California's GHG Reduction Goals and CCUS

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WESTCARB Acknowledgments, Disclaimers

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- **Disclaimers:**
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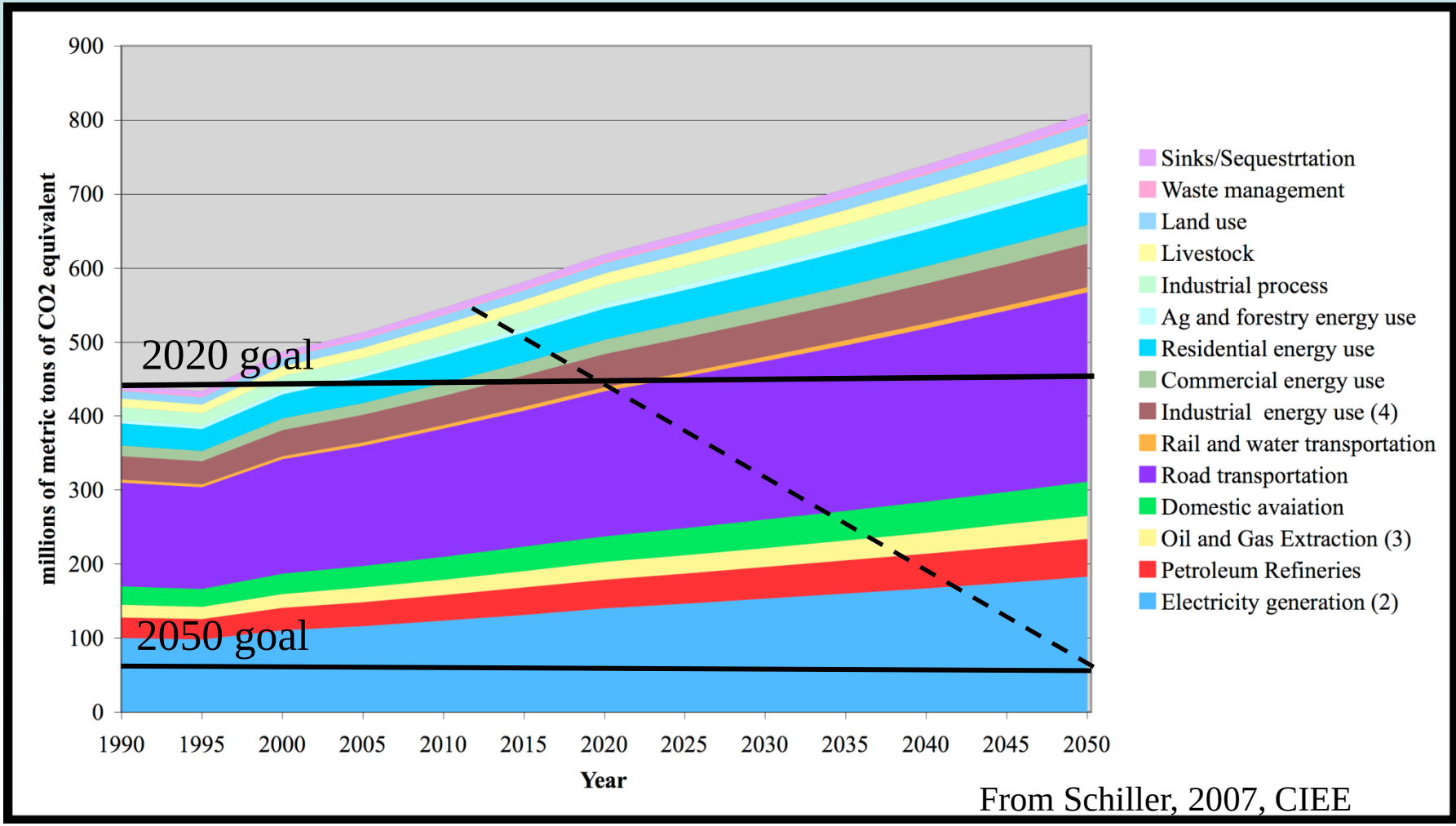
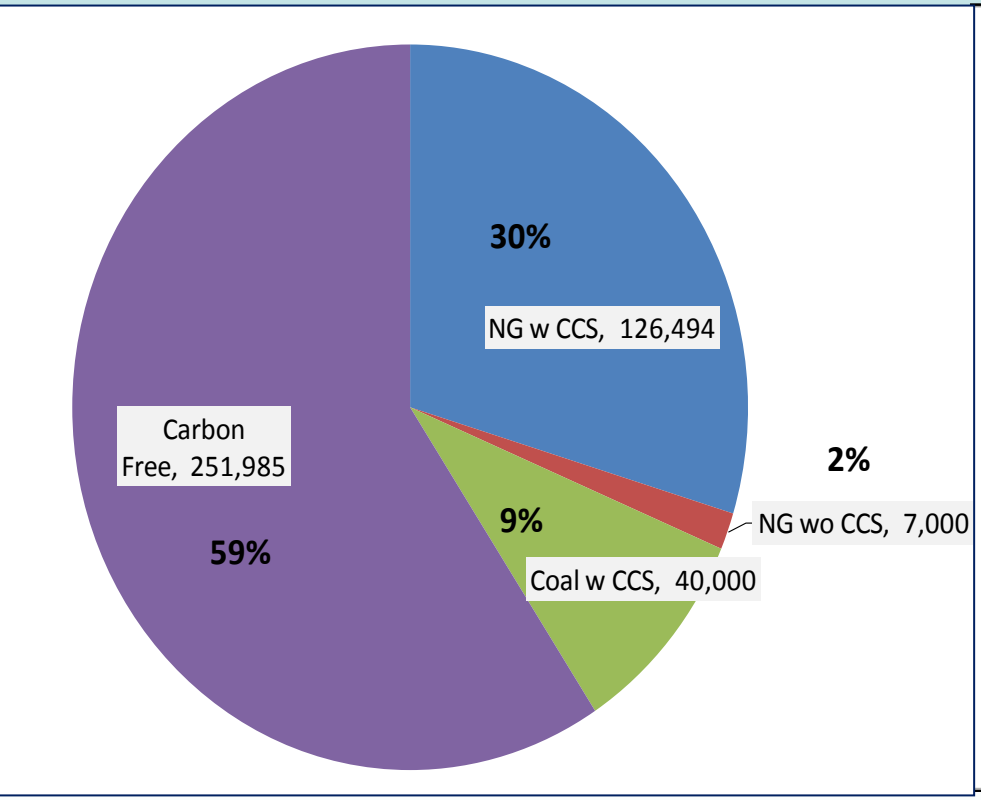
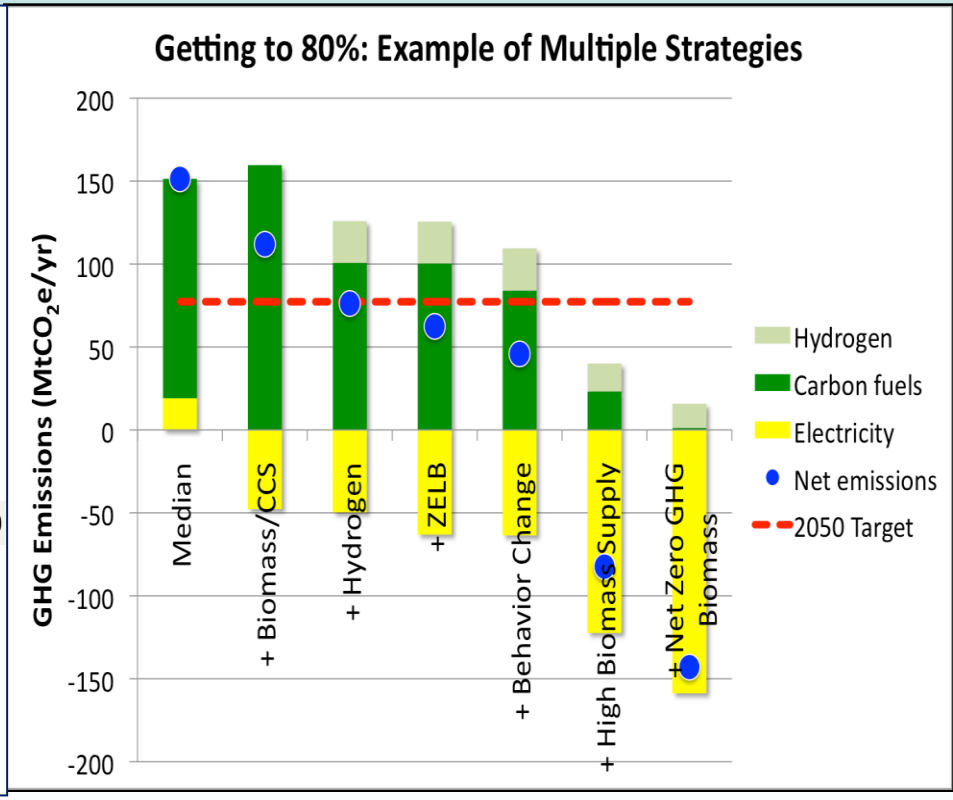
The required rate for GHG reduction to 2050 is 7MMT/yr with no emissions growth after 2020



From Schiller, 2007, CIEE

In scenarios of strategies to reach 2050 goals—CCUS is necessary





Source: The Implications of Early Deployment of Carbon Capture and Storage in California

http://www.uscsc.org/Files/Admin/Educational_Papers/CCS_Potential_in_CA.pdf

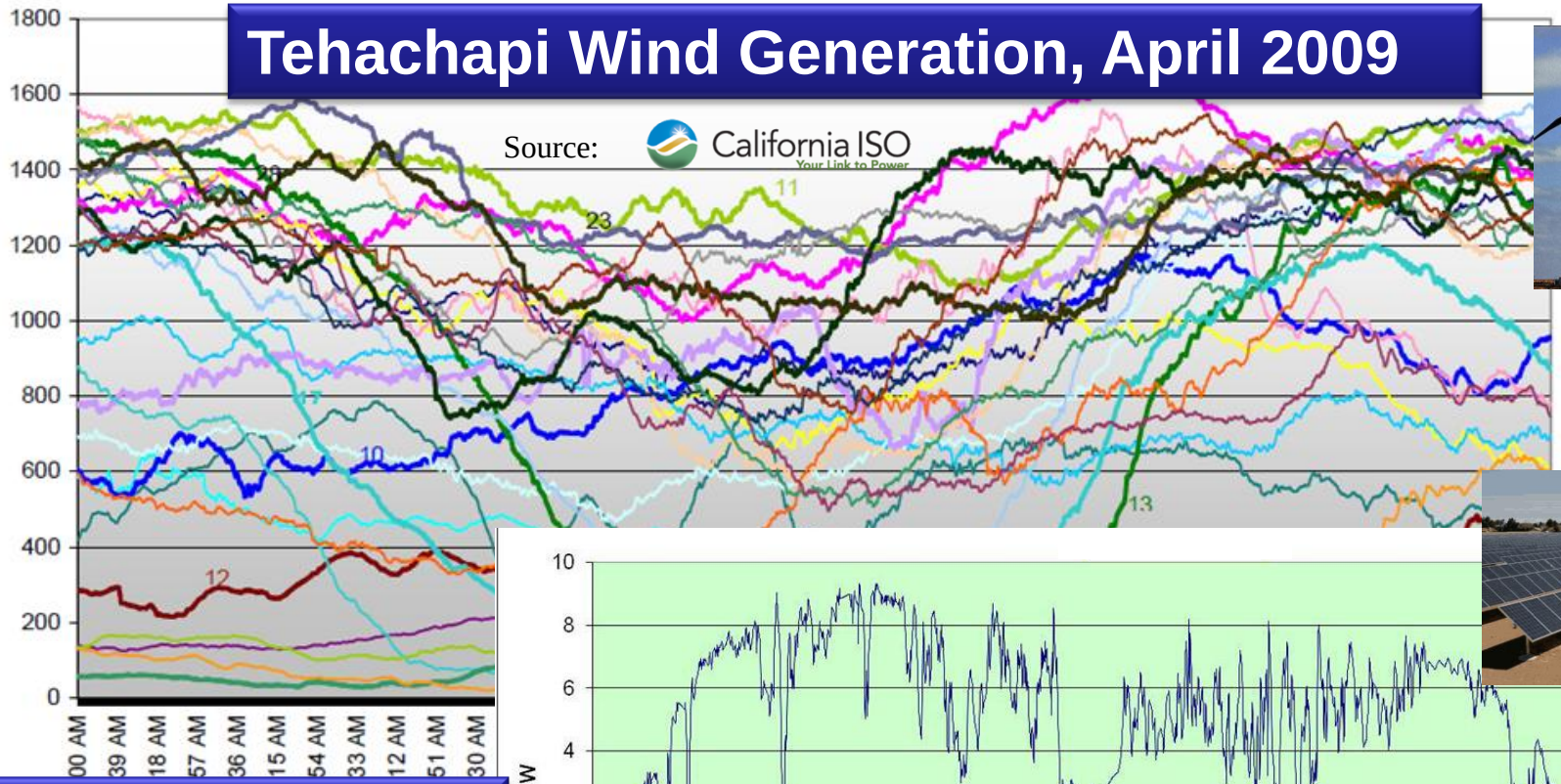
Source: California's Energy Future: The View to 2050

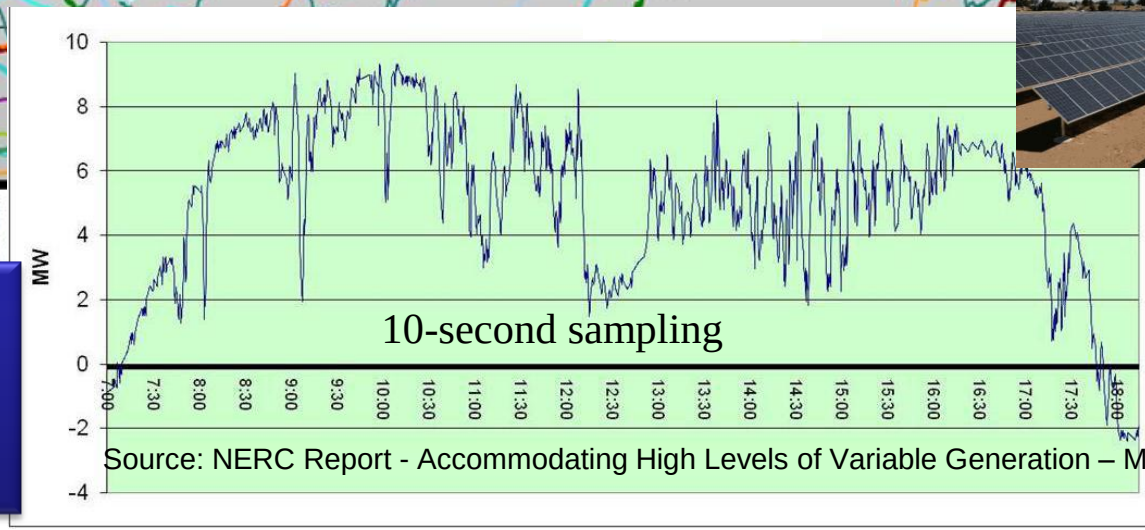
http://www.ccst.us/publications/2011/2011energy.php

High amounts of wind and solar require natural gas to balance intermittency

Courtesy of M. Brown, CIEE

Tehachapi Wind Generation, April 2009

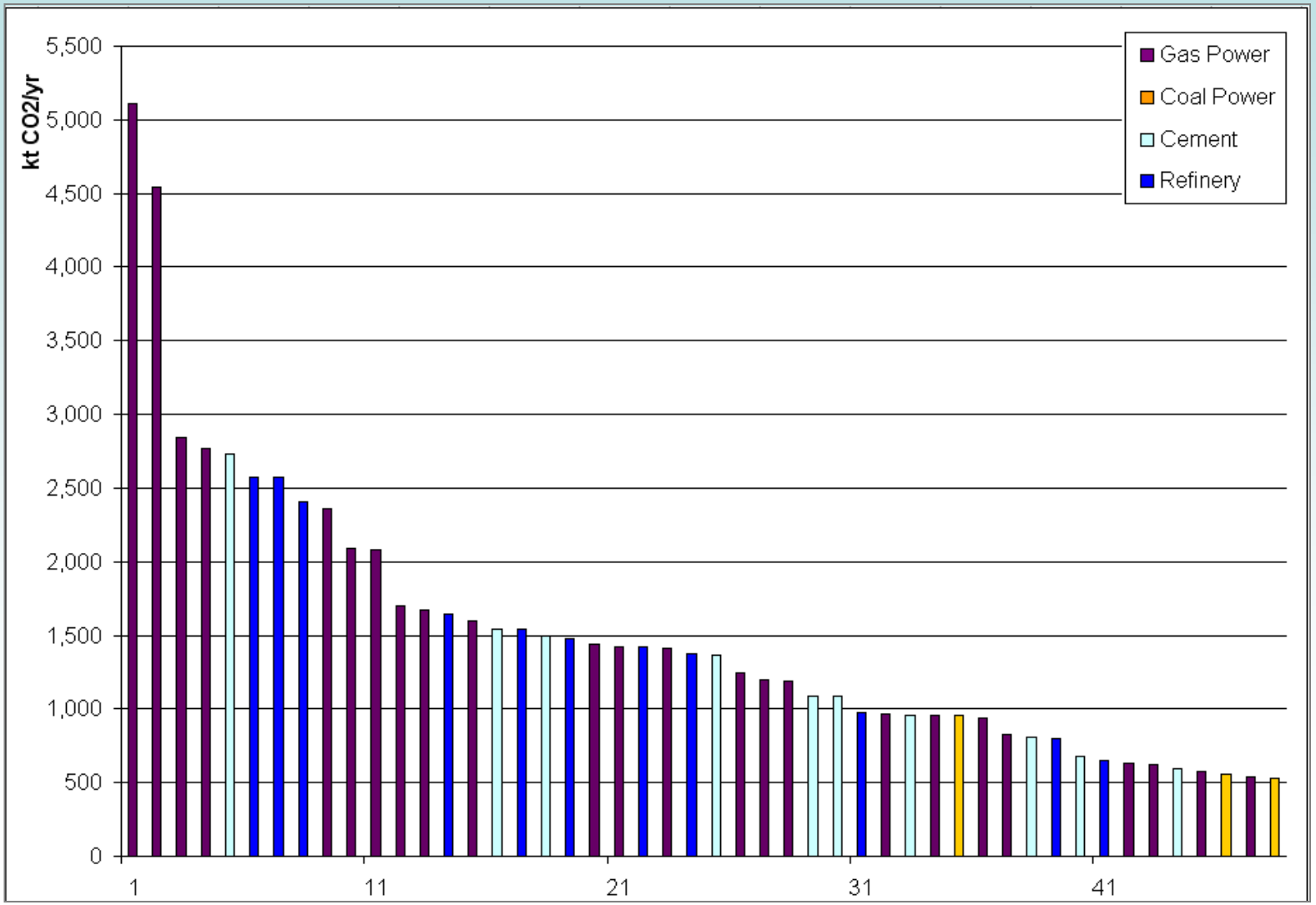




Solar PV output on partly cloudy day in Nevada

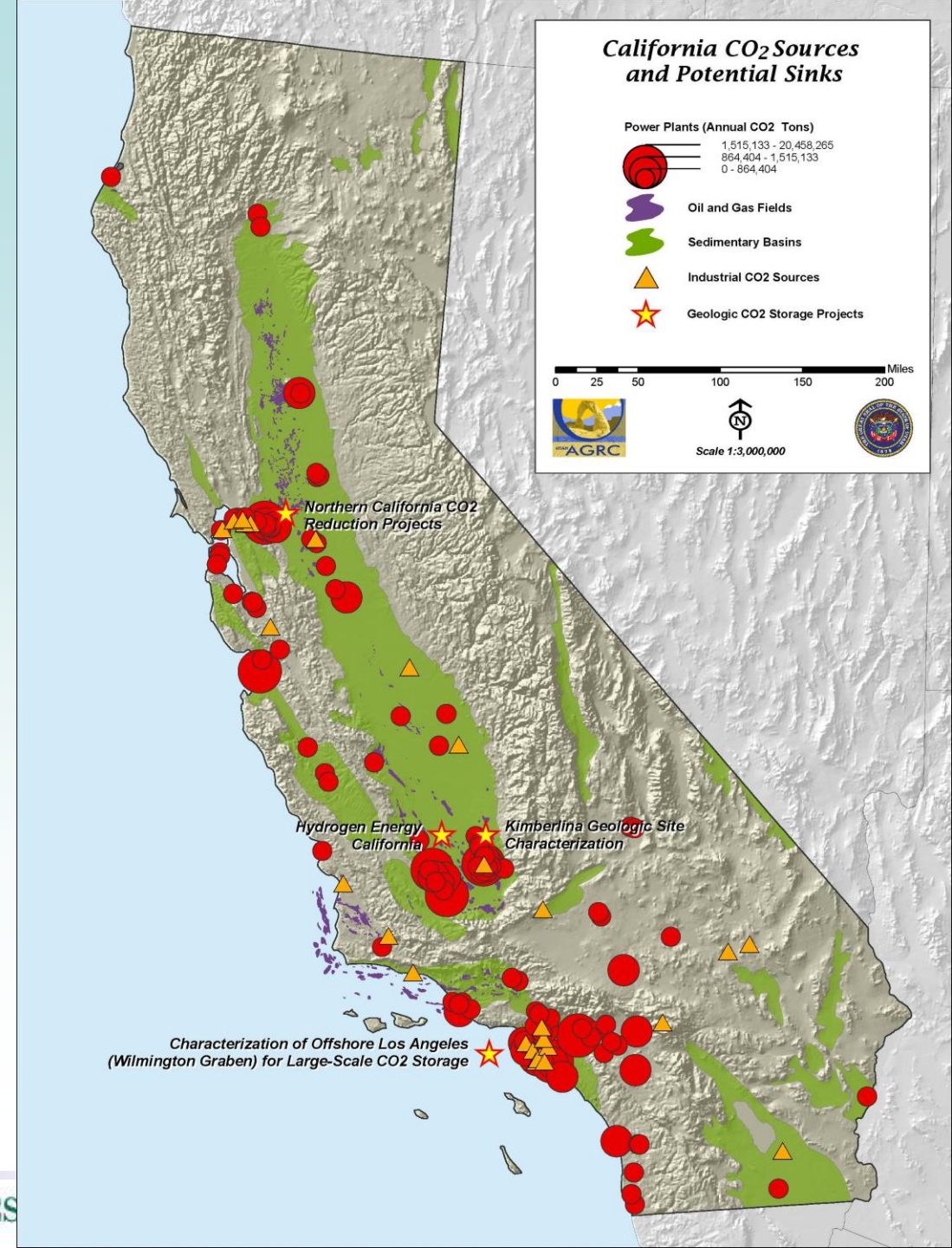
Source: NERC Report - Accommodating High Levels of Variable Generation – March 2009

The largest CO_2 point sources in California today are natural gas power plants



Sources, Storage Sites and Projects

- Large industrial and power plant CO_2 sources coincide with the state's major sedimentary basins
- Many also are in close proximity to oil and gas fields
- State is host to several CCUS projects

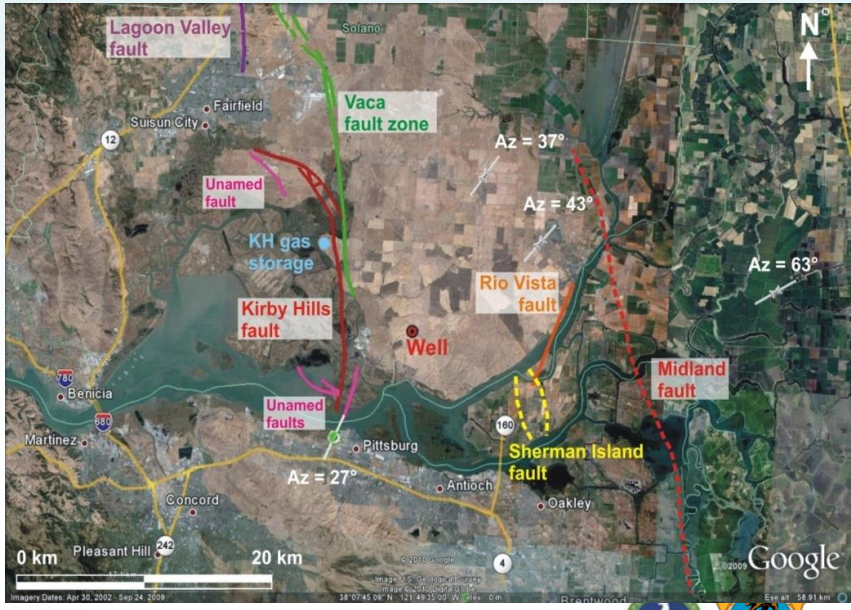


Challenges (perceived or real) for CCS development

- Risks from subsurface uncertainty
  - Low injectivity and storage capacity
  - Seismic hazards
  - Leakage into groundwater
- Cost (primarily from capture technology)
- Engineering & permitting of capture retrofits
- Pipeline permitting, right-of-way, infrastructure
- Competing mineral vs. storage pore space rights
- Long-term stewardship/liability
- Chain of custody for carbon “credit”

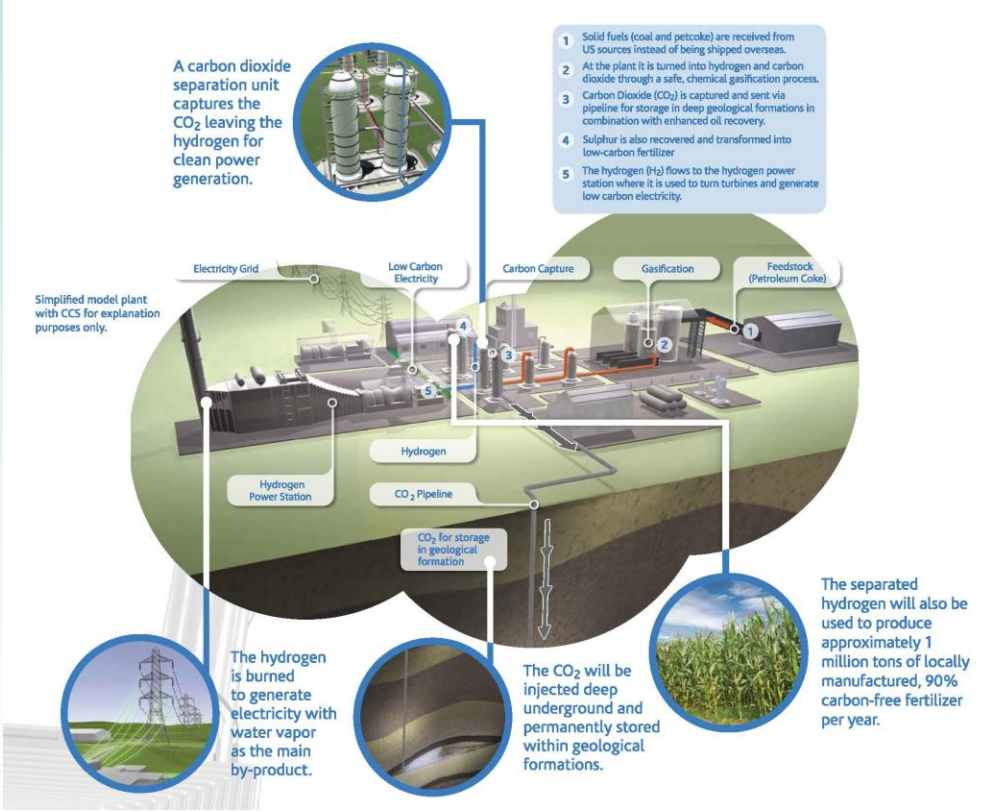
WESTCARB focuses on researching risks from subsurface uncertainty

- Storage resource
  - Injectivity
  - Capacity
  - Seal integrity
- Monitoring and verification
  - Technology
  - Methodology
- Risk assessment methodologies
  - Leakage
  - Natural and induced seismic hazards

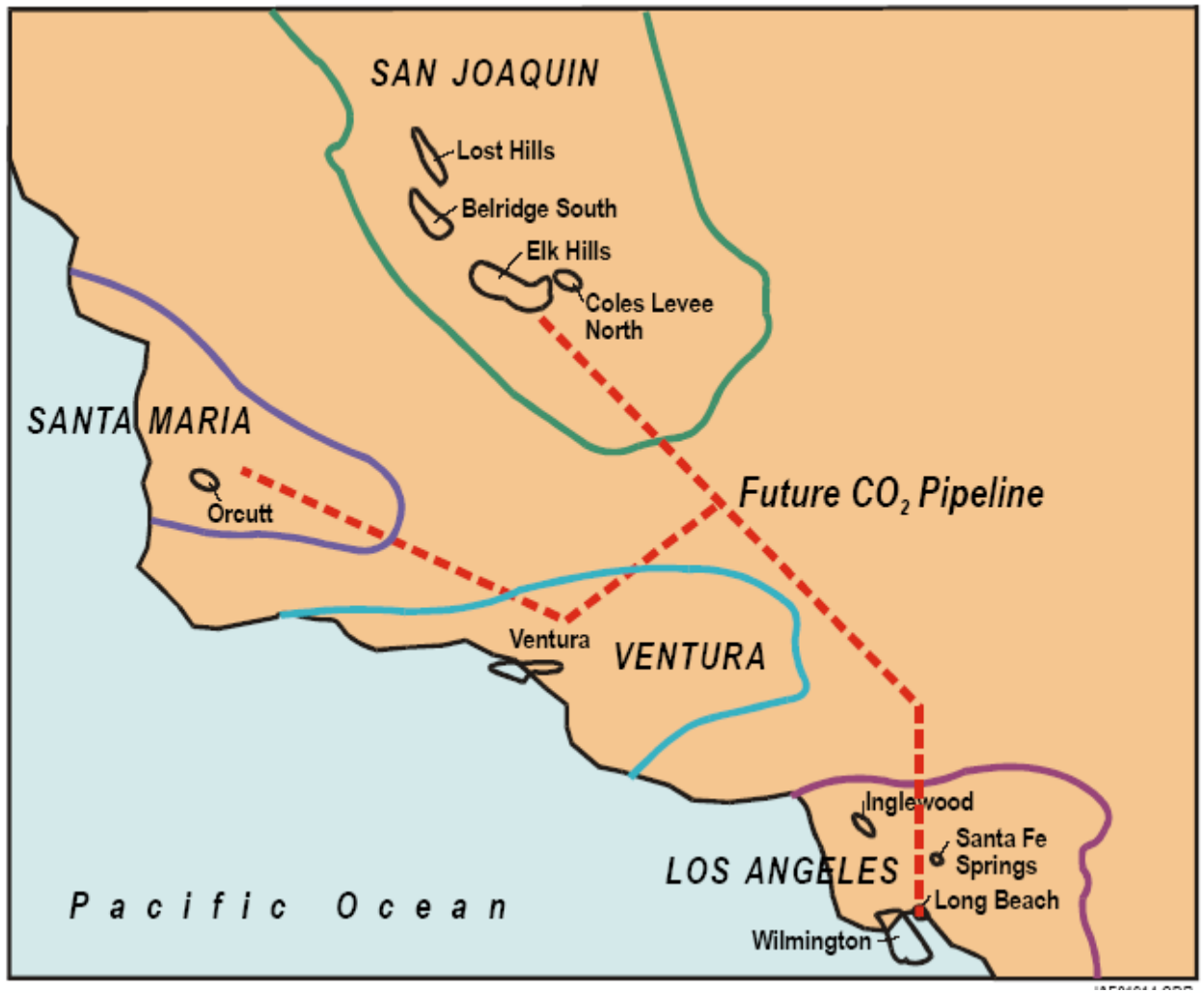


California's First Commercial-scale CCUS Project: Hydrogen Energy California

- A 300 MW Combined Cycle Power Plant with Flexible Generation
- A fertilizer manufacturing plant with multiple products
- A CO_2 pipeline and EOR sequestration of 90% of project's CO_2
- Approximately 3 million tons of CO_2 sequestered through EOR annually



Many California oil fields are suitable for CO_2-EOR



- 172 fields studied in 4 basins
  - 88 fields amenable to CO_2-EOR
  - 59 miscible
  - 29 immiscible
- Up to 5 billion barrels additional oil recoverable

Advanced Resources International, Inc, 2005, Basin Oriented Strategies for CO2 Enhanced Oil Recovery: California, NETL.

Advantages of combining CO_2-EOR and carbon storage

- For carbon storage: lowers risk
  - Greater subsurface certainty from detailed exploration
  - Demonstrated retention of buoyant fluids over millions of years and through many natural seismic events
  - Existing oil field infrastructure
  - Revenue from CO_2
- For California: revitalize oil industry and reduce oil imports
  - Oil production has declined 47% since 1985
  - California has no other source of CO_2 for EOR except anthropogenic emissions
  - Crude imports into the state for refineries forecast to increase by up to 104 million barrels by 2030
  - Revenue and jobs

Summary/Conclusions

- California will need CCUS to meet its long-term GHG reduction goals
- Combining CO_2 storage with EOR lowers project risk and will improve California's future economy
- Remaining challenges are surmountable
  - Infrastructure costs—capture and pipeline
  - Permitting/regulation that facilitates industry-led projects while ensuring public safety and verifying GHG reduction goals
  - Scientifically defensible monitoring and accounting methods for CO_2 storage, especially with EOR or other utilization

Back-up slides

Seismic Hazards

- "Underground Carbon Dioxide Storage Likely Would Cause Earthquakes" – The notion of mitigating harmful carbon dioxide emissions by storing the gas underground is not practical because the process is likely to cause earthquakes… LA Times, June 18, 2012
- "Earthquake Triggering and Large-scale Geologic Storage of Carbon Dioxide" – We argue here that there is a high probability that earthquakes will be triggered by injection of large volumes of carbon dioxide into the brittle rocks of continental interiors….Zoback and Gorelick, PNAS online June 18, 2012
- "Induced Seismicity Potential in Energy Technologies"– Projects that inject large volumes of fluids over long periods of time such as CCS may have potential for larger induced seismic events though insufficient information exists…continued research is needed…National Research Council prepublication report, June 15, 2012.