



## WESTCARB Overview

***Phase I Accomplishments,  
Phase II Plans***

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Portland, OR  
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## WESTCARB Addresses Five Major Questions in a Phased Program

- Where are the sources of CO<sub>2</sub> and how much is there?
- Where can it be stored?
- How much will it cost (and over what time scale)?
- Will it be safe?
- Are existing regulations adequate?

***Phase I characterizes regional opportunities  
Phase II tests promising storage options at pilot scale:  
4-year, \$25M effort***

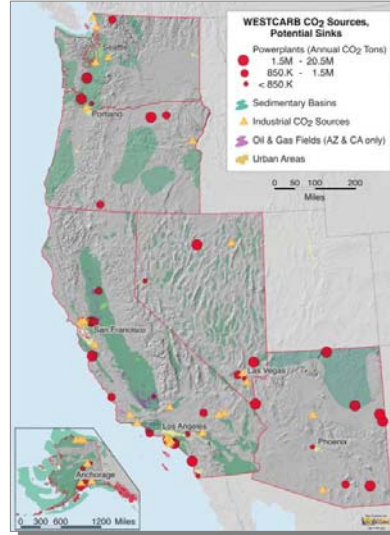


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## Point Sources in Proximity of Broadly Distributed Sedimentary Basins

- Characterized sources account for about 80% of total industrial and utility sector emissions
- Sedimentary basins defined; geologic and oil and gas field data assembled
- Data reside at Utah AGRC, publicly accessible, part of national database

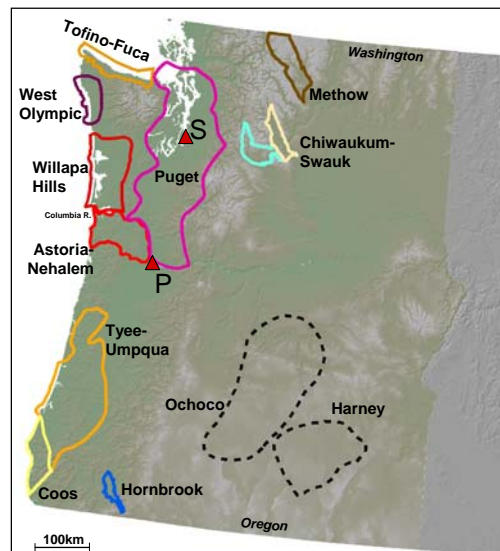


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## Sedimentary Basins in Oregon and Washington

- Coastal Ranges
  - Western Tertiary basins in Oregon cover 20,000 sq mi
- Puget Trough
  - Coal as well as saline formations
- Several Interior basins
- 30+ unconsolidated basins



From Steve Thomas,  
Golder Associates

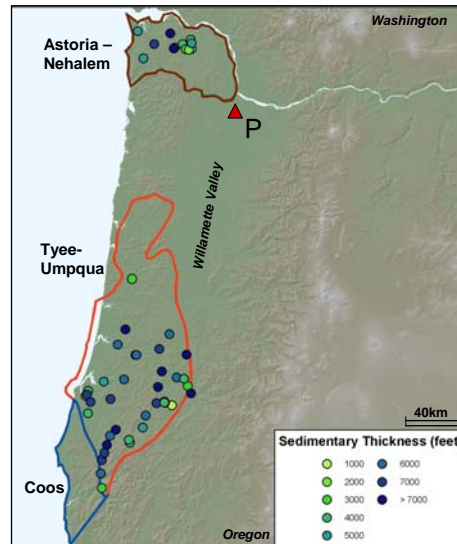


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## Coastal Range Basins of Oregon

- Three main basins
  - Extend beneath Willamette Lowlands
  - Very thick sedimentary units
- Tye-Umpqua Basin
  - Massive Tye sandstones
- Coos Basin
  - Marine sequence up to 10,000 ft thick
  - Coalcedo and Fluornoy properties:
    - Porosities: 18–43%
    - Permeabilities: 4.5–1,800 md



From Steve Thomas, Golder Associates

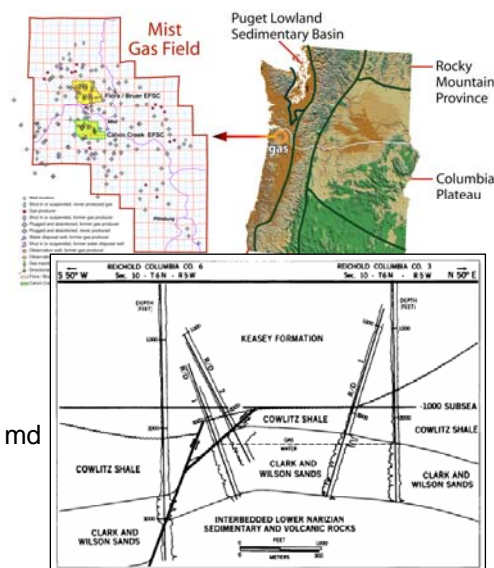


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## Coastal Range Basins of Oregon

- Astoria-Nehalem Basin
  - Extensively faulted/folded
  - Mist Gas Field (65 BCFG)
  - C&W Sands:
    - Porosities: up to 39%
    - Permeabilities: 1–1,400 md

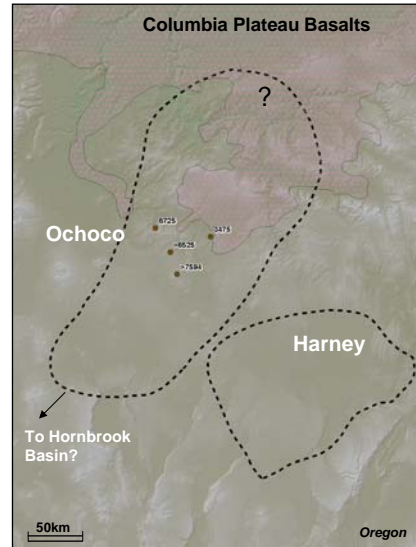


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## Interior Basins

- Ochoco Basin
  - >5,000 feet of fluvio-deltaic sandstones/conglomerates
  - Overlies metasedimentary basement
- Hornbrook Basin
  - ~4,000 feet sequence
  - Hornbrook Fmn. sandstones:
    - Porosities: 6.3-18.6%
    - Permeabilities: up to 1.2 md



From Steve Thomas,  
Golder Associates

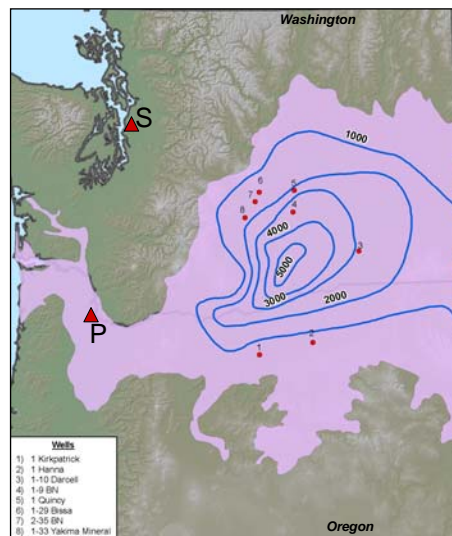


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## Sub-Columbia Plateau - Basalt thickness

- Significant challenges
  - Limited existing data
  - Basin boundaries poorly understood
  - Difficult and expensive drilling
- Rattlesnake Hills Gas Field (Yakima)



From Steve Thomas  
Golder Associates

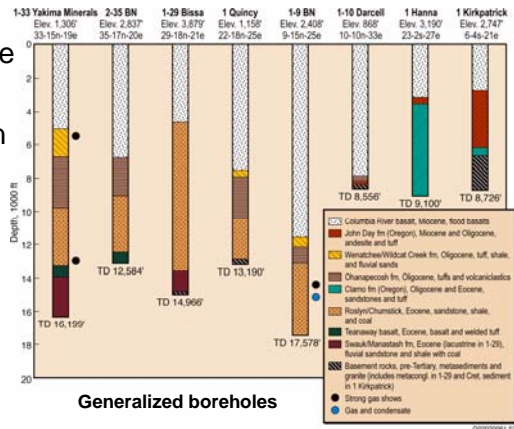


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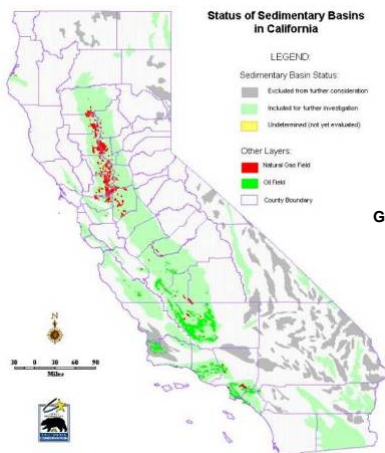
## Sub-Columbia Plateau

- Thick basalt flow sequence (up to 15,000 ft)
- Several deep investigation boreholes
  - Fluvial sandstones and conglomerates
  - Volcanic tuffs and shale interbeds
  - Sandstone properties:
    - Porosities: 4– 22%
    - No permeability data
- Basement of older metasedimentary rocks

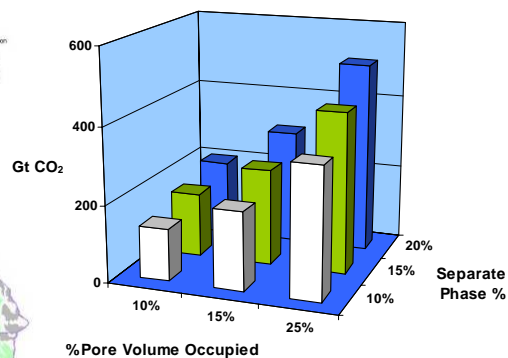


From Steve Thomas, Golder Associates

## California Sedimentary Basins Are Prime West Coast Sequestration Targets



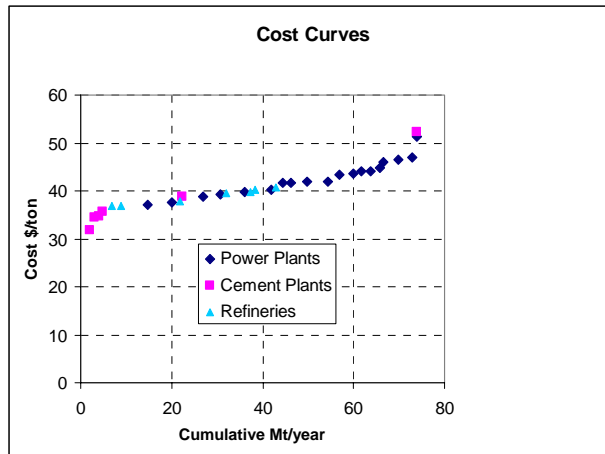
Range of Saline Formation Capacity



From Sally Benson, LBNL

## Capture is Most of the Cost of Geologic Sequestration

- Using current, amine-based technology, capture is 70-80% of total cost
- New approaches are being studied



Capture costs for retrofitting existing CA plants

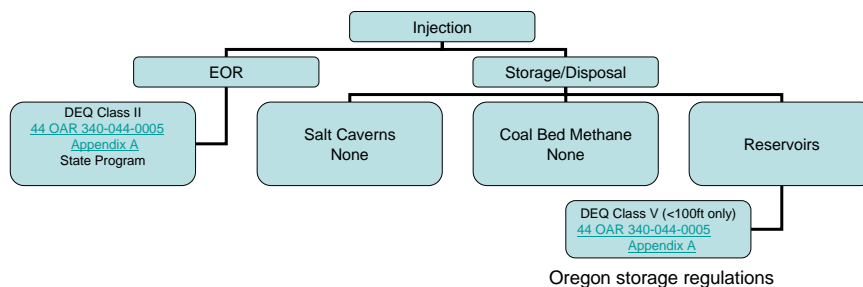


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## Current Regulatory Framework Has Been Reviewed

- Regulatory framework varies from state to state
- Comparative assessment of regulations for enhanced oil recovery, natural gas storage, and underground waste injection
- Comparative assessment of regulations covering land use changes required for forest sequestration



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## Outstanding Issues

- Is CO<sub>2</sub> injection disposal or storage, or does it matter?
- Is CO<sub>2</sub> a product or a waste, or does it matter?
- Is CO<sub>2</sub> injected as a liquid or a gas, or does it matter?
- Is CO<sub>2</sub> injection into a depleted oil/gas reservoir with no EOR/EGR a Class II injection?

STATE	REGULATING AGENCY	WELL/PERMIT TYPE if Not EOR related	REGULATIONS CITED
Alaska	EPA OGCC share Class II primacy w/EPA	Class V	40CFR144-148 20AAC25; 31 AK O&G Conserv. Act Ch31.05
Arizona	EPA no primacy w/state OGCC	Class I	40CFR144-148 12AAC7; ARS 27-516
California	EPA DOGGR share Class II primacy w/ EPA	Class I	40CFR144-148 14CCR Div2, Ch2, 4; Public Resources Code 30262
Nevada	DEP DOM BLM joint interagency cooperation	Don't know, Class I prohibited	NAC445A.810 to 445A.925 NAC Ch522; NRS 455A.470 43CFR Ch2 Part3160
Oregon	DEQ DOGAMI	Class V, <100ft well only Interagency cooperation	44 OAR 340-044-0005 and Appendix A OAR Ch.632 Div. 10; ORS 520
Washington	DOE	Class V	40CFR144-148; WAC173-218

From Jean Young, Terralog

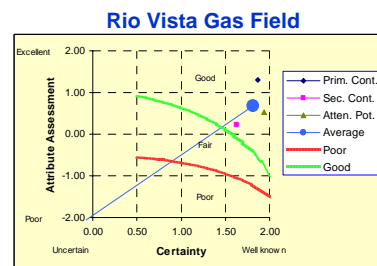
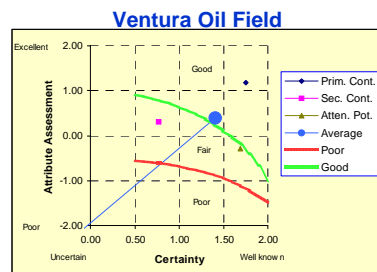


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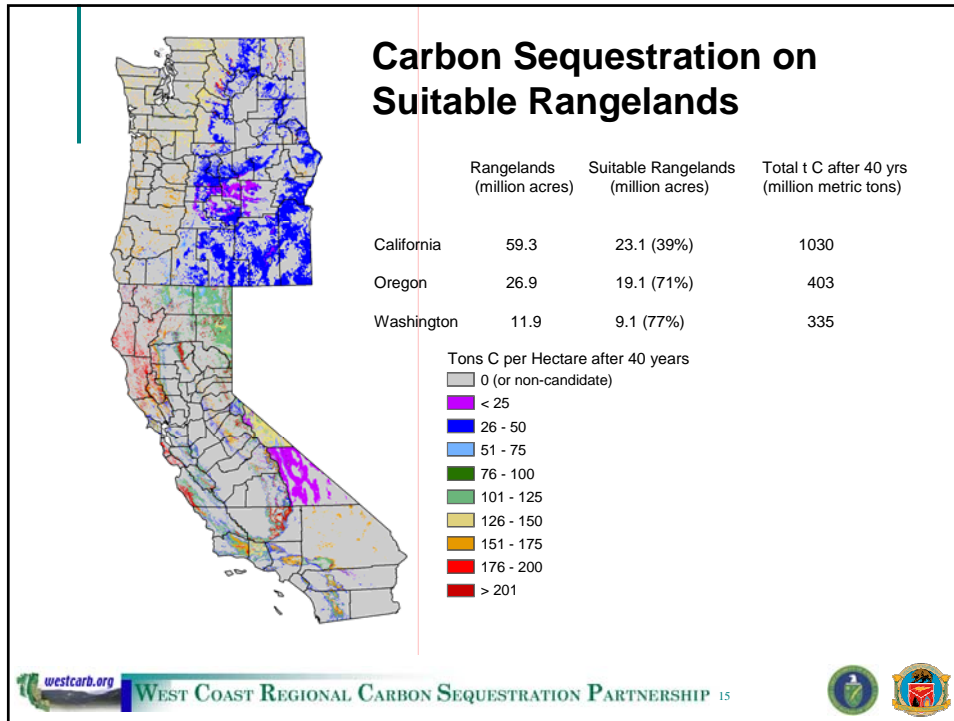
## Tool Developed for Selecting Geologic Storage Sites

- Spreadsheet model for ranking/screening of sites, focused on assuring containment
- Three main controlling characteristics:
  - Primary containment potential
  - Secondary containment potential
  - Attenuation potential
- User can:
  - Evaluate and score various attributes
  - Specify the importance of various attributes through weighting factors
  - Specify uncertainty inherent at sites



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### Terrestrial Storage Costs after 40 Years

	California		Oregon		Washington	
	Area million acres	Quantity MMT CO <sub>2</sub>	Area million acres	Quantity MMT CO <sub>2</sub>	Area million acres	Quantity MMT CO <sub>2</sub>
<b>Grazing Lands—Afforestation</b>						
< \$2.40/metric ton CO <sub>2</sub>	3.61	1138	1.43	341	4.34	897
< \$10/metric ton CO <sub>2</sub>	17.1	3228	16.86	1395	9.04	1217
< \$20/metric ton CO <sub>2</sub>	20.1	3347	19.12	1476	9.08	1220
<b>Crop Lands—Afforestation</b>						
< \$2.40/metric ton CO <sub>2</sub>			0	0	0.03	8
< \$10/metric ton CO <sub>2</sub>			2.25	484	1.76	159
< \$20/metric ton CO <sub>2</sub>			5.18	693	5.59	425
<b>Forests—Rotation Extension 5 yr extension, 20 yr contract</b>						
< \$2.40/metric ton CO <sub>2</sub>		0		0		6.08
< \$10/metric ton CO <sub>2</sub>		0		0.37		7.17
< \$20/metric ton CO <sub>2</sub>		7.25		1.80		13.55

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## Improved Fire Management Has Sequestration and Other Benefits



Source: Dr. Sam Sandberg, USDA Forest Service Pacific Wildland Fire Sciences Laboratory

- Reduce net GHG emissions from combustion
  - 1.03 MMTCO<sub>2</sub>e/yr in Oregon
- Avoid ecosystem-changing fires
- Reduce cost of fire fighting, insurance, property damage
- Avoid fossil fuel emissions



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## 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

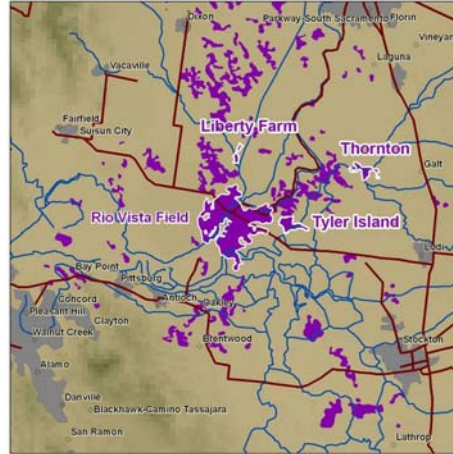


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## Rosetta-Calpine Gas Reservoir and Saline Formation Pilot Test

- Lead industrial partners: Rosetta Resources and Calpine
- Validate sequestration potential of Central Valley sediments
- Test CO<sub>2</sub> Storage Enhanced Gas Recovery
- Focus on monitoring



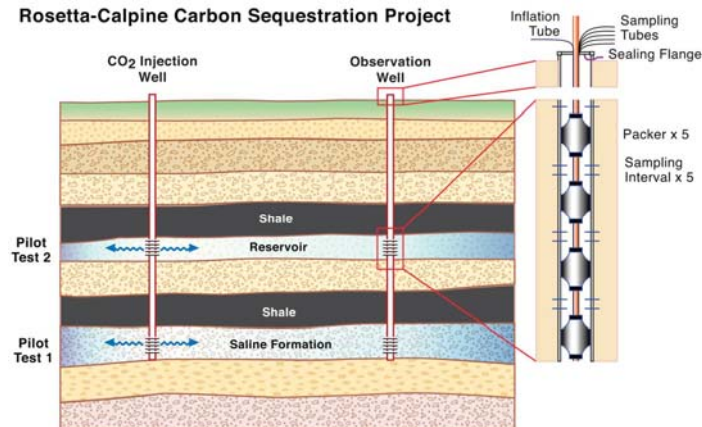
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## Rosetta-Calpine: Two-Well Pilots

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

Rosetta-Calpine Carbon Sequestration Project



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## Phase II Terrestrial Sequestration Pilot Objectives

- 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



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## Lake County Pilot: Collaboration at Federal, State, and Local Levels

- 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



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