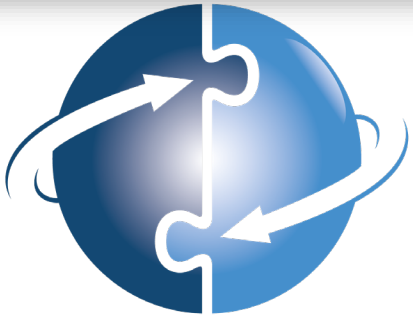
Re-purposing Fossil Fuel Infrastructure and Expertise for Low-carbon Energy Systems



ENERGY FUTURES INITIATIVE

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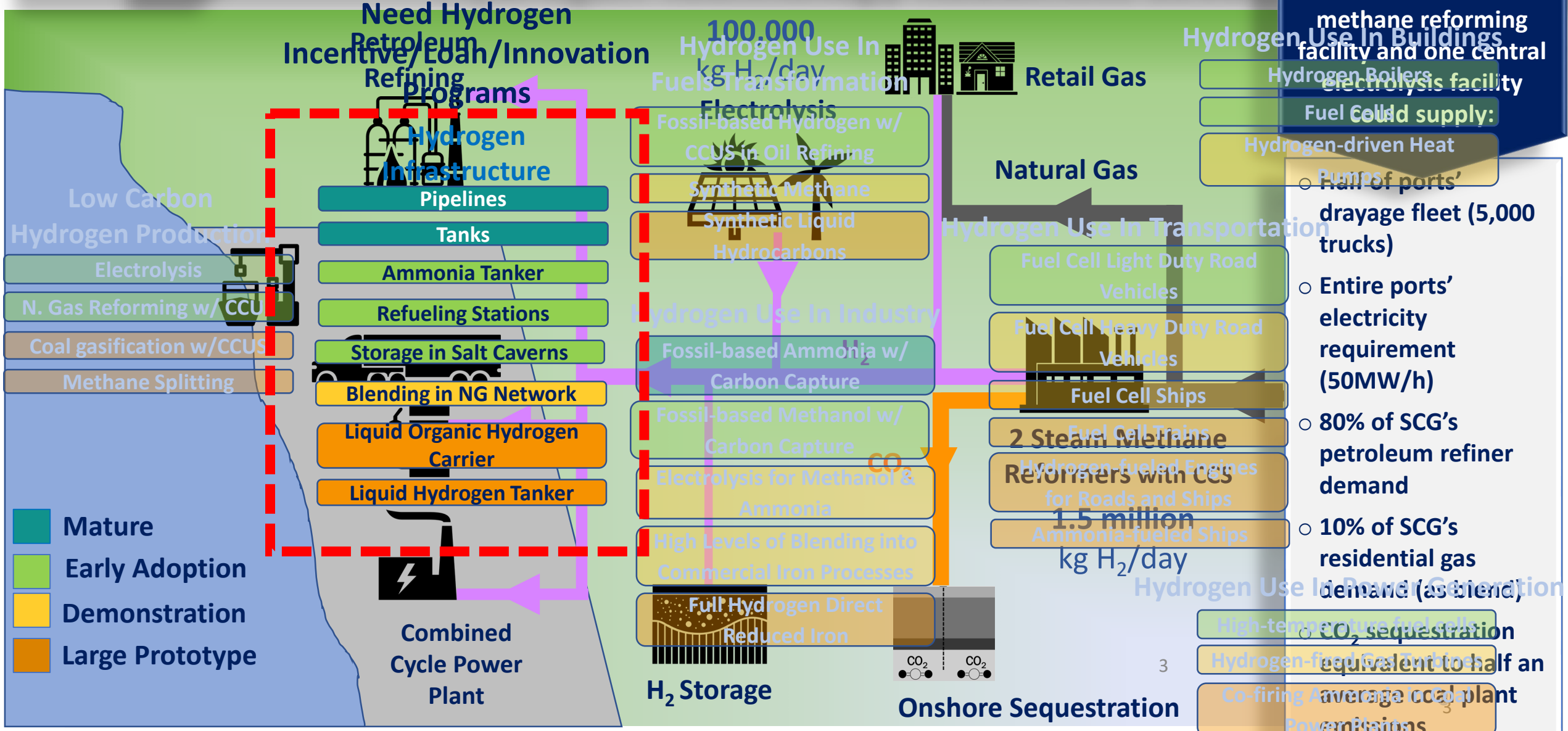
California Air Resources Board
June 15, 2020

Leveraging Existing Carbon Infrastructure to Support Decarbonization Pathways

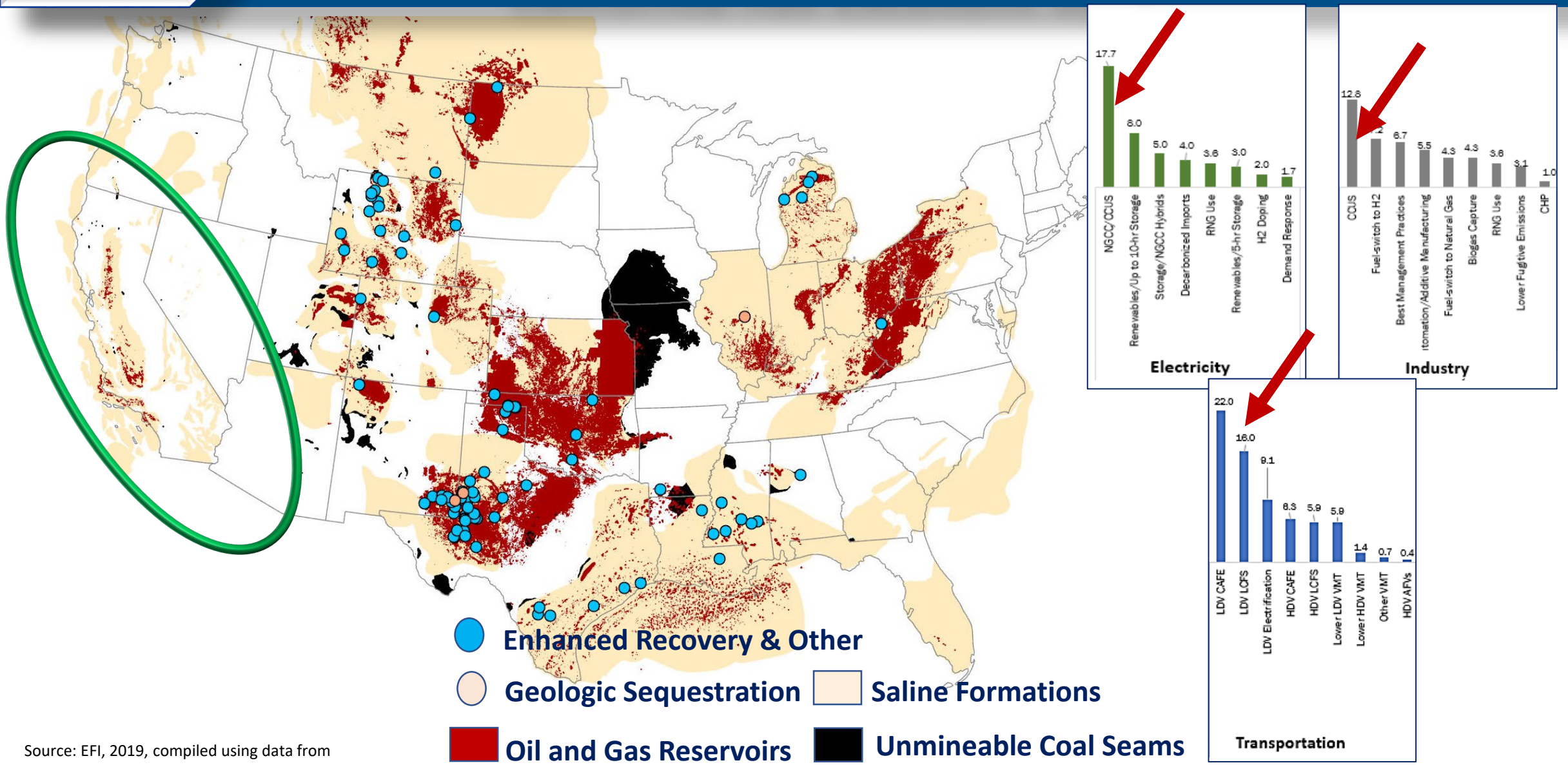
Negative Emissions Technologies /Carbon Capture, Utilization, and Storage (CCUS)	• Applying industry expertise to CCUS technologies for direct-air capture (DAC) and bioenergy with carbon capture and storage (BECCS)	• Applying industry expertise: CCUS technologies for DAC and BECCS	• Using compression technologies similar to those in NG infra-structure for CO_2 • Rail and roadway = existing infrastructure • Leveraging pipeline rights-of-way	port of LPG/LNG for liquid CO_2 • Marine vessels for CO_2 using the same technology as existing LPG or LNG tankers • Port infrastructure for loading • Offshore facilities for subsea injection	formations • Using industry expertise in large-scale CO_2 separation and sequestration • Applying technologies for drilling and injection, subsurface characterization, and site monitoring, same as in the O&G sector • Leveraging similarities with NG storage, acid gas disposal, and CO_2-EOR
Renewable Natural Gas (RNG)	• Processing technologies are similar to NG processing	• Minimal processing for using RNG for power generation in gas turbines	• Doping in NG pipelines • Leveraging pipeline rights-of-way	• Utilizing existing fuel storage and transportation hubs	• Leveraging industry expertise with NG storage
Smart Systems/ Platforms	• Applying process automation for improved refinery performance	• Creating smart generation solutions: NG-battery and NG-solar	• SCADA expertise • Improving the efficiency of transport of RNG, H_2, CO_2 • Enhanced leak detection	• Using transport management systems and other IoT applications • Data tracking of supply chains	• Optimizing revenues from grid-scale storage systems

Decarbonization pathways are as much about infrastructure as they are about technology. The transition to a low-carbon future could potentially be improved by seeking opportunities to leverage California's existing physical and intellectual infrastructure, technological expertise and its skilled and ready workforce.

Example of a "Hydrogen Hub": Ports of LA and Long Beach, Hydrogen Technology Readiness Levels



Potential Carbon Sequestration Sites: California has Excellent Options



Source: EFI, 2019, compiled using data from the EPA and NETL

EFI Clean Energy Innovation Index/ Breakthrough Technologies

- Federal and private clean energy innovation are complementary
- Key platform technologies hold great potential to unlock significant clean energy innovation
- A four-step process is used to identify breakthrough technologies that have the potential to aid government, industry and thought leaders in efforts to transform the energy sector

National Network for Manufacturing Innovation centers, NASA labo and facilities, the top 100 research universities, and the major Federally Funded Research and Development Centers (FFRDCs). There is a significant clustering of innovation capabilities

Analyze key drivers of clean energy technology breakthroughs

Digitalization, big data & smart systems

The difficult to decarbonize sectors

Integration of platform technologies

Systems and supply chains

Develop selection criteria for breakthrough technologies

Technical merit

Market viability

Compatibility

Consumer value

Identify the universe of emerging energy technologies that have critical features across various timescales

Identify innovation areas with significant breakthrough potential

Critical innovation areas identified are:

- Storage and battery technologies
- Advanced nuclear reactors
- Technology applications for industry and buildings as sectors that are difficult to decarbonize including hydrogen, advanced manufacturing technologies; and building technologies
- Systems: electric grid modernization and smart cities
- Deep decarbonization/large-scale carbon management; carbon capture, use and storage at scale; sunlight to fuels; enhanced biological and oceans sequestration

Source: Advancing the Landscape of Clean Energy Innovation, 2019, EFI, IHS Markit

Lithium, Cobalt, Nickel Production/Reserves, Need for Expertise in Global Supply Chains

US should –

- *Increase its diplomatic and investment focus on Western Hemisphere and Africa*
- *Protect supply chains for minerals/metals needed for wind, solar and batteries*
- *Support new domestic environmentally-responsible mining activities for key minerals/metals*
- *Support innovation in mining efficiency and in earth abundant materials for wind, solar and batteries*
- *Use renewable energy for electricity needed in mining operation*
- *Promote humane mining conditions around the world*
- *Start metals and minerals recycling programs <u>now</u>*

Source: USGS, 2019

https://www.schedulereader.com/blog/oil-and-gas-industry-overview