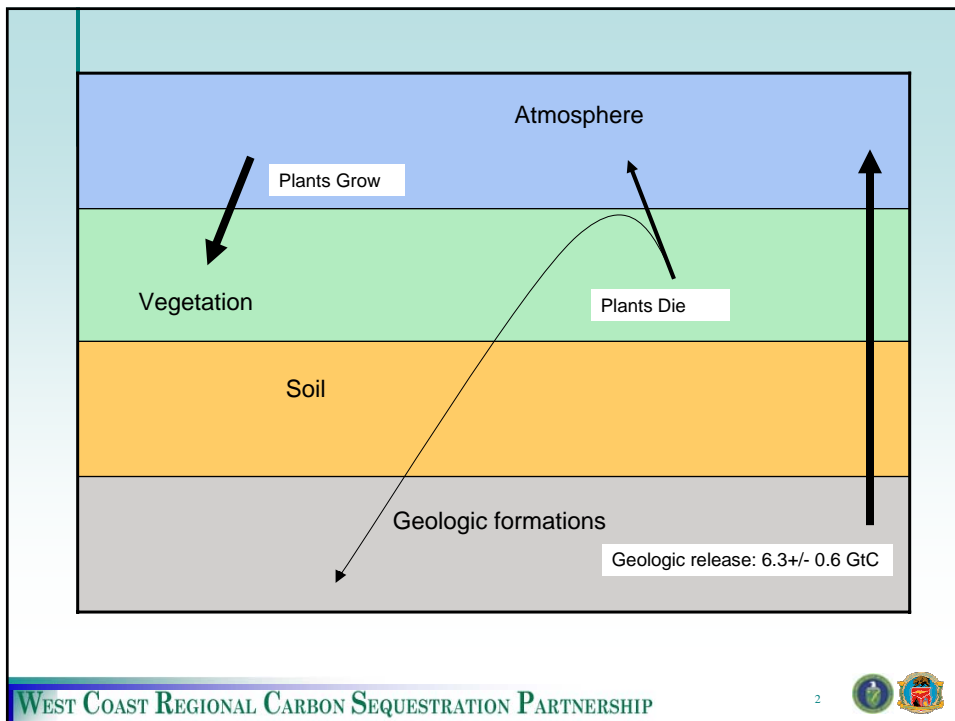





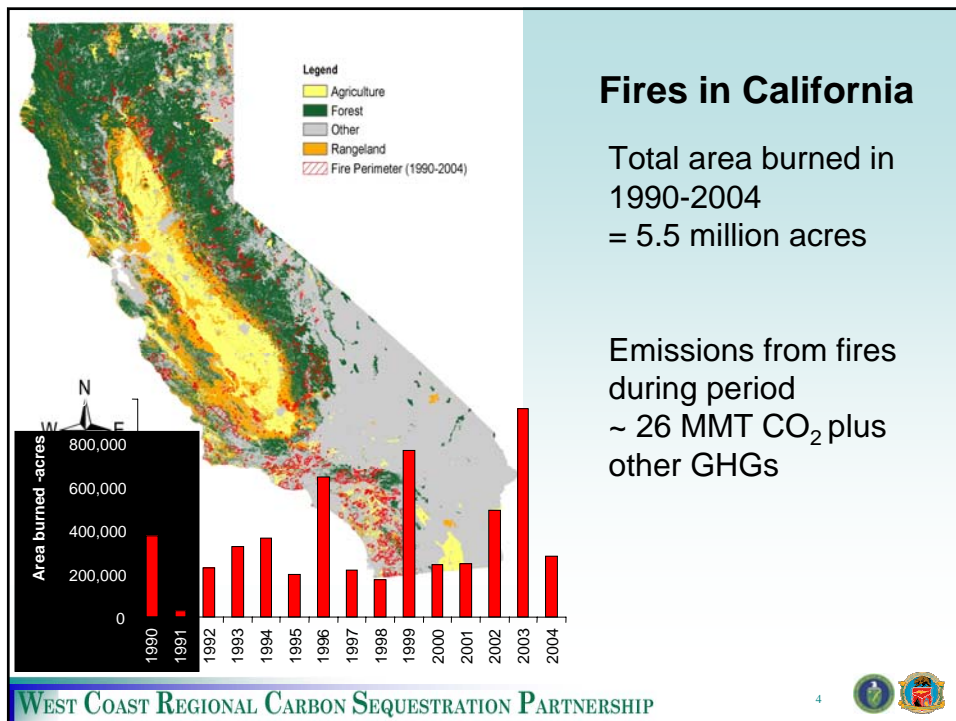
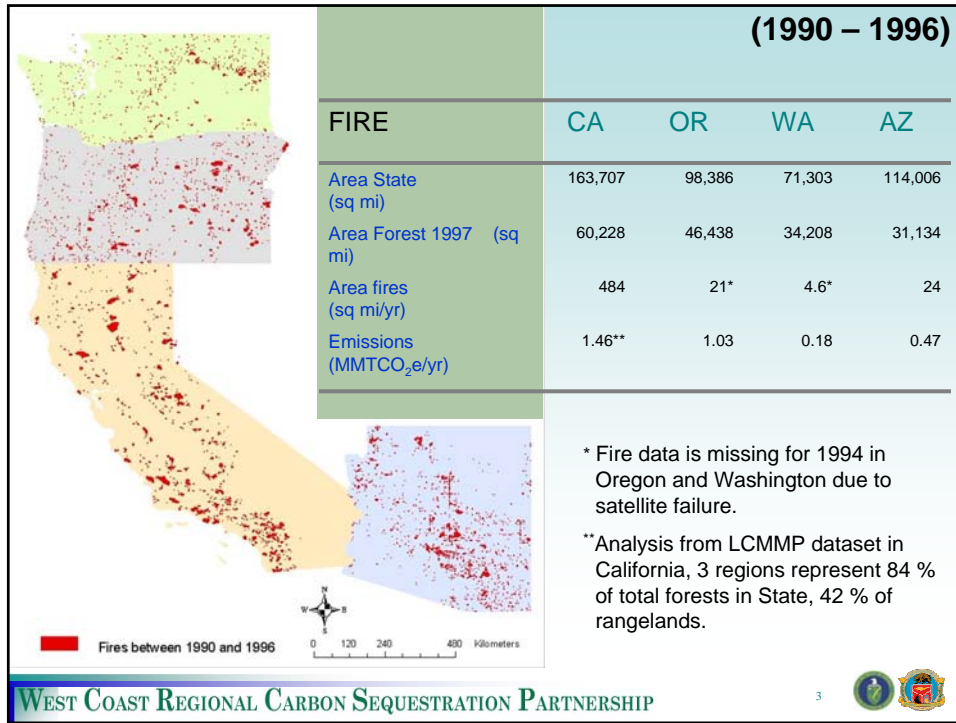
WESTCARB Annual Business Meeting

Opportunities for a Combined Terrestrial and Geologic Sequestration Pilot Project

John Kadyszewski
Winrock International

*Phoenix, Arizona
November 9, 2006*





Feedstocks

- Bioenergy Plan for California
 - 30 million dry tons available
 - 4 MDT used today at 28 power plants
- Western Governor's Association projects 10,000 MW of new biomass-fired power generation and additional new capacity for liquid fuels
- Use of biomass feedstocks constrained by cost of collection



Heat vs. Power vs. Liquid Fuels

- Heat for thermal applications
 - Each \$10 per ton fuel adds \$0.63/million BTUs
- Power generation
 - Each \$10 per ton fuel cost adds \$0.01/kWh
- Liquid fuels
 - Each \$10 per ton fuel cost adds \$0.10/gallon



California Air Emissions from Biomass Burning

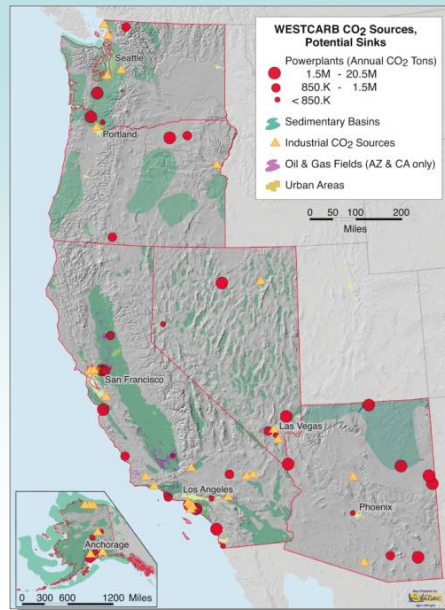
10 yr annual average tons/day	Reactive Organic Gases	CO	NOx	SOx	PM10
Agriculture	19.3	216	5.6	0.2	25.6
Range	23.5	309	3.7		45.3
Forest	28.4	720	6		52.1
Wildfire	128.4	2,482	79.4	24.5	253.4
Wood-Fired Boilers	0.37	50	5.1	0.5	1.1

Source: California Air Resources Board Emissions Inventory 2004



WESTCARB Phase III Pilot Project Options

- Matching geologic basins with potential sources of CO₂
- Selection Criteria
 - Location
 - CO₂ volume
 - Cost



Potential Biomass Sources of CO₂

- Ethanol Production Facility
- Biorefinery
- Advanced Combustion Systems
- Capture from co-firing biomass with coal



West Coast Ethanol Plants

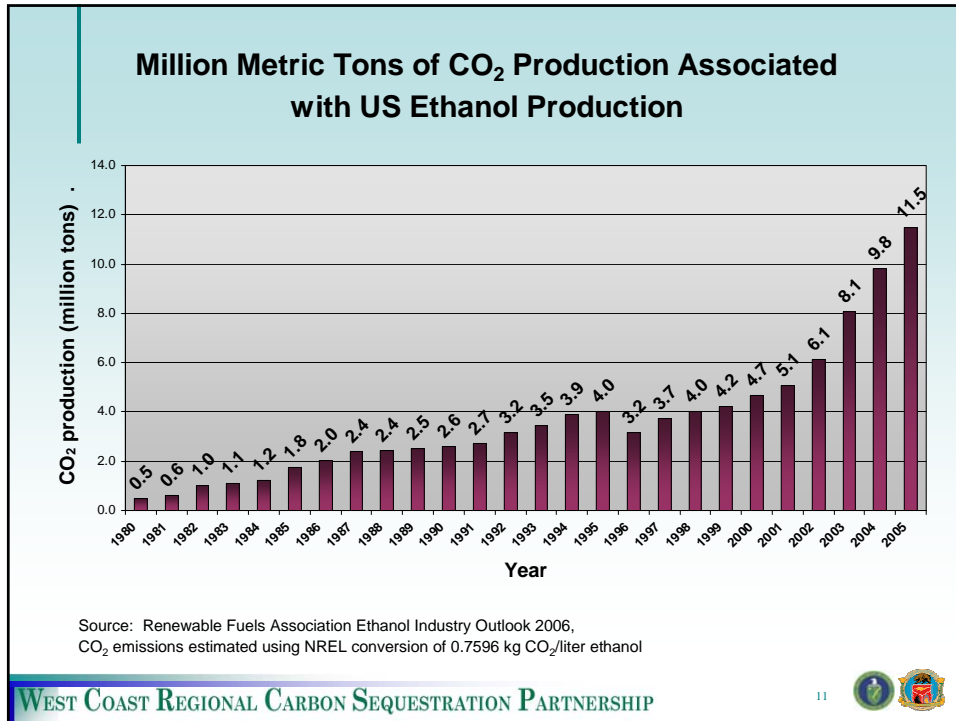
- Two large operating plants in California
 - Goshen: 25 million g/yr
 - Madera: 35 million g/yr
- New 35 million g/yr plant under construction in Boardman, Oregon
- Three additional plants planned by 2008
- CO₂ production from a 35 million gallon/yr plant will be about 100,000 tons of CO₂ per year

Pacific Ethanol Madera Refinery



Source: Pacific Ethanol





Markets for CO₂

- Current global use of CO₂ in the merchant market is about 20 million t/yr
- Total U.S. consumption of CO₂ about 8 million t/yr (does not include EOR or other captive markets)
 - Approximately 70% goes to the food and beverage industry
 - CO₂ associated with ethanol exceeded 11.5 million t in 2005
 - Price in the merchant market ranges from \$30-120/ton delivered depending on the region
 - Raw gas ranges from \$3-25/ton also depending on region

WEST COAST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

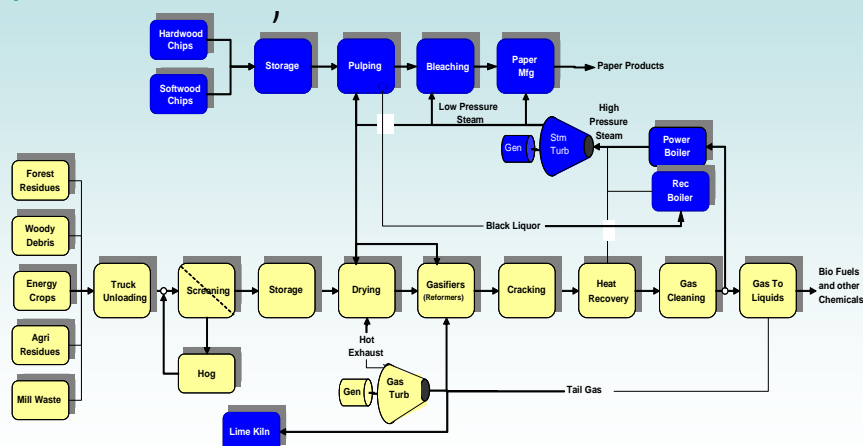
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Biorefinery

- Thermal process to make syngas from wood and ag residues that can then be converted to liquid fuels using catalysts
- Pulp and Paper Industry Agenda 20/20
- Potlatch Feasibility Study for Cypress Bend, Arkansas
 - Integrated facility supplies heat and power for mill
 - Yield: 50-55 gallons per dry ton
 - With oxygen-blown gasifier, also produces concentrated CO₂ stream
 - 1800 ton per day plant could produce about 250,000 tons CO₂ per year



Potlatch Biorefinery Schematic



Advanced Combustion Systems

- Oxygen-blown combustion or gasification systems could produce power from biomass fuels with relatively pure CO₂ emission streams
- Prototypes not likely to be ready for WESTCARB Phase III pilot project



Co-Firing Biomass Fuels with Coal

Fuel requirements

- Assuming Heat Rate 11,000 BTU/kWh
- Capacity Factor 80%

Power Output	Biomass Fuel Required
30 MW	212,000 MT
50 MW	353,000 MT
80 MW	565,000 MT



Potential Associated Terrestrial Sequestration

Assuming conversion to forest with 20 or 40 year rotations

Power Output	Land Required	Carbon Value after 40 yrs at \$10/mtCO ₂	Retrofit cost for blended fuel boilers
30 MW	53,000 acres	\$12.8 Million	\$1.5 - 6 Million
50 MW	89,000 acres	\$21.6 Million	\$2.5 - 10 Million
80 MW	142,000 acres	\$34.6 Million	\$4.0 - 16 Million



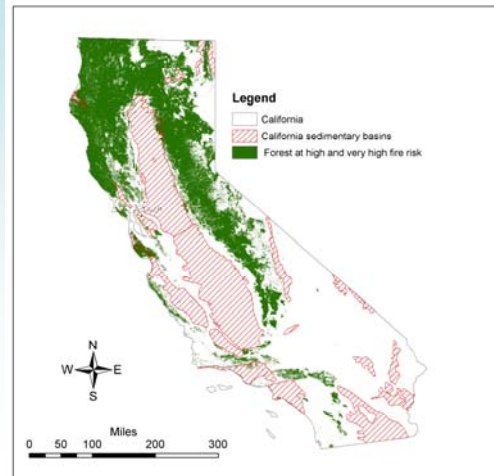
Additional Benefits of Co-Firing

- Elimination of CO₂ emissions for sustainably harvested biomass
 - Negative CO₂ emissions with geologic sequestration
- Reduction of SO₂ emissions – ~95-99% reduction
- Reduction of NO_x emissions – Up to 80% reduction for woody biomass
- Reduction of mercury emissions – ~99% reduction
- Potential renewable energy credit

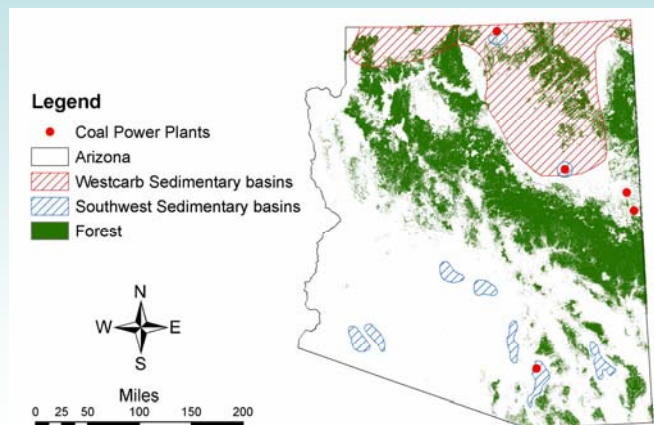


Linking Terrestrial Sequestration with Geologic Sequestration in California

- Revenues from energy markets can help pay for removal of hazardous fuels from forests at risk of uncharacteristically severe fires
- Some candidate conversion processes produce relatively pure CO₂ streams that could be sequestered in geologic formations



Linking Terrestrial Sequestration with Geologic Sequestration in Arizona



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