The Current Energy Transition

Hydrogen, Energy Storage, CCUS, Critical Minerals

Franek Hasiuk, PhD

Summary

- Current energy transition is one of many the industry has (and will) experience
- Its major parts are:
  - Hydrogen Economy
  - Energy Storage
  - Carbon Capture/Use/Storage
  - Critical Minerals
- It’s not scary,
  it’s opportunity!

Kansas Geological Survey

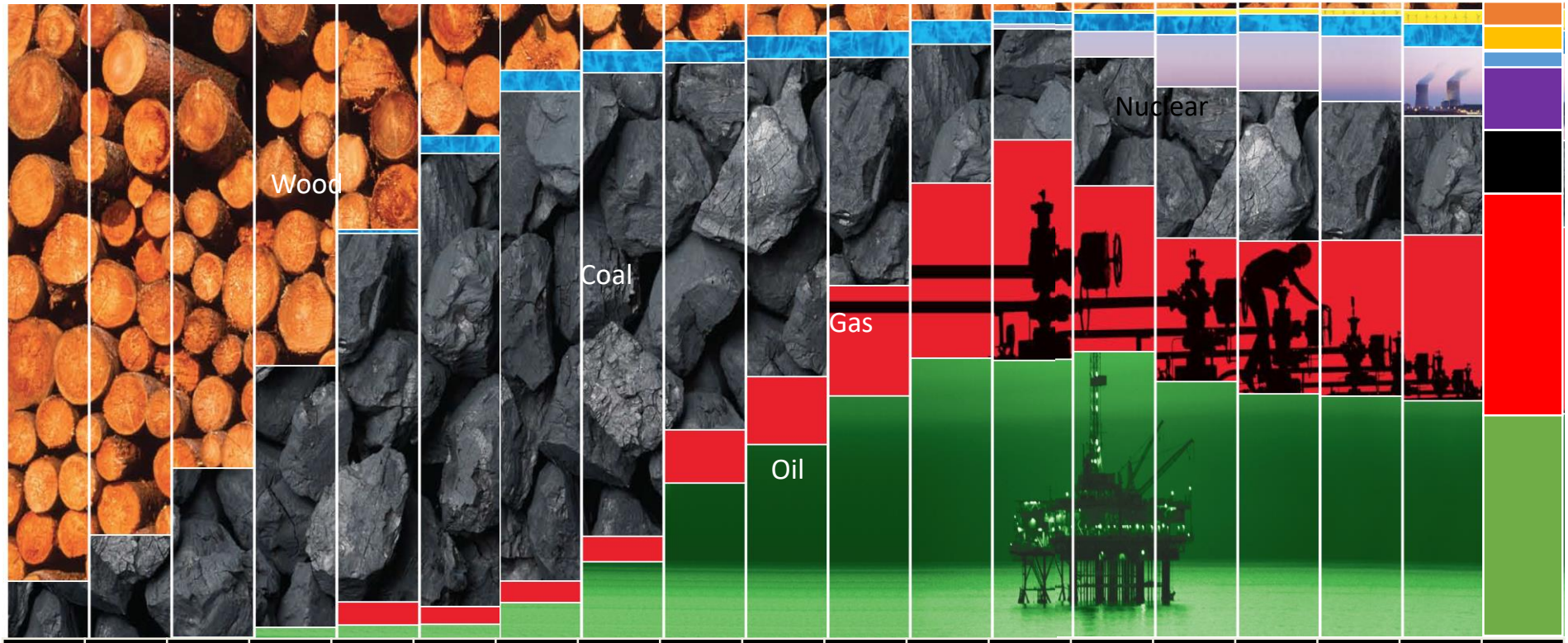
- "A research and service unit of the University of Kansas"
- ~120 employees + students
- Operates under statute to investigate resources of Kansas
- Provides scientific research and remains neutral on policy
- Our research **must be** relevant to Kansas
  - Groundwater/surface water
  - Economic geology (Oil, Gas, Helium, Injection, Sand/Gravel, Limestone, Salt, Coal, Lead-Zinc)
  - Carbon capture/use/storage; Energy Storage
  - Geological mapping and geographic data
  - Induced seismicity and shallow geophysics

Franek Hasiuk, PhD

- Education:
  - PhD, MS, University of Michigan
  - BS Geology / BA Classics, U Iowa
- Work experience:
  - Kansas Geological Survey (3.5y)
  - Iowa State University (6y)
  - ExxonMobil (4y)
  - U Iowa Water Plant (4 y)
- Expertise:
  - Traditional and Transitional Energy
  - Limestones
  - 3D Printing

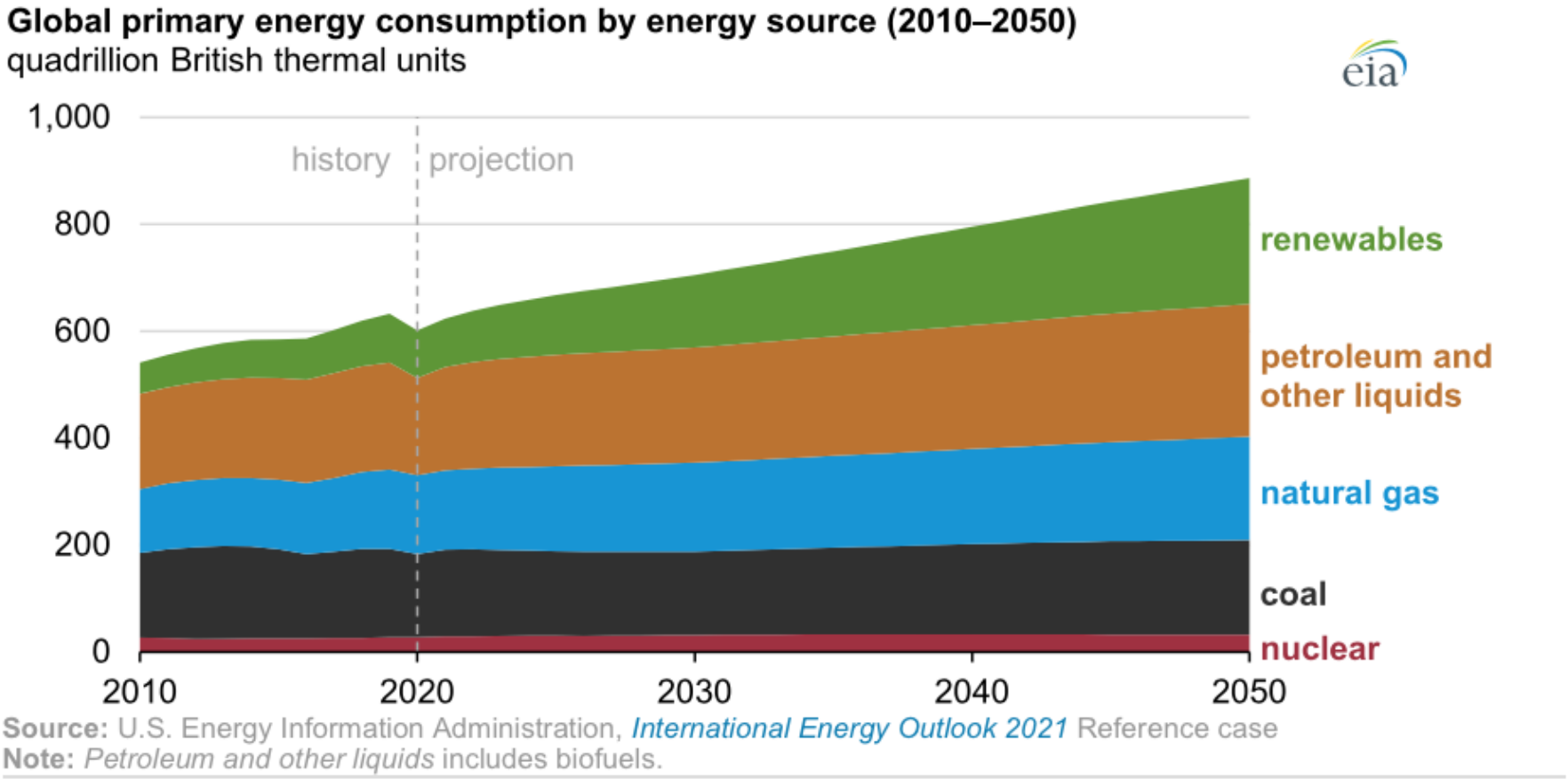
Fuel diversity has changed over time

2020 EIA Actual

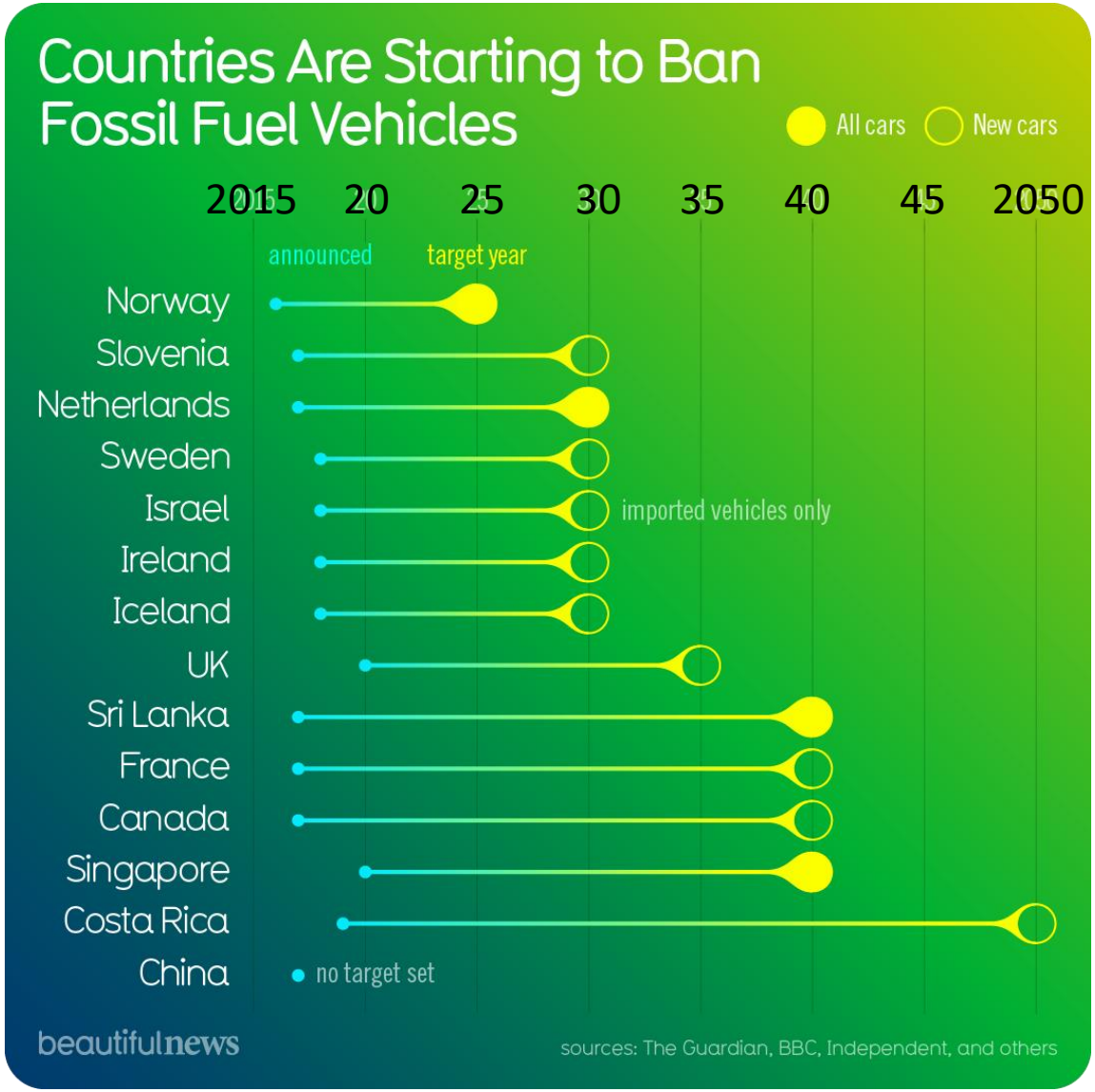


ExxonMobil Energy Outlook 2009

50% Growth in Energy Usage by 2050



Banning combustion engines



Early retirement of coal assets

BUSINESS

Zimmer coal-fired plant near Cincinnati to close five years early

Mark Williams The Columbus Dispatch

Published 1:03 p.m. ET Jul. 21, 2021

View Comments

Evergy to close coal-fired power plant just outside of Lawrence

OTHER NEWS

APR 30, 2021 - 11:31AM

CHAD LAWHORN
Editor
clawhorn@ljworld.com

SHARE TWEET

photo by: Associated Press

What we don’t want to happen

~1900, New York City, drowning in manure

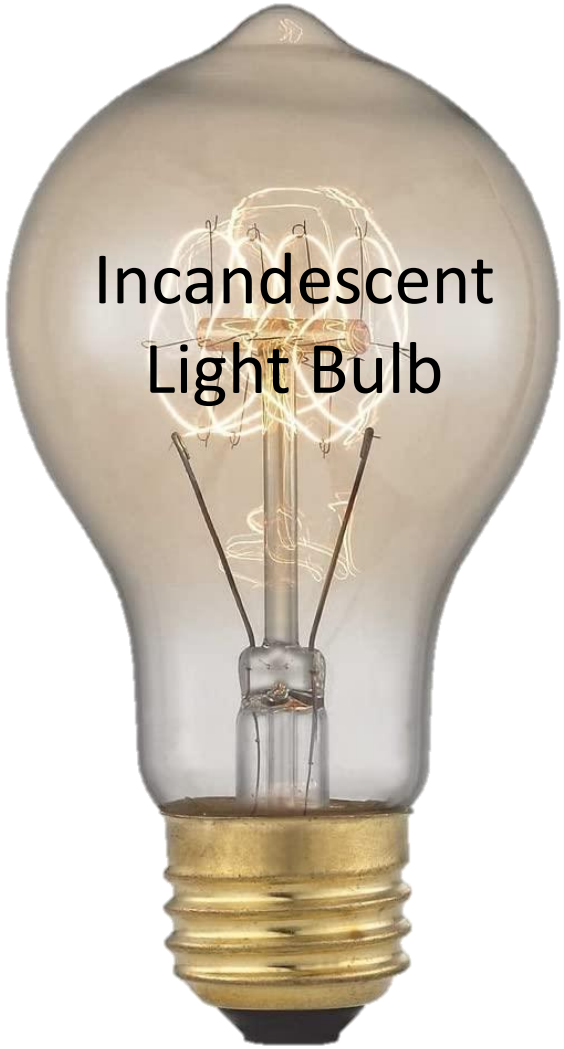
MORTON STREET, CORNER OF BEDFORD, LOOKING T
MARCH 17, 1893.

Transitions in History—Lighting

Lamp
(Whale Oil)

Lamp
(Kerosene)

Incandescent
Light Bulb

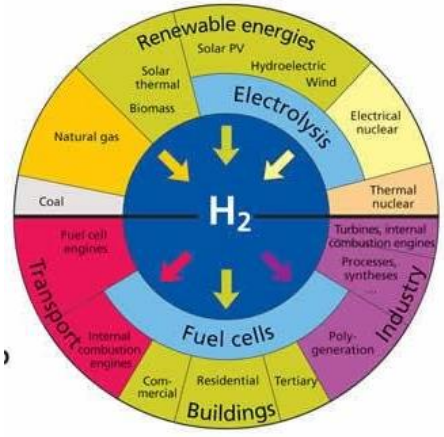


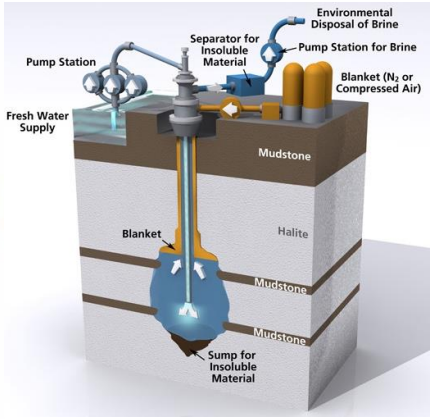
“Grand Ball Given by the Whales…”

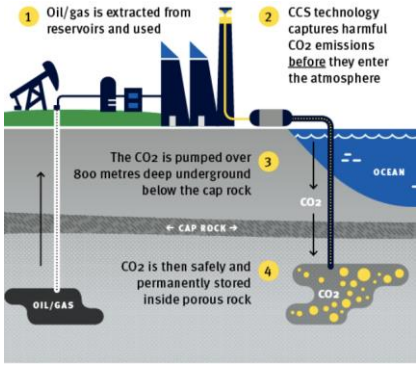
“…in honor of the discovery of the Oil Wells in Pennsylvania.”

Energy Transition Has Key Technologies

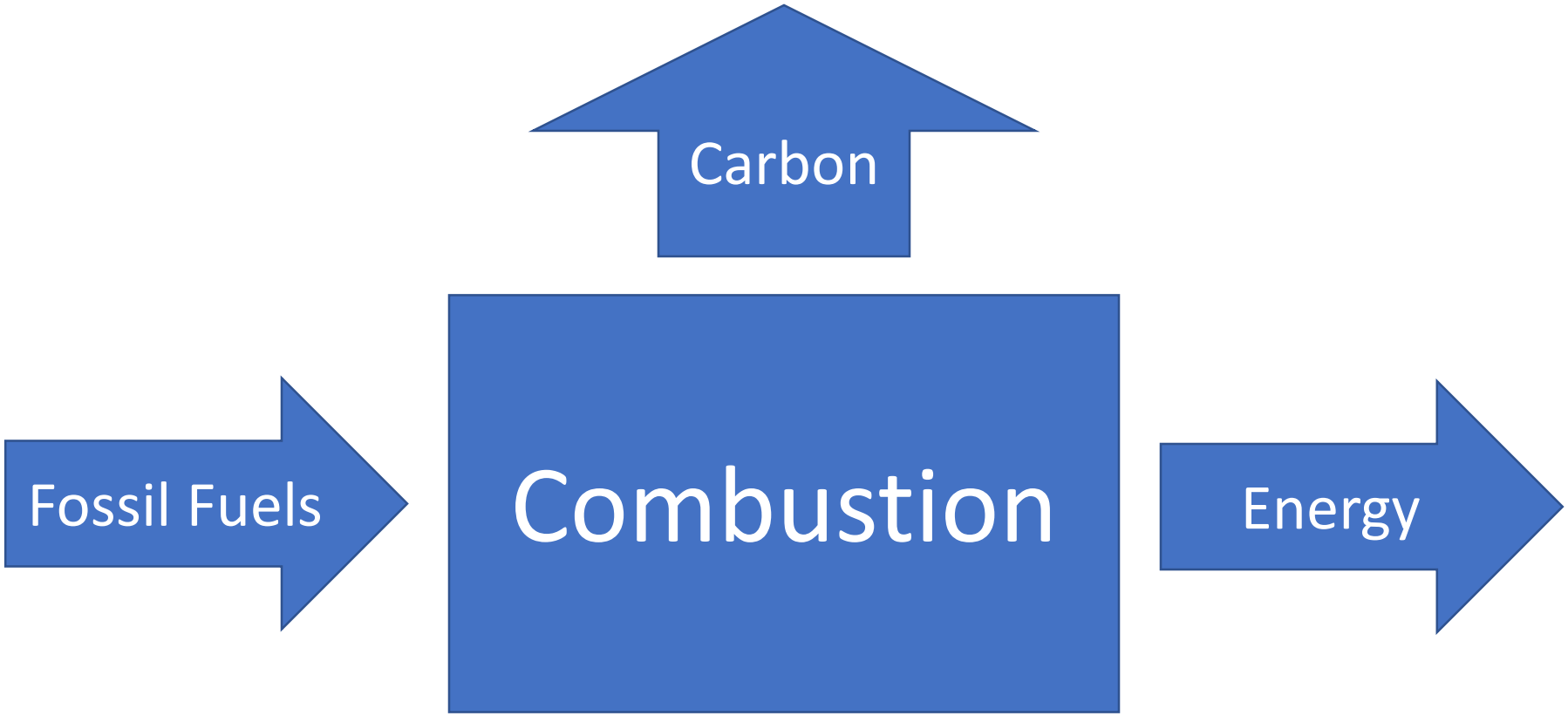
Hydrogen Economy	Energy Storage	Carbon Capture, Use, and Storage	Critical Minerals
• Can be burned with natural gas • Transport fuel • Industrial uses	• Manages variable production of power from renewables ***and*** fossil generators • Network benefits	• Gets CO_2 out of the atmosphere • Prolongs investments in current power plants	• Required for high tech manufacturing (e.g., solar panels, wind turbines, electronics, screens) • Complex to refine







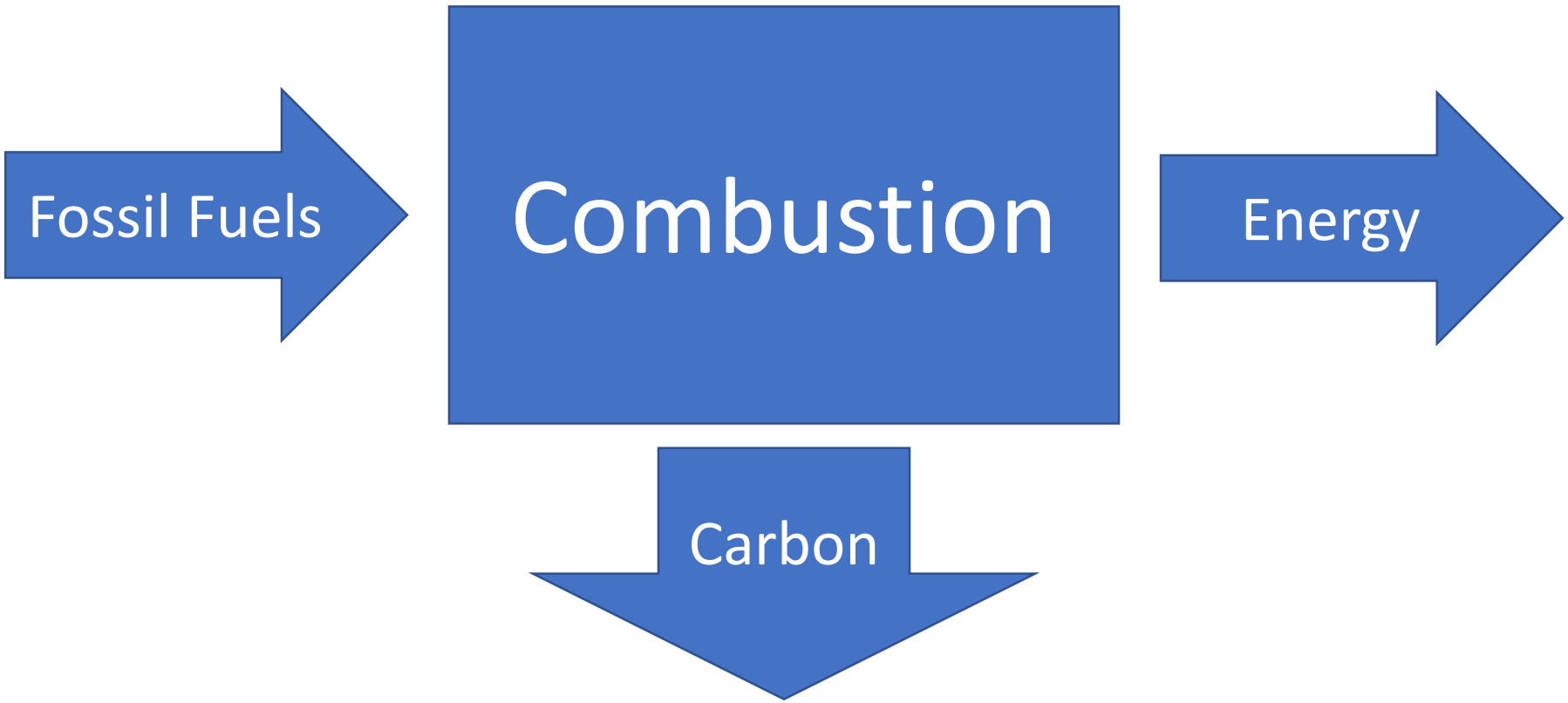
Current Fuel Cycle



Emits carbon to the atmosphere 😬

Carbon Capture System

Works for large sources of carbon emissions,
like industrial facilities ☺

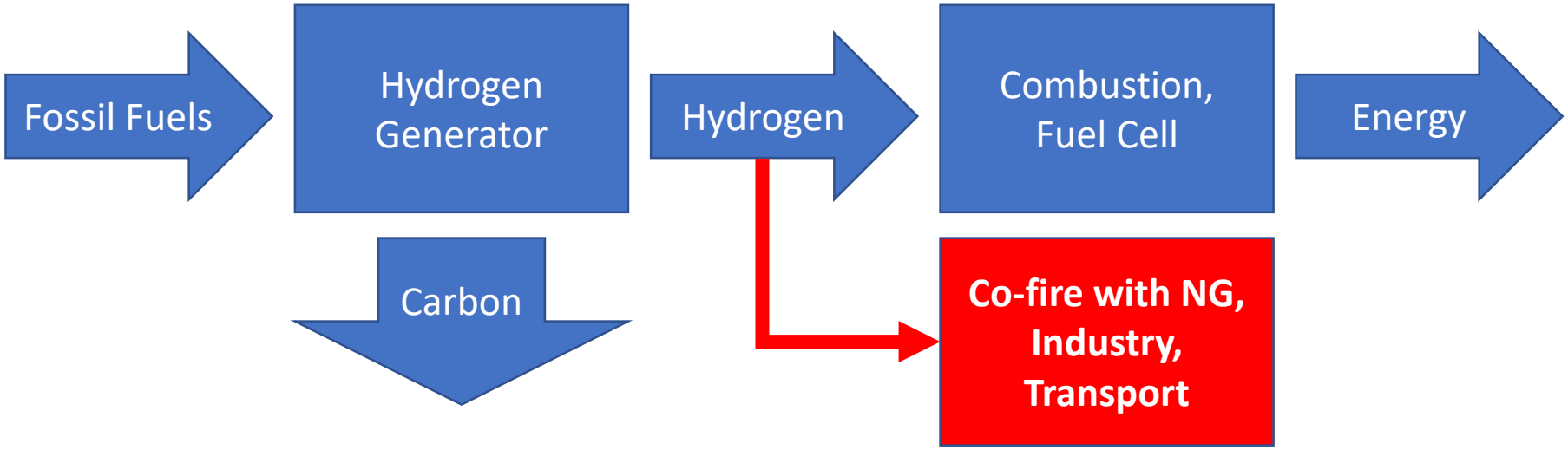


The Hydrogen System

Works for

Large sources (like industrial facilities) 😀

Small sources (like cars) 😃



AND we can do other stuff with the hydrogen! 😍

Hydrogen Economy

Hydrogen Production Today

Currently 99% of 10 MMT in the U.S. supplied by fossil fuels – least cost

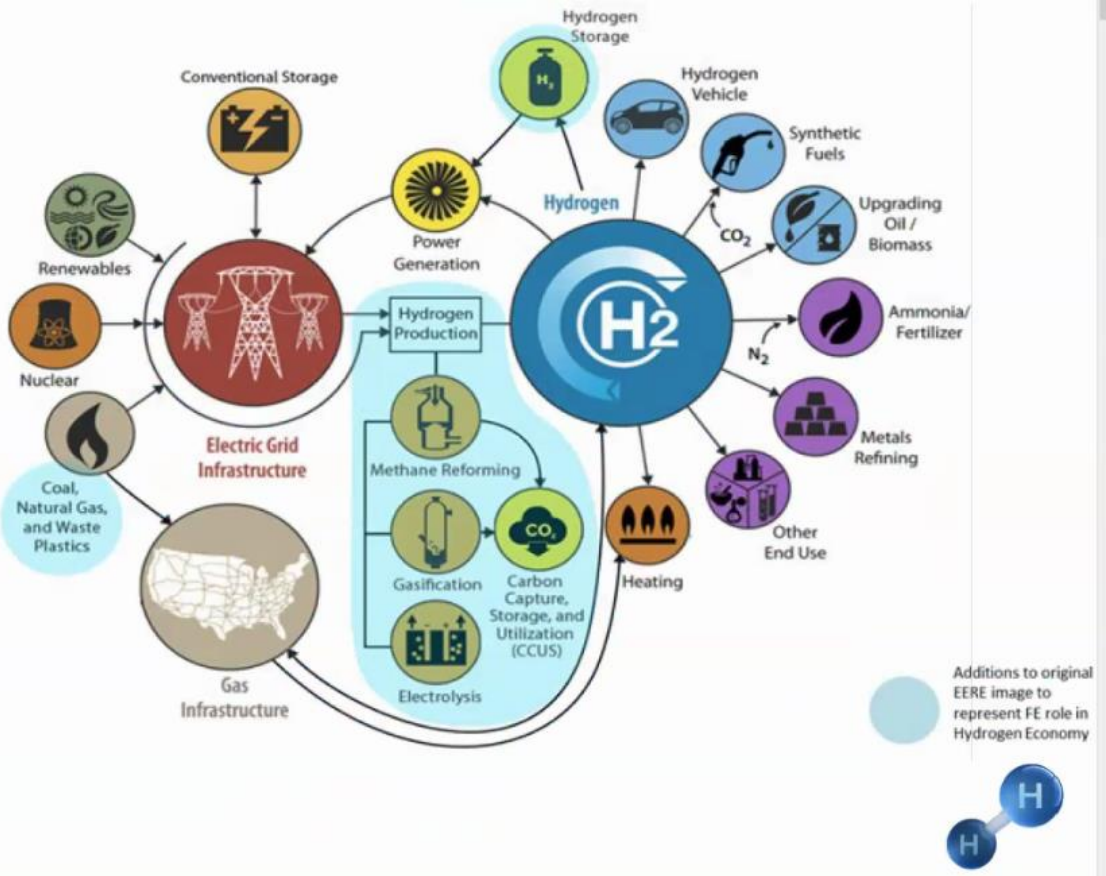
- **96% by SMR**
- **3% by gasification**
- **1% by electrolysis**

70 MMT generated globally

- **76% by SMR**
- **22% by gasification**
- **2% by electrolysis**

Small fraction includes CCUS

Economics dominates generation mix



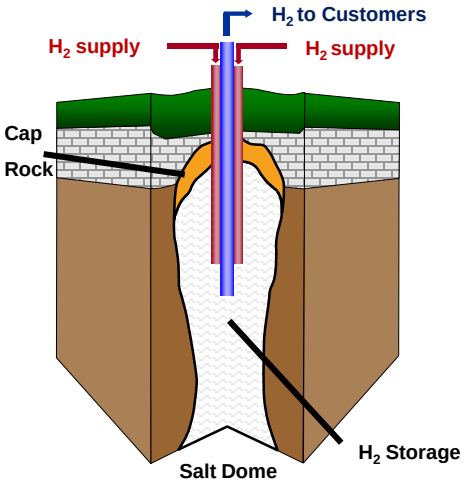
Carbon Utilization Research Council

The Hydrogen Economy

Coal	Black
Lignite	Brown
Fossil Fuel with Carbon Emission	Gray
Fossil Fuel with Carbon Capture	Blue
Renewables	Green
Nuclear	Pink

Linde Runs Hydrogen Network in Texas

- Salt cavern storage with 40 million m^3 working capacity (1.4 Bcf)
- 350-mile pipeline from Texas City, TX, to Lake Charles, LA
- Connects 50 customers
- 600 mscf/d rate



Gulf Coast Hydrogen Pipeline

Legislative issues around Hydrogen

- Permitting underground storage
  - Caverns
  - Pore Space
- Water usage
- Carbon storage issues

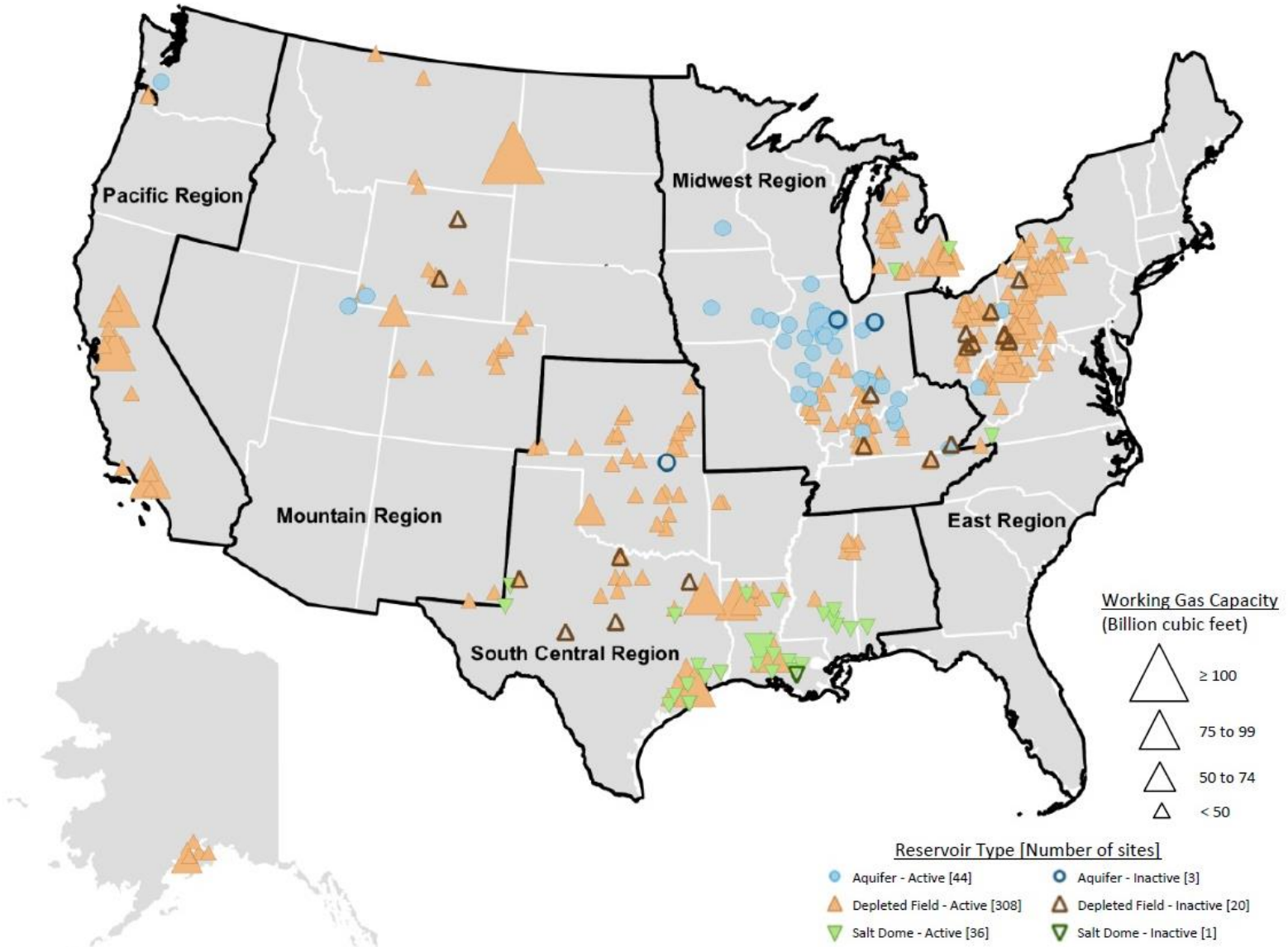
Energy Storage

We already do oil & coal storage

US Strategic Petroleum Reserve

Coal piles at coal power plants

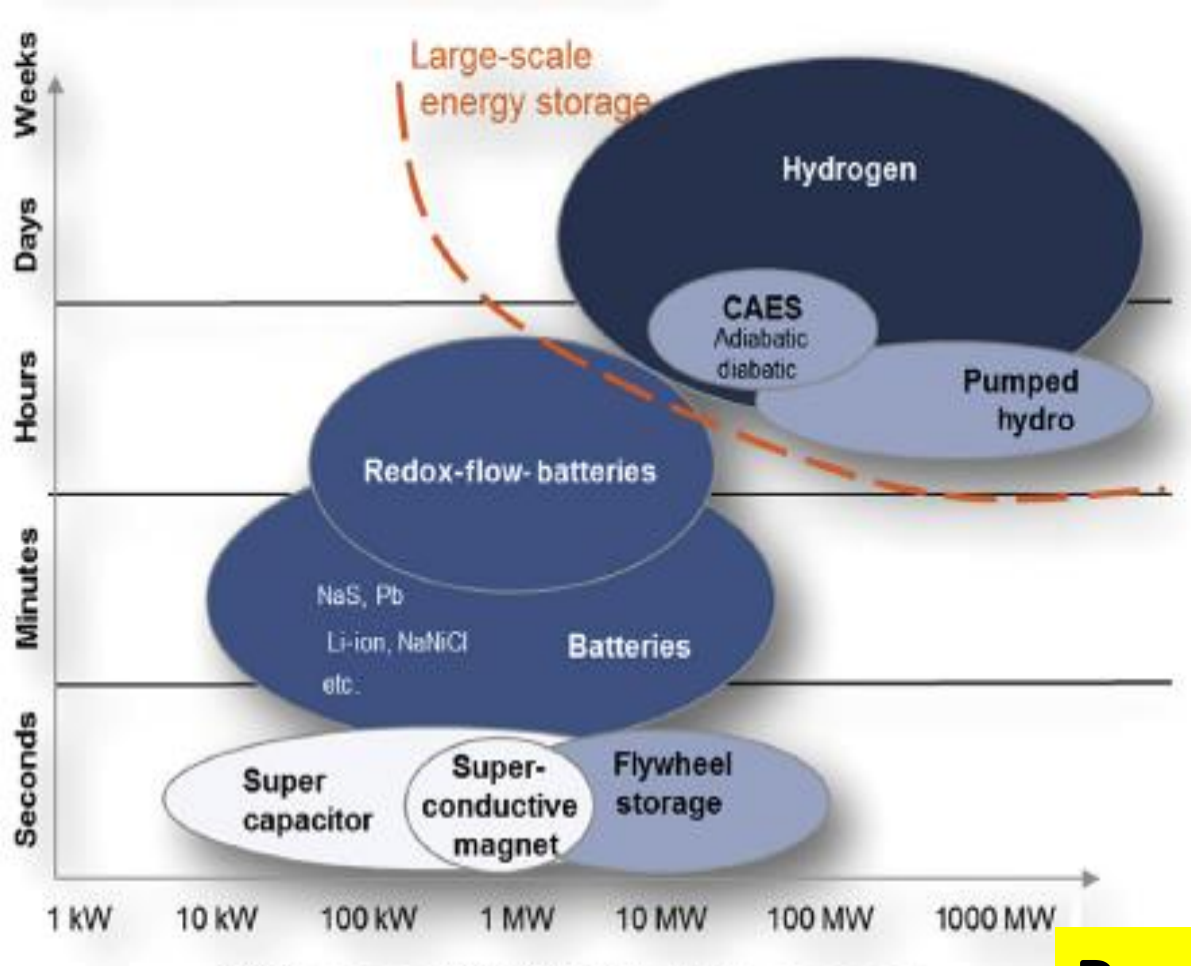
We already do natural gas storage



Energy storage solves problems

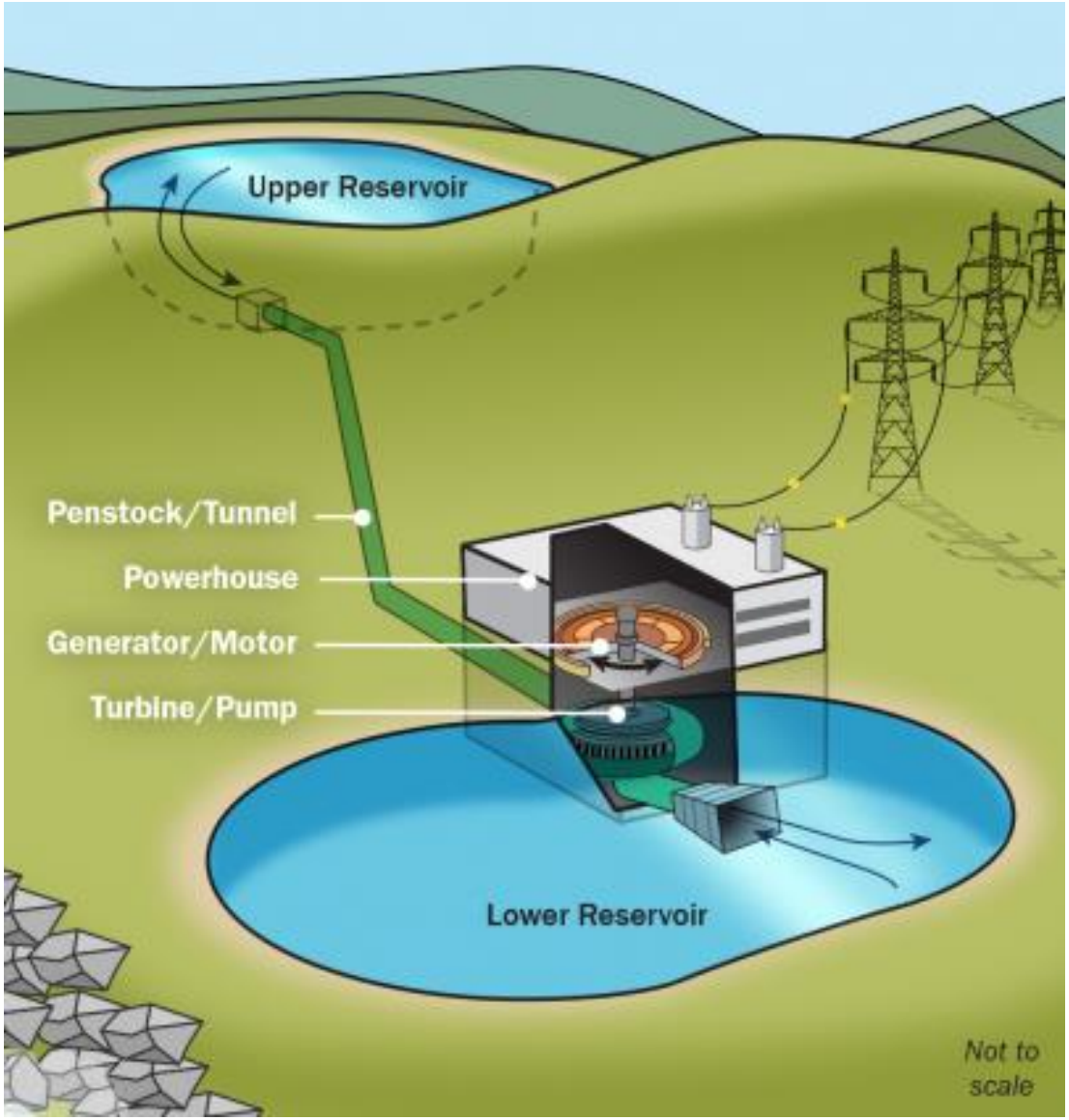
…associated with variable power production

Time Scale

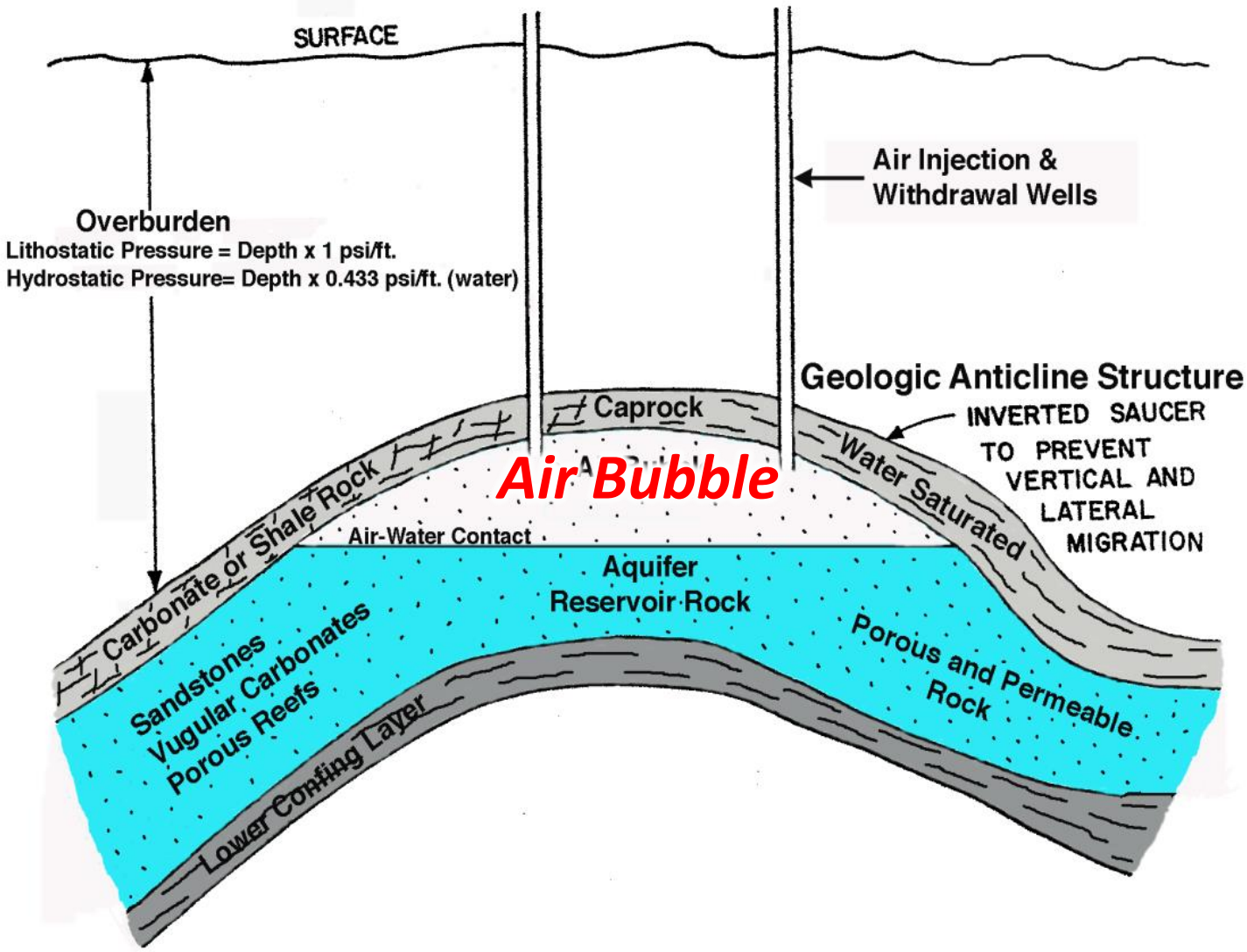


Power

Pumped Storage Hydropower



Compressed Air Energy Storage (CAES)



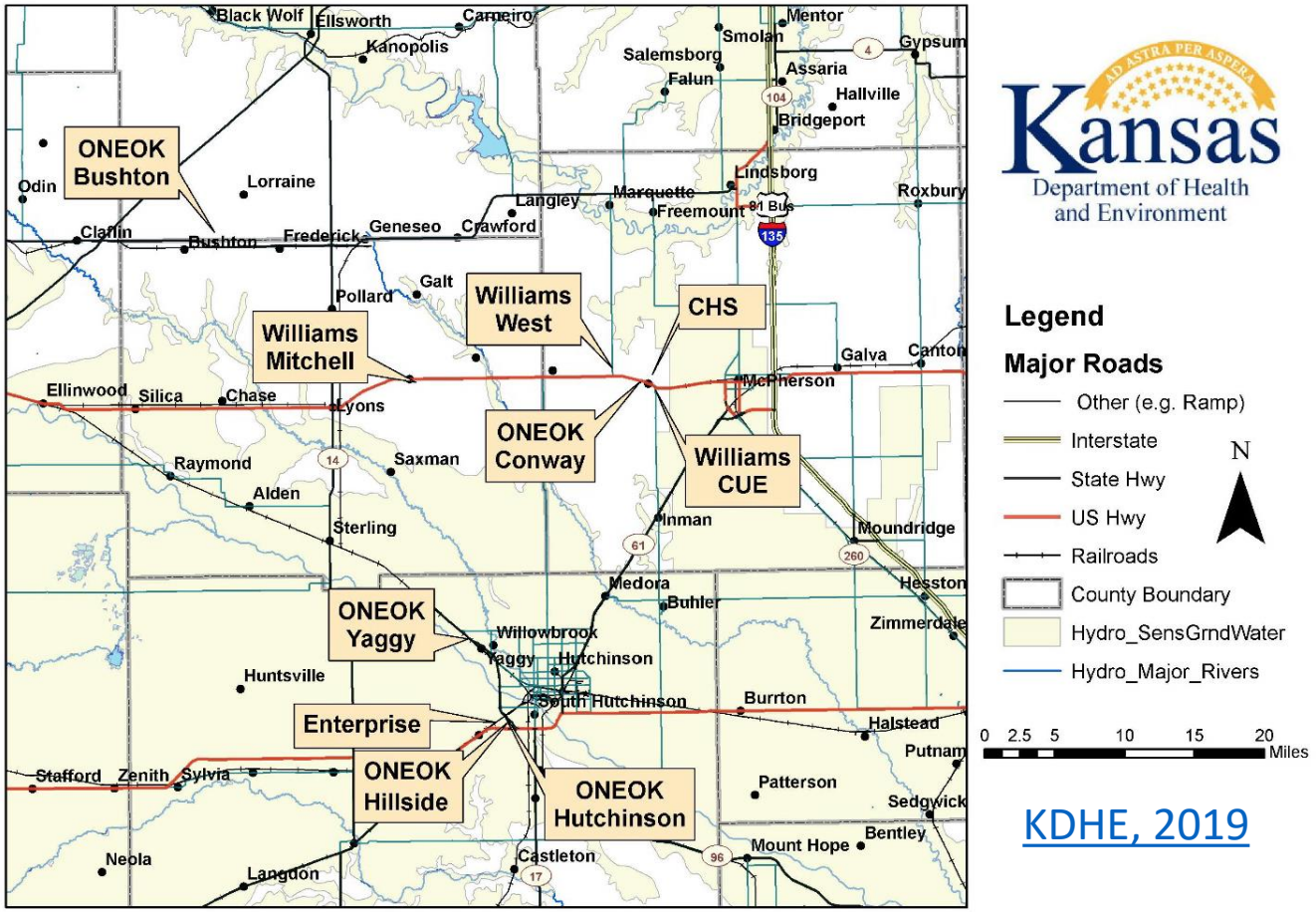
CAES operating for 30+ years in USA

McIntosh, Alabama, since 1991

Huntorf, Germany, since 1978

We already do storage of refined products

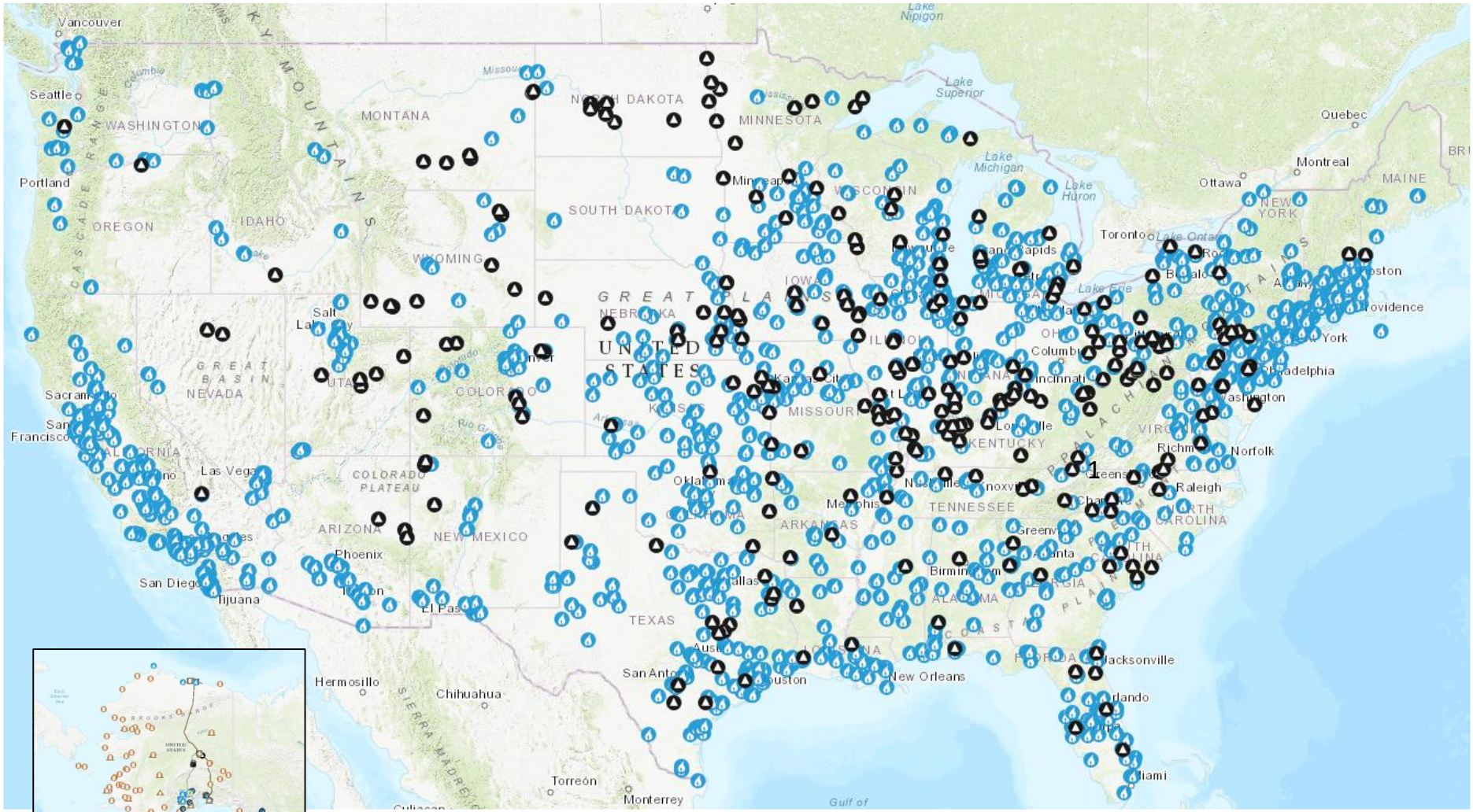
368 active wells (~750 total)
73 million barrels storage



Kansas Department of Health and Environment

KDHE, 2019

Salt Storage is broadly available



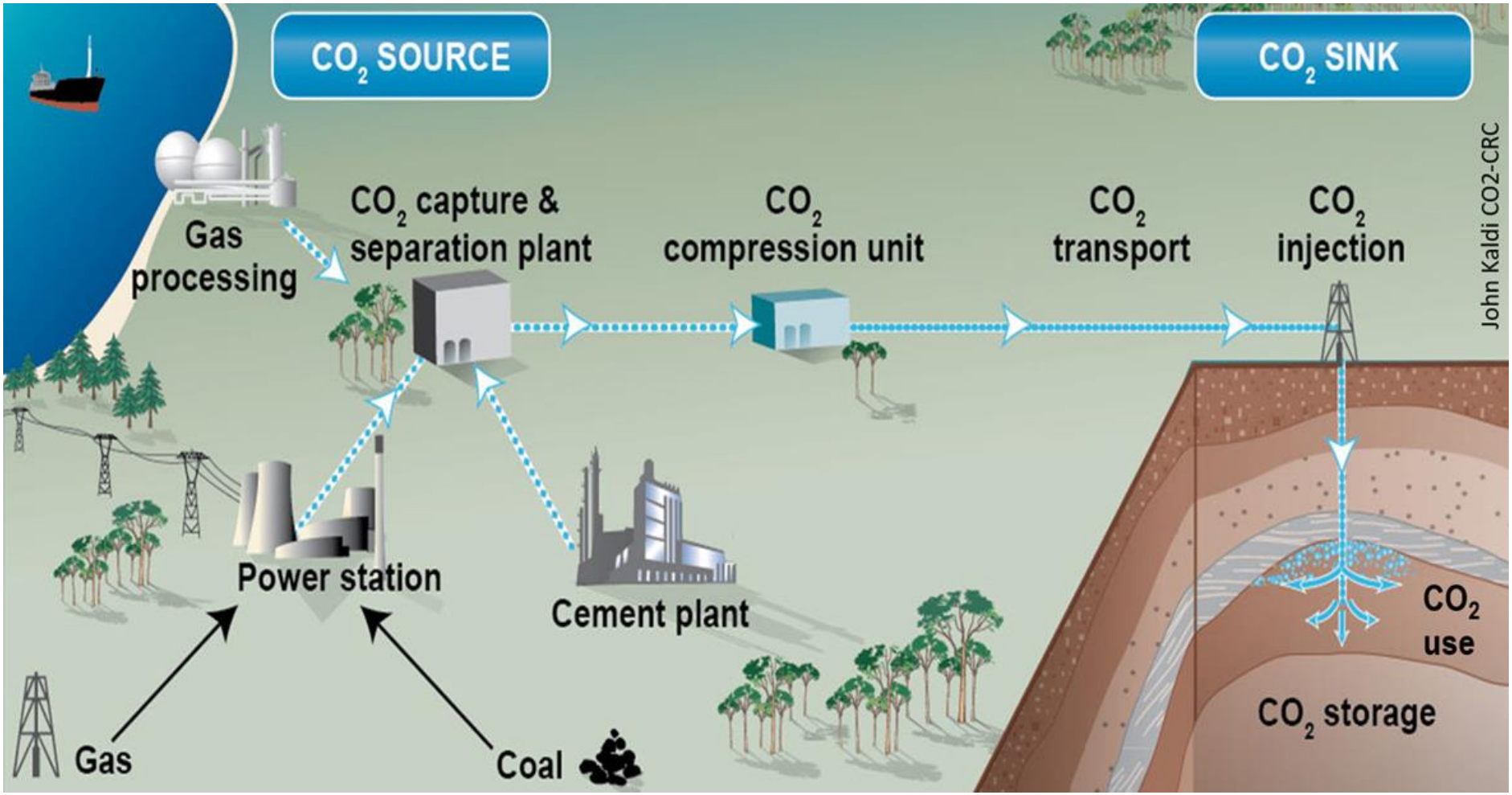
Map: EIA

Legislative issues around Energy Storage

- Permitting/zoning storage
  - Cavern (underground)
  - Pore space (underground)
  - Pumped hydro (surface)
- Monitoring for leakage, subsidence
- Effects on power rates

Carbon
Capture/Use/Storage

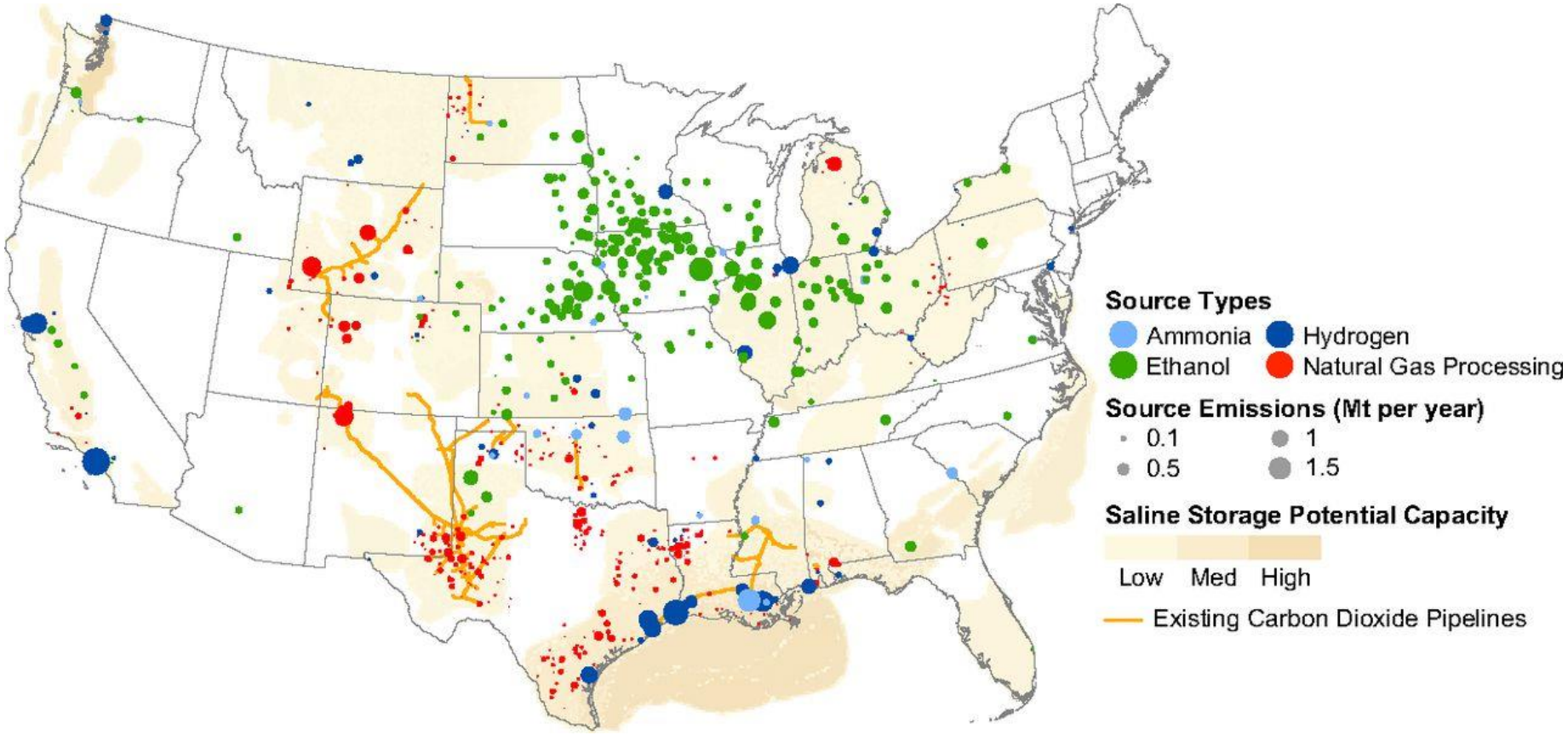
Carbon Capture/Use/Storage



AAPG Explorer

CO_2 can be captured from sources

CO_2 Sources in Lower 48



Edwards and Celia, 2018

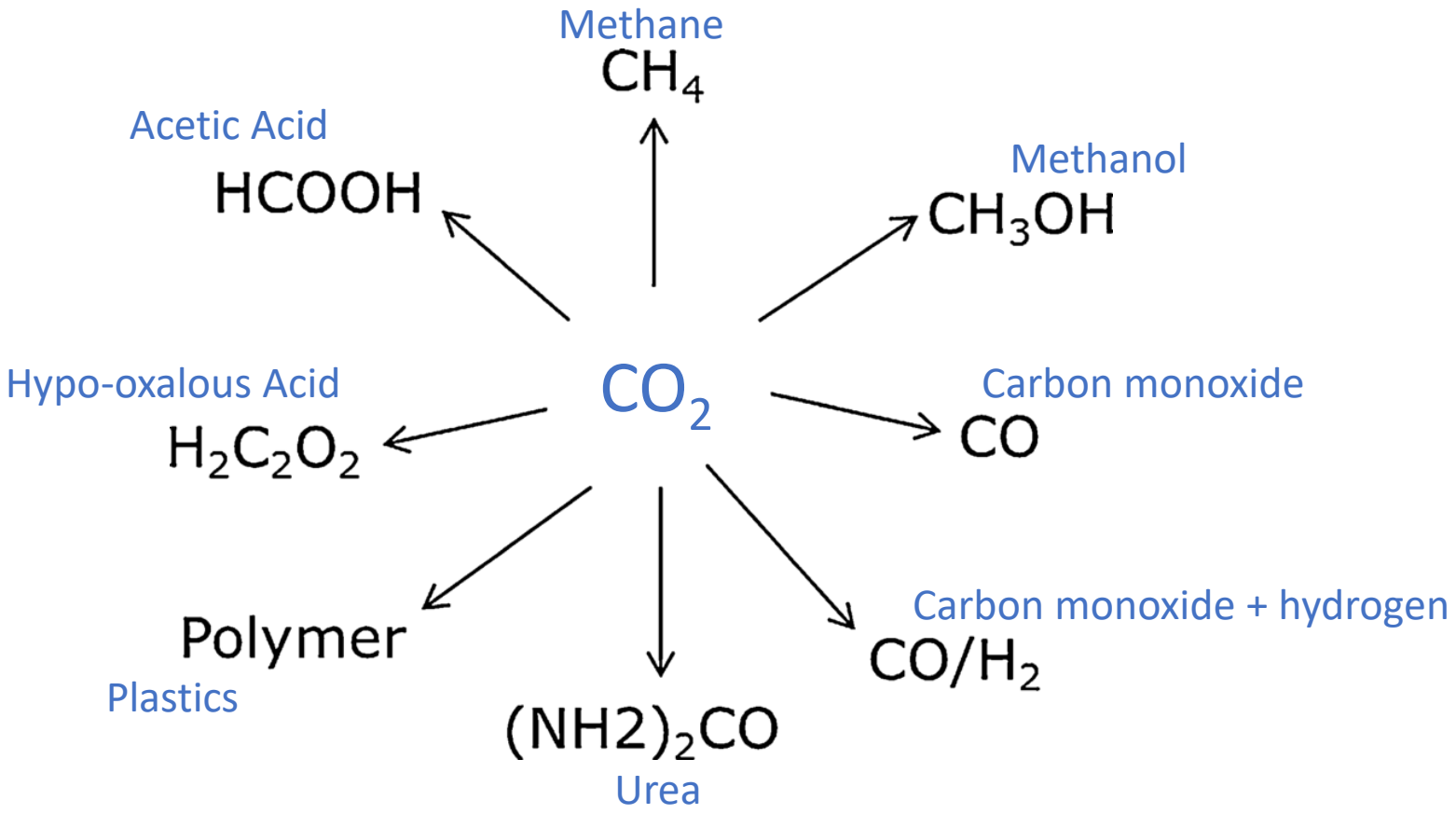
CO_2 can be captured from the air

- Can be located at best storage sites (no pipelines needed!)
- Currently, operates best in **hot** places

Advanced farming uses CO_2

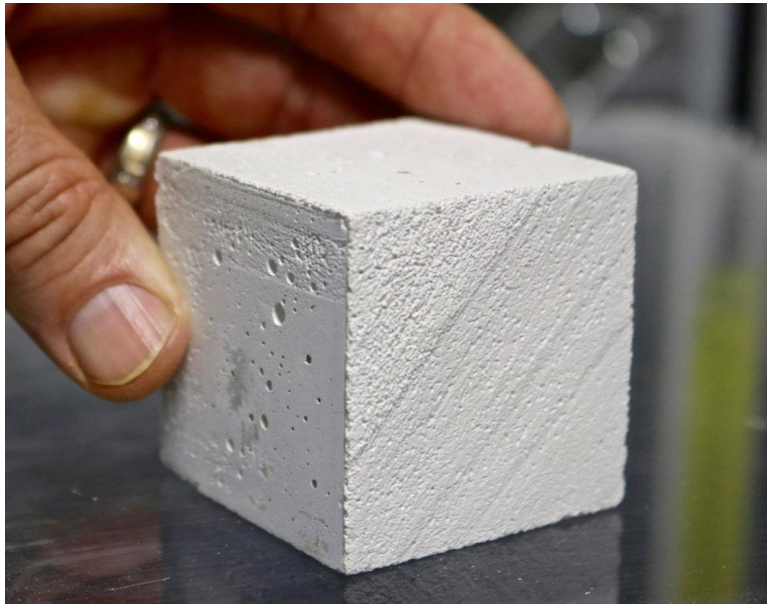
- Plants grow better with more CO_2
- Indoor farming can take advantage of CO_2 to increase production

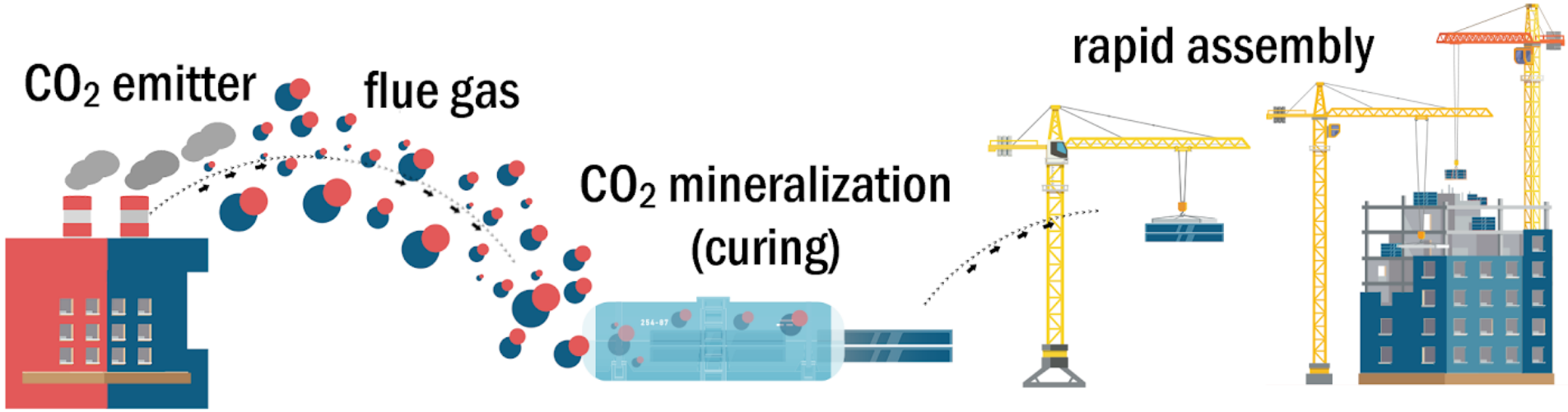
Chemical plants can use CO_2



Concrete can use CO_2

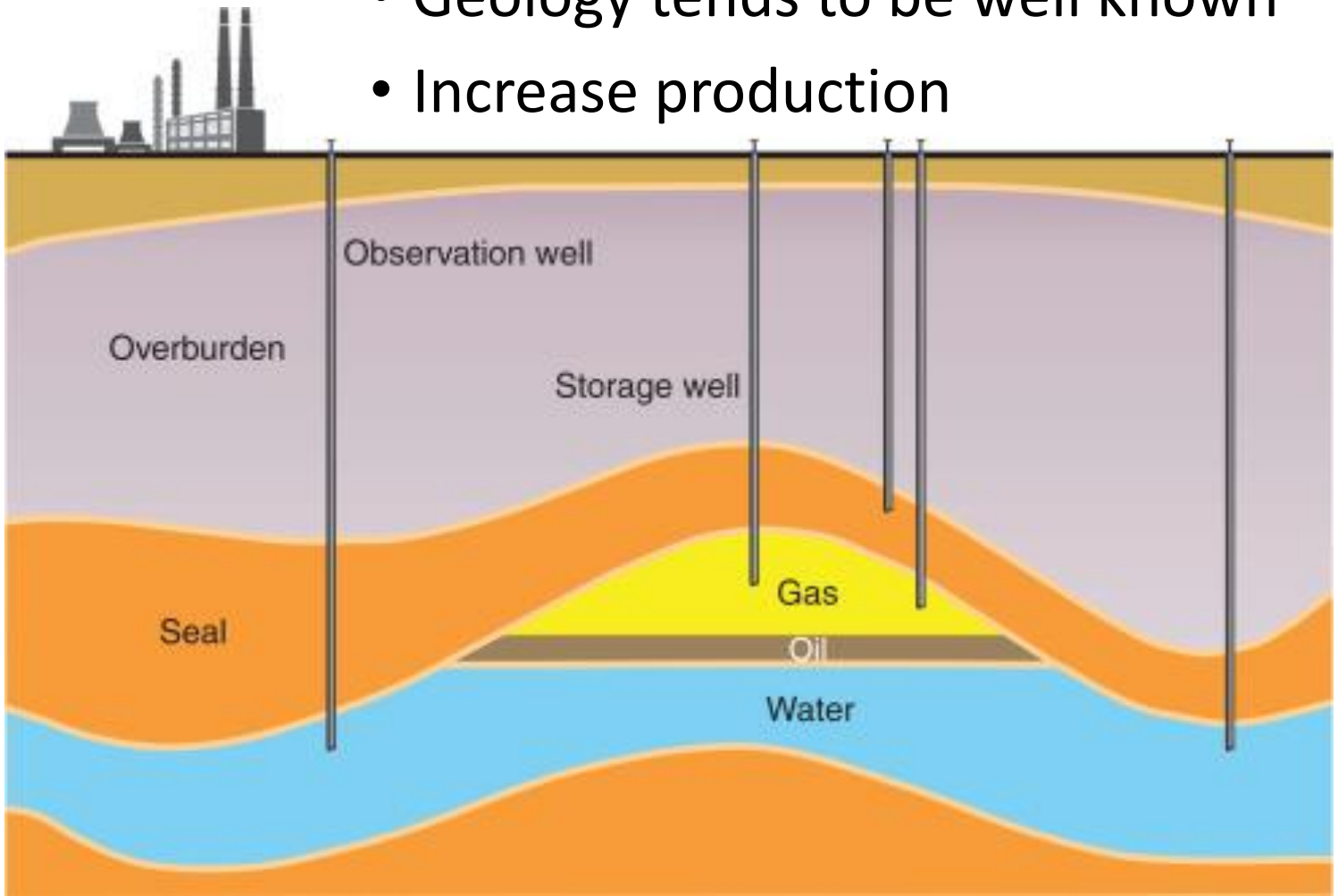
- Adding CO_2 to concrete makes concrete stronger
- It combines with calcium in the concrete to make limestone within the concrete





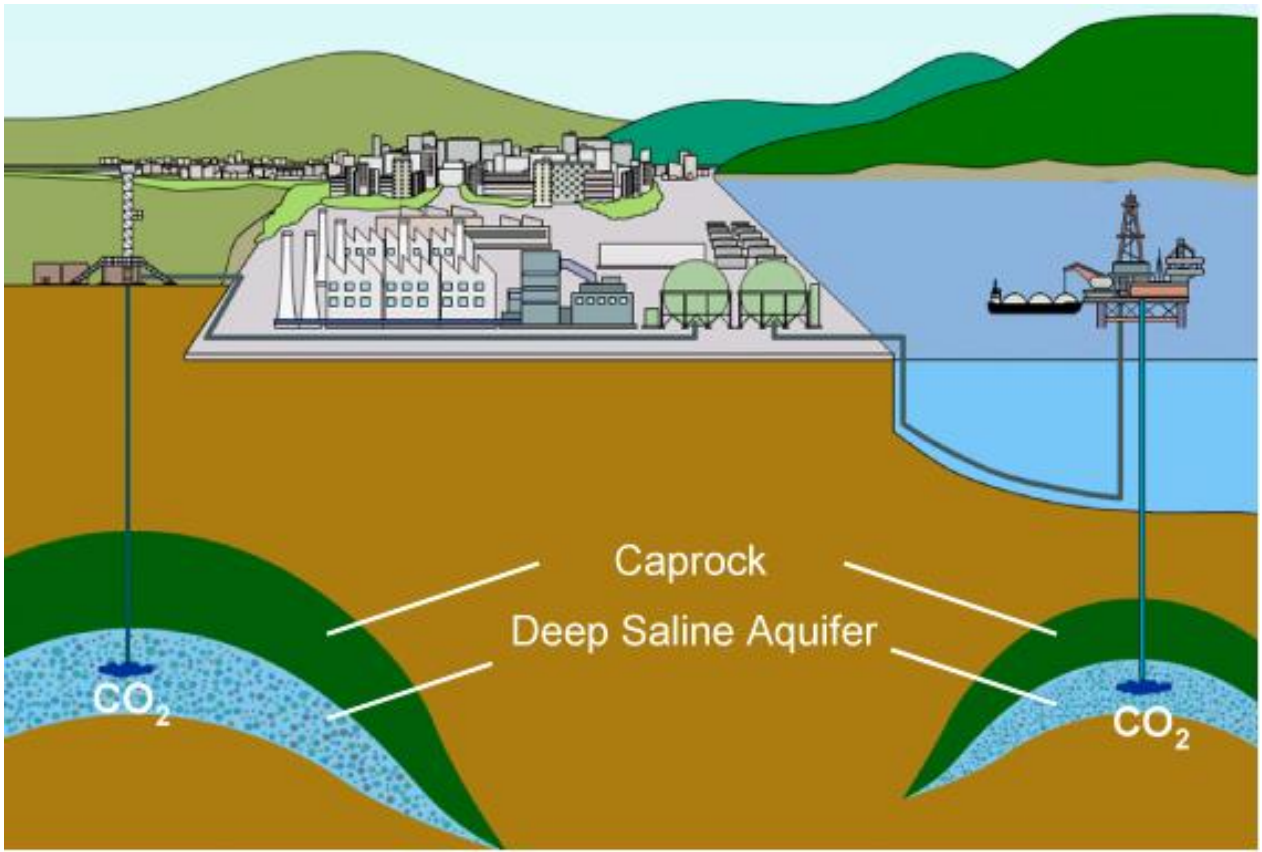
Old oil & gas fields can use/store CO_2

- Existing infrastructure
- Geology tends to be well known
- Increase production



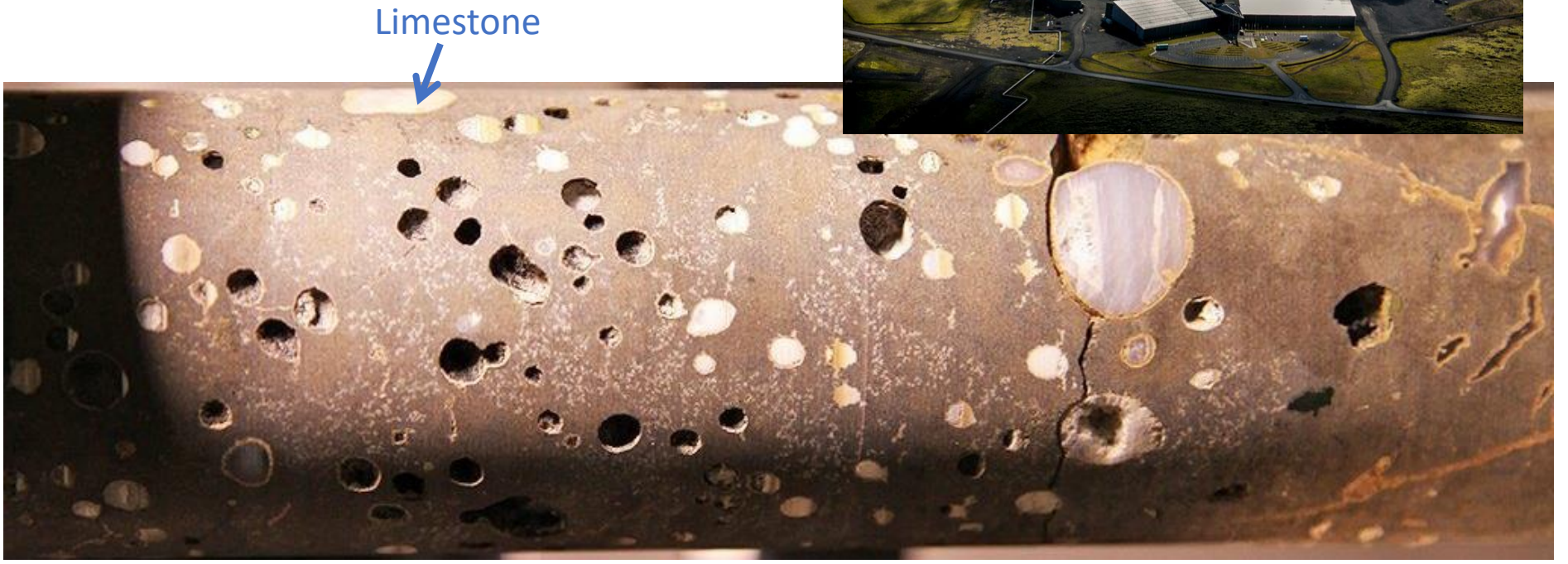
Deep saltwater aquifers can store CO_2

- Water is too salty to drink
- Fewer wells penetrate the caprock than in an oil or gas field
- More widely available than oil and gas fields



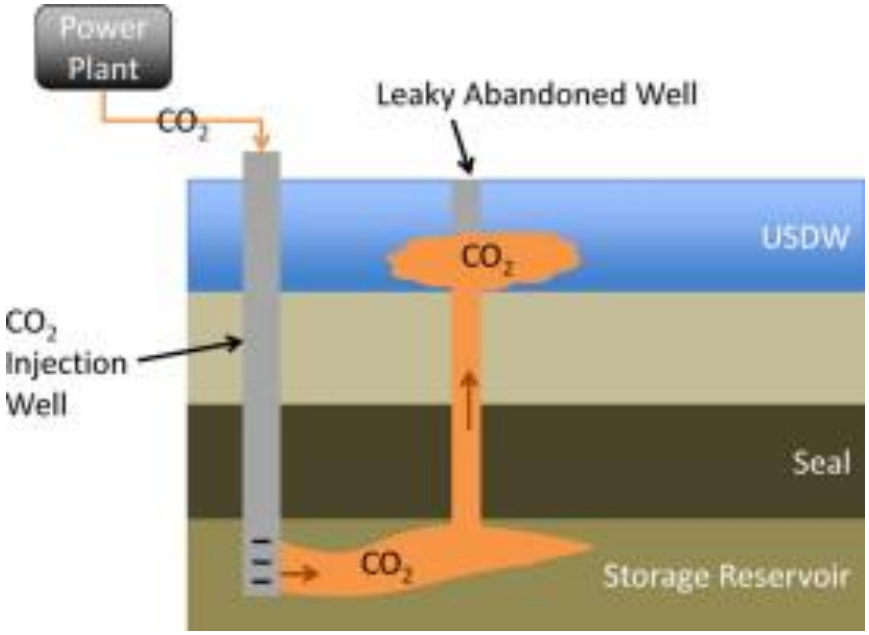
Basalt can store CO_2

- Carbon mixes with calcium to make limestone
- Solid storage



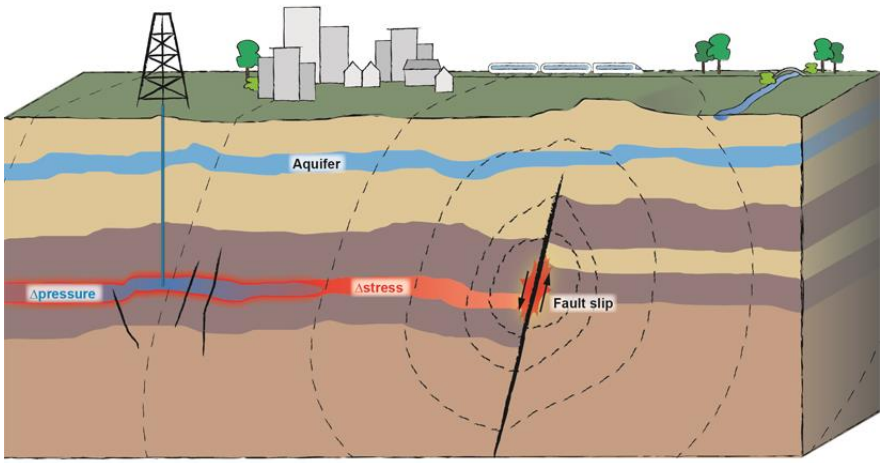
Storage risks

Leakage



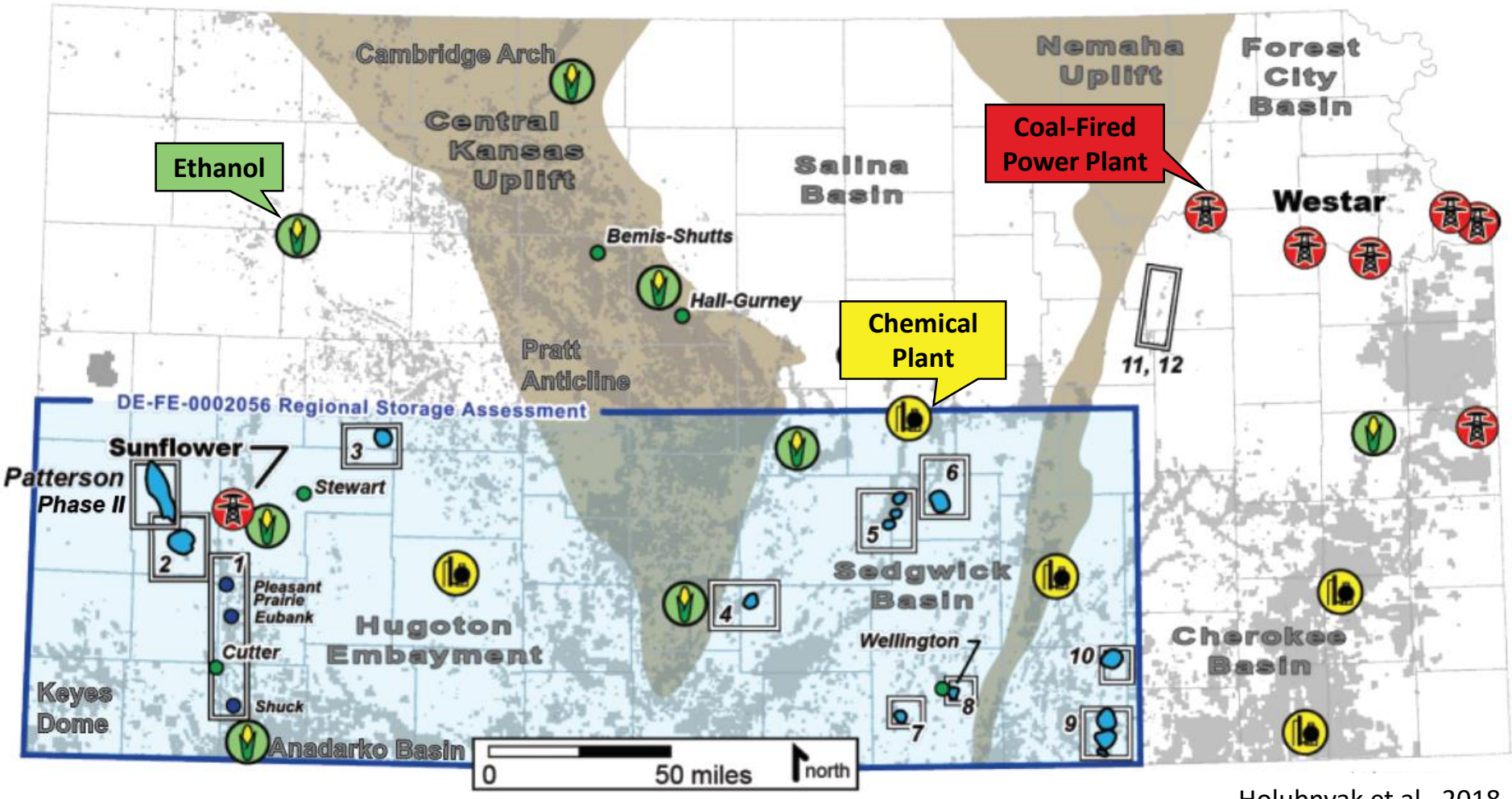
Hou et al., 2014

Earthquakes



Müller et al., 2021

Carbon Landscape in Kansas



Holubnyak et al., 2018

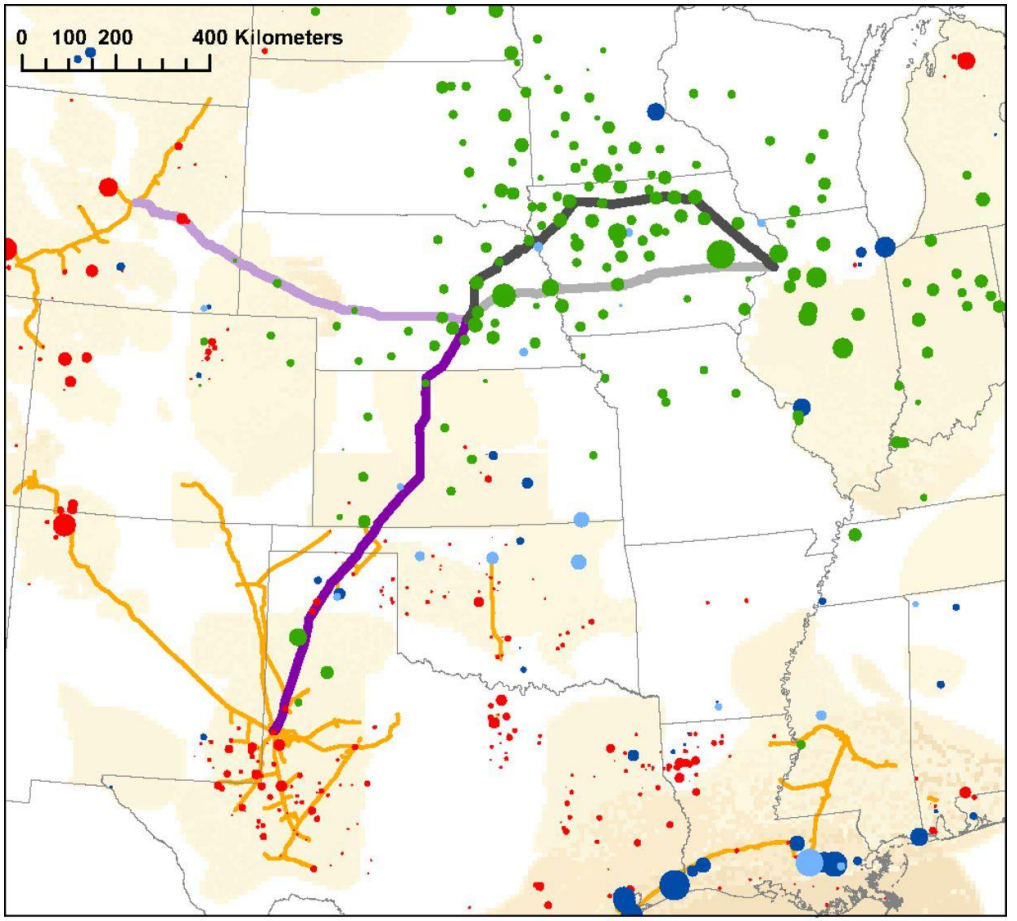
Pipelines can transport CO_2

Which route **minimizes**…

- Cost of materials
- Cost of labor
- Environmental impact
- Eminent Domain use

While **maximizing**…

- Sources
- Sinks



Edwards and Celia, 2018

Legislative issues around CCUS

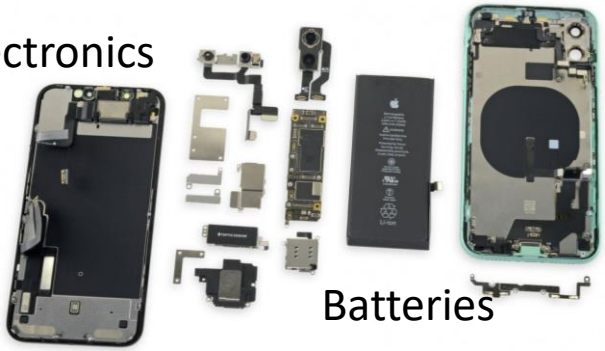
- Primacy in Permitting
  - Currently a 2-3 year EPA process
- Eminent domain for pipelines
- Unitization
- Pore space ownership
- Long-term liability
- Monitoring

Critical Minerals

“Critical Minerals” Drive Modern Technology

Electronics

Screens



Batteries

Super-Alloys and Magnets

Energy Act of 2020 CM Definition

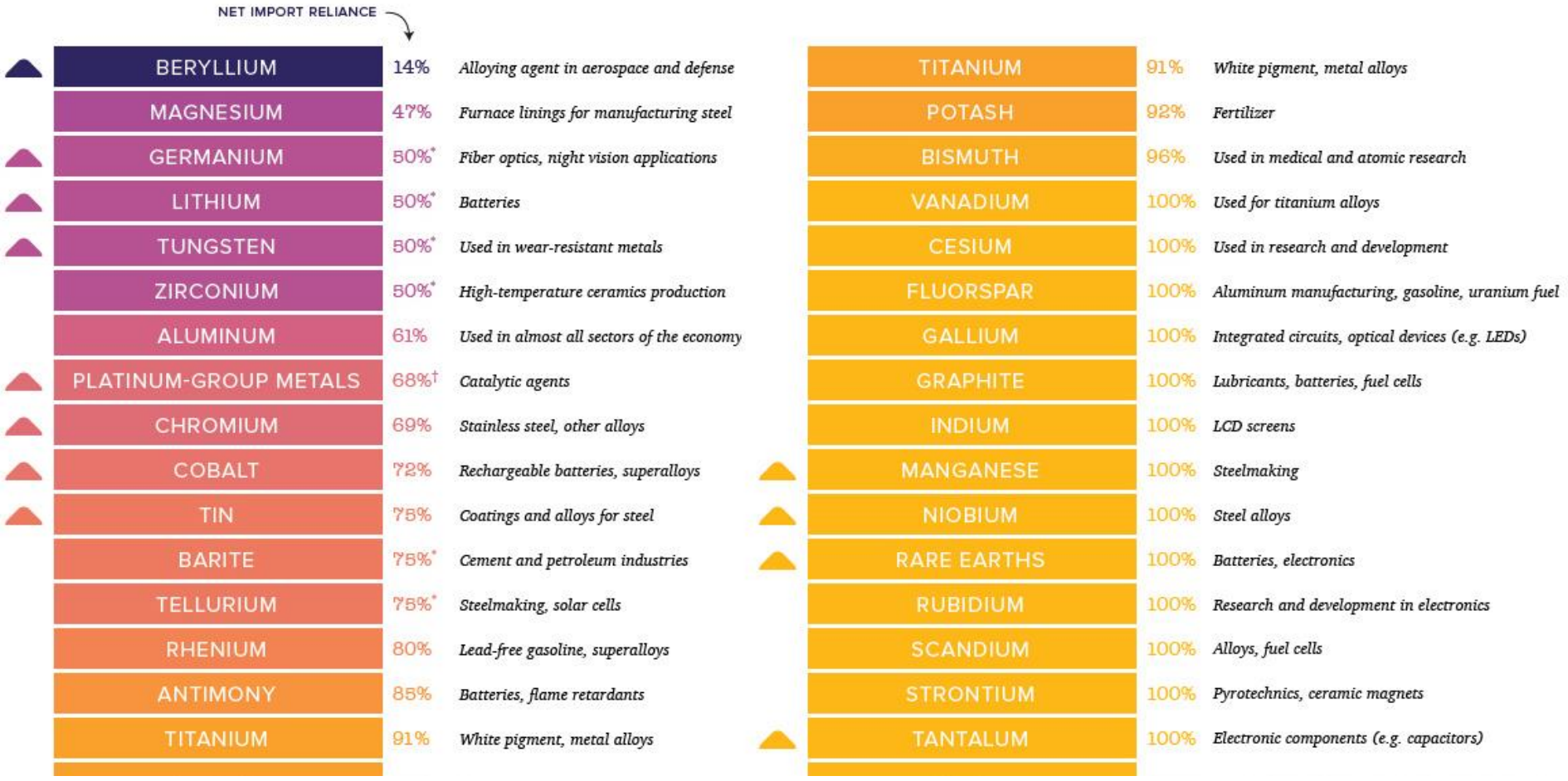
Critical minerals are defined as" essential to the economic or national security

i. supply chain of which is vulnerable to disruption
ii. serve an essential function in the manufacturing of a product

Does not include…

i. fuel minerals
ii. water, ice, snow
iii. sand, gravel, stone, pumice, clay

US relies on imported Critical Minerals



DOE CoreCM Initiative

FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

Department of Energy (DOE)
Office of Fossil Energy (FE)

Carbon Ore, Rare Earth and Critical Minerals (CORE-CM) Initiative for U.S. Basins

Funding Opportunity Announcement (FOA) Number: DE-FOA-0002364
FOA Type: Modification 000002
CFDA Number: 81.089

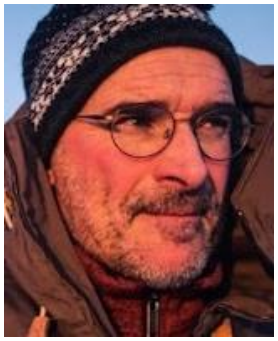
Legislative issues around Critical Minerals

- Permitting new mines, reopening old ones
- Water usage
- Recycling
  - Legacy mining wastes
  - Electronics waste

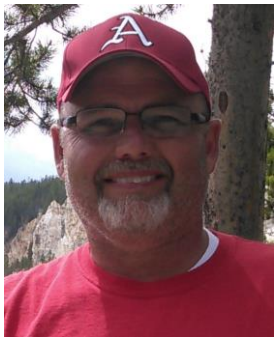
Latin Lesson Time

For more information, *contact your State Geologist!*

Alabama
Berry



Alaska
Dave



Arkansas
Scott

Colorado
Karen

Kansas
Rolfe

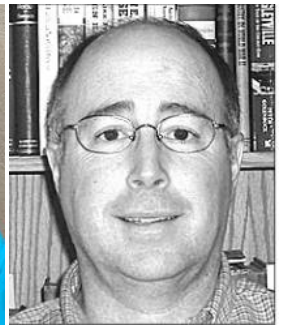
Louisiana
Clare

Mississippi
Dave

Montana
John

N. Mexico
Nelia

N. Dakota
Ed



Oklahoma
Nick

Texas
Tinker

W. Virginia
Jessica

Wyoming
Erin

Summary

- Current energy transition is one of many the industry has (and will) experience
- Its major parts are:
  - Hydrogen Economy
  - Energy Storage
  - Carbon Capture/Use/Storage
  - Critical Minerals
- It’s not scary,
  it’s opportunity!