



Carbon Dioxide Sequestration: Integration of National and Regional Perspectives

American Chemical Society

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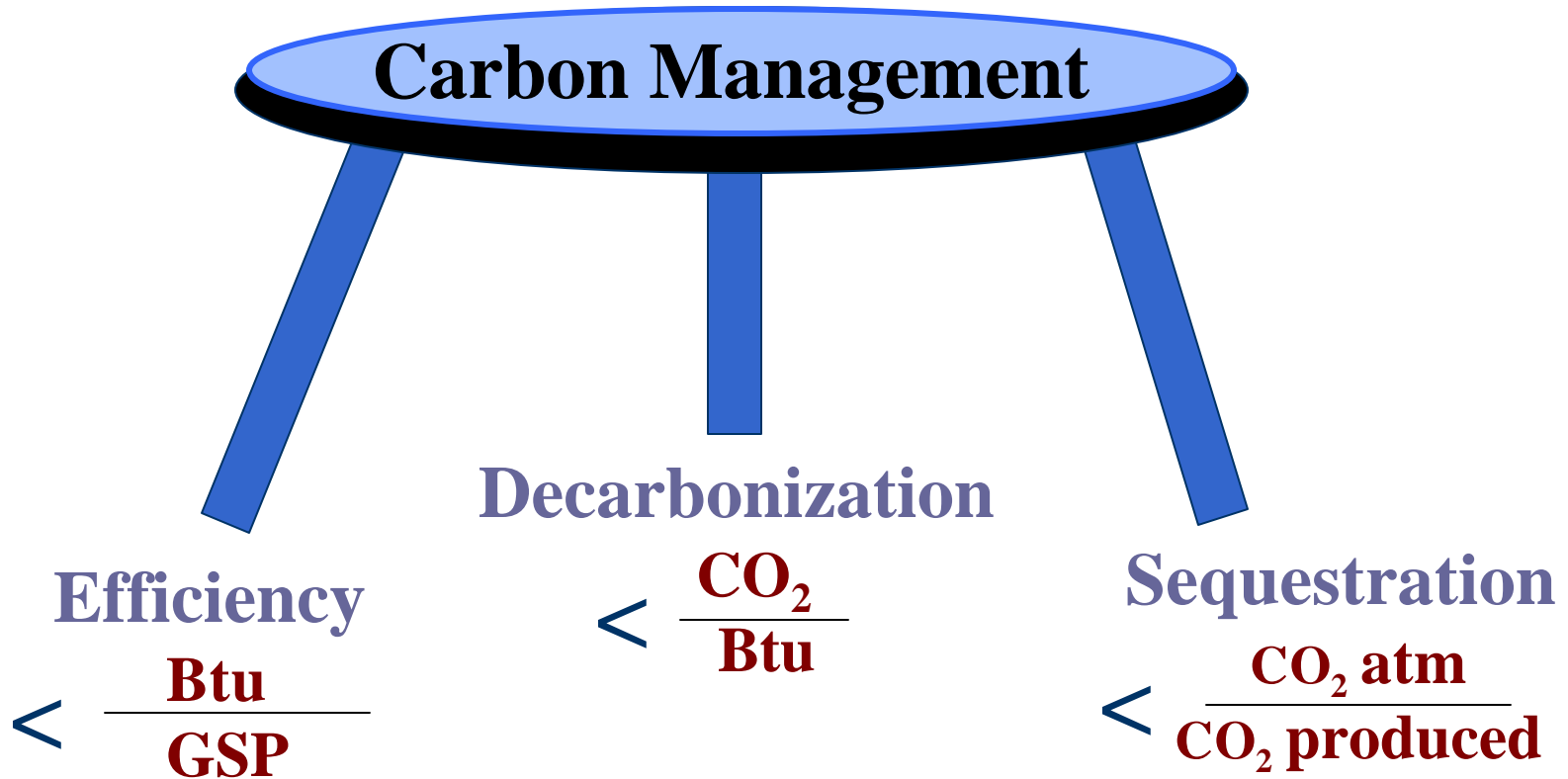
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and Larry Myer

California Energy Commission



Carbon Management: An Approach for Integrated Energy Systems Management



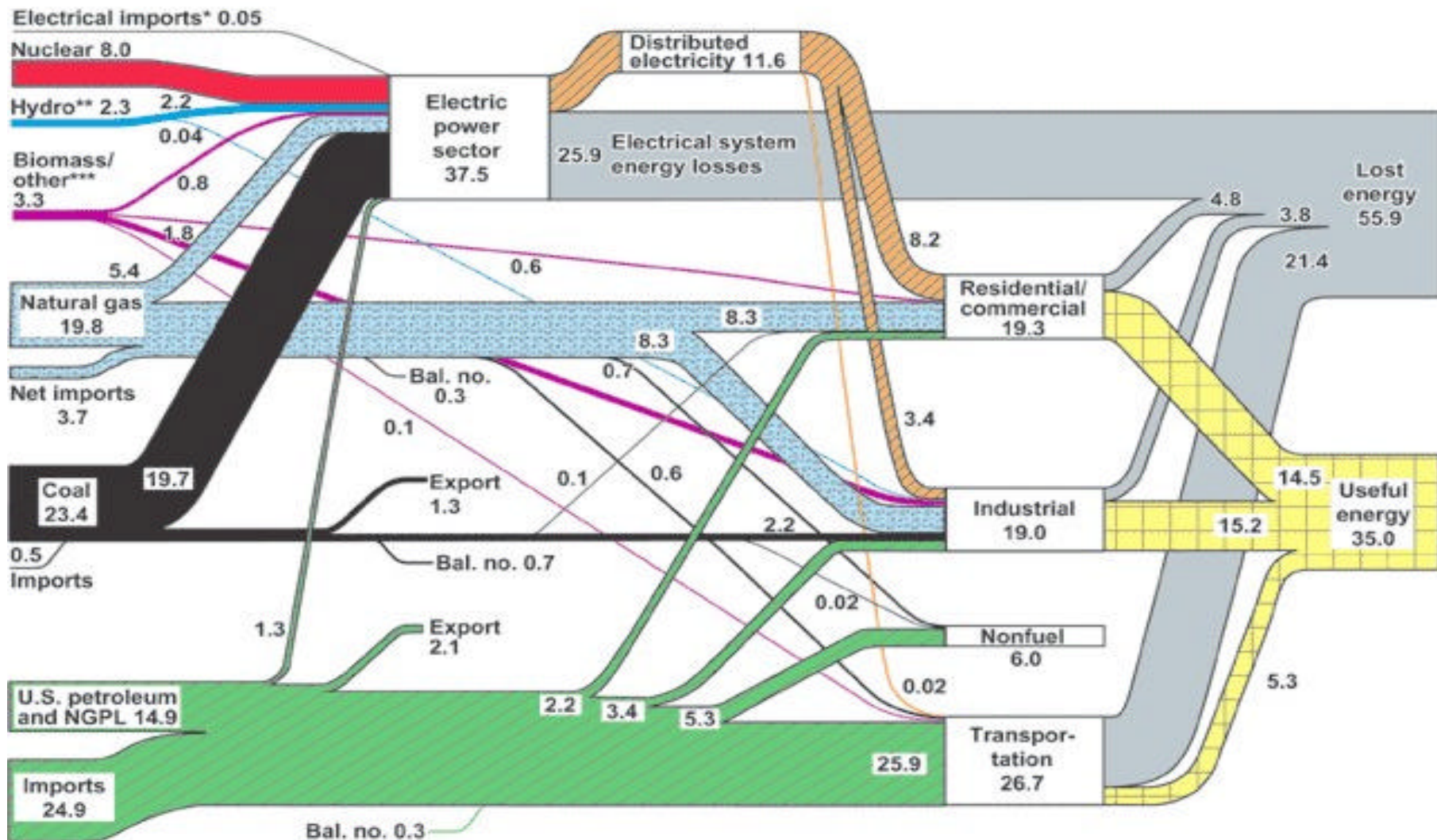


The Challenge We Face Is Daunting as We Enter Another “Fossil Fuel Economy”

- ★ 85% of U.S. energy in 1997
- ★ Relative abundance and low costs of fossil fuels
- ★ Sequestration limitations
 - ◆ Raw materials and financial commitments
 - ◆ Limited collateral benefits
 - ◆ Uncertain impacts

U.S. Energy Flow Trends – 2001

Net Primary Resource Consumption ~97 Quads



Source: Production and end-use data from Energy Information Administration, *Annual Energy Review 2001*

*Net fossil-fuel electrical imports

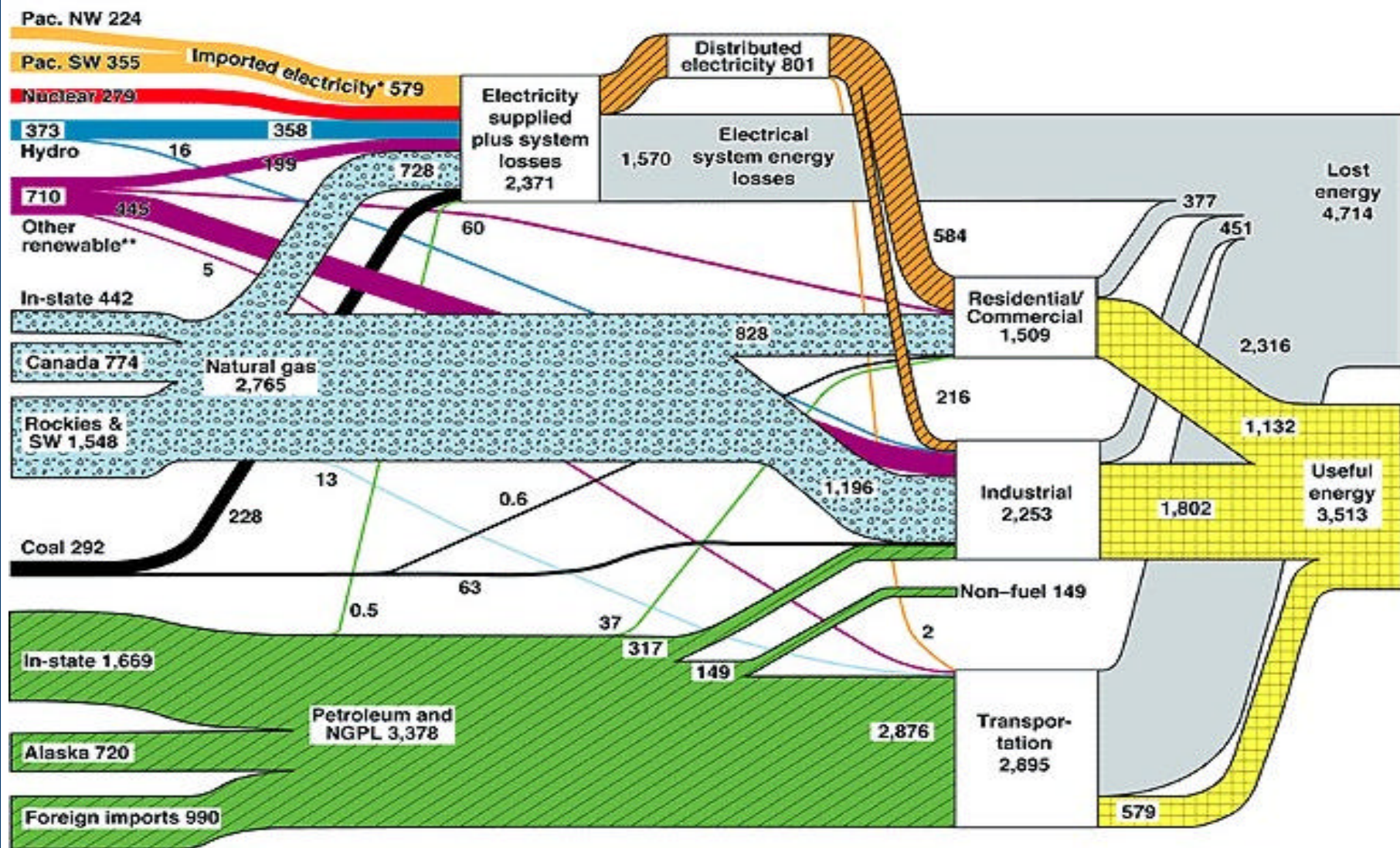
**Includes 0.2 quads of imported hydro

***Biomass/other includes wood, waste, alcohol, geothermal, solar, and wind.

August 2003
Lawrence Livermore
National Laboratory
<http://eed.llnl.gov/flow>

California Energy Flow Trends– 1999

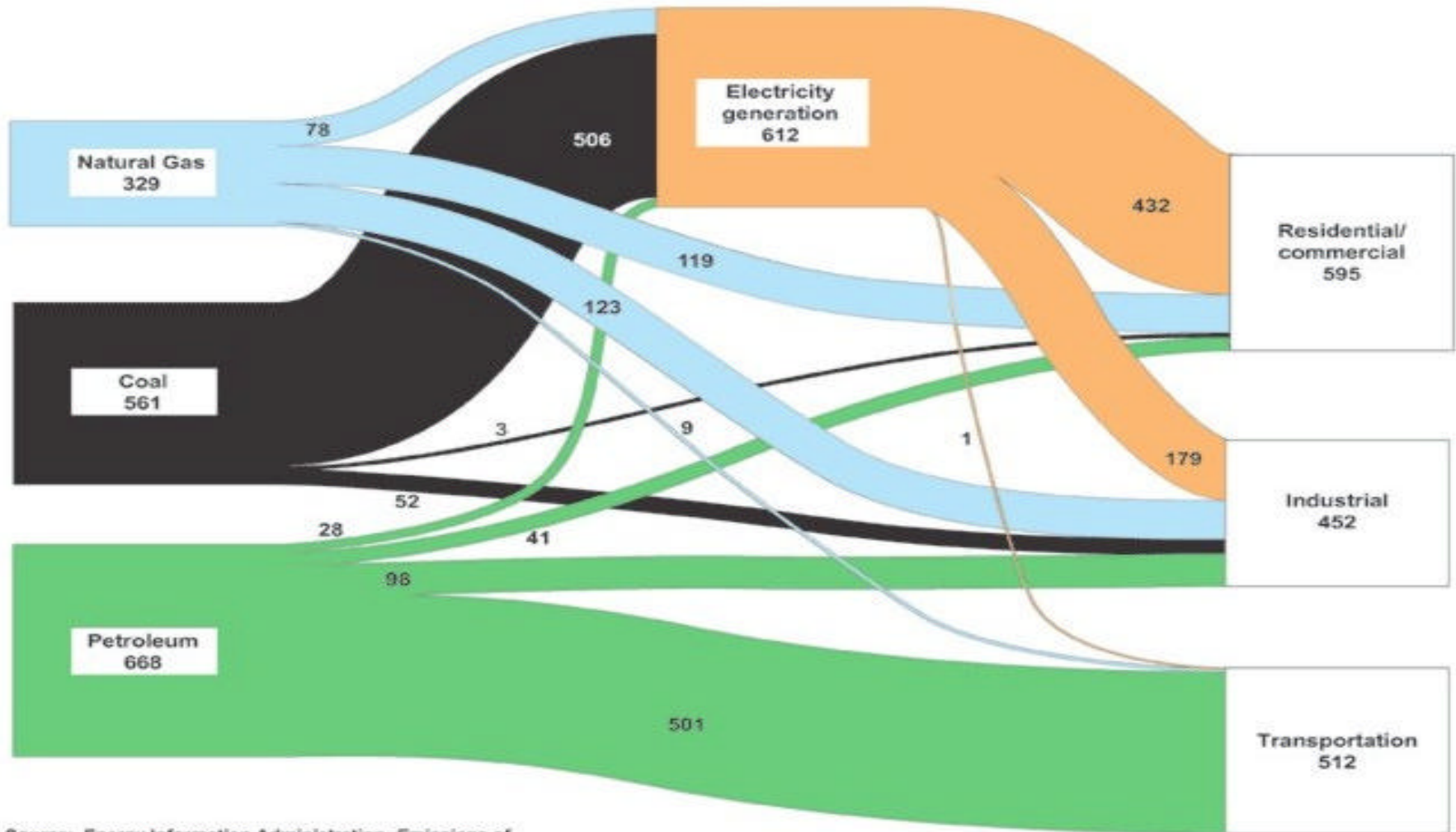
Net Primary Resource Consumption ~8375 Trillion Btu (8.375 Quads)



Sources: U.S. Department of Energy's Energy Information Administration and California Energy Commission.
 *Electricity flowing into the California control areas: CAISO, LADWP, and IID.
 **Other renewable includes geothermal, wood and waste, solar, and wind.



U.S. 2001 Carbon Emissions: 1547 MtC



Source: Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2001*

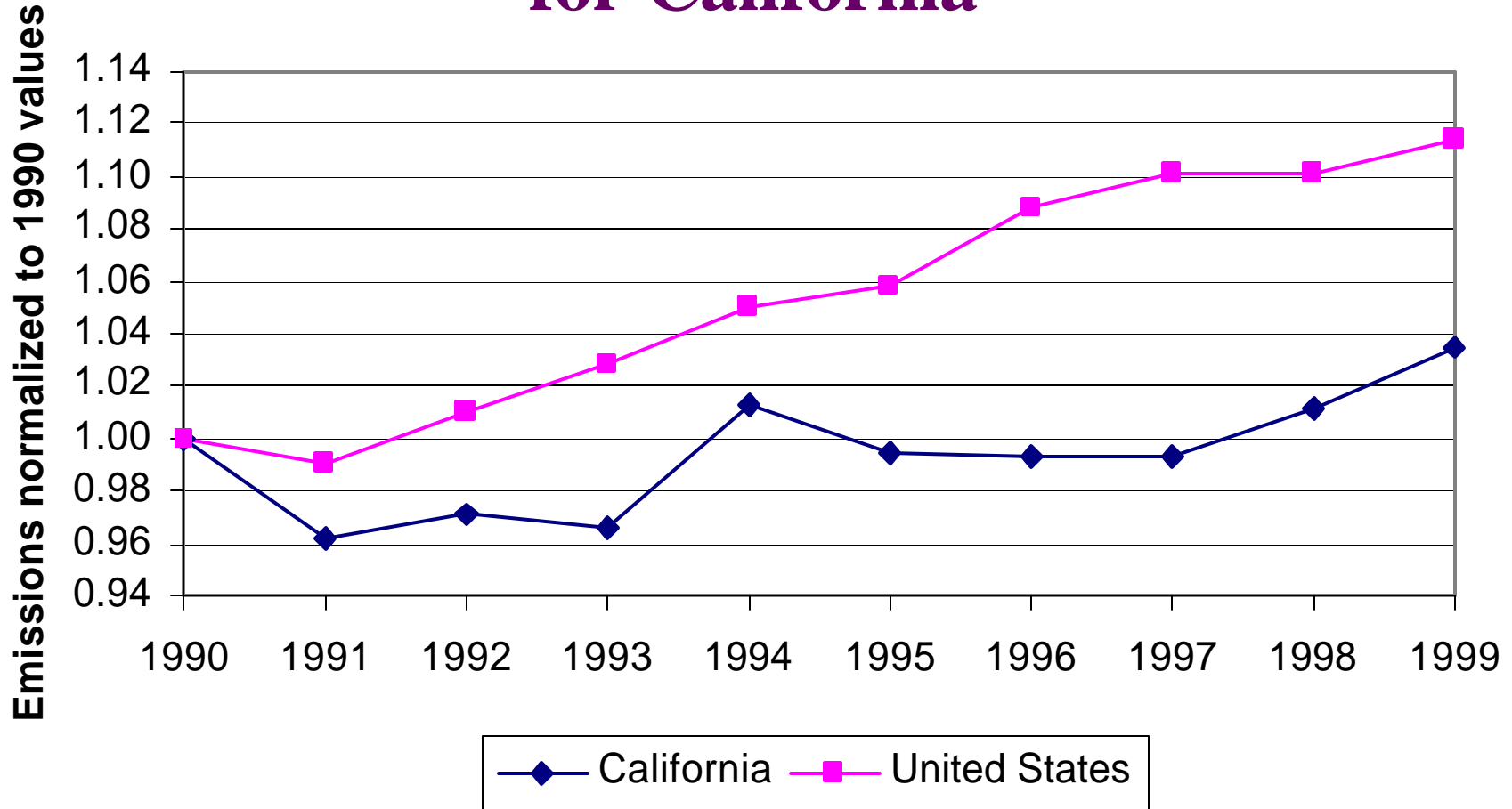
*Includes adjustments of 14.8 million metric tons of carbon (MtC) from U.S. territories, less 26.4 MtC from bunker fuels

Note: Numbers may not equal sum of components because of independent rounding

Lawrence Livermore National Laboratory, July 2003
<http://eed.llnl.gov/flow/>



1990-1999 Relative Gross Greenhouse Gas Emissions for California

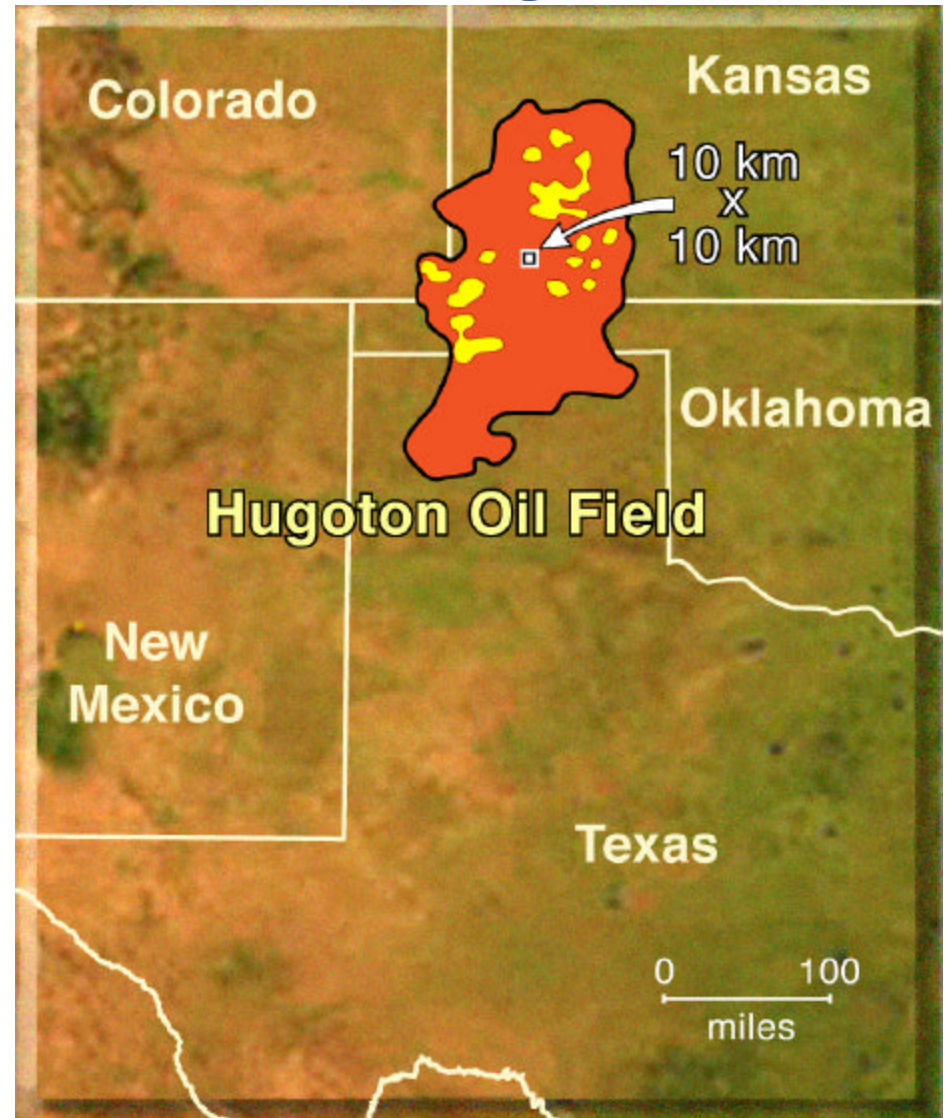




Geologic Sequestration Is a Large Scale Undertaking



- * 1000 MW coal-fired plant produces 30,000 ton of CO₂ per day for 30 years; project size on order of 110 km²
- * For today's utility emissions, need >180 such projects



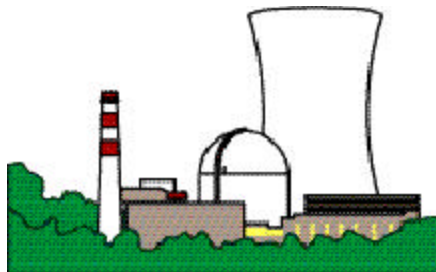
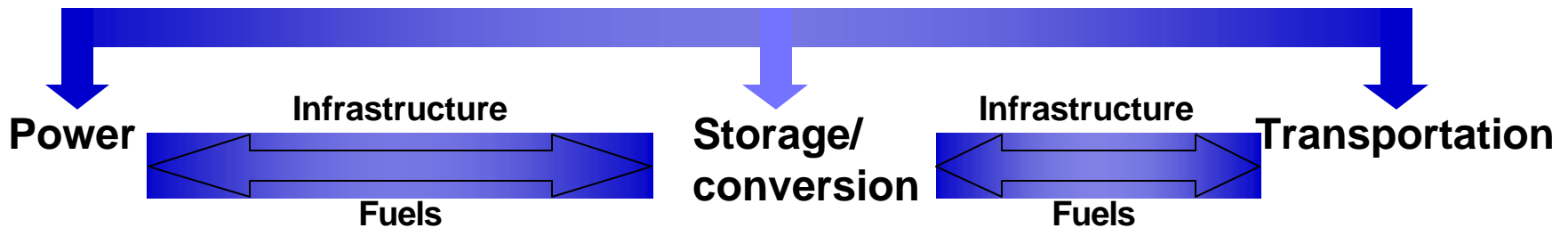


Integrated Energy Systems: Requires a Portfolio of Options

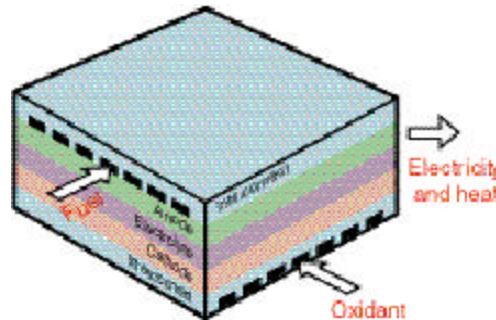
- Partnerships
- CRADAs
- Collaborative research

Test facilities

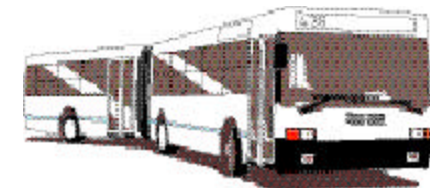
Systems engineering



- Renewable
- Fossil
- Nuclear
- Hydro



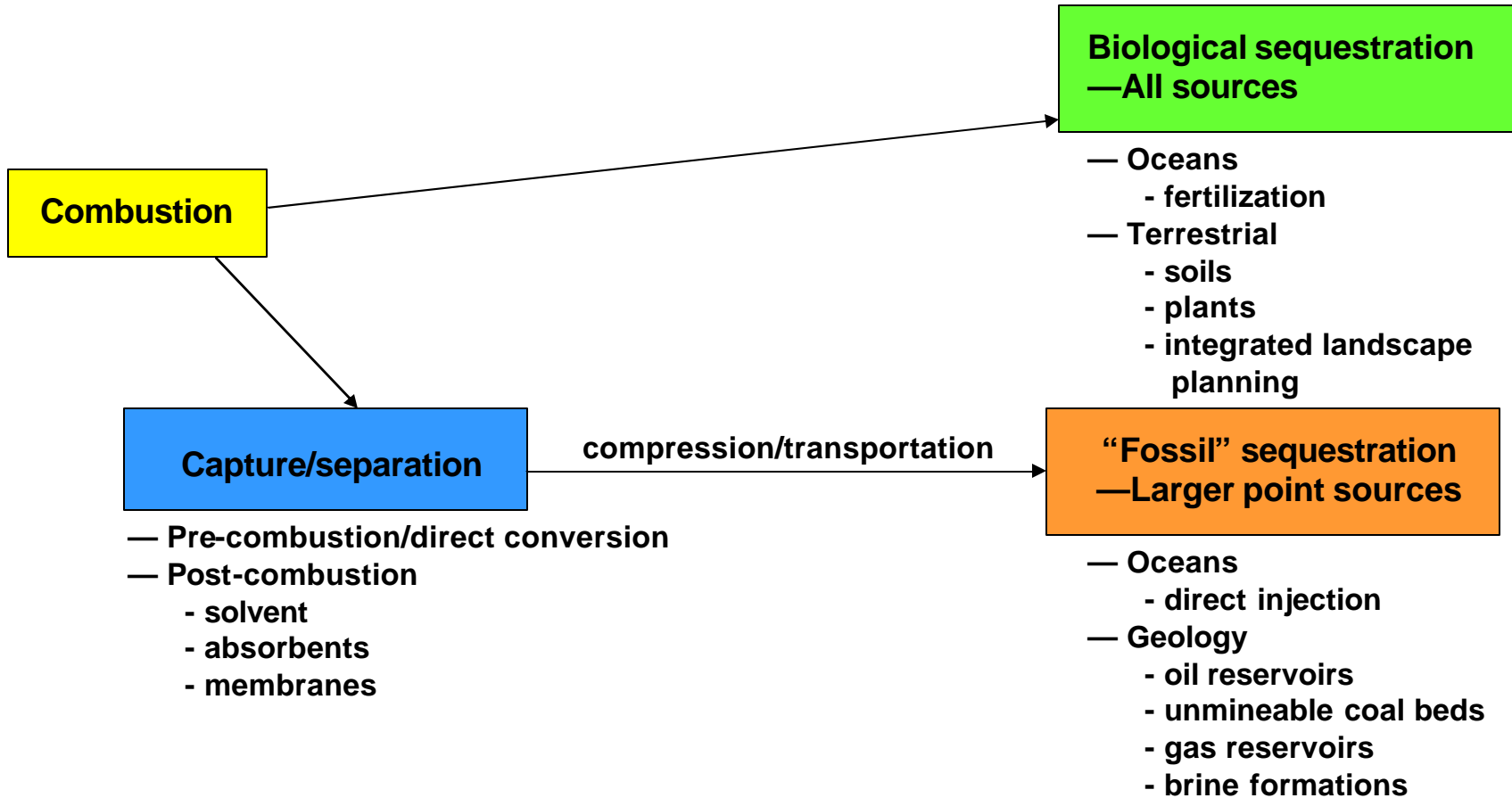
- Batteries
- Fuel cells
- Flywheels
- Hydrogen



- Automotive
- Heavy-duty vehicles
- Mass transportation



Systems approach: 100,000-foot level





Integration of Sequestration R&D Efforts Should Consider System Technology Platforms

- ★ Carbon processing (separation and capture)
- ★ Biological absorption (terrestrial, oceanic)
- ★ Engineered solutions (geological, oceanic)
- ★ Advanced characterization and monitoring technologies
- ★ Utilization of validated modeling and simulation decision tools



This Integrated Approach Must Address Cross-Cutting Policy/Technology Issues



- ★ Policy issues such as deregulation and changes in tax code to reduce CO₂ emissions
- ★ Comparative and life-cycle analyses vis-à-vis other technology options
- ★ Improved understanding of coupled biogeochemical cycles (e.g., H₂O, O₂, N) and their relationship to the carbon cycle
- ★ Improved and validated simulation models
- ★ Monitoring and validation of technology effectiveness



Any Government-Funded R&D Program Must Address These Concerns



★ **Risk/Uncertainty**

- ◆ **Costs**
- ◆ **Environment**
- ◆ **Safety and health**
- ◆ **Technical feasibility and efficiency**

★ **Environmental**

- ◆ **Understanding dangling impacts**
- ◆ **Uncertainties of new storage options**

★ **Verification**

- ◆ **Immediate effectiveness of technology**
- ◆ **Need for monitoring for longer-term storage**

★ **Perceptions**

- ◆ **Public**
- ◆ **Industry**



To Address the Intersection of Technology/Science/Public Policy Issues, DOE Has Developed a Set of Regional Carbon Sequestration Partnerships

- ★ Answer for technology—Sites for geological and terrestrial sequestration
- ★ Answer for science—Address risk and containment
- ★ Address public policy—Regulatory requirements and public perceptions



We Will Couple Current California R&D Efforts with Precepts of Carbon Management for the West Coast Regional Partnership



* **End-use efficiency and demand-side technologies**

- ◆ buildings and appliance technologies
- ◆ manufacturing, agriculture, water efficiency
- ◆ storage and conversion technologies

* **Clean technologies**

- ◆ renewables and small-scale fossil
- ◆ generation and control technologies that enhance environment
- ◆ new technologies with collateral benefits

* **Enabling technology improvement and development**

- ◆ models, sensors, and monitoring systems to improve technology system operation
- ◆ science base and model improvements to evaluate impacts of energy systems
- ◆ development of new integrated systems and economic models to improve understanding of market structure



Regional Partnership Overview



- ★ Partnership will evaluate options and opportunities for CO₂ capture and storage, transport, regulatory permitting, public outreach, monitoring and verification, and the environmental efficacy of sequestration
- ★ Partnership consists of state and local agencies, academia, research laboratories, energy producers and users, and non-profit organizations, in a multi-state region
- ★ Two phases:
 1. **data collection, assessment, and planning**
 2. **pilot validation tests**



Partnership Has Been Designed to Advance Practical Applications of Carbon Sequestration



- ★ Capture, transport, and geological storage options
- ★ Terrestrial sequestration opportunities
- ★ Regulatory analysis and permitting
- ★ Monitoring and verification
- ★ Economic and environmental efficacy
- ★ Public outreach and education
- ★ Information on regional source/sink relationships



California Energy Commission Has Assembled a Strong Team



- * **Policy and Coordination** (Western Governors' Association)
- * **State Resource Management, Environmental Protection, and Regulation** (CA Dept. of Forestry and Fire Protection, CA Dept. of Oil, Gas, and Geothermal Resources, CA Geologic Survey, CAL EPA, OR Dept. of Forestry, Nevada Bureau of Mines and Geology, WA Dept. of Natural Resources)
- * **Oil and Gas Companies** (AERA, BP, ChevronTexaco, ConocoPhillips, Occidental Petroleum, Shell)
- * **NGOs** (Pacific Forest Trust)
- * **Utilities** (PacifiCorp, Salt River Project, Sierra Pacific Resources, TransAlta)
- * **National Lab and Research Institutions** (Electricity Innovation Institute, Kearney Foundation, LBNL, LLNL, MIT, Stanford-GCEP, Winrock)
- * **Engineering Companies** (Advanced Resources International, Clean Energy Systems, KinderMorgan, Nexant, SFA Pacific, Terralog)
- * **Public Outreach/Education** (Cal State Bakersfield, Cal Poly, S.F. Dept. of Environment, Science Strategies, Western States Petroleum Association)



The Region Forms a Coherent Study Unit



- * Commonality in terrestrial sinks in WA, OR, and Northern CA
- * Significant CO₂ source—over 11% of U.S. anthropogenic emissions
- * Commonality and large potential capacity in geological sinks in CA, NV, and AZ
- * Significant potential for offsetting costs with EOR and EGR in California and Alaska North Slope

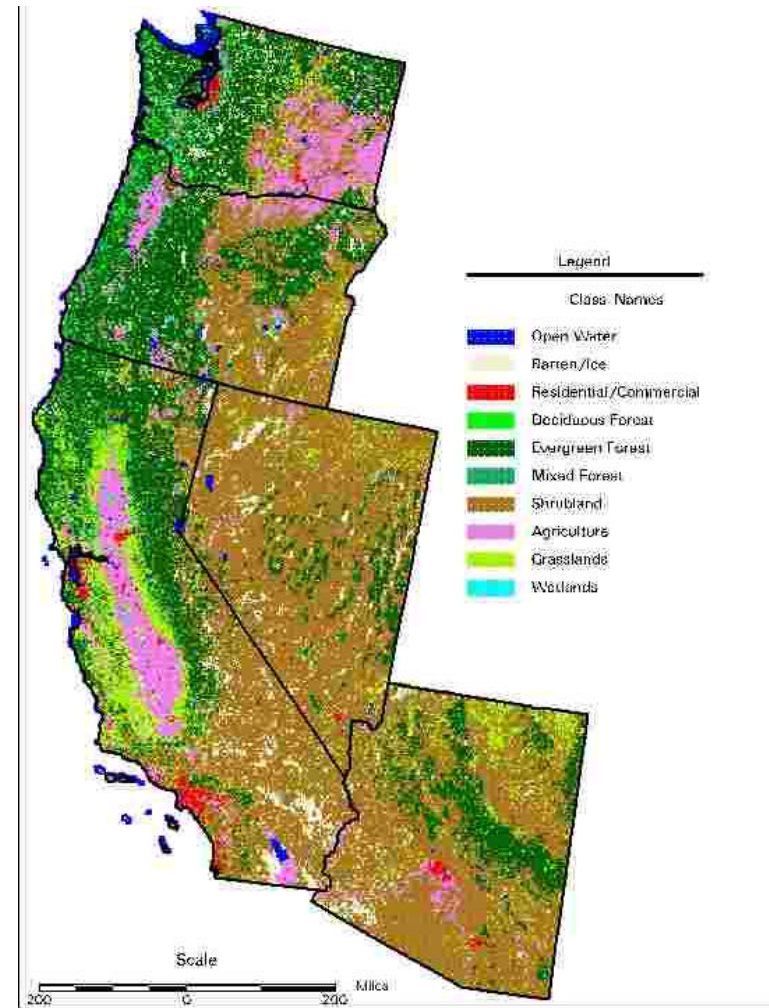




Regional Characterization: Data Collection



- ★ Terrestrial data includes land use, land cover, hydrology, soil maps, crop yields, land ownership, etc.
- ★ Point source data for power plants and major industrial sources: location, amount, processes
- ★ Transportation data with focus on pipelines, including right-of-ways and topography
- ★ Geologic data includes location, depth, formation properties, etc.

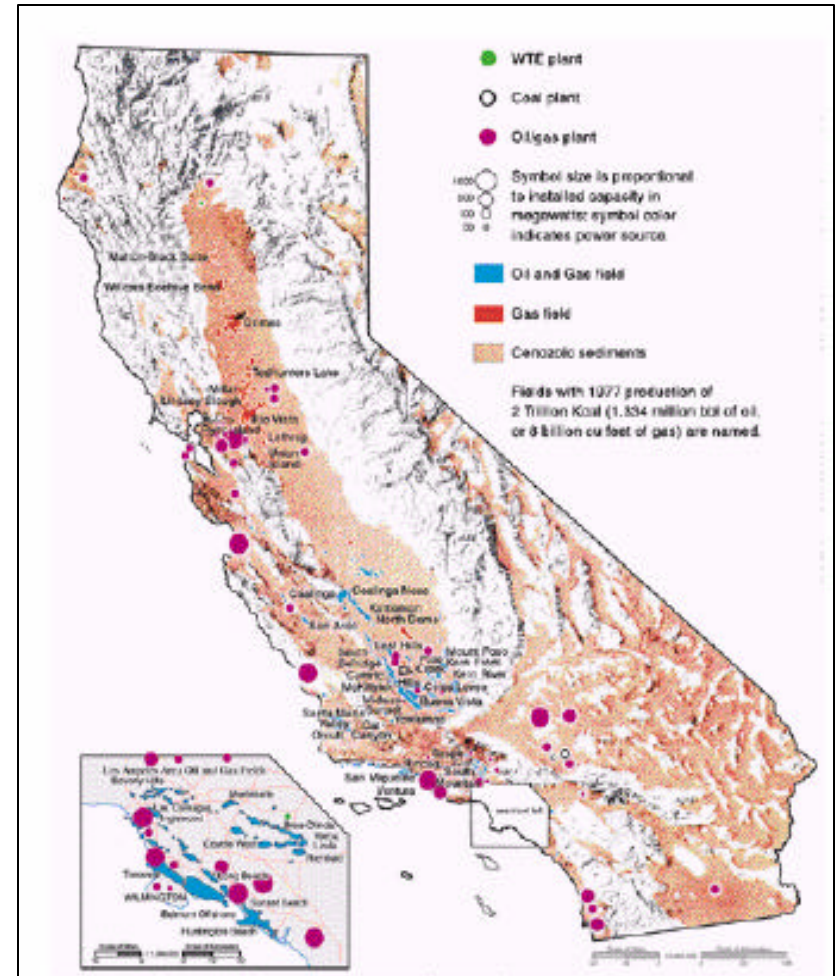




Regional Characterization: Data Integration



- * Winrock will develop two point terrestrial baselines for WA, OR, AZ, and CA
- * Complementary effort by Kearney Foundation on soil carbon storage in California
- * Consolidated GIS-based geologic sequestration database to be developed
 - **Source, transport, and site data**
 - **Cooperative effort with WGA, Utah AGRC, MIT, and CA Geologic Survey**



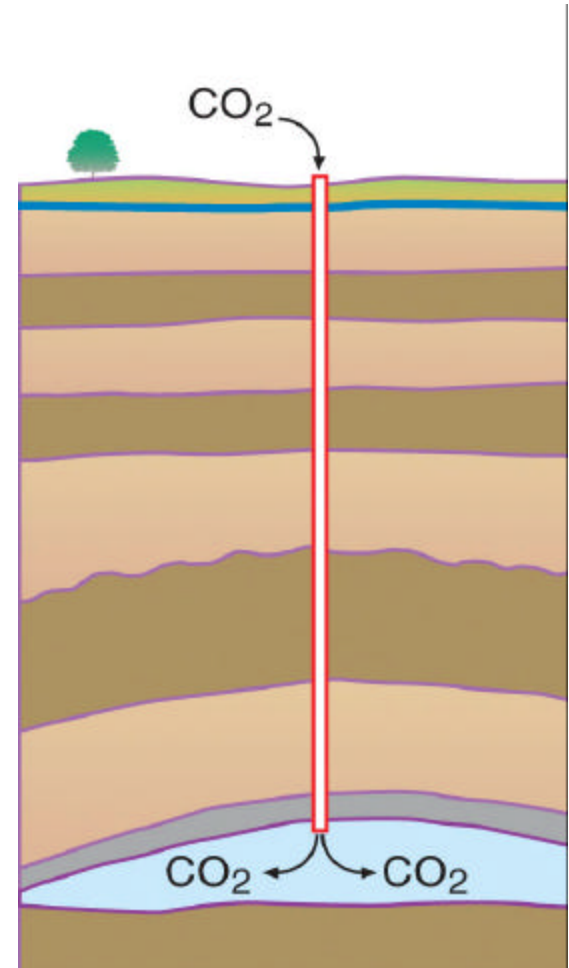
Power plants and oil/gas fields in California



Regulatory and Monitoring Issues Are Addressed



- * Regulations and permits will be compiled and assessed
- * Comparative assessment of regulations for enhanced oil recovery, natural gas storage, and underground waste injection
- * Develop protocols for monitoring and verification
 - ◆ Use potential pilot sites; perform simulations and assessment

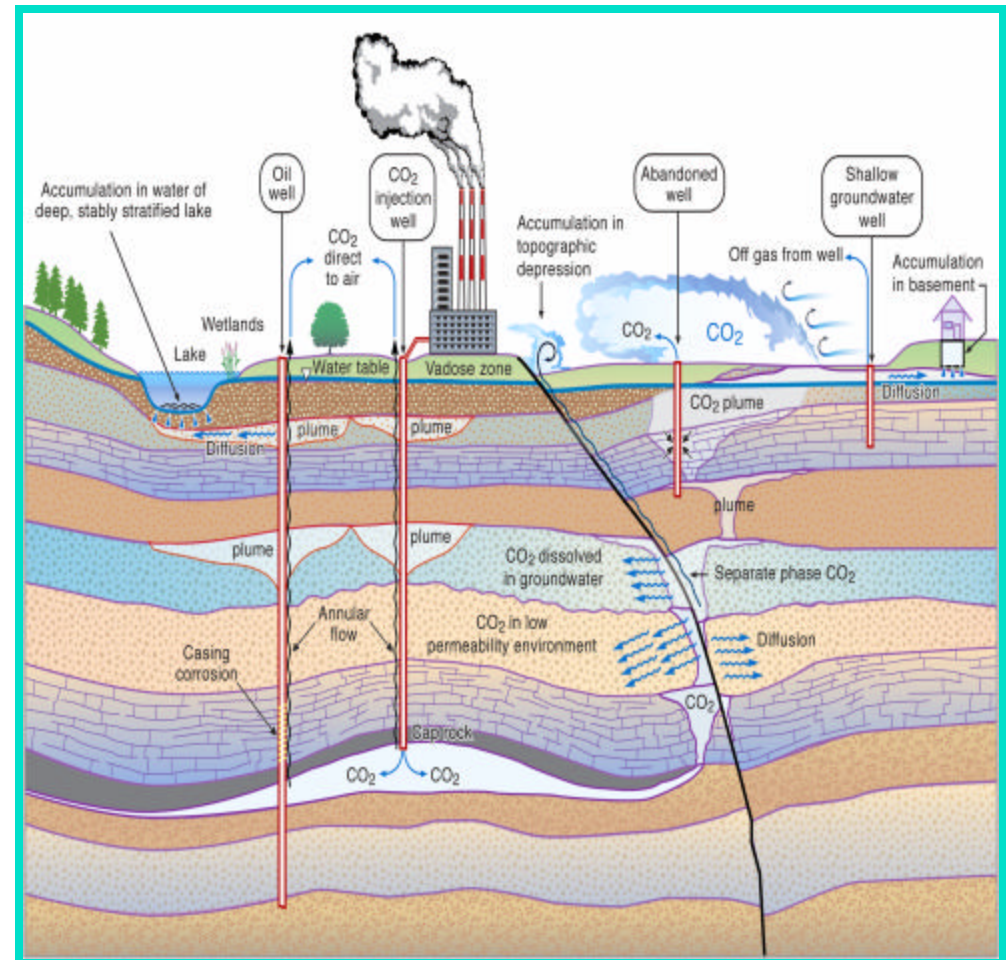




Methodology for Assessing Risk Is Needed



- ★ Focus on risk of leakage from geologic storage projects
- ★ Approach uses simulations based on identified FEPs (features, events, processes)
- ★ Use results in screening sinks





Developing Public Acceptance Is Key

- ★ Create Partnership web site
www.westcarb.org
- ★ Use existing channels, e.g., State forestry depts.
- ★ Develop educational materials; work with other partnerships
- ★ Hold stakeholders' meeting
- ★ Advice from NGOs, other stakeholders





West Coast Regional Partnership Will Be a Springboard for Deployment of New Technologies



- ★ Determine suite of technologies best suited for region, based on
 - ◆ Sources
 - ◆ Sinks
 - ◆ Current/future infrastructure
- ★ Determine regulatory issues and infrastructure needs for technology deployment
- ★ Develop educational materials to enhance public acceptance of technologies and evaluation of impacts related to public opinion
- ★ Identify least-cost options associated with sequestration alternatives
- ★ Evaluate environmental and public health risks and develop mitigation strategies



Driving to a Sustainable Future: The “E”s are Linked



- ★ Environment
- ★ Energy
- ★ Economics
- ★ Equity
- ★ Education

