Advancing Innovation with CCUS Hubs: A Case Study of Houston, Texas

NARUC Subcommittee on Clean Coal and Carbon Management / NARUC-DOE Coal Modernization and Carbon Management Partnership

APRIL 28, 2022| 2 – 3 PM (ET)

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- **Charles McConnell,** Energy Center Officer, University of Houston Center for Carbon Management in Energy
- **Michael Nasi,** Partner, Jackson Walker LLP

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Supported by the U.S. Department of Energy-NARUC Coal Modernization and Carbon Management Partnership

MAHAK AGRAWAL, M. Plan, M.P.A
Staff Associate II - Center on Global Energy Policy
Columbia University in the City of New York
ma4100@columbia.edu

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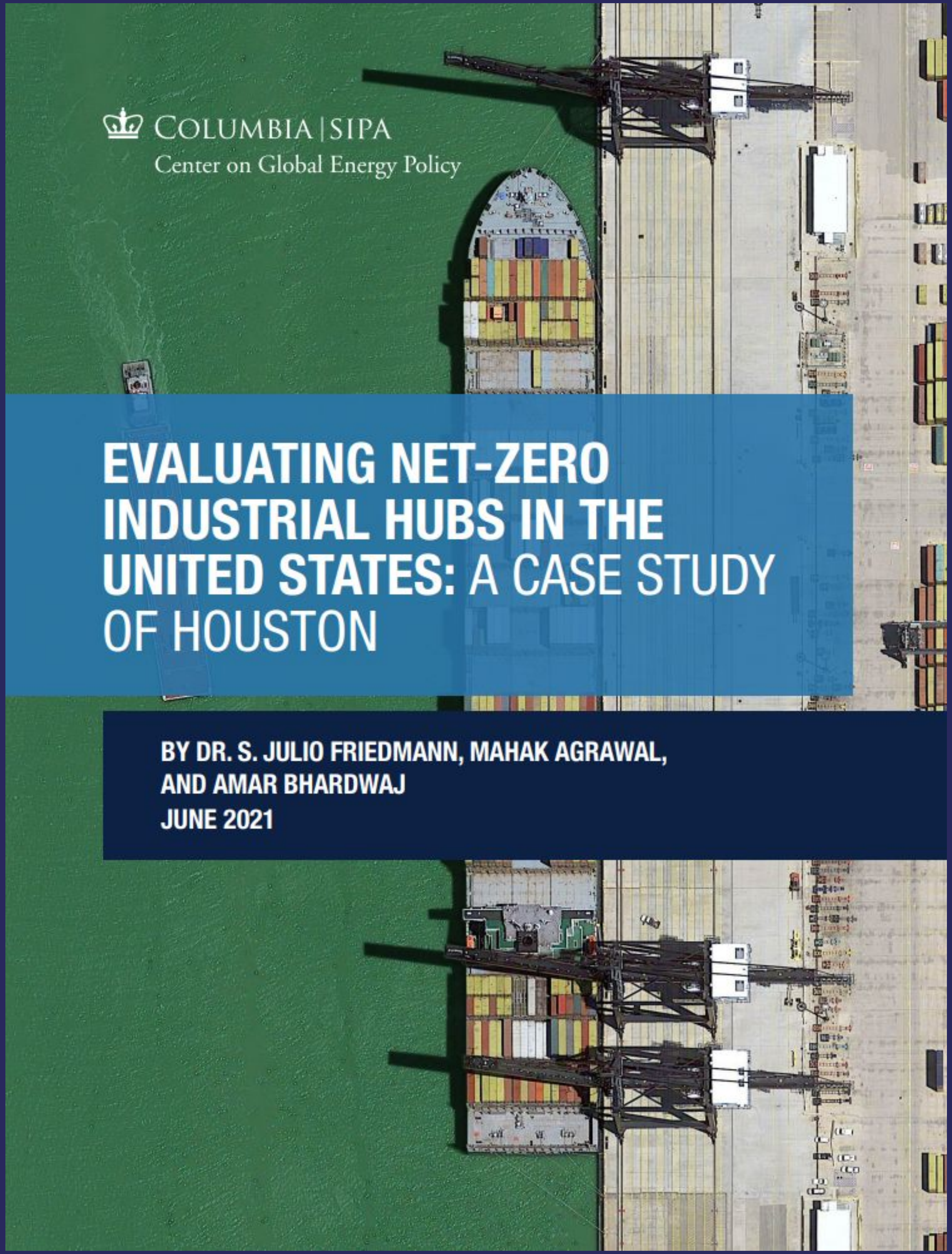
Concept of net-zero industrial hubs

A net-zero hub, or net-zero industrial hub, is a concentrated set of facilities, plants, and linked infrastructure dedicated to near-term reduction and long-term elimination of greenhouse gas emissions through the application of advanced clean energy and emissions control technology and possibly CO_2 removal technology. .



Value of net-zero industrial hubs

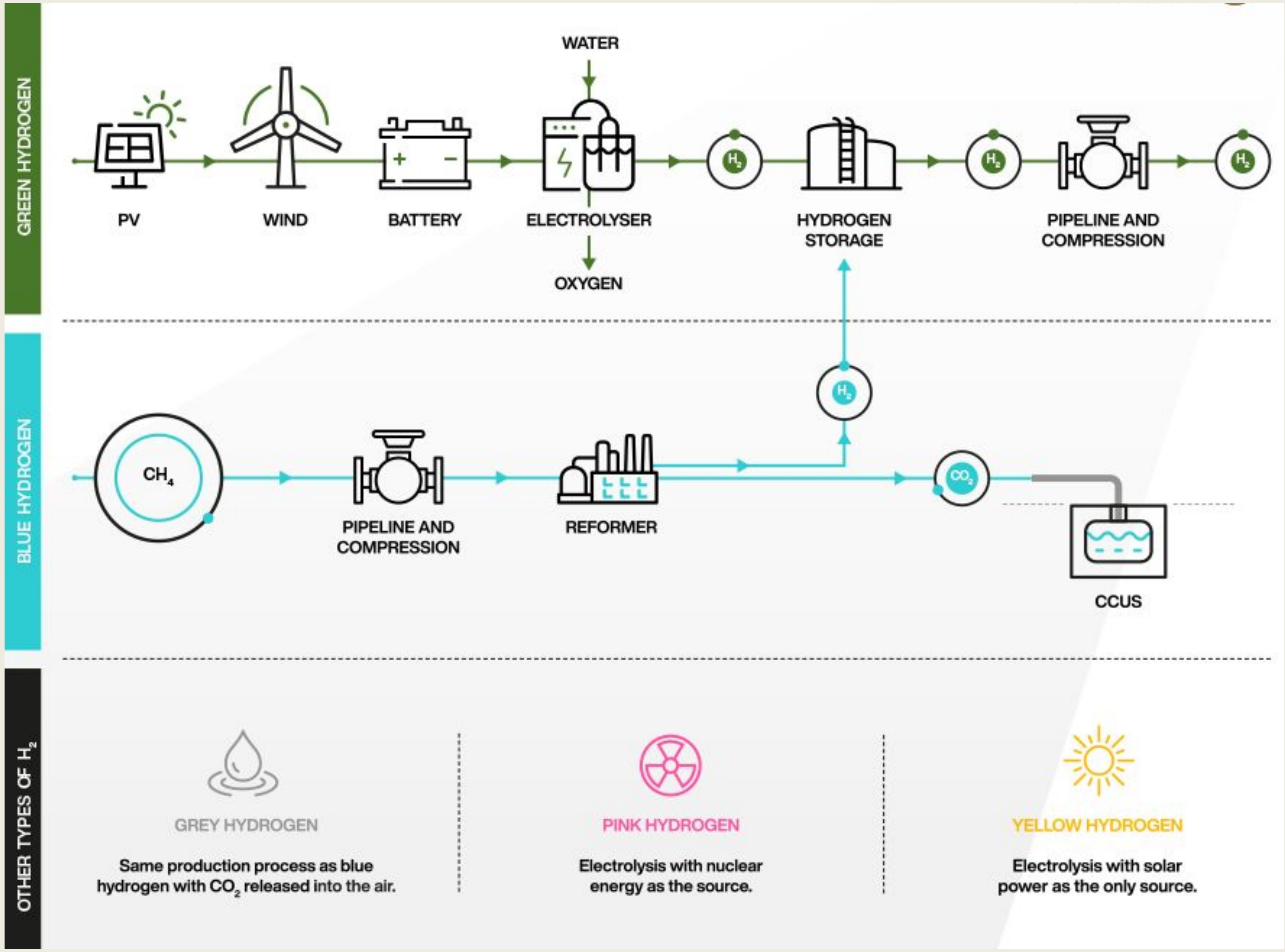
1. Maintain and create jobs via PPP and infrastructure development
2. Accelerate energy transition, particularly for hard-to-abate sectors
3. Provide support to core-infrastructure
4. Integrate multiple technologies across sectors
5. Reduce cross-chain risk for multiple sectors and markets
6. Reduce overall costs via economies of scale
7. Make the best use of local infrastructure, skilled labour pool, as well as planning, operations and safety

An aerial view of industrial area of Houston, Texas (Image sourced from Shutterstock, 2022)

Net-zero industrial hubs provide opportunities for 3 parallel clean energy pathways that are commercially viable at scale: CCUS, zero-carbon electricity and low-carbon hydrogen

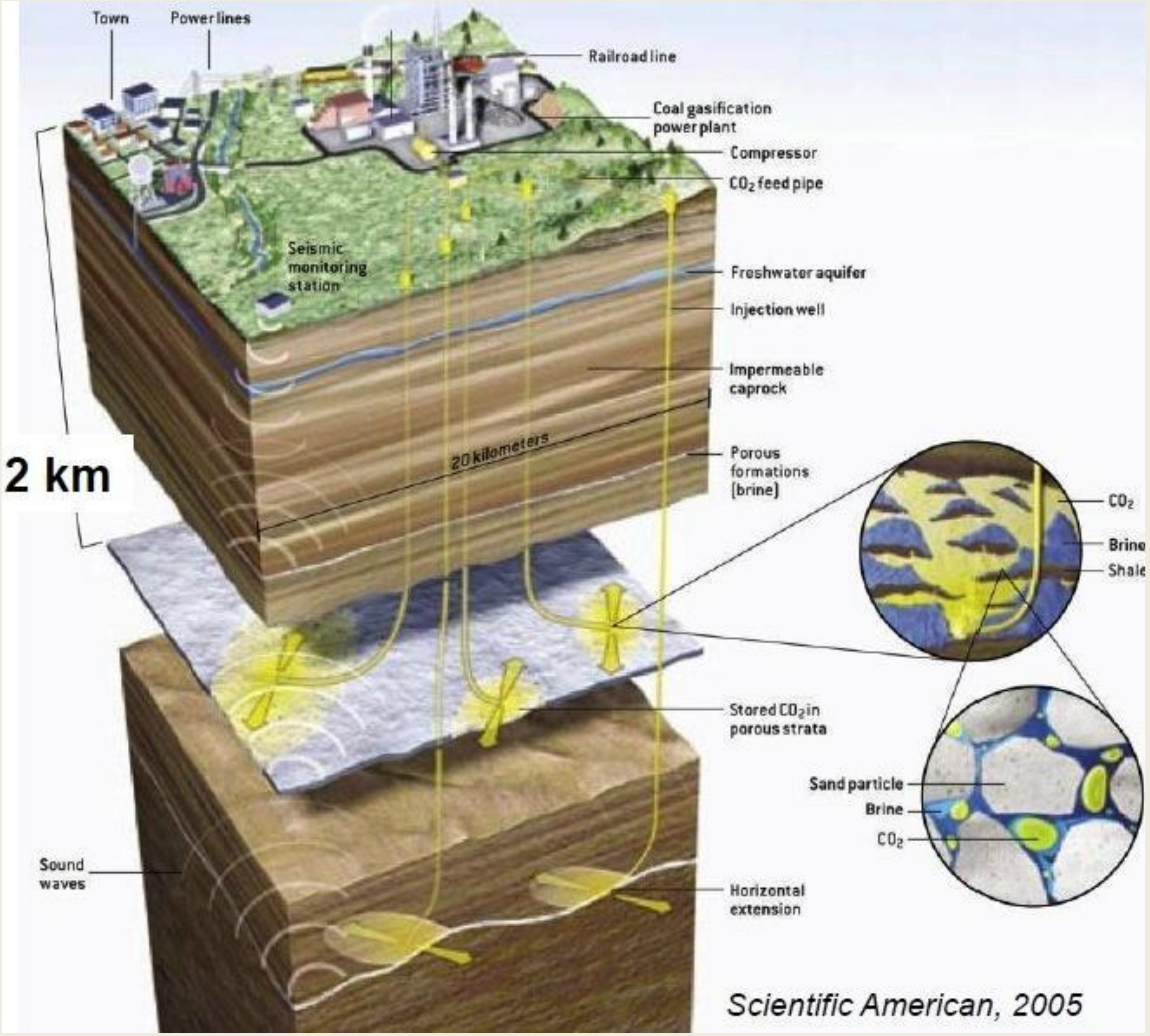
There are few technology options for industrial hubs

1. Low-carbon hydrogen
   - Green hydrogen (zero-carbon electrolysis)
   - Blue hydrogen (fossil hydrogen with carbon capture)
2. Biomass (biogas, biocoke, wood pellets)
3. Carbon capture and storage
4. Electrification with zero-carbon electricity



Different production pathways for hydrogen
(Image source: Petrofac, 2022)

Carbon capture and storage works and is cost effective



Capture: power plants and industrial sources

- Concentrate flue gas into pure streams of CO_2
- Substantial capital and operating expenses
- Cheaper than many alternatives

Storage: > 1 km depth

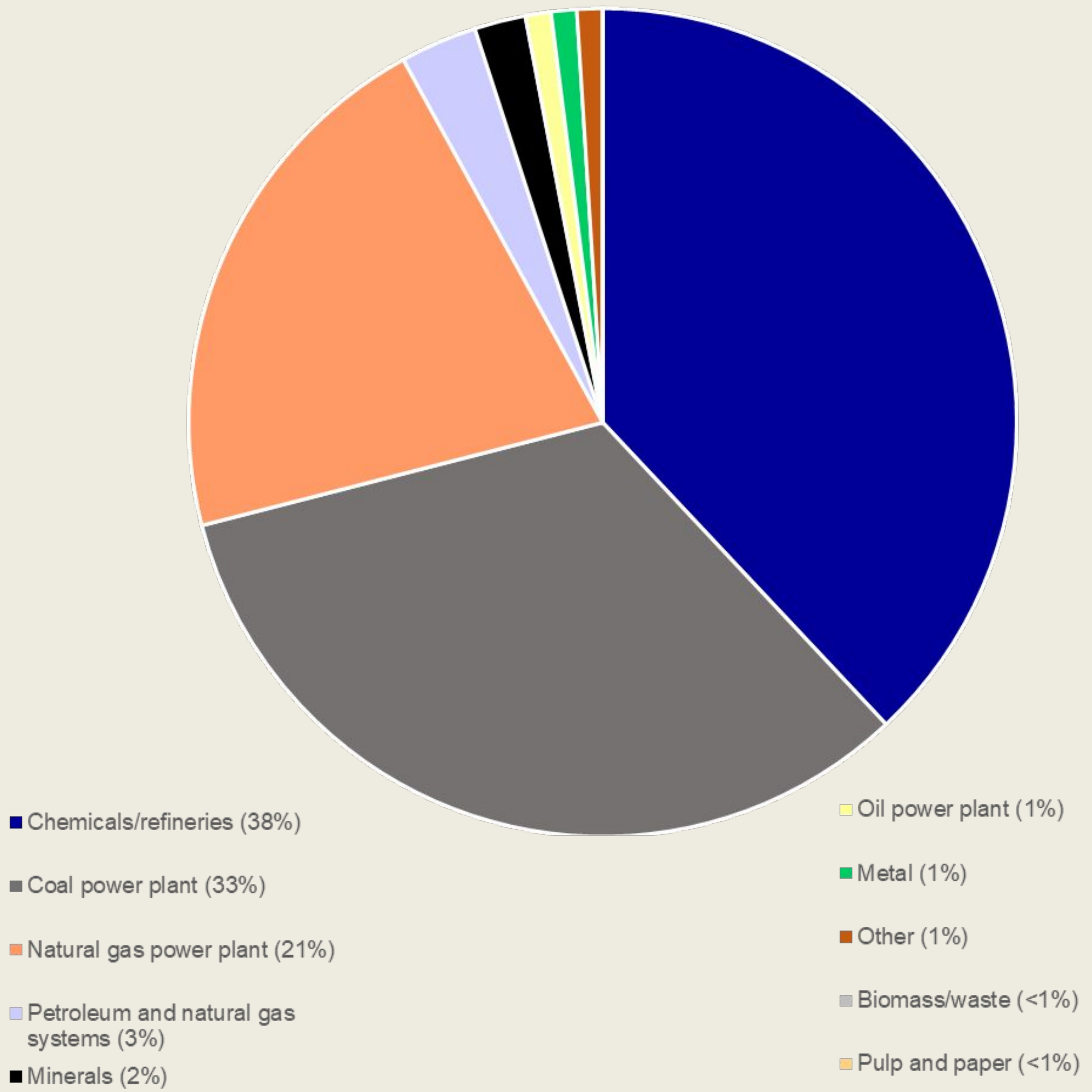
- Porous & permeable units with seals
  - Mostly in deep, brine-bearing formations
  - Also depleted oil and gas fields
  - EOR an option: not required
- Global capacity: 10-20 trillion tons CO_2
- US capacity: 2.8-12.6 trillion tons

CCS today

- 26 operating facilities worldwide
- 40 million tons CO_2/y (over 400 million cumulative)
- Operating from at power plants, steel mills, ethanol plants, hydrogen plants
- 100 new project announced in 2021 (most in US)

Industrial hubs in Texas

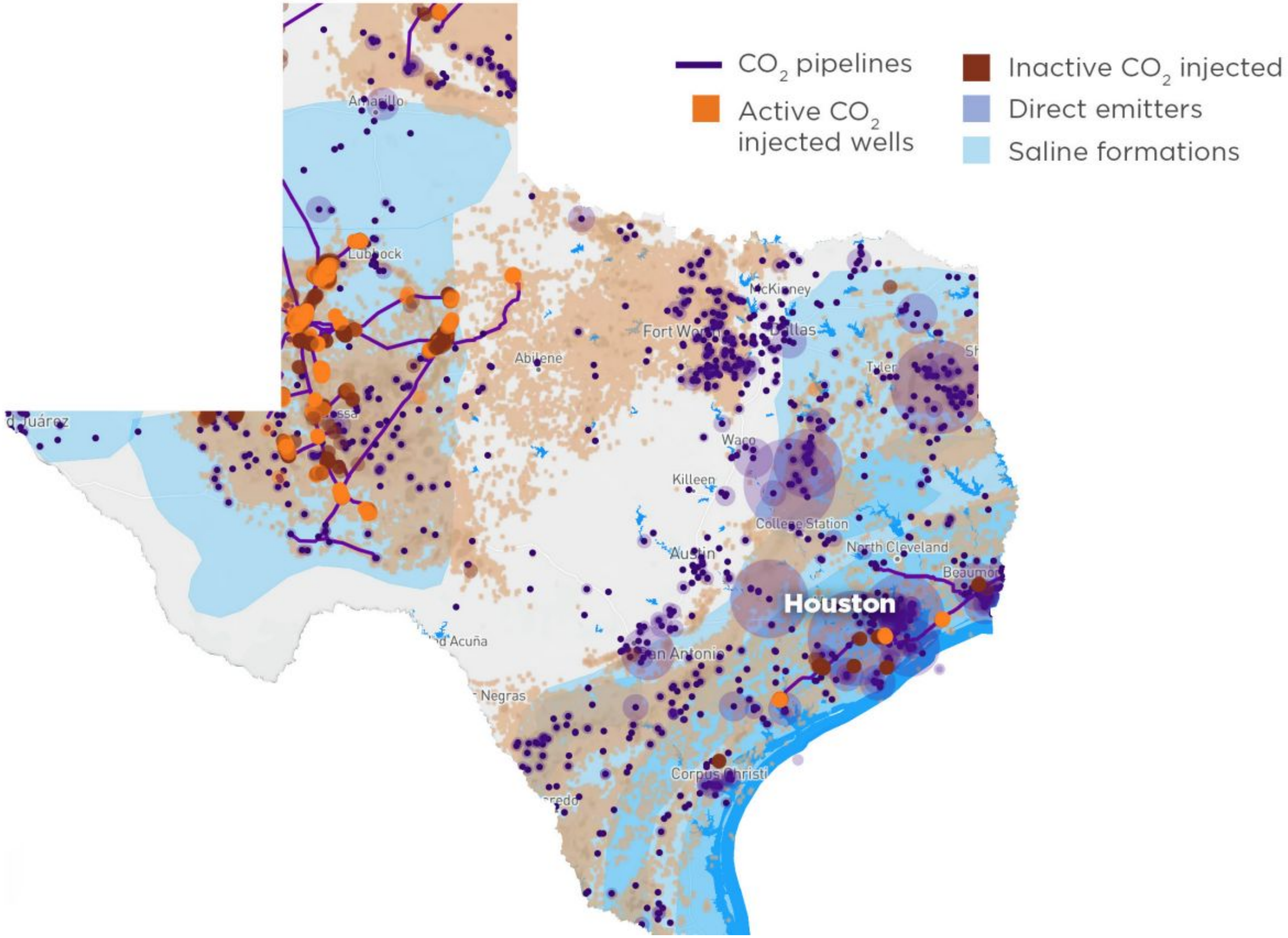
1. Texas exports $316 billion in goods every year
2. Texas represents 10% of U.S. manufacturing productivity
3. Home to second largest U.S. manufacturing workforce
4. Largest GHG emitter in the United States > for both industrial and power emissions
5. Key source of emission and pollution: large point sources, particularly chemical and refining industries, coal and natural gas power plants, oil power plant
6. Within Texas, Houston has the largest concentration of emission sources



Sectoral share of CO_2 emissions in Texas, 2020
(Data source: National Petroleum Council, 2020)

Opportunities for expansion and establishment of net-zero industrial hubs in Texas

1. Clustering of emission sources provide pathways to minimise footprint and costs for CO_2 retrofit infrastructure
2. Excellent and proximity to geological storage resources: significant subsurface pore volume for CO_2 storage near Houston and Gulf of Mexico
3. Proximity between storage locations and emission sources
4. Availability of the human capital
5. Texas controls and owns the first 10 miles of shelf from the shoreline > legal authority to develop natural resources for net-zero hub



Composite map of CO_2 storage capacity in saline formations and active oil fields in Texas
(Sourced from Medlock and Miller (2021) with data from NETL/NATCARB and the Gulf Coast Carbon Center)

Infrastructure costs for Houston net-zero industrial hub

Assumptions for gross estimation of costs:

1. Green hydrogen synthesis for local use via a 1Mt/y hydrogen facility.
2. 10 new CO_2 pipelines to move 20 Mt/y
3. Electricity upgrades for 50 TWh/y, including transmission and new renewable generation
4. New ammonia terminal capable of exporting 1.3 Mtpa of ammonia

Potential to reduce GHG emissions roughly 25 Mt.y at a cost of $28 billion.

Key elements	Dimension	Estimated costs ($ million)
Hydrogen - new production, all green	1 Mt/y H2 14 GW electrolyser capacity ($800/kW)	$11,000
CO2 pipelines - focus on existing source	20 Mt CO2/y - 30 miles 10 pipelines (2 Mt/y) 8 onshore, 2 offshore	$500
Electricity upgrades - zero carbon electricity for green hydrogen and port electrification	50 TWh/y 40% capacity factor Even split: solar/ onshore wind/ offshore wind	$4,000 transmission $12,000 new generation
Port infrastructure	1.3 Mt/y ammonia (incl. storage tanks, docks, ammonia pipelines, dredging)	$1,000 (full facility) $100 docks, etc

Estimated costs for key infrastructure elements in a Houston net-zero hub, 2021

Existing policy support

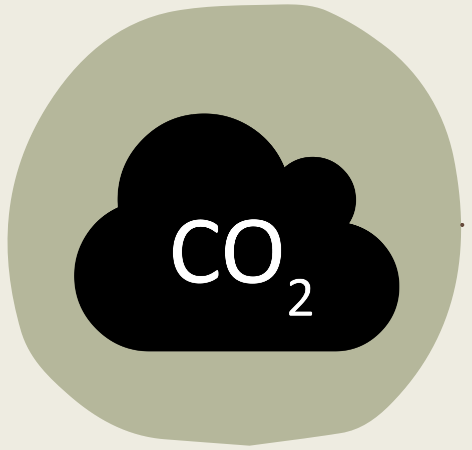
1. **The Federal Sustainability Plan** (Dec 2021)
    a. Net-zero emissions from overall federal operations by 2050
    b. 100% carbon pollution free electricity by 2030, including 50% on a 24/7 basis
2. **Bipartisan Infrastructure Law** (Infrastructure Investment and Jobs Act) (Nov 2021)
    a. $7.5 billion to build out a national network of EV chargers
    b. $65 billion investment in clean energy transmission and grid
3. **Tax credits**
    a. 45Q tax credit for carbon sequestration > proposed by CATCH Act for increase in value to $85/ton of CO_2 captured and stored in saline geologic formations and $60/ton for CO_2 + EOR. Also eliminated the annual CO2 capture thresholds for power, industrial, carbon utilisation and DAC projects.
    b. Production Tax Credit (PTC) and Investment Tax Credit (ITC) extended for a year in December 2020
    c. 30% ITC for offshore wind projects that begin construction before December 31, 2025
    d. Blender's Tax Credit > $1.00 gallon of biodiesel or renewable diesel used in blending process

Emerging policy support

1. **CLEAN Future Act**
    a. National emissions reduction target to achieve 100% clean economy by 2050, and reduce GHG emissions by 50% by 2030 from 2005 levels
    b. $200 million in federal grants for preparation of State Climate Plans to achieve emission reduction goals
    c. Office of Energy and Economic Transition in the White House
    d. $100 billion from 2021-2030 to electrification of transportation systems
    e. Federal Clean Electricity Standard (CES)
2. **Climate provisions from the Build Back Better Bill**
    a. ~$550 billion for clean energy transition
    b. $320 billion in tax credits for producers and buyers of wind, solar and nuclear power
    c. ~$6 billion for owners to replace gas powered furnaces and appliances with electric version
    d. Billions for R&D for carbon capture and DAC

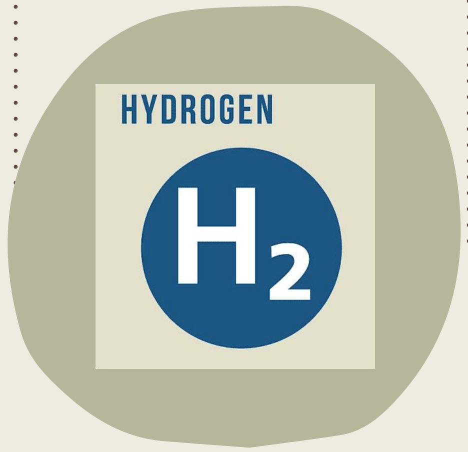
Flow of funds

$2 billion/yr



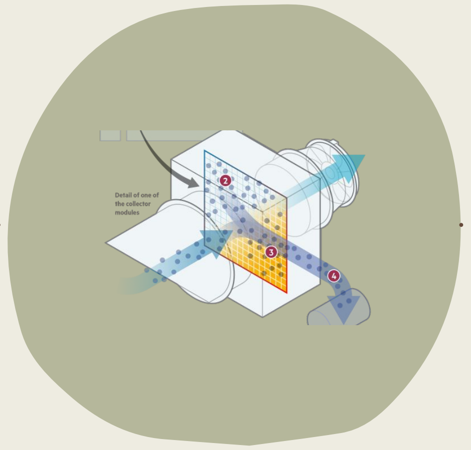
- SCALE Act
- CO_2 pipeline infrastructure
- Deptt. of transportation

$8 billion



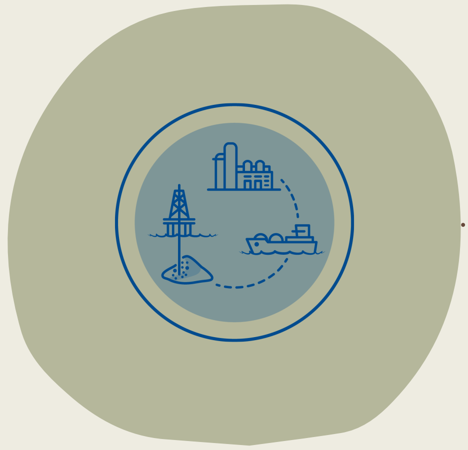
- Infrastructure Investment and Jobs Act (IIJA)
- Hydrogen hubs

$3.5 billion



- Direct air capture hubs
- New Office of Large Scale Demonstrations

$8 billion



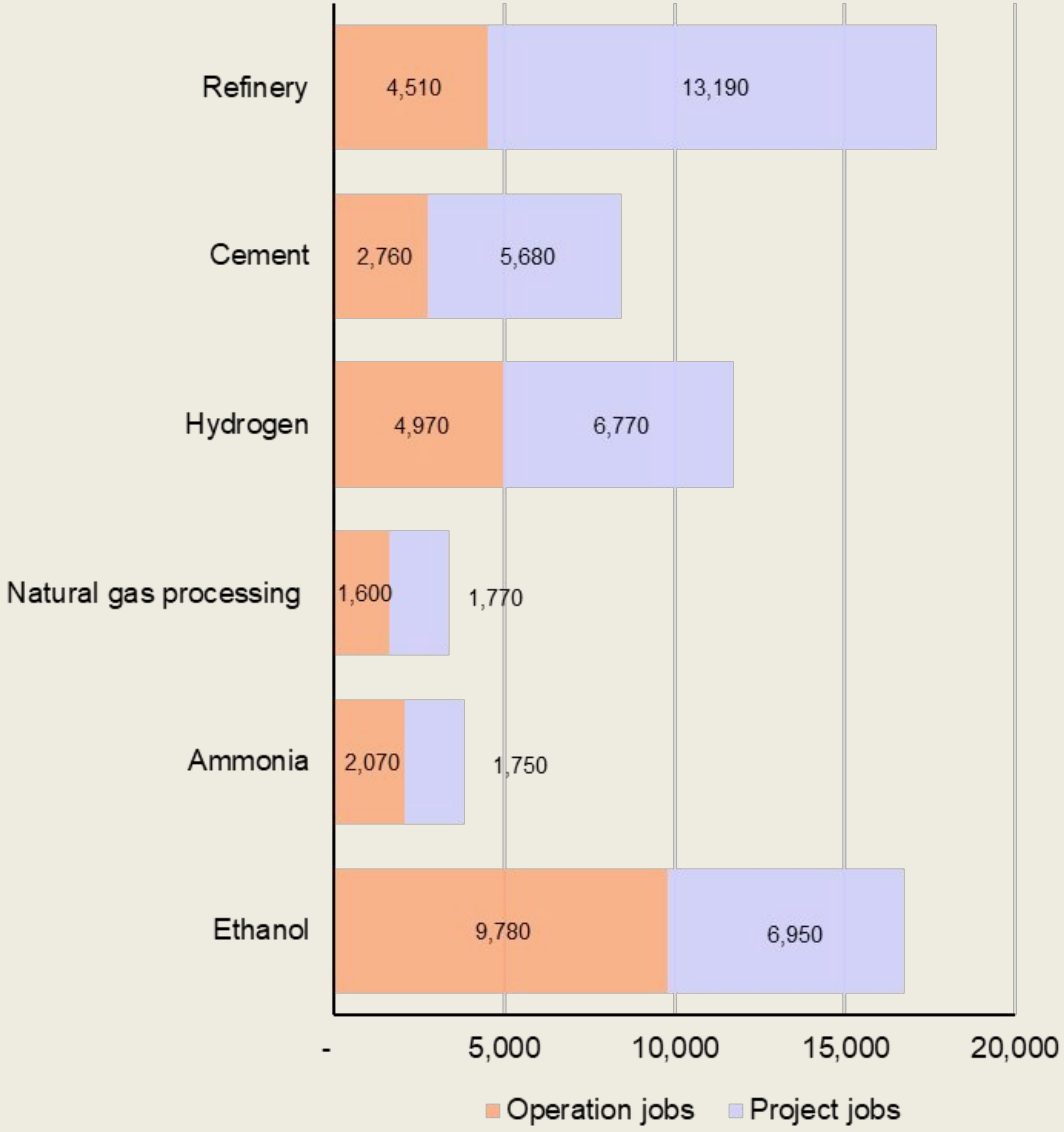
- Clean fossil/ CCS
- Loan program office

$2 billion + $6 billion/yr

- Rural clean fossil
- USDA > rural electric program ($6B)

Benefits of industrial hubs in Houston, Texas

1. Realising the vision of Houston Climate Action Plan 2020 > reduce GHG emissions by 40% (as compared to 2014 levels) by 2030 and achieve carbon neutrality by 2050
2. Drive economic growth and employment > deployment of CCS with 45Q credits could generate ~40,000 jobs in Texas
3. New avenues and opportunities for new companies and circular economy industries (recycling CO_2 for fuels, building materials, etc)
4. Reduce air pollution in key industries and other sectors



Total job years from carbon capture retrofits with 45Q enhancements
(Source: Ben King, Whitney Herndon, John Larsen and Galen Hiltbrand, 2020)

Role of public utility commissions

- pre-approving project facility siting and environmental criteria
- streamlining permit process for CO2 pipelines

Siting

- Include carbon capture as a power generation option for regulated utilities
- Utilities to consider CCUS while submitting integrated resource plans (IRPs)

Planning

- Speed or ease cost recovery of CCS deployment on new or existing power plants
- Rate recovery on construction work in progress
- Periodic adjustment

Cost recovery

- % of retail electricity sales to come from low- & zero-carbon clean electricity
- Regulate the periodic increase in share of clean electricity

Clean electricity standard compliance

- Similar to managing natural gas, wireless, etc
- Dedicated to supply CO_2 to customers

CO_2 utility

- Procurement method to lower transaction costs and promote system-side zero-carbon distribution generation projects

Low-carbon energy auction mechanism

Got questions?

Email: ma4100@columbia.edu

Scan the QR code to connect on LinkedIn

Thank you.

Innovating CCUS in the Gulf Coast & Integrating CCUS in Utility Resource Planning

Charles McConnell, UH CCME
&
Mike Nasi, Special Counsel, SSEB & Partner, Jackson Walker LLP

DISCUSSION OUTLINE

1. Innovating CCUS in the Gulf Coast
2. Viability of CCUS Instead of Retirement
3. Domestic Importance of CCUS
4. International Urgency of CCUS

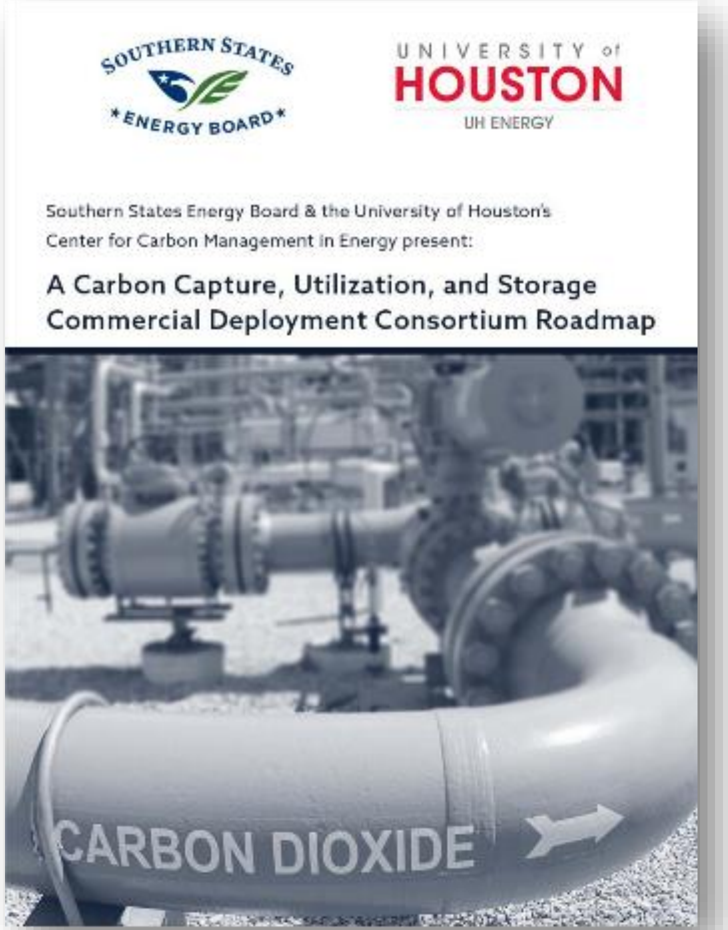
Jackson Walker LLP

PART I

Innovating CCUS in the Gulf Coast

CCUS Commercialization Consortium

- Coordinate the capabilities and experience of industry, academia, and government to accelerate CCUS deployment in the Southern region, address key challenges, and promote regional technology transfer and knowledge dissemination – in response to NPC study
- Leverage the experience and membership of SSEB, the location and expertise of UH-CCME, and Consortium membership to address Transformative Challenges – 2022 activities have been identified
- Membership now includes over 40 companies and organizations



Consortium Roadmap cover page. Developed with significant input from Consortium members.

Consortium – Leadership Team Membership

NATIONAL ENERGY TECHNOLOGY LABORATORY
SOUTHERN STATES ENERGY BOARD
UNIVERSITY of HOUSTON
UH ENERGY

Advanced Resources International, Inc.
Baker Hughes
BATTELLE
BERKSHIRE HATHAWAY ENERGY
bp
BUREAU OF ECONOMIC GEOLOGY
CARPENTER GLOBAL, LLC

Chevron
Denbury
DOW
EDF ENVIRONMENTAL DEFENSE FUND
EERC
ENBRIDGE
Enhanced Oil Recovery Institute
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CRESCENTRI RESOURCE INNOVATION

ExxonMobil
HUNTON ANDREWS KURTH
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MARATHON

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Minnkota Power COOPERATIVE
nrg
OXY
PHILLIPS 66
PPDG

REPSOL
Shell
Southern Company
USEA
United States Energy Association
wood.
wsp

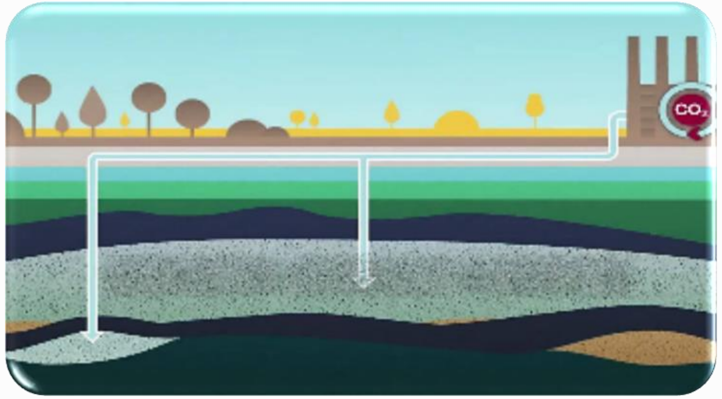
WARWICK Capital Partners
GREATER HOUSTON PARTNERSHIP

CHALLENGES & OPPORTUNITIES

Carbon Capture

Transportation

Storage



- Technology maturity
- Capture Cost of CO_2 (3/4 of total CCUS cost)
- Electricity cost for compression
- Separation cost to purify CO_2

- Permits & Regulations
- Public acceptance
- Eminent Domain
- Cost of pipeline design and operating expense
- Infrastructure improvements

- Primacy
- Class 6 wells
- Low cost of oil
- Cost of surveillance (Liability for releases)
- Induced seismicity

Phase I: Activation (2030)

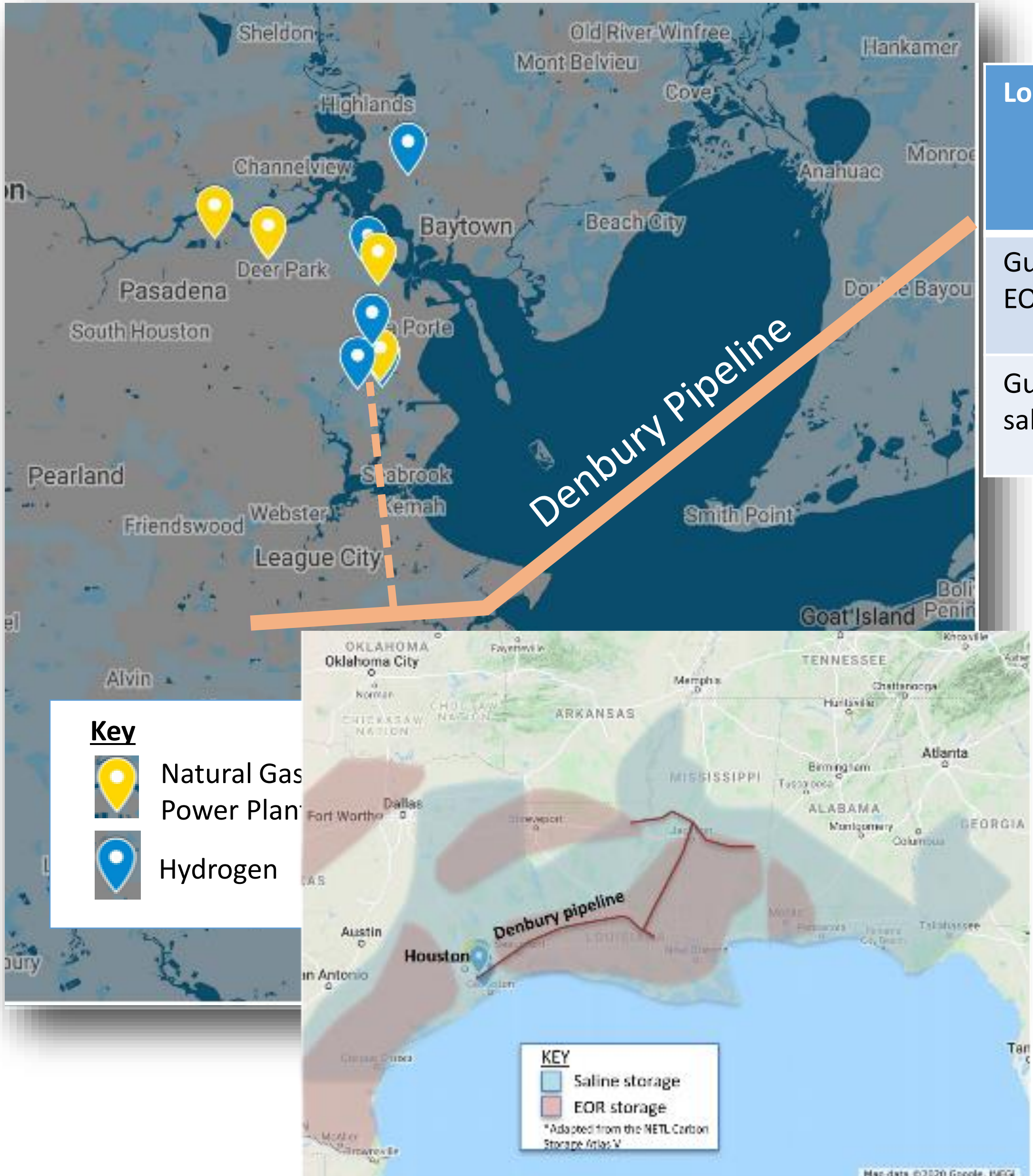
Capture

Facility type	Captured emissions (MM tons/yr)	Total investment (bil US$)
Hydrogen	5.7	$1.1
Natural gas power plants	7	$2.5

Transport

Pipeline	Available capacity (MM tons/yr)	Total investment (bil US$/yr)
Denbury	12.9	$0.12

- **Hydrogen emissions prioritized** due to cheaper capture cost.
- **Natural gas power plants second** due to increasing pressure from investors.
- **Denbury currently utilized at 1/3 capacity**.



Storage

Location	Available storage (bil tons)	Total investment (bil US$/yr)
Gulf Coast EOR	1.4	$0.12
Gulf Coast saline	1,500	

- **Significant EOR storage** is available along Gulf Coast in the form of disparate oil fields.
- Denbury has identified **multiple EOR fields along the pipeline's path**.
- **Saline storage is sufficient** to handle Denbury capacity **for 75 years.**

Phase II: Expansion (2040)

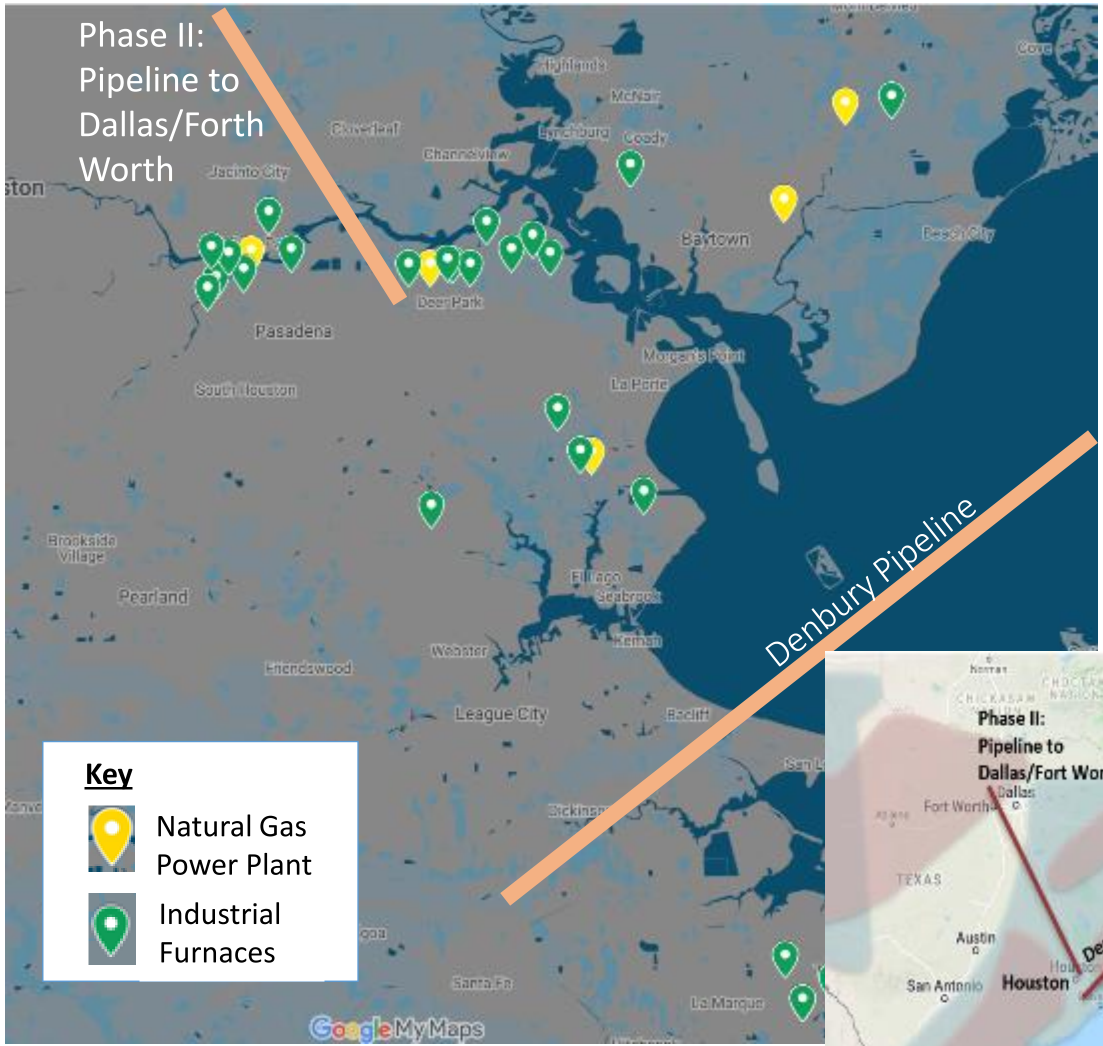
Capture

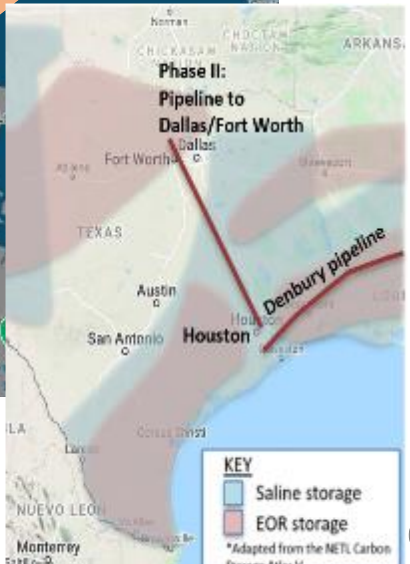
Facility Type	Captured emissions (MM tons/yr)	Total Investment (bil US$)
Natural Gas Power Plant	6.4	2.2
Industrial Furnaces	13.5	6.4

Transport

Pipeline	Available capacity (MM tons/yr)	Total Investment (bil US$)
East/Central Texas	20	$0.5

- **Build 250-Mile** Houston -to- East/Central Texas **Pipeline**
- **Industrial Furnaces** are included to expand annual capture of CO2
- Additional **Natural Gas Power Plants** are involved in the expansion of capacity transportation





Storage

Location	Available storage (bil tons)	Total Investment (bil US$/yr)
East/Central Texas EOR	3.6	TBD
East/Central Texas saline	501	

- **EOR and Saline storage** is available in East/Central Texas
- **Leveraging the demand for CO_2 EOR**, offering a relatively larger **economic benefit**

Phase III: At-Scale (2050)

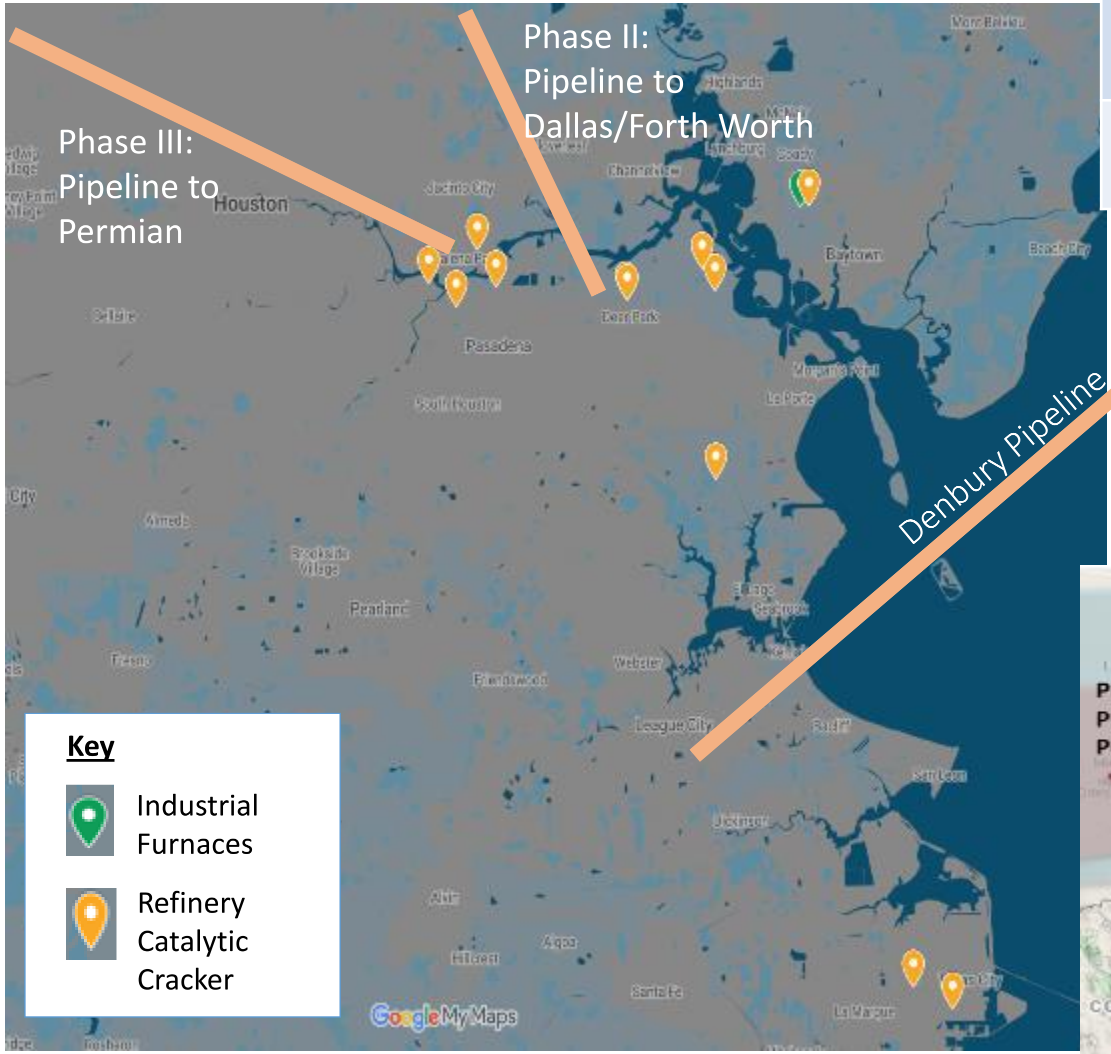
Capture

Facility Type	Captured emissions (MM tons/yr)	Total Investment (bil US$)
Industrial Furnaces	a	2.8
Refinery Catalytic Cracker	7.8	1.4

Transport

Pipeline	Available capacity (MM tons/yr)	Total Investment (bil US$)
Permian	20	$1

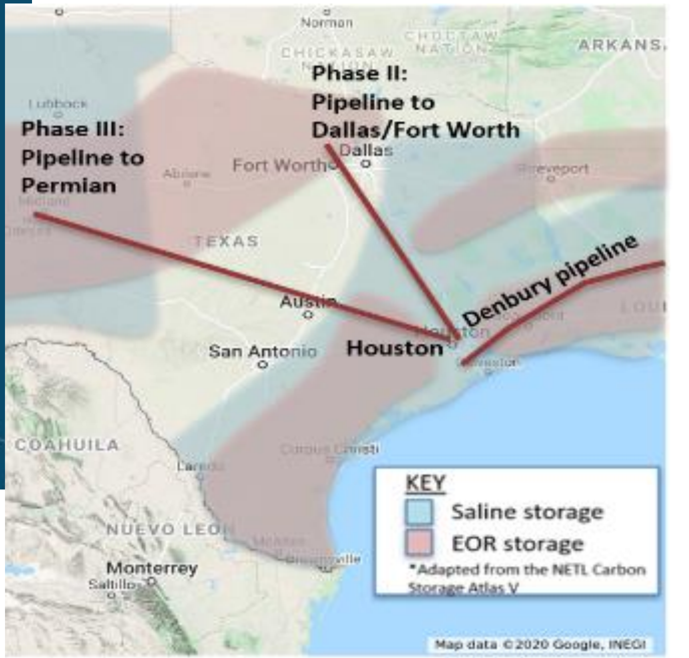
- **Build 500-Mile** Houston -to- Permian **Pipeline**
- **Refinery Catalytic Cracker** are included to expand annual capture of CO2
- Projected pipeline from Houston to the Permian Basin will **help with the economic feasibility of both carbon capture and pipeline projects**



Storage

Location	Available storage (bil tons)	Total Investment (bil US$/yr)
Permian EOR	4.8	TBD
Permian saline	1000	

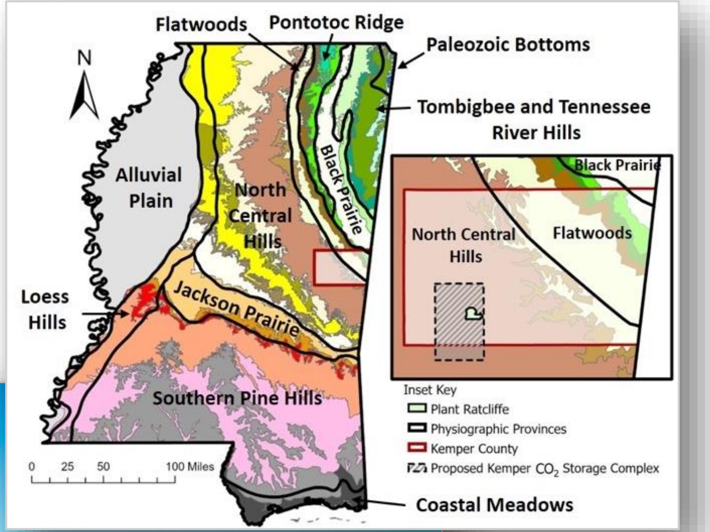
- **Large-scale of EOR and saline storage** available in the Permian Basin
- Storage capacity in the Permian will permit to **achieve net zero in carbon goal**



CarbonSAFE - Project ECO_2S Phase III (MS)

- Identify a storage complex capable of storing 50 million metric tons over 30 years
- **Estimated storage capacity of almost 1 billion metric tons (P_{50})**
- Three new characterization wells drilled and 92 linear miles of 2D seismic acquired
- Drafting EPA UIC Class VI permit

Location of Kemper County, MS and the state's physiographic provinces. Also indicated is the ECO_2S area of interest. Figure courtesy of ARI.



Research Partners

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Specialized Partners & Vendors

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PROJECT ECO2S

Stratigraphic test well drilling activities in Kemper County, MS. Image courtesy of Spectrum Environmental.

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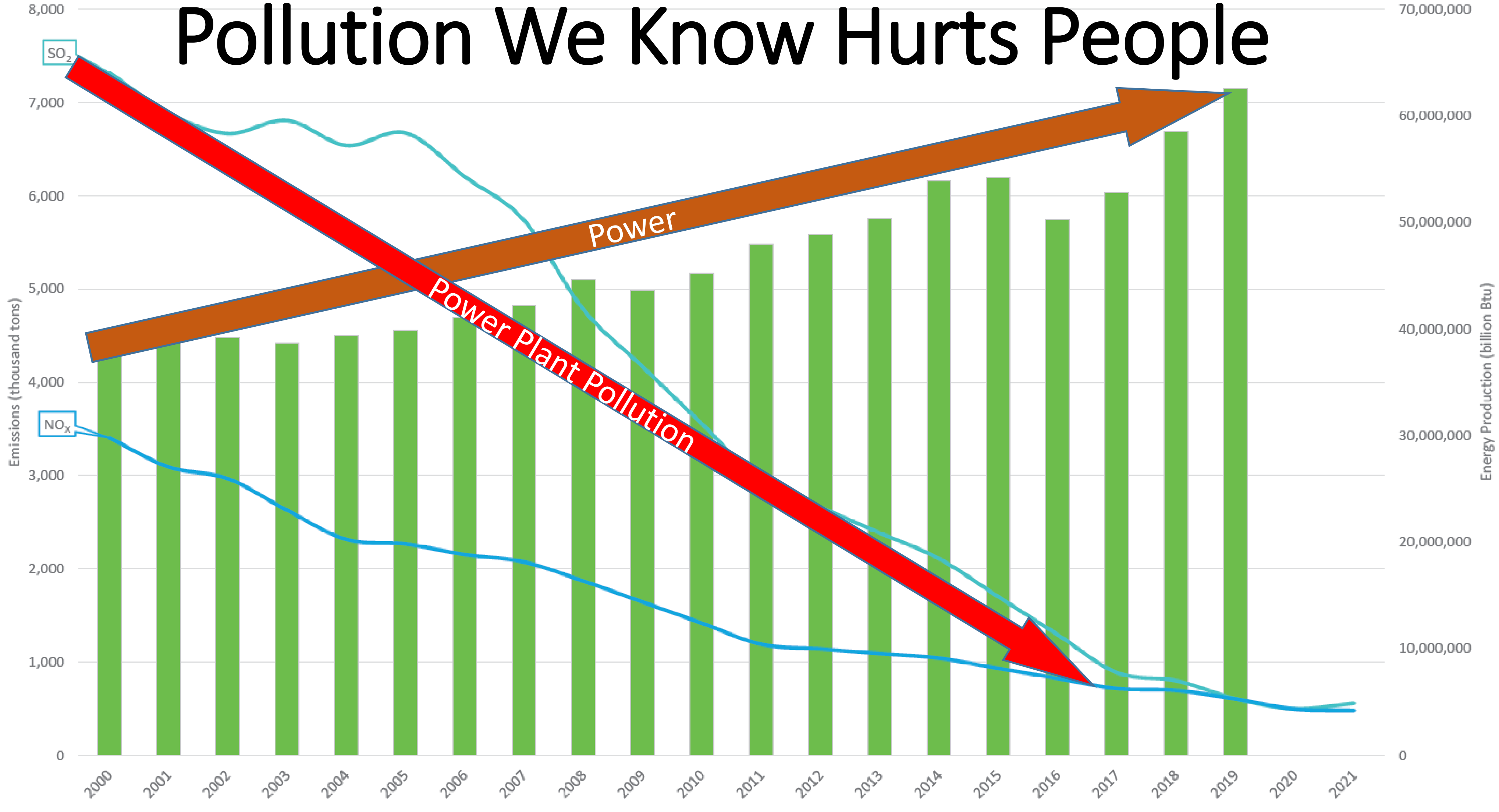
PART II

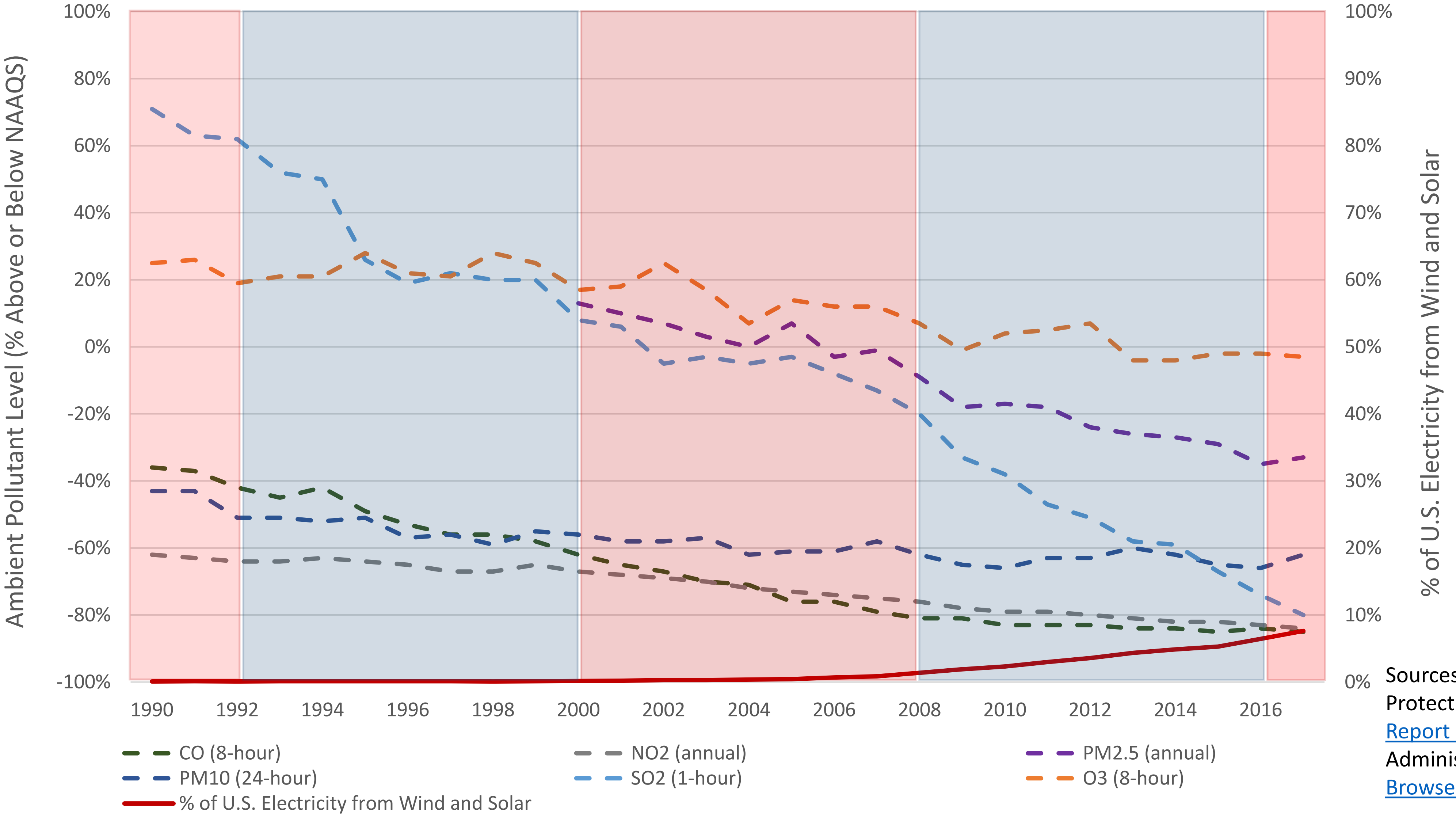
Why CCUS is a Viable Alternative to Premature Retirement

We Have Internalized the Externalities of the Pollution We Know Hurts People



Source: U.S. Energy Information Administration, **State Energy Data System (SEDS): 1960–2019**; U.S. EPA, **Air Pollutant Emissions Trends Data** (Data file: "State Tier 1 CAPS Trends, Criteria pollutants State Tier 1 for 1990–2021").

REMEMBER: We Made our Air Safe with Technology, Not Anti-Fossil Fuel Ideology

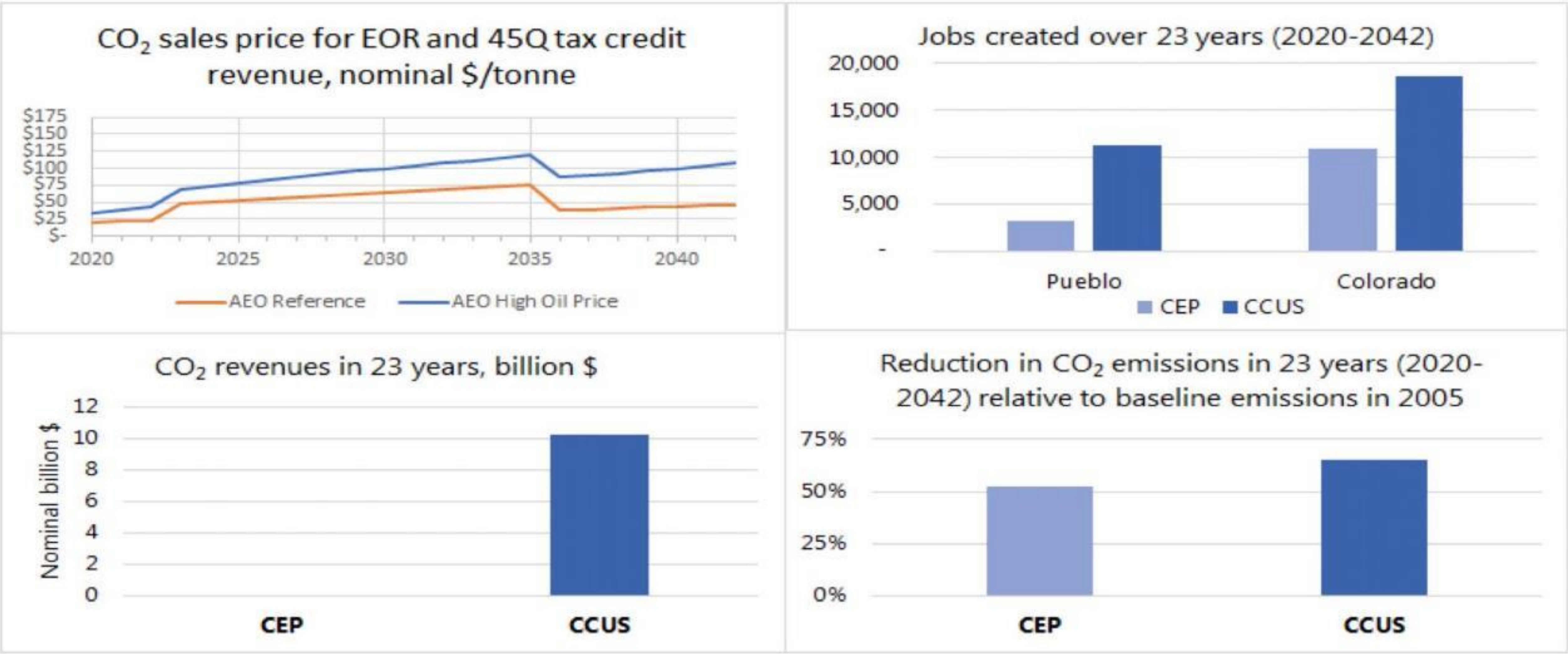


Sources: Environmental Protection Agency, Air Trends Report 2018; Energy Information Administration, Total Energy Data Browser

WHY CCS SHOULD BE EVALUATED BEFORE ASSETS ARE RETIRED

WIND/SOLAR/STORAGE	KEY CONSIDERATIONS	CCUS RETROFIT
• Low Capacity Factors • Transmission Additions • Reliability Penalty • Resilience Penalty • Shorter Project Life • Supply Chain Disruption	**LCOE is an Academic Discussion - Focus Should be on “Levelized Cost of Dispatchable & Delivered Energy (LCODDE)”**	• High Capacity Factors • No New Transmission • High Reliability • On-site Fuel Resilience • Long & Stable Life • Functions as Flexible Load • Dual Units = More Flexibility
• Bird Strikes • Habitat Destruction • Lithium/Cobalt Mining for Batteries • Rare Earths for Turbines & Solar	**Non-GHG Externalities**	• Air Quality Not Impacted < Known “Safe” Levels (NAAQS) • Successful & Established Coal Reclamation Programs
• Backup Power Emissions • Life-Cycle GHGs From Construction & Land Use • Missed R&D opportunity	**GHG Externalities**	• No Backup Power Required – (24/7 carbon-free resource) • R&D Drives Down Future Costs (global game changer)
• Dependence on Minerals & Products Not Mined/Made in US	**Economic Impact & Geopolitical**	• Domestic fuels (coal & gas) + export commodity (oil & tech)

DOE STUDY: Demonstrates Viability of CCUS Retrofit Alongside Consideration of Retirement/Replacement with Wind/Solar/Storage (Tax Equity Owner reduces cost to the consumer even more!)



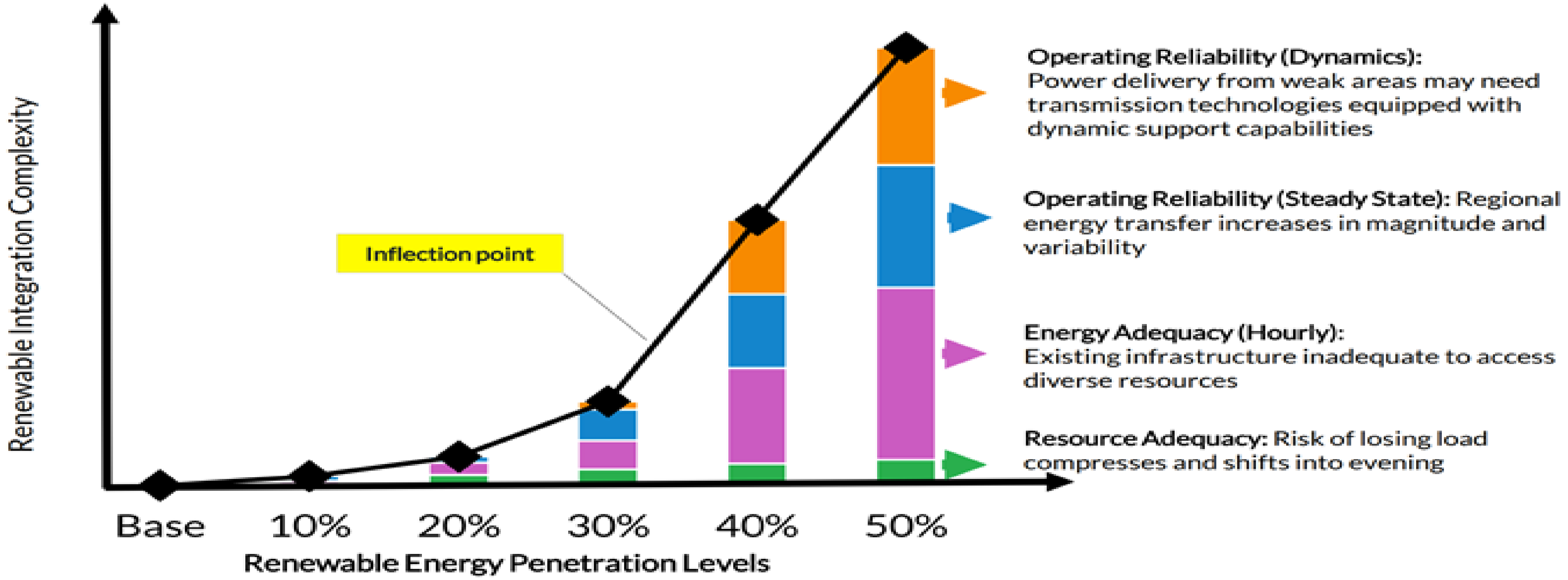
PART III

Why CCUS is Domestically Important

MISO Concerns = ERCOT Harsh Reality

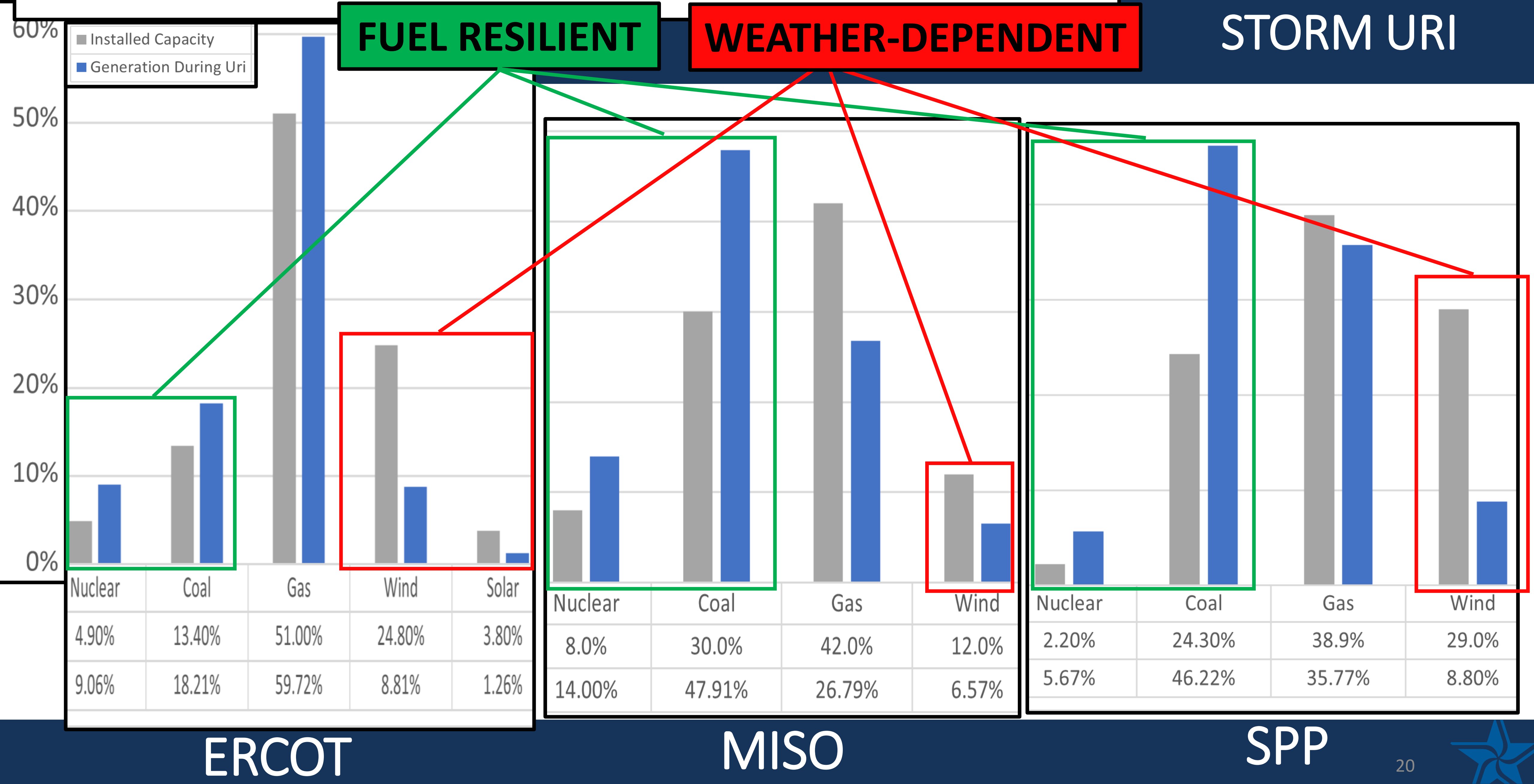
-Renewable Penetration > 33% Creates Reliability Problems

These resource changes will significantly impact grid performance with complexity increasing sharply after 30% penetration levels



MISO

Installed Capacity vs. Performance: DURING WINTER STORM URI



ERCOT

	Nuclear	Coal	Gas	Wind	Solar
Installed Capacity	4.90%	13.40%	51.00%	24.80%	3.80%
Generation During Uri	9.06%	18.21%	59.72%	8.81%	1.26%

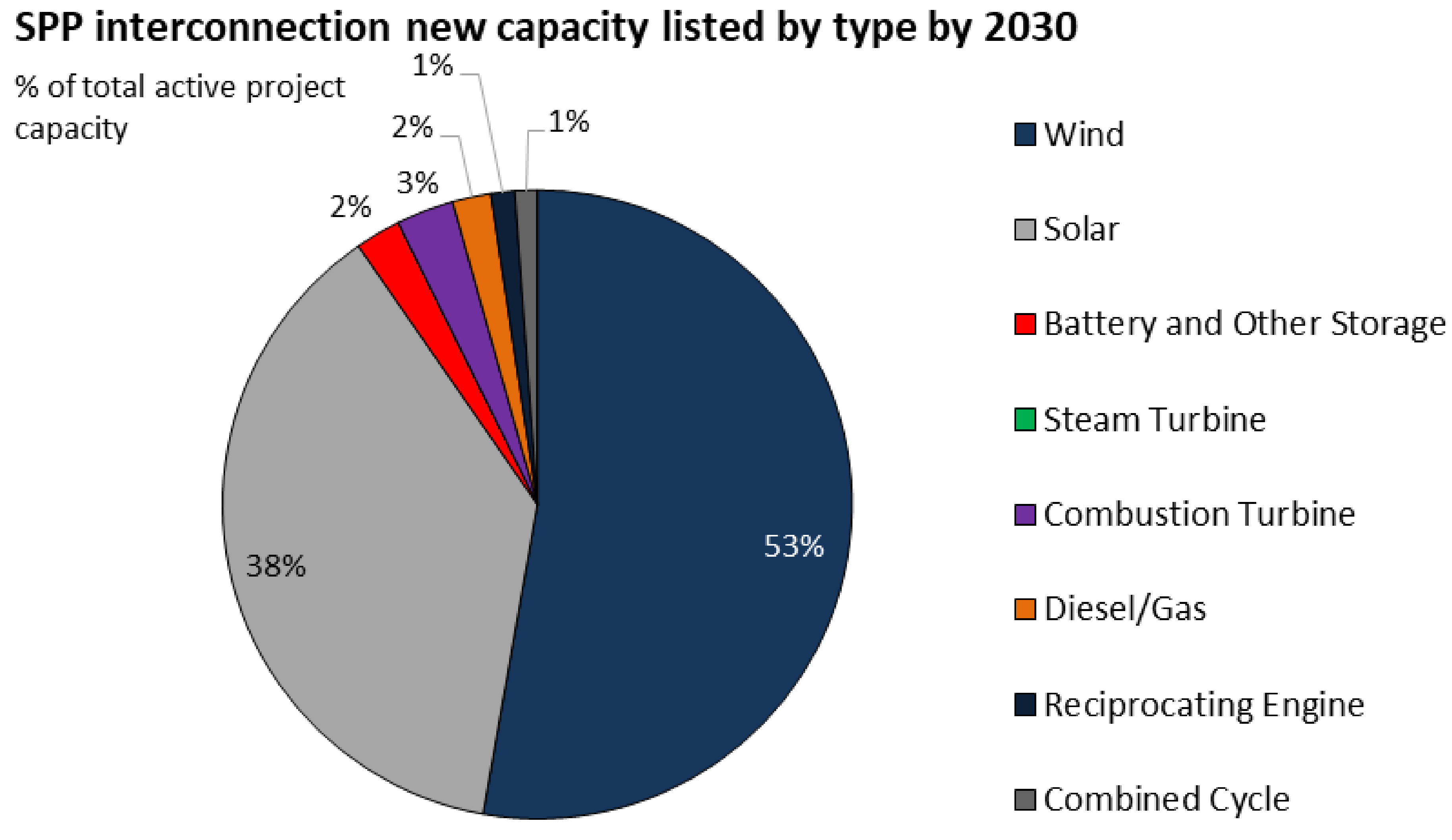
MISO

	Nuclear	Coal	Gas	Wind
Installed Capacity	8.0%	30.0%	42.0%	12.0%
Generation During Uri	14.00%	47.91%	26.79%	6.57%

SPP

	Nuclear	Coal	Gas	Wind
Installed Capacity	2.20%	24.30%	38.9%	29.0%
Generation During Uri	5.67%	46.22%	35.77%	8.80%

A Look to the Future in SPP

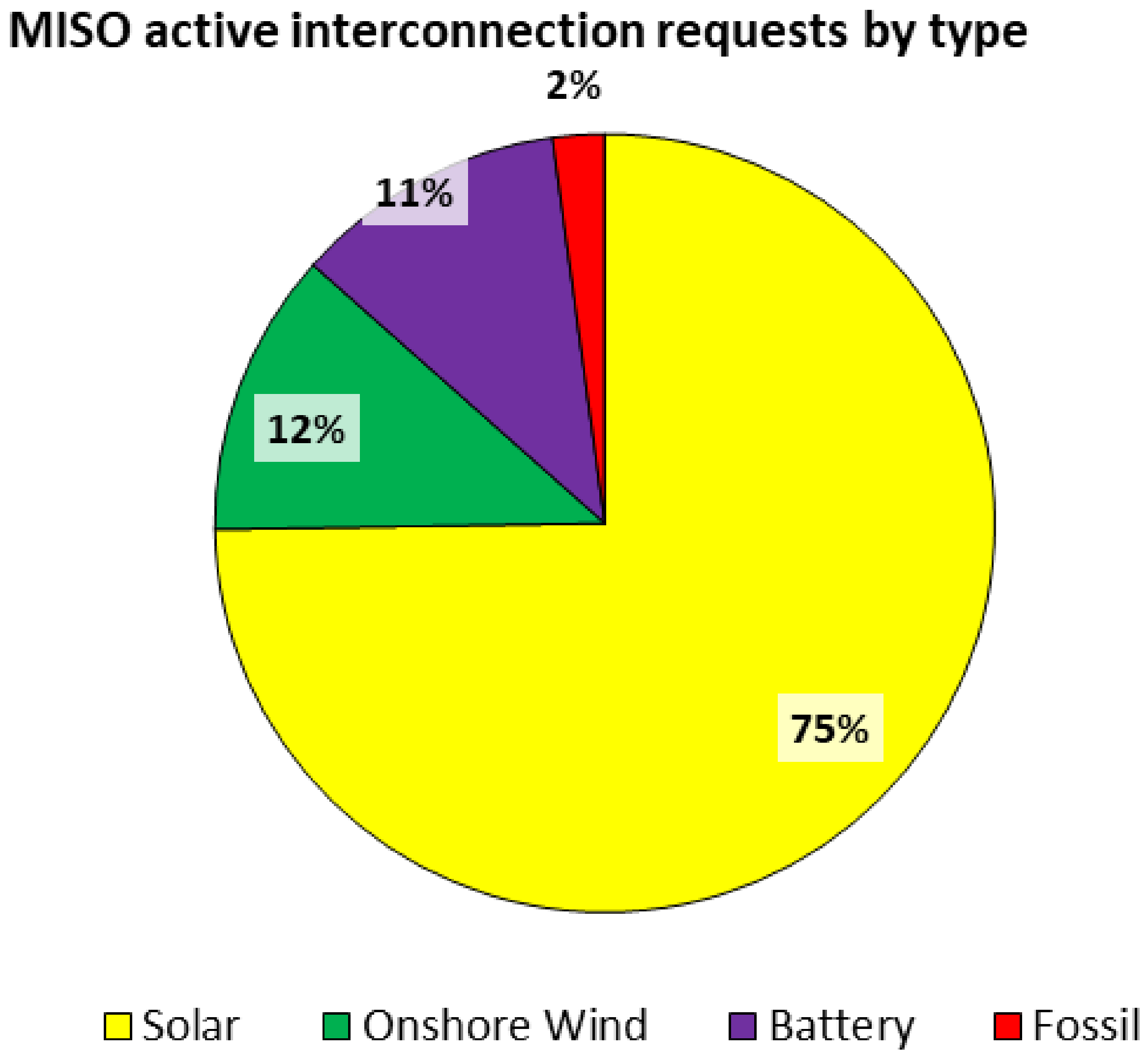


Source: Energy Ventures Analysis

Similar Story in MISO

- New generation scheduled for MISO is 88 percent wind and solar(100,000 MW)
- 11 percent battery (13,000 MW)
- 2 percent fossil (2,500 MW)

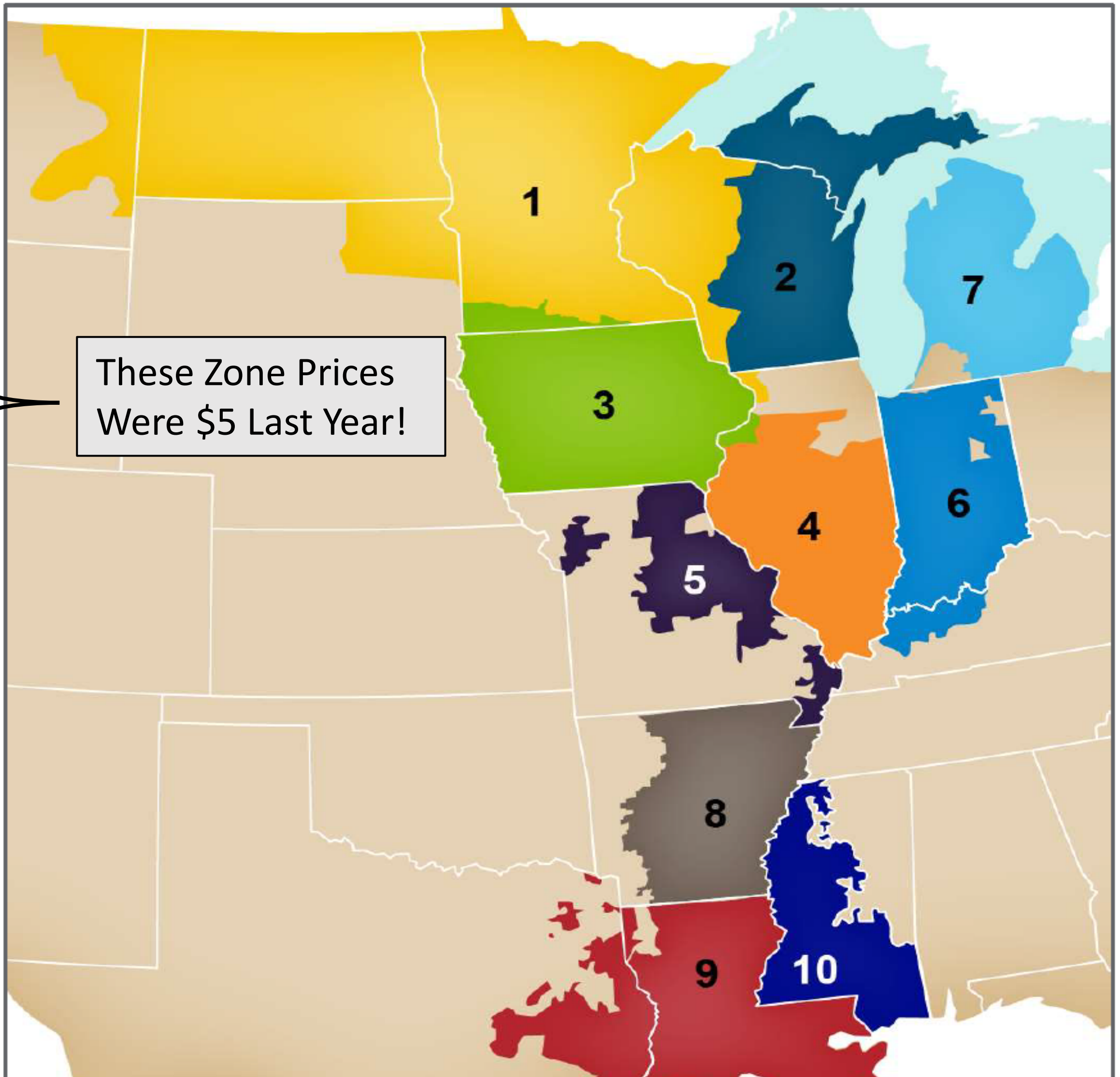
Source is: MISO Interconnection Queue
https://www.misoenergy.org/planning/generator-interconnection/GI_Queue/



Clearing prices from MISO's 2022-2023 PRA reflect capacity shortfalls in four zones, exposing nearly 8 GW in MISO North/Central to the Cost of New Entry

Zone	Local Balancing Authorities	Price $/MW-Day
1	DPC, GRE, MDU, MP, NSP, OTP, SMP	$236.66
2	ALTE, MGE, UPPC, WEC, WPS, MIUP	$236.66
3	ALTW, MEC, MPW	$236.66
4	AMIL, CWLP, SIPC, GLH	$236.66
5	AMMO, CWLD	$236.66
6	BREC, CIN, HE, IPL, NIPS, SIGE	$236.66
7	CONS, DECO	$236.66
8	EAI	$2.88
9	CLEC, EES, LAFA, LAGN, LEPA	$2.88
10	EMBA, SME	$2.88
ERZ	KCPL, OPPD, WAUE (SPP), PJM, OVEC, LGEE, AECI, SPA, TVA	$133.70-236.66

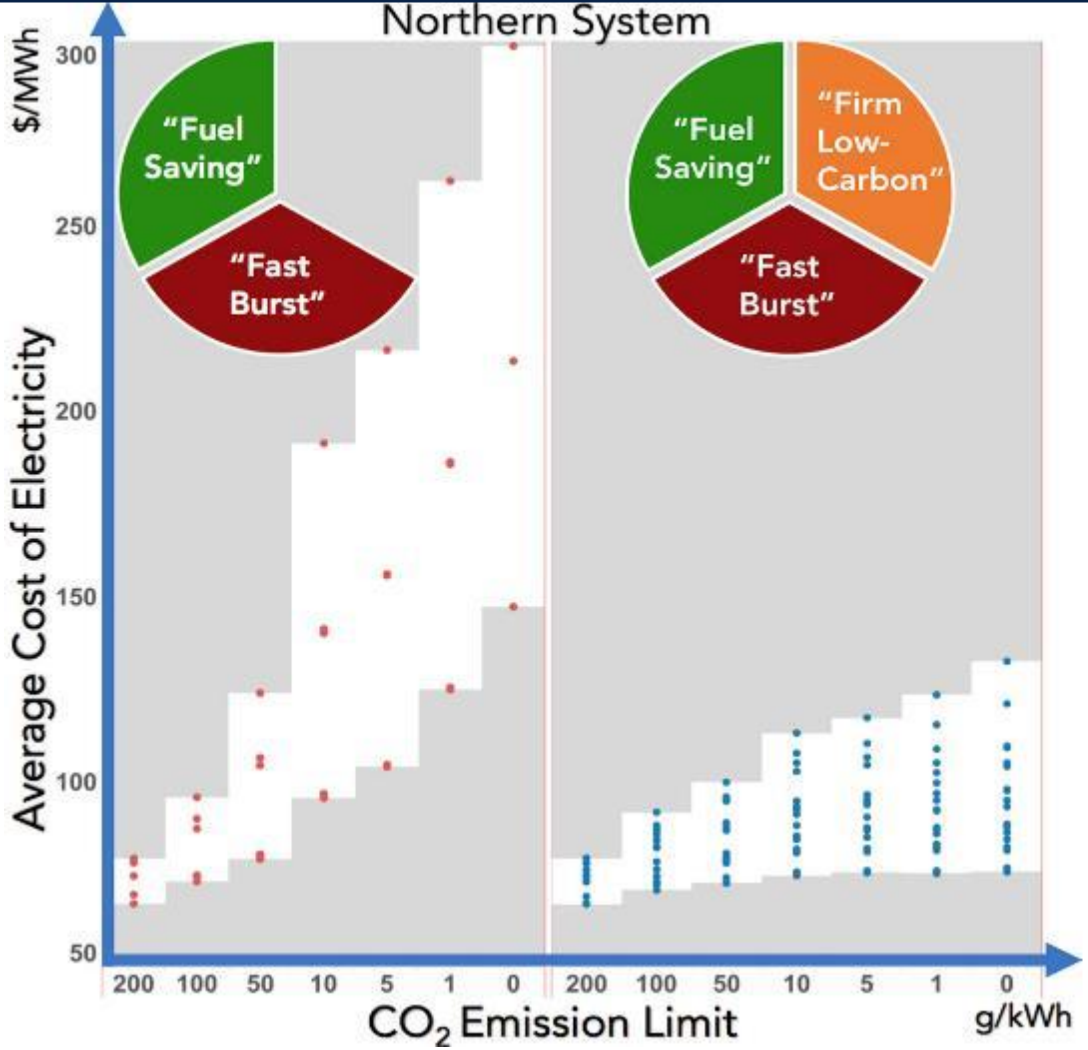
These Zone Prices Were $5 Last Year!



MIT Study Shows Exponential Cost-Escalation if We Attempt Carbon Mitigation Without Large-Scale Carbon Capture on Fossil Fleet

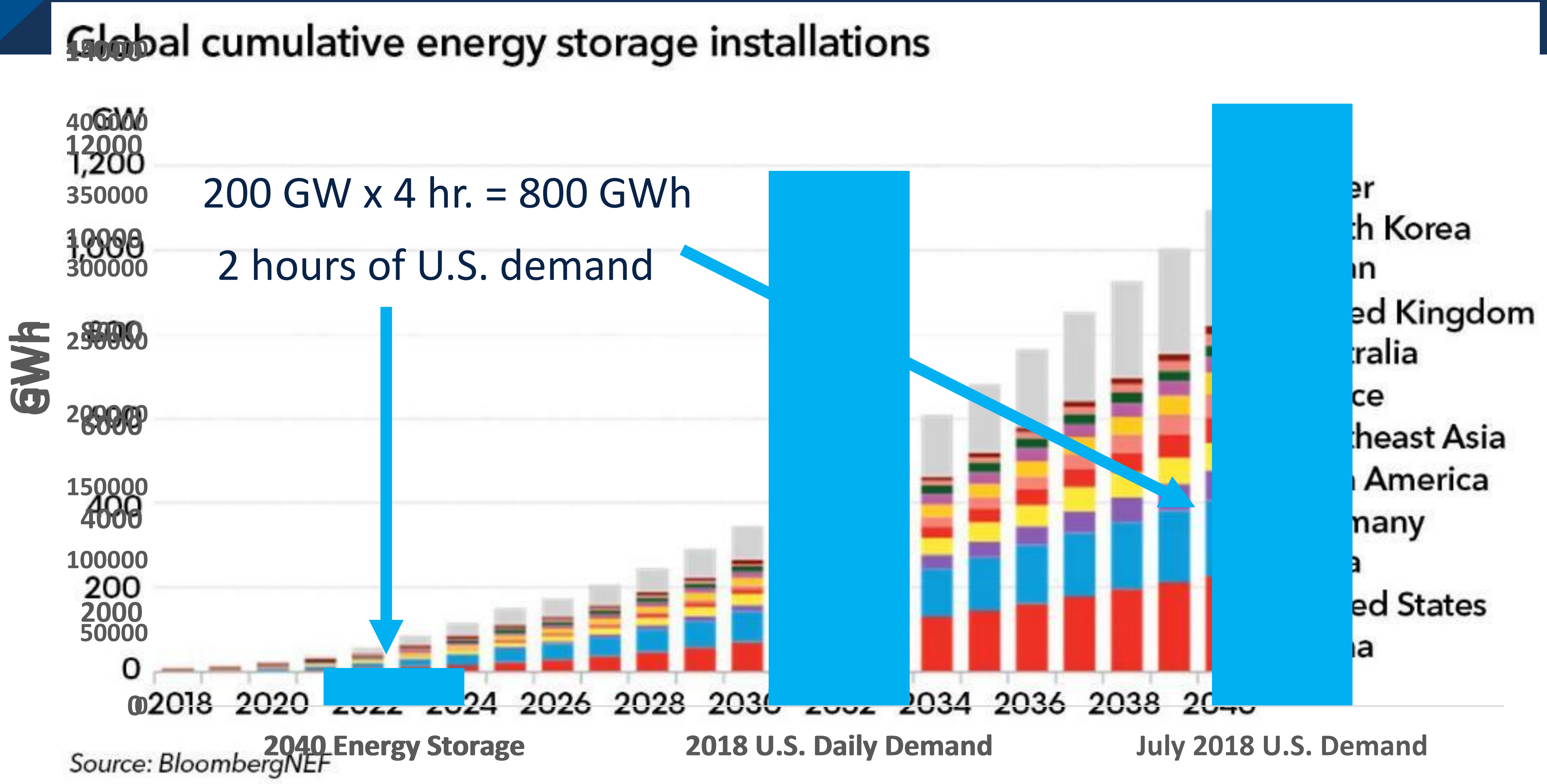
Without these [firm] resources, electricity costs rise rapidly as CO2 limits approach zero. Batteries and demand flexibility do not substitute for firm resources.

– Sepulveda et al.



Source: Sepulveda et al, *Joule* 2(11), 2018, 2403-2420
https://doi.org/10.1016/j.joule.2018.08.006

Battery Technology Is Not the Problem, Scale Is



Note: Demand forecasts are from Bloomberg New Energy Finance.

Not All Carbon Reductions are Created Equal

- Because carbon captured from a dispatchable fossil fuel plant innovates CCUS & provides 24-7 low-carbon power, it is a critical reliability component of any decarbonization strategy.
- If we are serious about mitigating anthropogenic CO2 & ensuring market transparency, regulatory approvals/planning must ensure that ratepayers know the true and total cost of their low-carbon options so they can make an INFORMED decision about whether existing coal and gas plants should be retired BEFORE THEY ARE GONE FOREVER.

PART IV

Why CCUS is Internationally *Essential*

Not All Carbon Reductions are Created Equal

- With the premature retirement of every coal or gas plant, we lose a vital opportunity to commercialize and drive down the cost of the one technology that is an essential part of any realistic and cost-effective decarbonization effort.

- According to the IPCC's latest report, carbon capture and sequestration are essential to every decarbonization scenario that does not significantly deprive the developing world the opportunity to energize and improve lives.

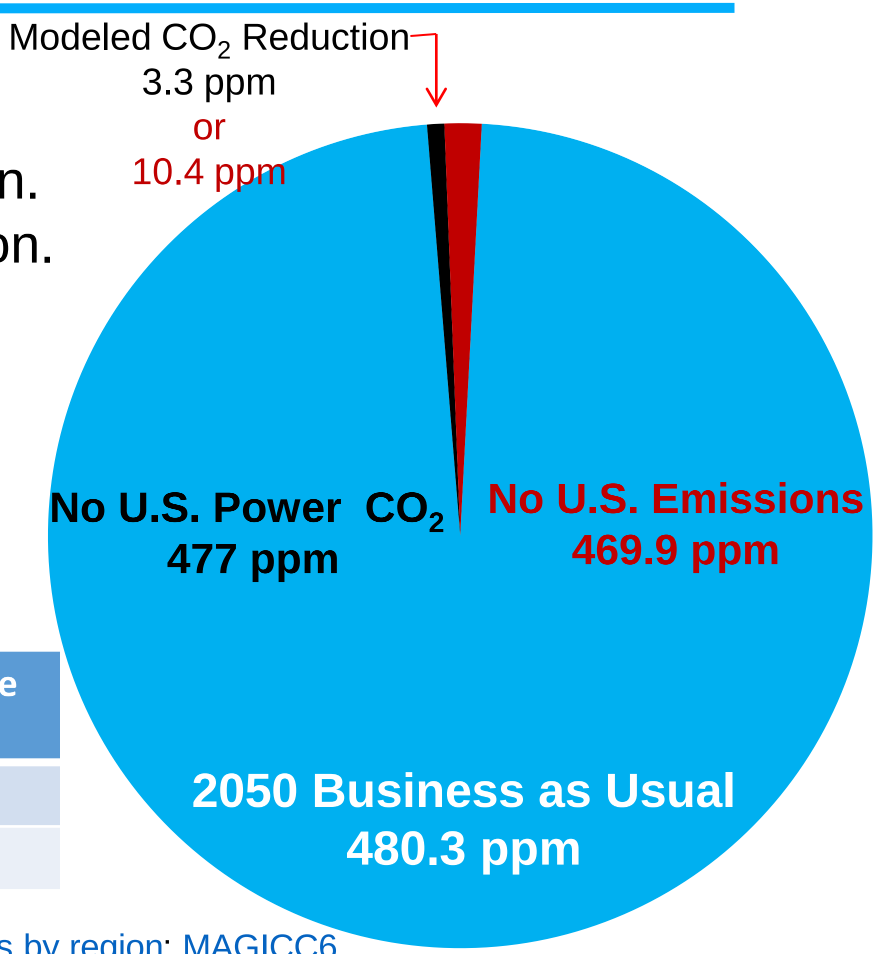
DOMESTIC CARBON MITIGATION WON'T MOVE THE NEEDLE – GLOBAL DEPLOYMENT OF U.S. TECHNOLOGY WILL

<u>2050 IMPACT OF DECARBONIZING ELECTRICITY</u>:

- NO COAL FLEET = 2.06 ppm (0.4%) reduction in CO_2 concentration.
- NO FOSSIL FLEET = 3.3 ppm (0.7%) reduction in CO_2 concentration.
- Modeled global temperature reduced by a mere 0.016°C.

<u>2050 IMPACT OF DECARBONIZING ENTIRE U.S.:</u>

- 10.4 ppm (2.2%) reduction in CO_2 concentration.
- Modeled global temperature reduced by 0.053°C.

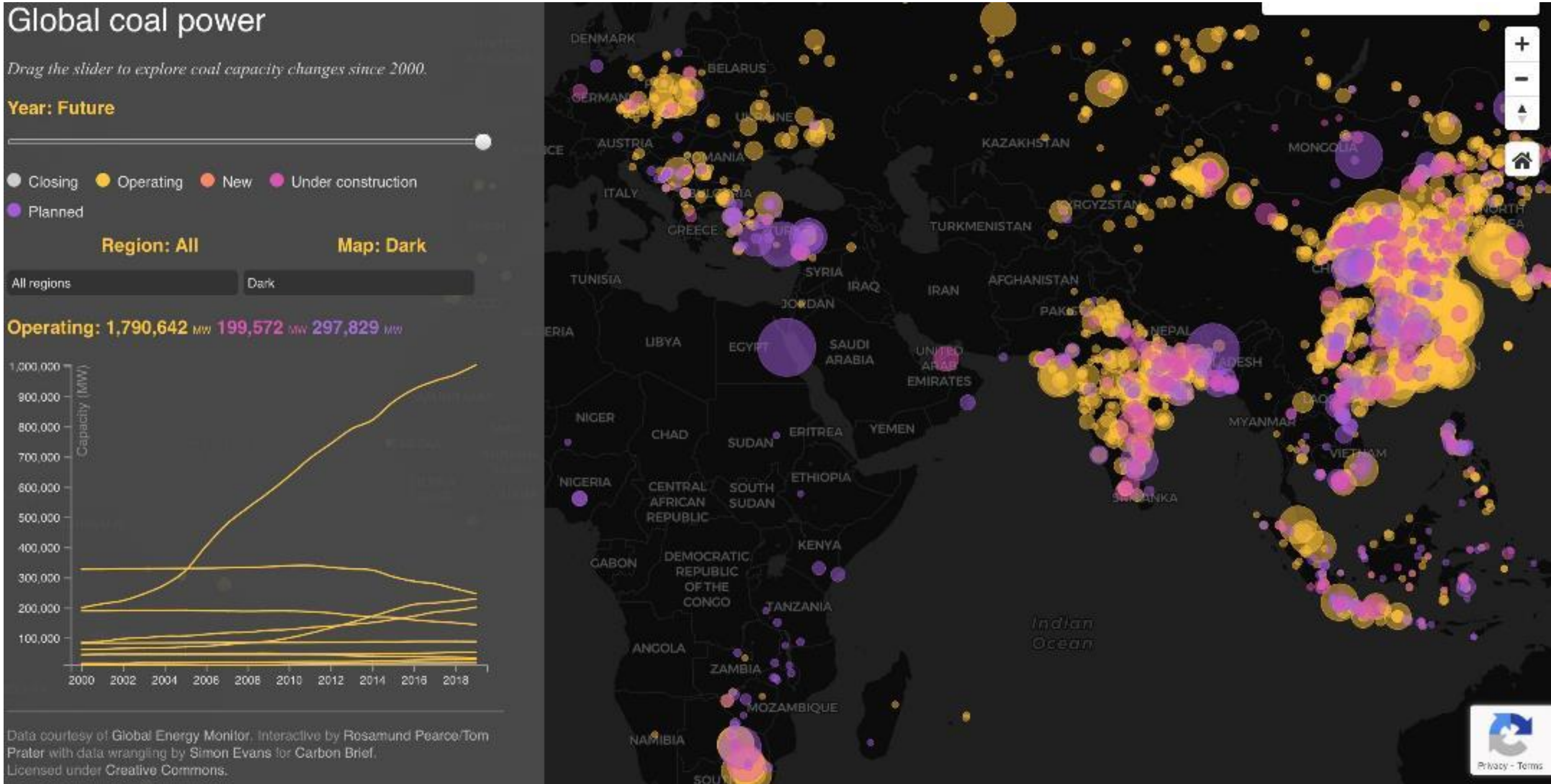


CO2 Emissions	2010	2020	2030	2040	2050	% Change
World	30,834	34,972	36,398	39,317	42,771	+38.7%
U.S.	5,571	5,260	4,839	4,867	5,071	-8.9%

Sources: Energy Information Administration, International Energy Outlook 2017, World carbon dioxide emissions by region; MAGICC6 Model; Intergovernmental Panel on Climate Change Fifth Assessment Report Working Group I, Summary for Policymakers; National Oceanic and Atmospheric Administration Global Land and Temperature Anomalies.

Good Internet Tool to Show How the World Continues to Expand Coal Use and, thus, the Need for CCUS Retrofits

LINK:
[Mapped: The world's coal power plants in 2020 (carbonbrief.org)]



Shanghai – 1990


30 YEARS LATER
That is 12 NYCs EACH YEAR!
In all human history we have reached 3.5 billion of urban settlers, and in the next 30 years we are going to have 3 billion more…Imagine the changing rate — what we have done in all human history, we nearly will do in the next 30 to 40 years.
Joan Clos, Director, UN Settlement Program

The Last Time We Added Three Billion People to Cities

(1950-2010)

- Oil demand grew from 10 million b/d to 88 million b/d
- Natural gas use rose from 8 Tcf to 113 Tcf
- Coal demand increased from 2 billion to 7.1 billion tons
- Steel consumption increased from 200 to 1,400 million tons

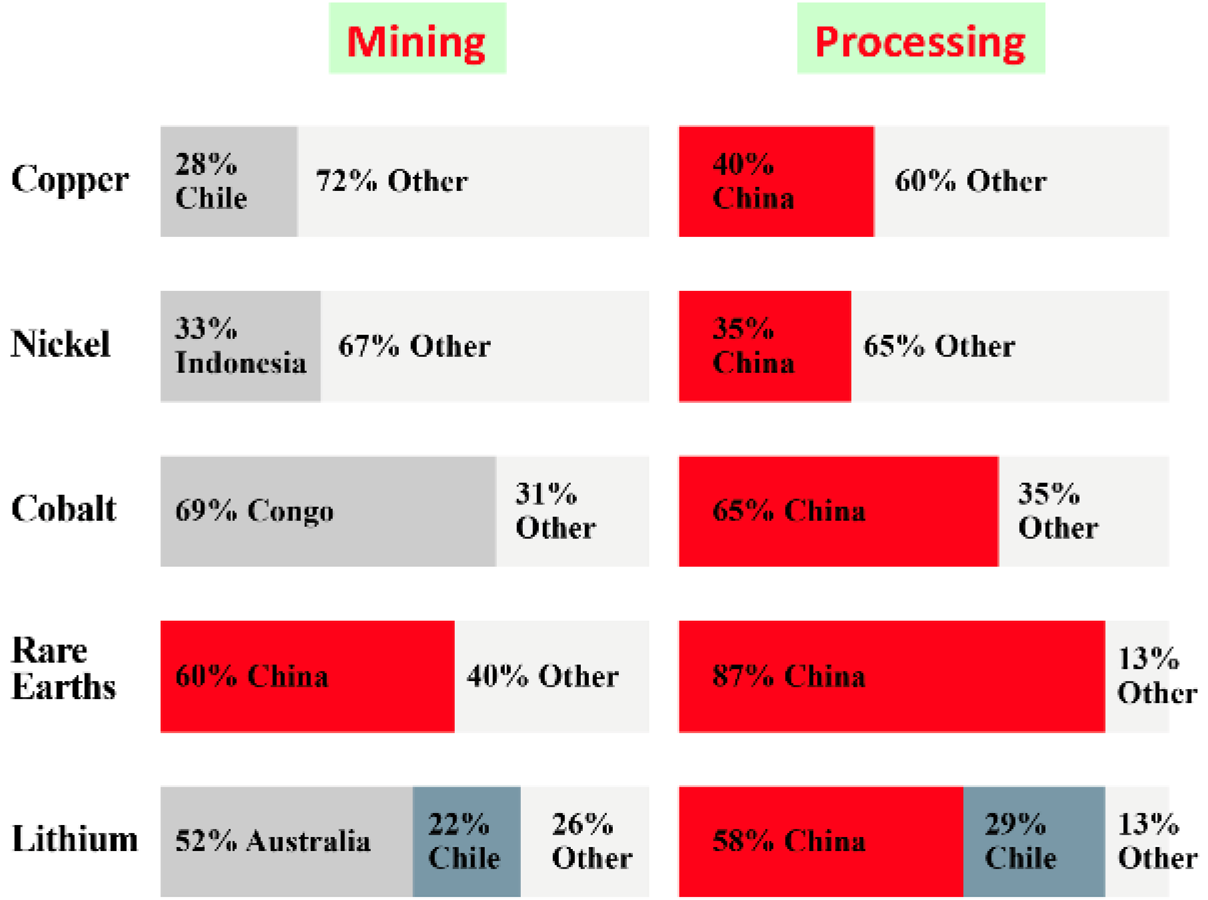
WHO WILL SUPPLY THIS OIL, GAS, COAL, & STEEL?

& this time there will also be a massive expansion in batteries & critirical minerals, all of which are dominated by the Chinese.

Sources: EIA; IEA; Worldwatch Institute; World Steel Association

Will We Hand the World's Geopolitical Security to China?

Energy Minerals: New Supplier Dependencies



QUESTIONS?

UPCOMING NARUC EVENTS

- **NARUC Innovation Webinar Series:** University-Sponsored Energy Innovation Centers, May 1y
- **DOE-NARUC Coal Modernization and Carbon Management Webinars:** continuing throughout spring and summer 2022
- **DOE-NARUC Coal Modernization and Carbon Management Energy Transition Workshop:** Wednesday, June 22, 1 – 4 pm CT in Chicago, IL at the Mid-America Regulatory Conference annual meeting.
- **NARUC Summer Policy Summit:** July 17 – 20 in San Diego, CA
  - Subcommittee on Clean Coal and Carbon Management panel unpacking *West Virginia v. EPA* decision expected from the Supreme Court this spring
- **DOE-NARUC Coal Modernization and Carbon Management site visit to NETL:** summer 2022. Travel reimbursement available for commissioners.

THANK YOU

Commissioner Brent Bailey, Mississippi

NARUC staff supporting the Partnership:

- Jasmine McAdams, jmcadams@naruc.org
- Kiera Zitelman, kzitelman@naruc.org