Energy Storage and Carbon Capture and Storage (CCS)

Emerging Clean Generation Technologies

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Current Issues 2021
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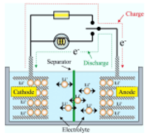
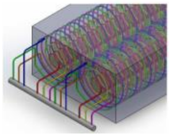
Energy Storage: Low-Carbon Enabler

- Variable renewable energy (VRE) is projected to grow significantly to reduce greenhouse gases
- Energy storage is needed to provide power when renewables cannot and for grid stability and reliability
  - 1–4 hours duration: Lower VRE, fossil use prevalent
    - Batteries



  - 4–48 hours duration: Medium VRE, some fossil backup
    - Potential for non-battery types



  - Weekly or seasonal duration: High VRE
    - Low-carbon fuels, e.g., hydrogen

- Dispatchable, reliable, safe, and cheap—and preferably synchronous

A huge amount of "bulk" energy storage will be needed – TWhs

Energy storage will require longer durations and larger scales

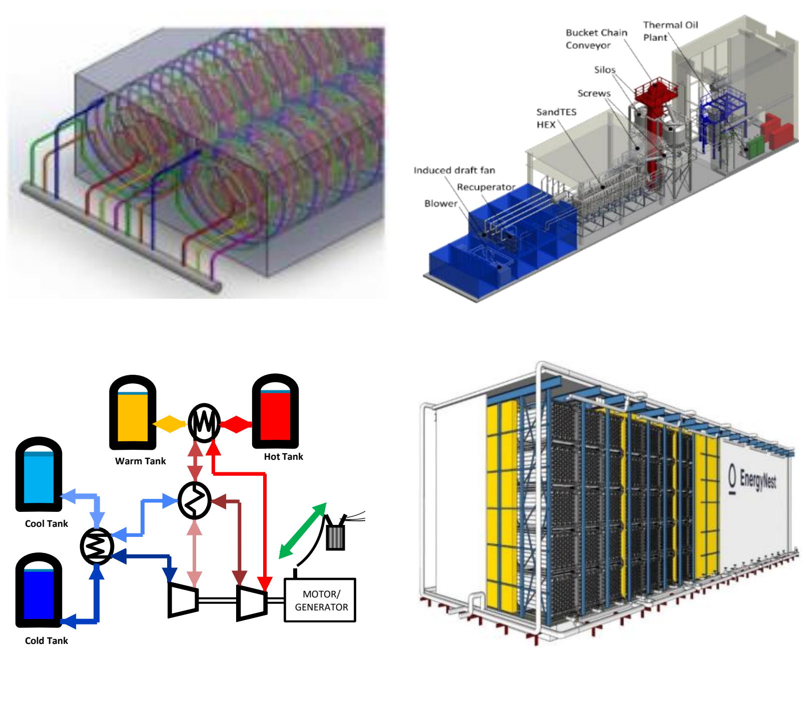
Energy Storage Types

Electrochemical

Reversible chemical reaction generates an electrical potential difference

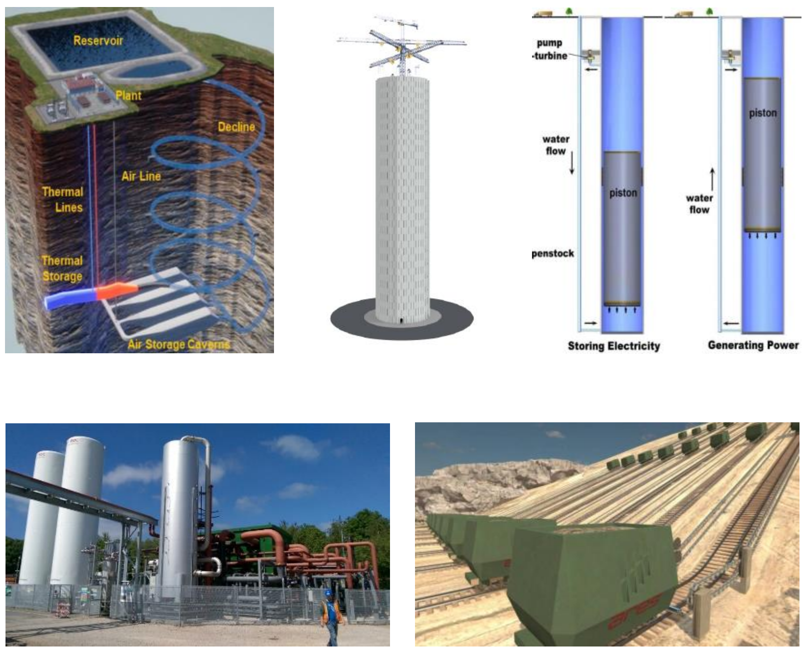
Thermal

Energy storage achieved by heating a bulk media



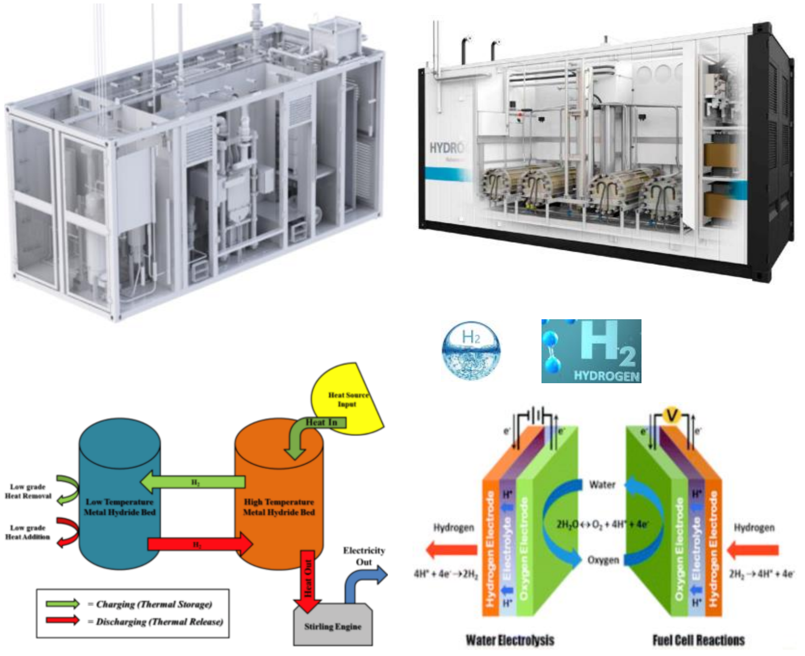
Mechanical

Kinetic or potential (compression or gravitational)



Chemical

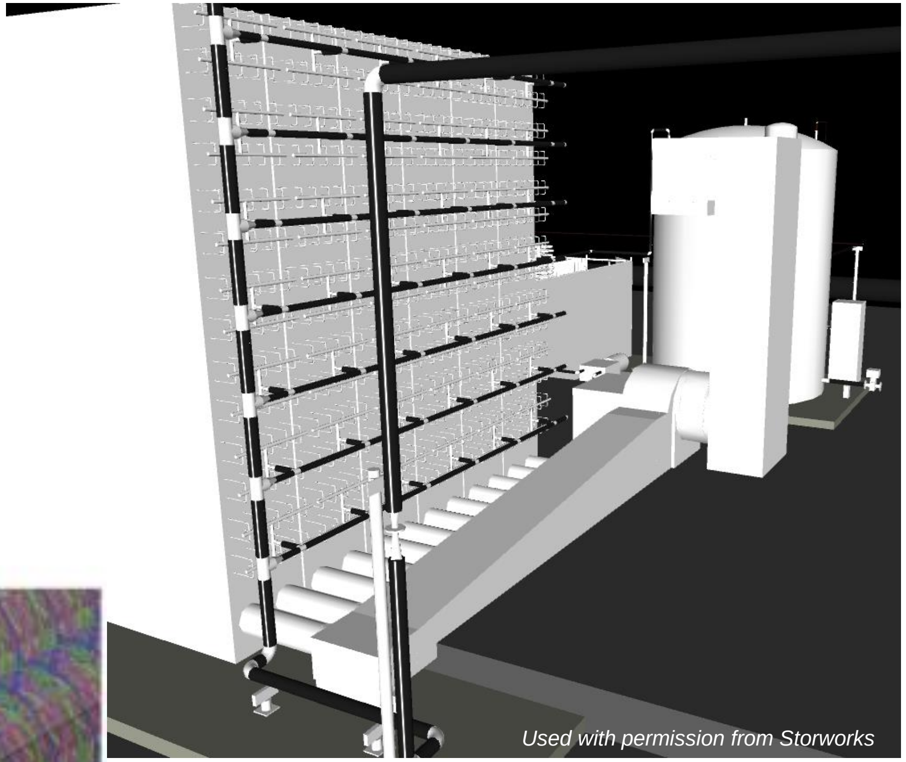
Reaction produces product that can generate heat or power



Advancing technology today in store for tomorrow

Example: Concrete Thermal Energy Storage (CTES)

- Design, construct, and test a 10 MWh-e CTES system integrated to a Southern's Plant Gaston
- Low-cost material: $68/tonne
- Solid 'thermocline' structure used to store thermal energy; steam tubes embedded into concrete as coils
- Details (per block)
  - 20 tube coils, 7 m^3, 18.6 tonnes material
  - 0.75 x 11 x 12.5 m (road/rail transport)
- CTES Assembly
  - Arrangement: 10 high by 6 wide
- Operation for 11 months



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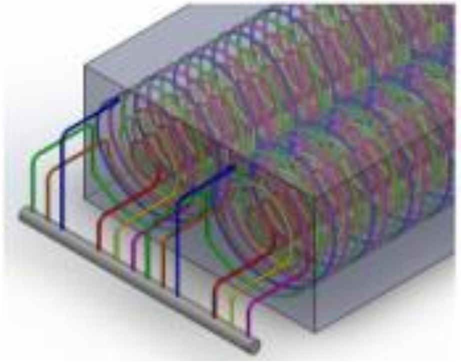


Tube internal arrangement

Construction has started with operation in 2022

Production of Hydrogen (H_2)

- H_2, ammonia, biofuels, and synthetic fuels are referred to as Alternative Energy Carriers (AECs)
- AECs are not primary sources of energy, rather they are created by converting other energy sources to a fuel that can be readily transported and **stored**
- H_2 can be produced using various industrial processes, energy sources (e.g., fossil fuels, biomass, electricity) and water
- Electrolysis must use low- or no-carbon electricity and gasification/SMR must use CCS to reduce CO_2 emissions

Energy penalty occurs during each conversion step
"No free lunch"

48%

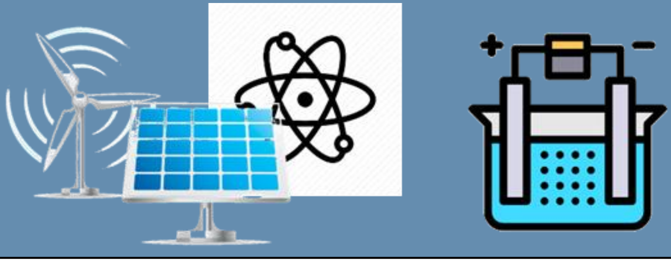
Steam methane reforming (SMR)

48%

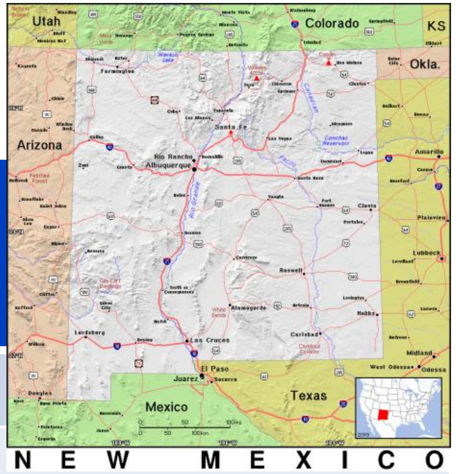
Gasification of coal, oil, and biomass

4%

Electrolysis using low- or no-carbon electricity



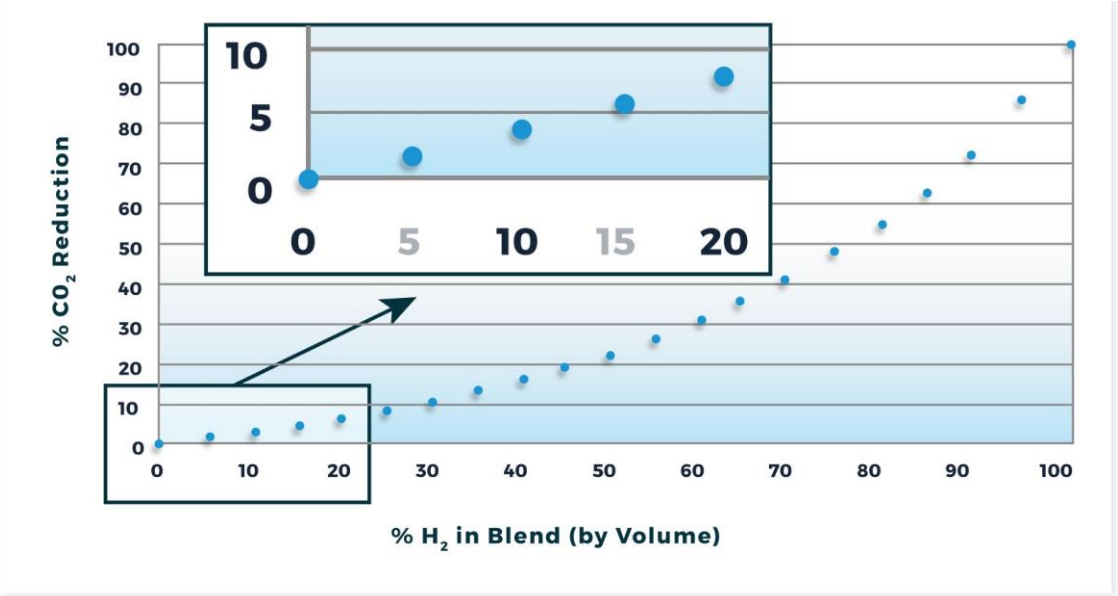
What is the Scale and How Much Electricity is Consumed by Electrolysis for H_2 Production?



Scenarios	Annual H_2 production (MMt)	Electricity Consumption (TWh)	Percent global electricity use 2018	Context
Current H_2 production, X				
All H2 production methods	70			
Electrolysis (US)	0.5	26.6	0.1	Exceeds The Land of Enchantment's electricity consumption
Replace 30% H_2 sourced from coal with electrolysis	21	1,097	4.1	~ Russia's electricity consumption Reduces global CO_2 emissions by 1%
Replace 100% H_2 sourced from all fuels with electrolysis	70	3,657	13.7	~ 88% of US generation
Estimated H_2 demand growth by 2050				
Shell model, 2X	131	6,843	25.6	2x current production
Hydrogen Council, 8X	564	29,462	110	Exceeds global electricity consumption

H_2 Transportation and Storage Challenges

- H_2 contains 1/3 the energy of natural gas at normal working conditions
- Blending H_2 in natural gas pipelines
  - <20% blends will likely require little to no changes in end-use equipment and appliances
  - >20% will likely require upgrades to end-use equipment/appliances, compressor stations, valves, etc., but pipeline materials could potentially be repurposed
- Hydrogen's lower volumetric energy density creates storage challenges



Blending H_2 into NG does not result in an equivalent 1 to 1 reduction in CO_2 emissions

The **Low-Carbon Resources Initiative** (LCRI) is a five-year R&D commitment focused on the advancement of low-carbon technologies for large-scale deployment across the energy economy. This initiative is jointly led by **EPRI and GTI**.

FOCUS

Multiple options and solutions to establish viable low-carbon pathways

Technologies for hard-to-decarbonize areas of the energy economy

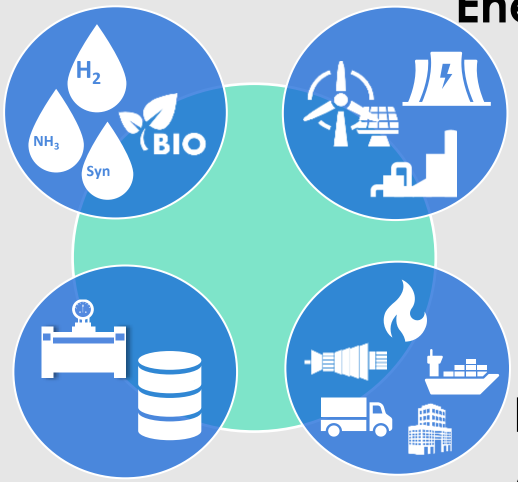
Affordable, reliable, and resilient integrated energy systems for the future

RESEARCH AREAS

Hydrogen | Ammonia | Synthetic/ Derivative Fuels | Biofuels

Production Pathways

Integrated Energy Systems



Storage & Delivery

End Use Applications

VALUE

Independent, objective research leveraged by global engagement and collaboration

Comprehensive value chain approach across adjacent sectors

High-impact results that accelerate technology time to market

Opportunities for Deploying Carbon Capture and Storage

COAL

GAS

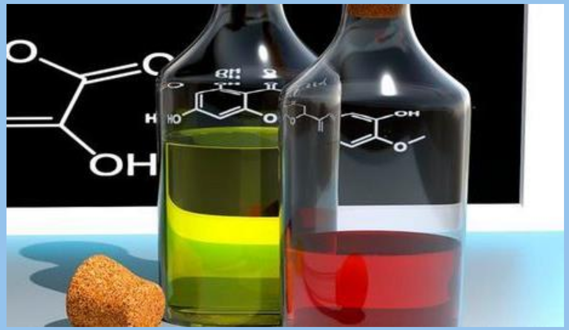
BIOMASS

CONCRETE

STEEL

PETRO CHEMICAL

HYDROGEN



SYNTHETIC FUELS

DAC

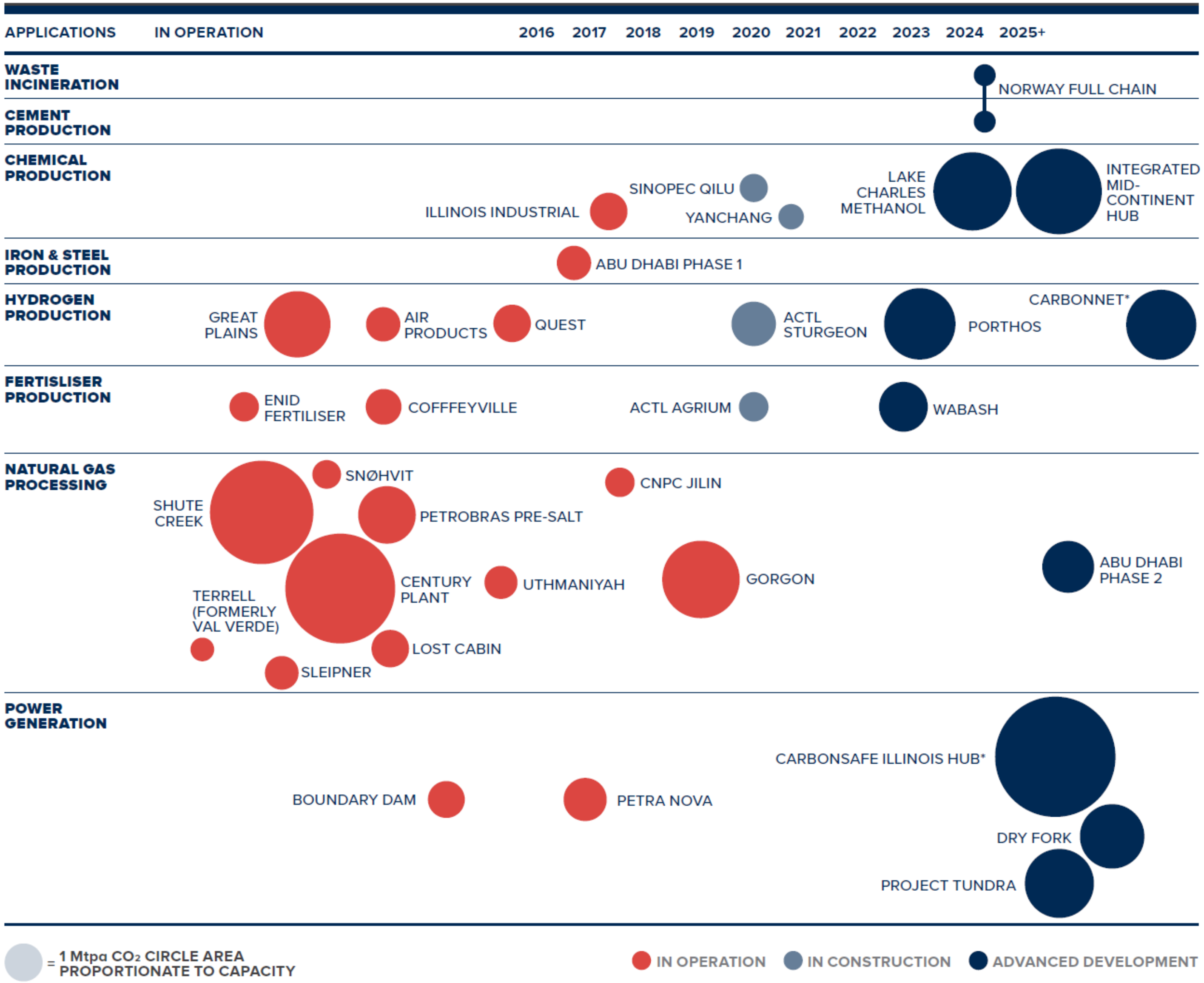
Global CCS Project Experience

Source: Global CCS Institute, 2019.The Global Status of CCS: 2019. Australia.

Compare bubble size at right with those below

Largest coal-fired power station in the world
6,720 MW

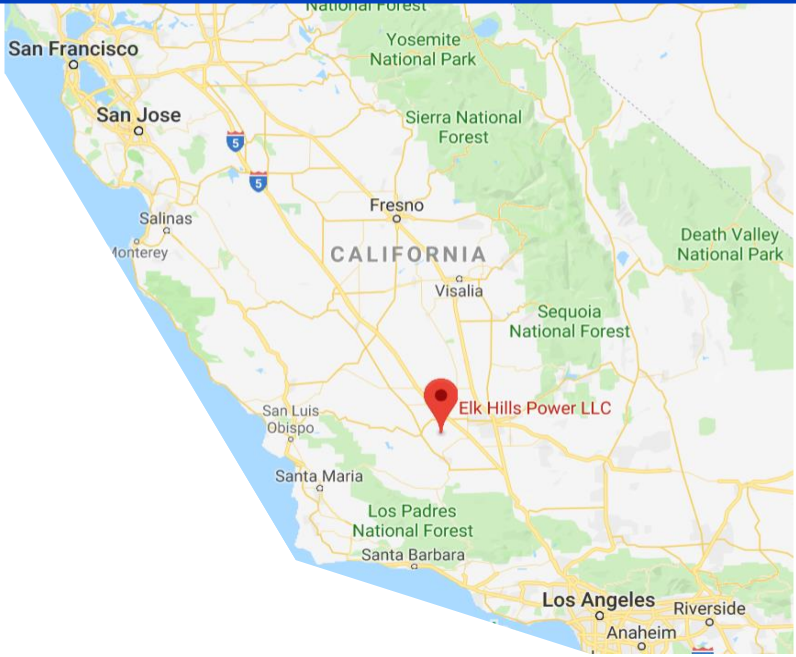
Largest natural gas fired power station in the world
5,597MW

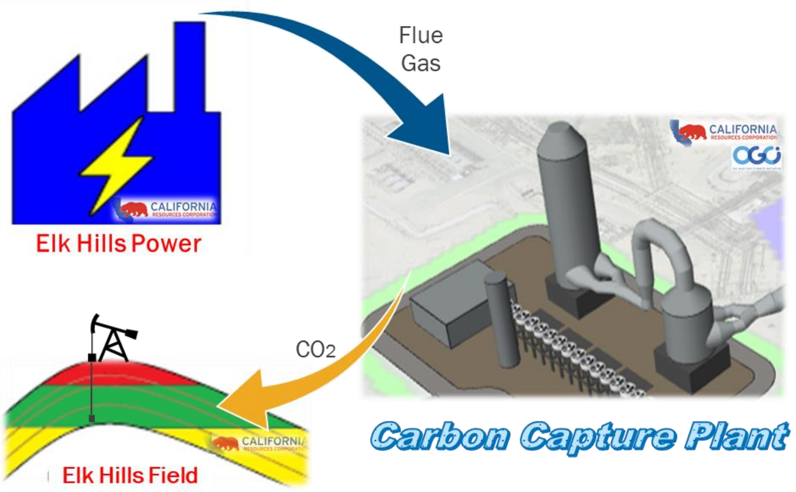


* Calculated emissions using average CO_2 emission intensity for the US fleet (NG and coal are 0.42 and 1.0 tCO_2/MWh, respectively). Actual plant emission intensity may differ.

Overview: CalCapture FEED Study

- Project Objectives
  - Determine technical and economic feasibility of deploying Fluor's Econamine FG+SM post-combustion carbon capture process on CRC's 550 MWe NGCC Elk Hills Power Plant (EHPP)
  - Captured CO_2 used for enhanced oil recovery (EOR) and/or storage
- Project Team
  - EPRI, California Resources Corporation (CRC), and Elk Hills Carbon, LLC, a Joint Venture between CRC and Oil and Gas Climate Initiative
- Funding Total $8,644,807
  - DOE: $6,915,845 (80%)
  - Cost-Share: $1,728,962 (20%)
- Performance Dates
  - October 1, 2019 – September 30, 2021
- Commercial Drivers
  - EOR, Federal 45Q, CA Low Carbon Fuel Standard, CA Cap & Trade provide significant commercial drivers

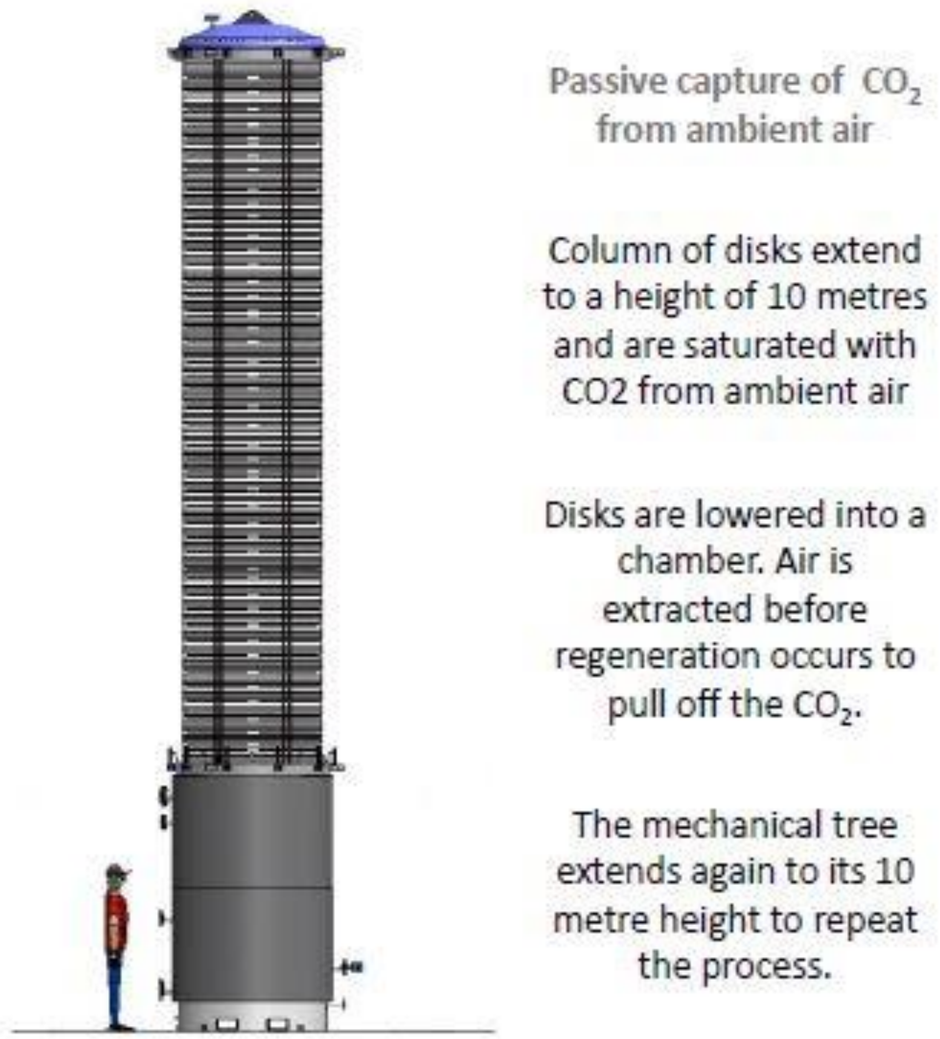




Direct Air Capture (DAC)

- Project Objectives
  - The project will provide the design basis for blueprints for commercial plants and a thorough techno economic analysis (TEA) and life cycle analysis (LCA) of a fully integrated system for multiple climates
  - 1 ton/day for cluster of 12 trees
- Project Team
  - Carbon Collect Limited, EPRI, Arizona State University, Trimeric Corporation, PM Group Global
- Funding Total
  - DOE: $2,500,000
  - Cost share: $781,330
- Performance Dates
  - September 1, 2021 – May 31, 2023
- Commercial Driver
  - Scalable carbon capture that can be co-located with geologic storage resources

MechancialTree™carbon farm



Together…Shaping the Future of Electricity