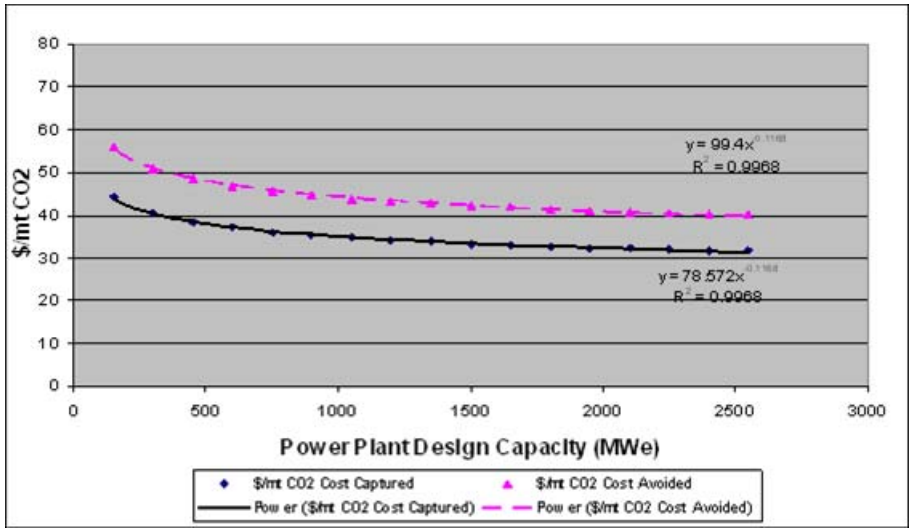
Phase II Activities—Source-Sink Matching (cont'd)

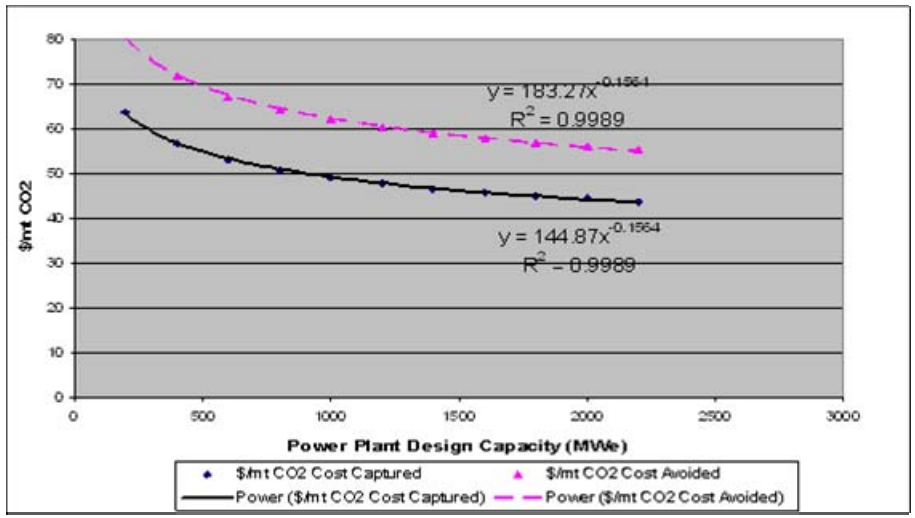
- Consider topography and existing rights-of-way in determining paths between sources and sinks
- Balance capacities of sources and sinks when doing match



Phase II Activities—Source-Sink Matching (cont'd)

- Review all capture algorithms and update with current information
- Revise capture cost algorithm from generic model used in Phase I to specific models for each type of CO_2 source





Outline

- Project overview
- Geologic storage pilot tests
- CO_2 capture characterization
- **Terrestrial pilots and characterization**

Phase II Terrestrial Sequestration Overview

- Objectives
- Shasta County Pilot
  - Afforestation
  - Fuel treatments to reduce uncharacteristically severe fires
  - Conservation management on timberlands
- Lake County Pilot
  - Fuel treatments to reduce uncharacteristically severe fires
  - Assess sequestration potential for hybrid poplars
- Additional Characterization Activities
  - Enhanced fire analysis
  - Sequestration potential of fast-growing species
  - Improved baseline methodologies for conservation and fire

Phase II Objectives: Terrestrial Sequestration

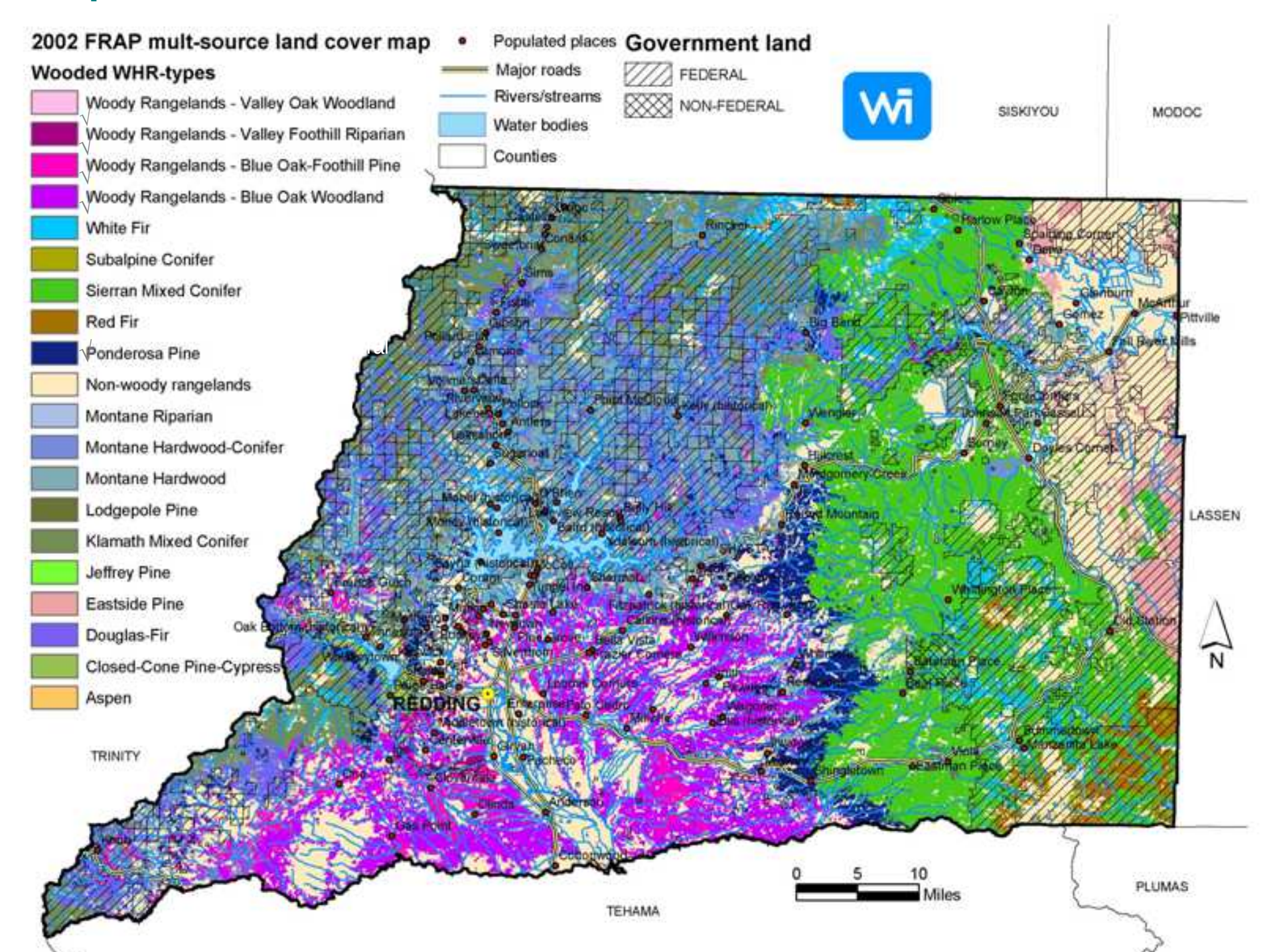
- Validate afforestation potential for rangelands
  - Determine baselines
  - Use plantings of native species across suitable rangeland site classes to establish sequestration potential on rangelands
  - Determine growth rates and establishment costs for fast-growing species adapted for dry sites
- Develop and implement methodology for determining credits for reducing emissions from uncharacteristically severe fires
  - Assess sequestration benefits and costs for implementing new fire management methods
  - Achieve market recognition of methodology for measuring and reporting carbon benefits from changing fire management
- Implement project to reduce emissions through conservation and sustainable management of forest lands

Shasta County Partners

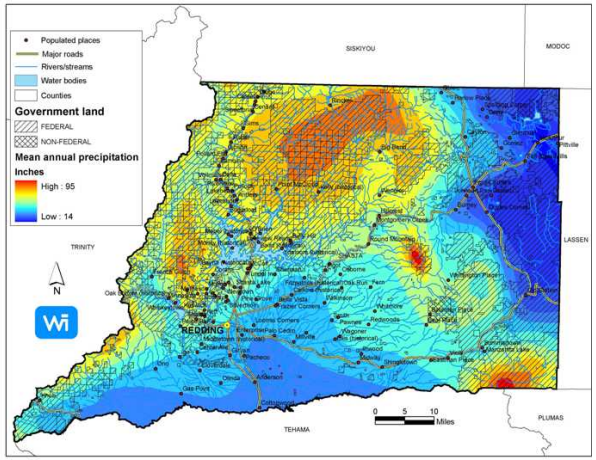
- Western Shasta RCD
- WM Beaty and Associates
- Pacific Forest Trust
- Wheelabrator Shasta
- California Climate Action Registry
- Climate Trust
- California Department of Forestry and Fire Protection
- California Energy Commission
- California Forest Products Commission
- US Forest Service
  - Pacific Southwest Research Station
  - Pacific Northwest Research Station (Pacific Wildland Fire Sciences Laboratory, FERA)
  - Shasta Trinity National Forest
- National Park Service
  - Whiskeytown National Recreation Area
  - Lassen Volcanic National Forest
- Bureau of Land Management
- Pacific Gas & Electric
- Bascom Pacific LLC

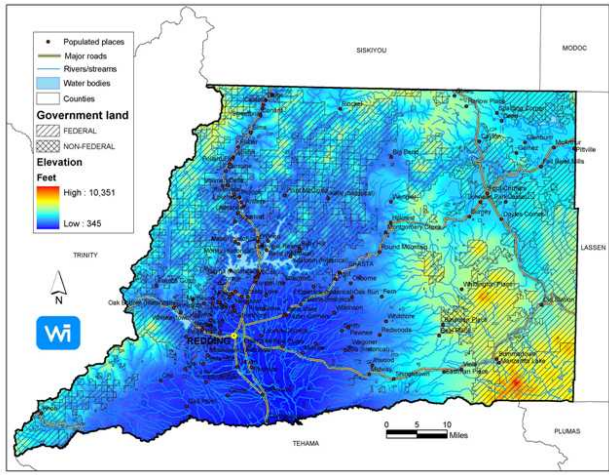
Validate Afforestation Potential of Rangelands

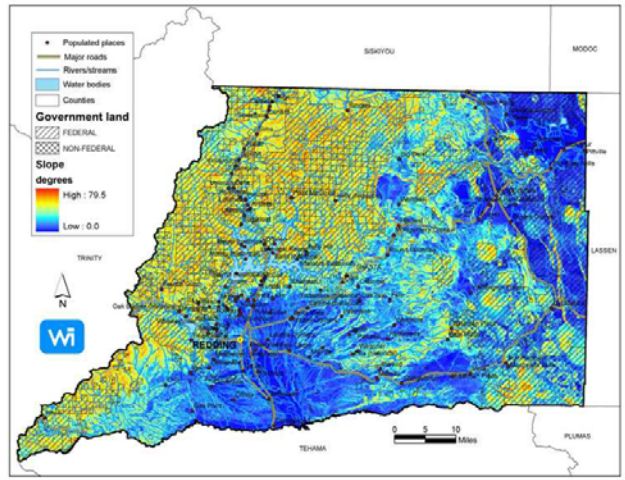
- Classify lands according to potential for afforestation
- Set criteria for distribution of pilot plantings
- Prepare plan for planting
- Convene technical panel to review choices
- Review site history and take initial field measurements (baseline)
- Collect data on establishment and maintenance costs

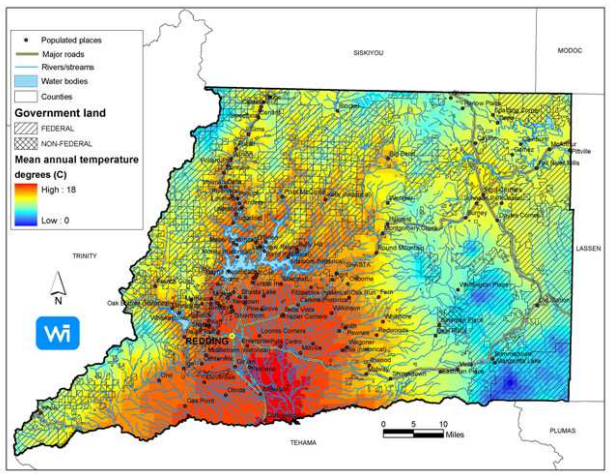

2002 FRAP mult-source land cover map
Wooded WHR-types
Woody Rangelands - Valley Oak Woodland
Woody Rangelands - Valley Foothill Riparian
Woody Rangelands - Blue Oak-Foothill Pine
Woody Rangelands - Blue Oak Woodland
White Fir
Subalpine Conifer
Sierran Mixed Conifer
Red Fir
Ponderosa Pine
Non-woody rangelands
Montane Riparian
Montane Hardwood-Conifer
Montane Hardwood
Lodgepole Pine
Klamath Mixed Conifer
Jeffrey Pine
Eastside Pine
Douglas-Fir
Closed-Cone Pine-Cypress
Aspen
Populated places
Major roads
Rivers/streams
Water bodies
Counties
Government land
FEDERAL
NON-FEDERAL
SISKIYOU
MODOC
LASSEN
PLUMAS
TEHAMA
TRINITY
REDDING
N
0 5 10
Miles

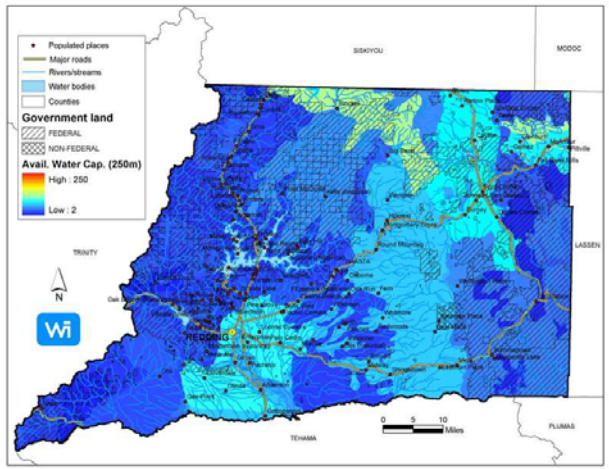
Inputs for Classification





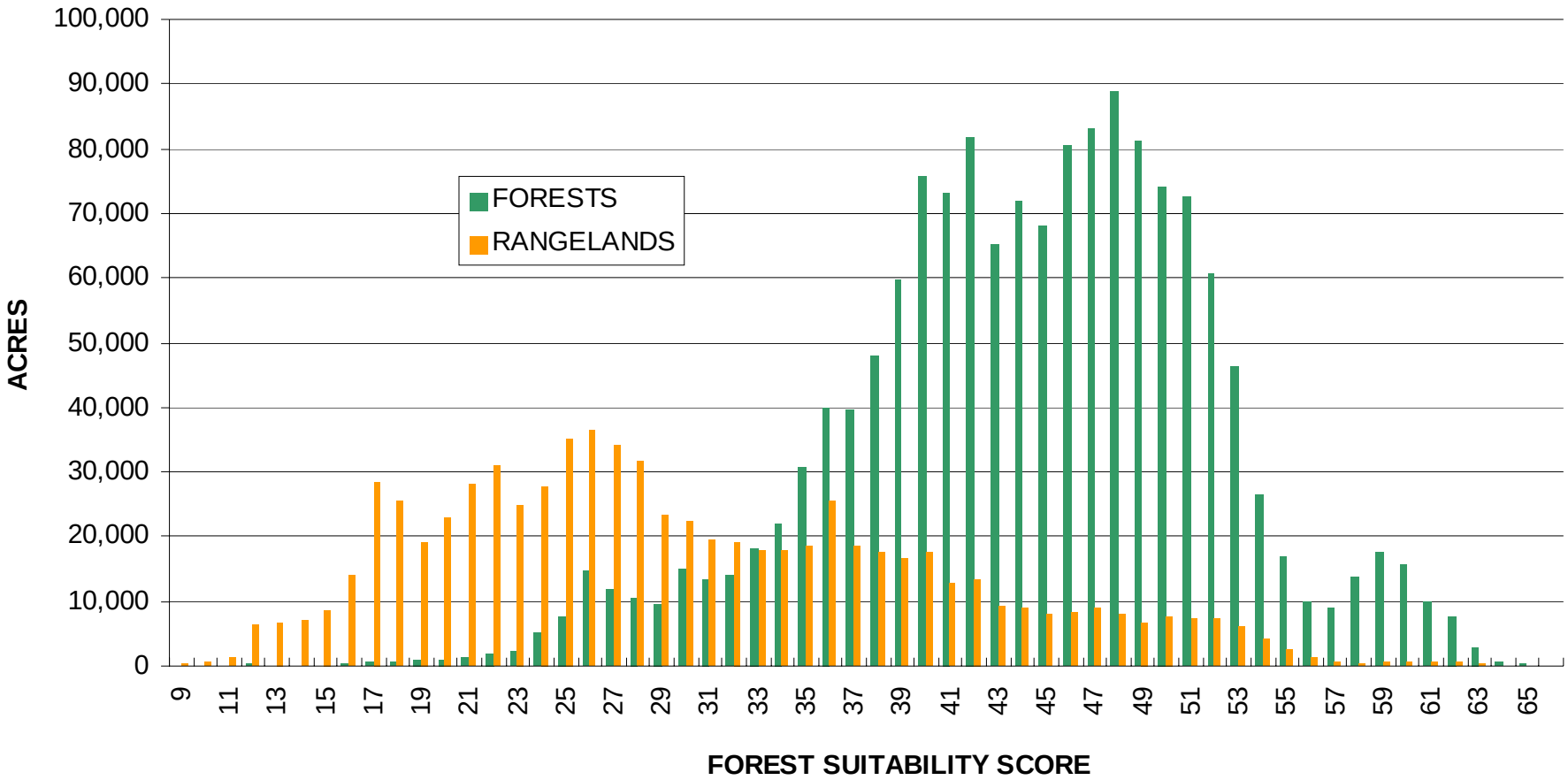




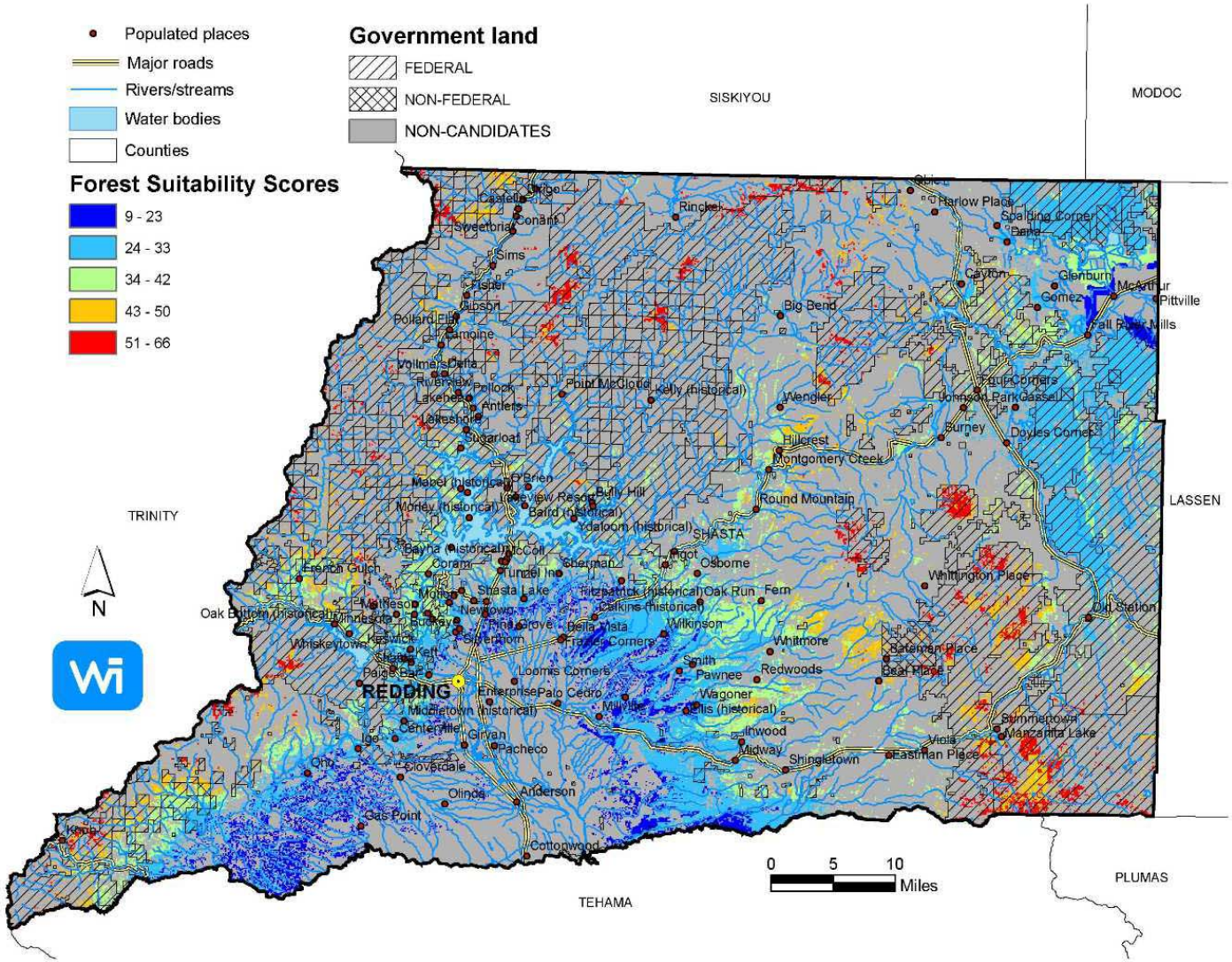


Shasta County Forest Suitability

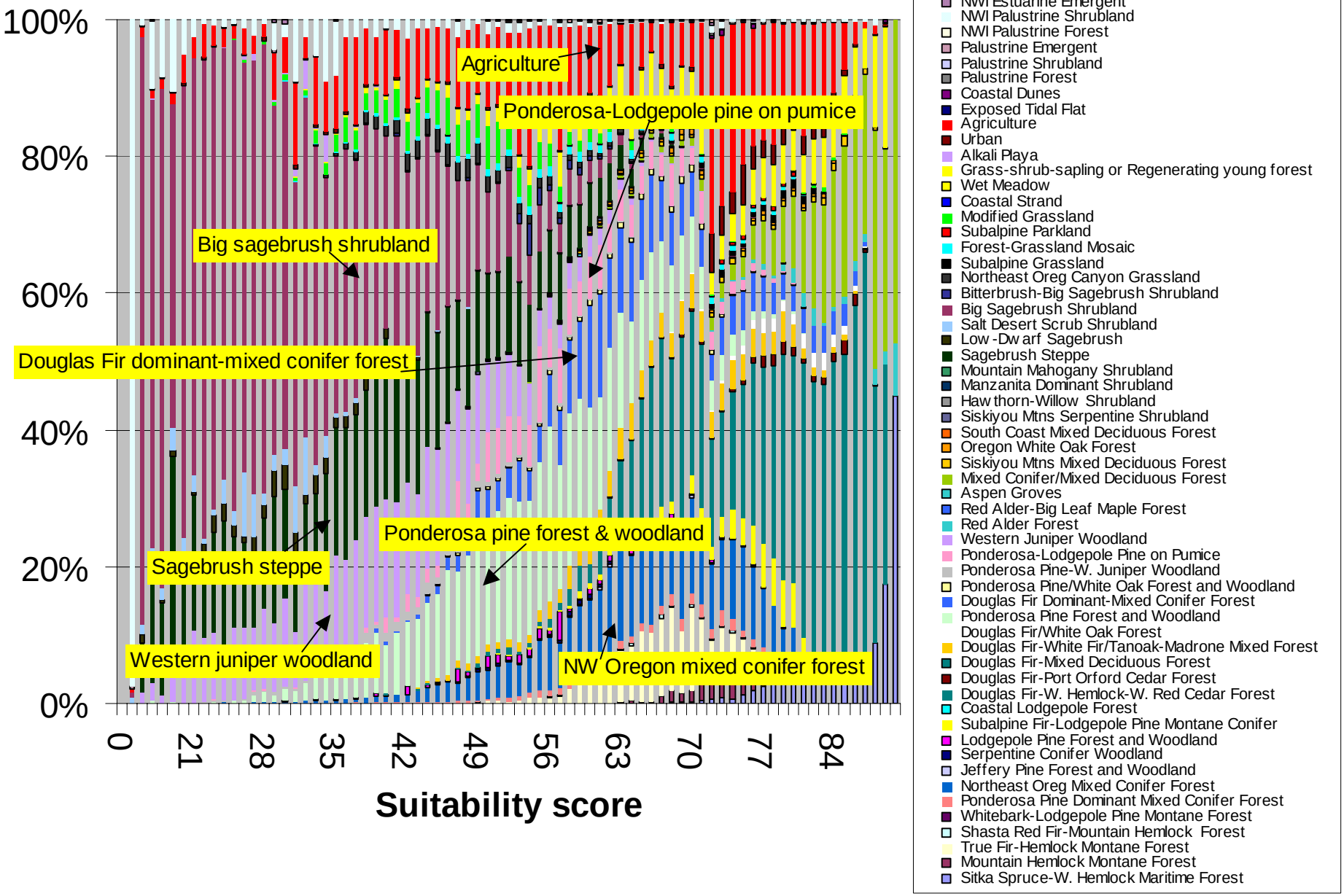
Overlap of rangeland classes in Shasta County (with canopy closure <40%) that have the same biophysical characteristics as current forests ~550,000 acres or 73% of rangelands in county



Existing Rangelands Suitable for Forests



Species Mix for Various Suitability Scores



Site History and Initial Carbon Stocks

Lake County Partners

- Lake County Resources Initiative
- Oregon Department of Forestry
- Oregon State University
- Greenwood Resources
- California Climate Action Registry
- Climate Trust
- Oregon Forest Resources Institute
- Collins Company
- Jeld-Wen Timber and Ranch
- US Forest Service, Fremont National Forest
- Bureau of Land Management

Develop Methodology for Fire Credits from Reducing Hazardous Fuels

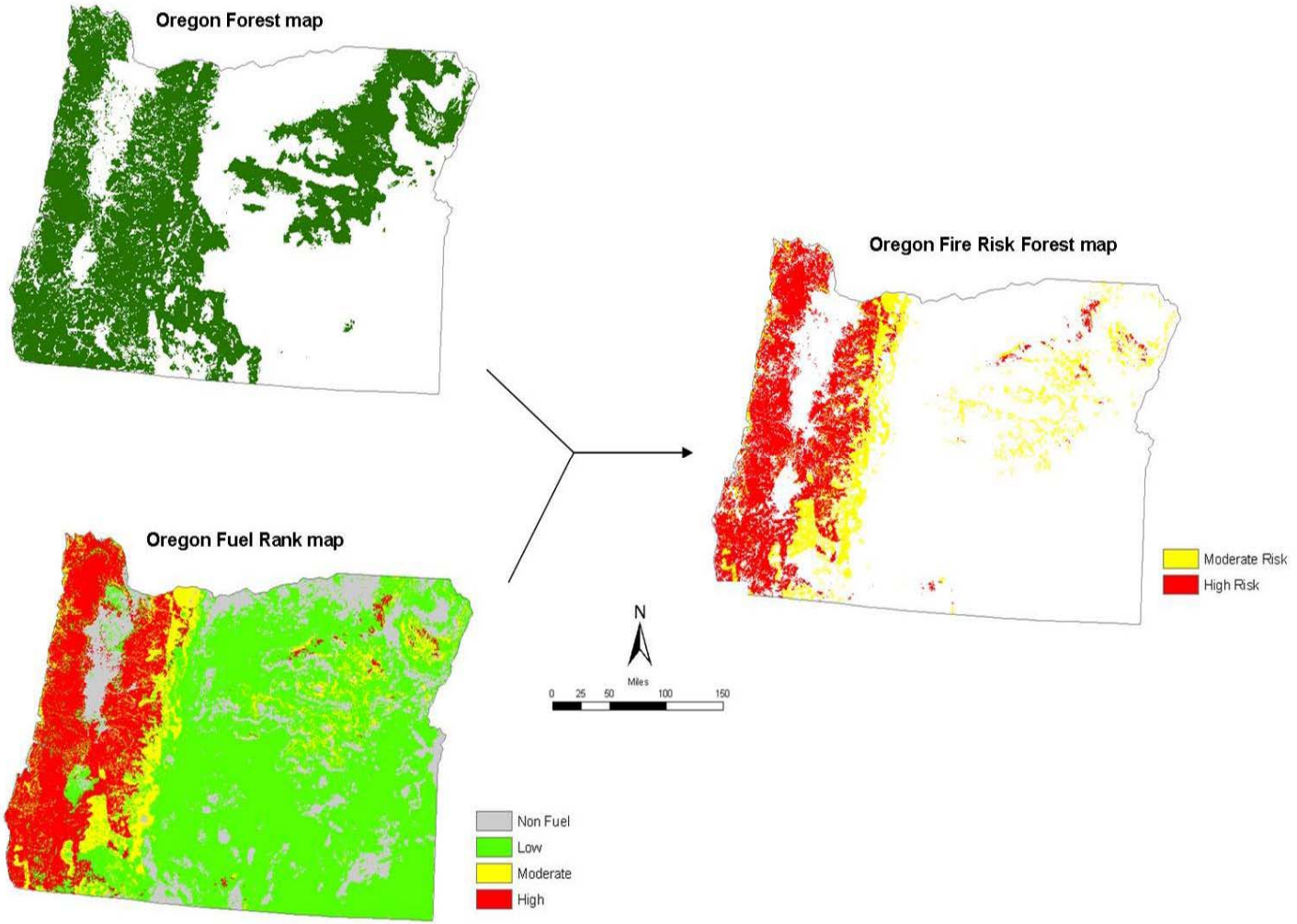
- Convene technical panel to identify available data and relevant models that assess the effect of fire on carbon stocks
- Review and test relevant models
- Prepare draft methodology
- Review pilot site characteristics
- Collect field data from chronosequenced sites
- Use field data to validate methodology

First Challenge—Setting Baseline

2004 French Gulch Fire

- Assign fire risk and set rules to predict intensity
- Quantify loss of carbon stocks due to fires of different intensities
- Predict fire return intervals
- Determine existing carbon stocks on lands at risk

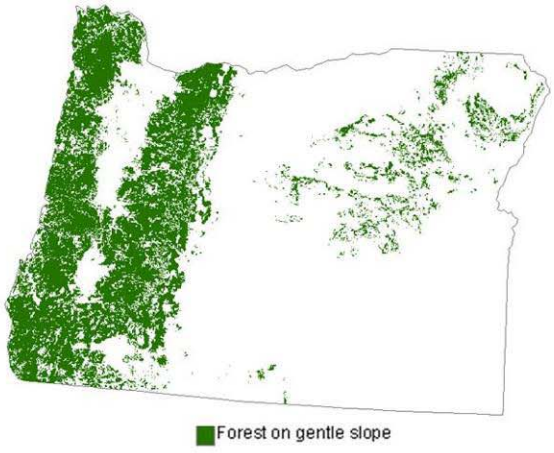
Fire Risk

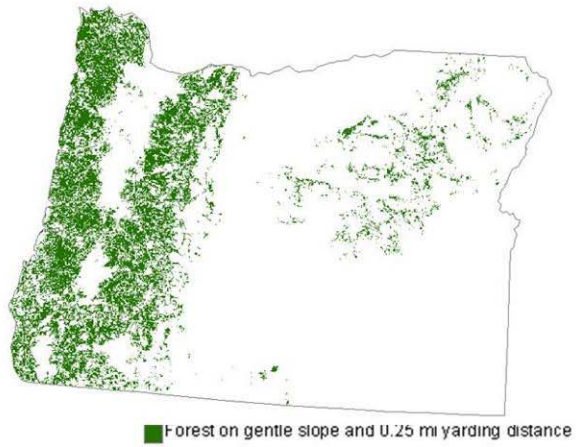

Oregon Forest map
Oregon Fuel Rank map
Oregon Fire Risk Forest map
Moderate Risk
High Risk
N
Miles
0 25 50 100 150
Non Fuel
Low
Moderate
High

Fuel Treatments to Reduce Uncharacteristically Severe Fires

- Review and classify lands where fuel treatments will occur
- Design measurement and monitoring plan
  - Measure overall carbon stocks
  - Measure removals of hazardous fuels
- Carry out fuel treatments
  - Transport fuels to biomass energy facility
  - Collect data on transport and treatment costs
  - Analyze carbon benefits from biomass energy component

Suitability of Sites for Fuel Treatment





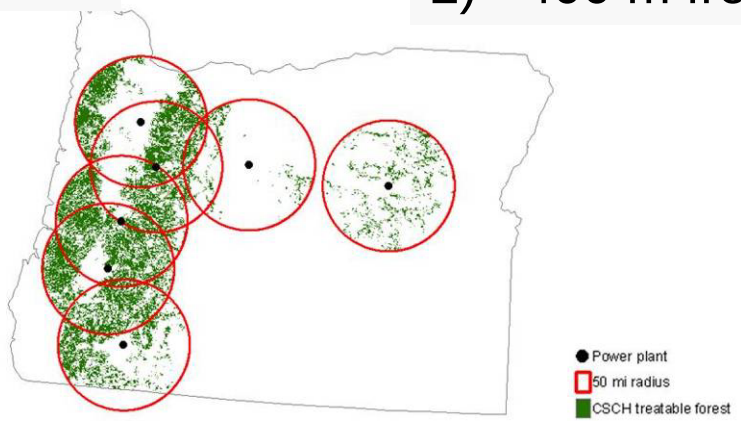
N

Miles

0 25 50 100 150

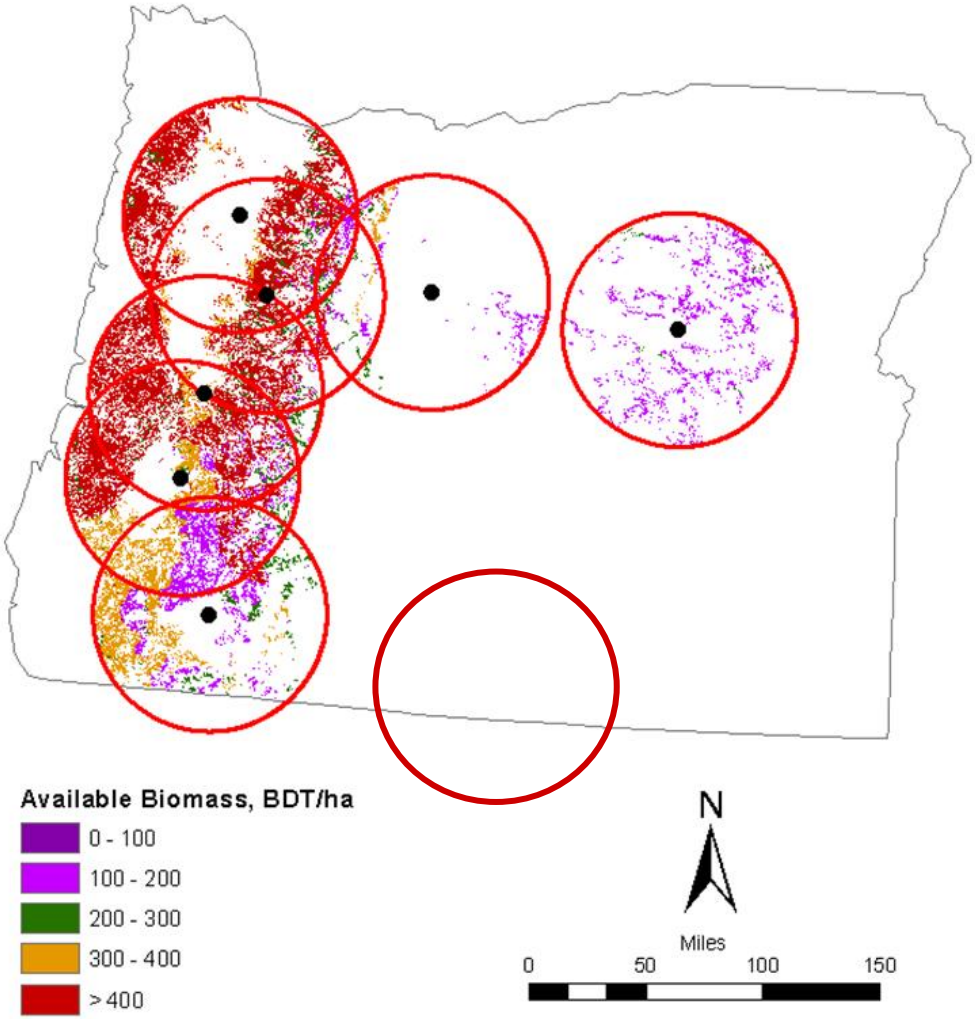
1) Slope <40%

2) <400 m from road



3) Within 50 miles of power plant

Available Biomass Fuels Near Power Plants



Lake County does not currently have a biomass energy plant. The Oregon Solutions Project is trying to identify sufficient fuel to attract a private investor to build a plant.

Additional Characterization

- Extend fire analysis to other sites
  - Collect field data from chronosequenced sites to improve accuracy of emission estimates across various forest types found in the region
  - Review opportunities for new sites where forest lands are at moderate to severe risk of fire on lands with <40% slope within 400 meters of existing roads and sufficient potential fuel within 50 miles

Additional Characterization Activities

Evaluate sequestration potential for fast-growing species

9 years diameter growth

- ***Douglas Fir*** 4 dry t/acre/yr
  ~50 year rotation
- ***Hybrid Poplar*** 10 dry t/acre/yr
  6-8 year rotation

Source: Jon Johnson Associate Professor
Washington State University

Achieve Market Recognition and Validation

- Climate Trust
- California Climate Action Registry

Outreach

- Stakeholder meetings
- California Forest Products Commission
- Oregon Forest Resources Institute