LSU | Center for Energy Studies

Louisiana and the energy transition: reconciling industrial decarbonization, capital formation, and growth.

Louisiana Air and Waste Management 2022 Annual Meeting (Louisiana Section). October 26, 2022. L'Auberge Casino & Hotel. Baton Rouge, LA

David E. Dismukes, Ph.D.
Center for Energy Studies
Louisiana State University

Introduction: Why industrial decarbonization?

Increasing emphasis on net zero GHG emissions

Over the past several years, several states have announced a goal of **reducing greenhouse gas (“GHG”) emissions to “net zero” by a date certain**.

These state level initiatives also align with those of the **current Biden administration**.

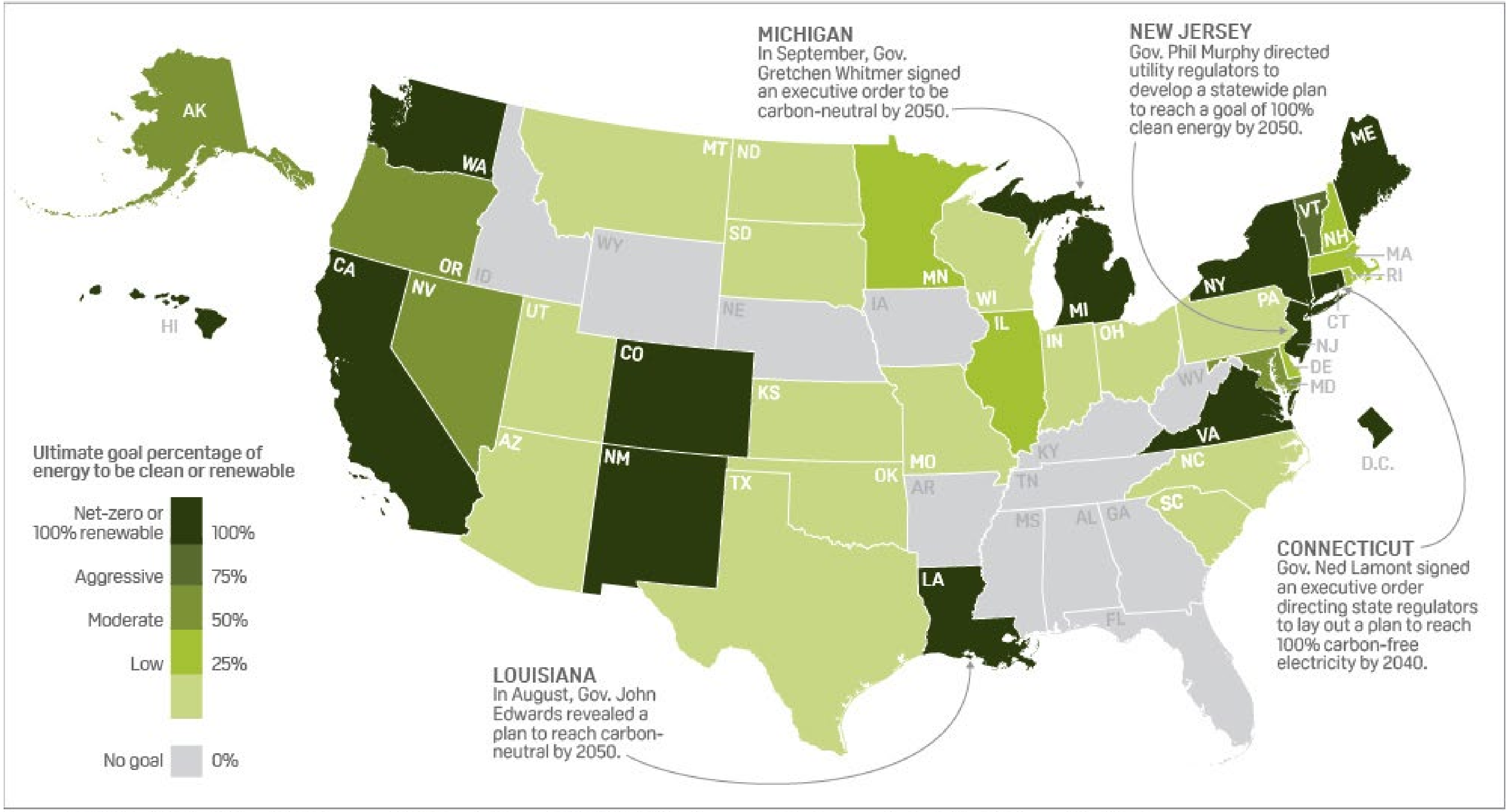
This can be a very ambitious goals for some states, particularly those that have large industrial sectors, particularly those that include chemical manufacturing.

The challenges can be difficult for industrial states since: (a) they have **high relative GHG emissions levels** and (b) the **availability of substitutes and alternatives to traditional fossil fuels can often be limited.**

State climate goals and initiatives

GROWING NUMBER OF US STATES RACE TO NET-ZERO EMISSIONS, 100% RENEWABLE POWER

There are now 12 states, plus Washington DC, with 100% renewable generation or net-zero carbon emission goals or aspirations in the coming decades. The latest to join the energy transition to clean power are Louisiana, Michigan, Connecticut and New Jersey where governors announced plans or signed executive orders. They follow Colorado, which made the move in late 2019, and Virginia, which announced the change earlier this year. While many Southeast states do not have official goals, many utilities have set their own net-zero emission targets.



Source: S&P Global Platts, National Conference of State Legislatures, ERCOT, Cal-ISO, other associated sources for individual states and territories

Source: S&P Global.

Louisiana importance

Governor-appointed advisory board **unanimously approved the plan** (Feb 1).

Defines a plan to reduce Louisiana's GHG emission to 26-28% of 2005 levels by 2025; 40-50% of 2005 levels by 2030; and "net zero" by 2050.

Plan calls for **industry to reduce GHG emissions** by using renewables, efficiency, and fuel switching to resources like hydrogen.

LOUISIANA CLIMATE ACTION PLAN

CLIMATE INITIATIVES TASK FORCE
RECOMMENDATIONS TO THE GOVERNOR
February 2022

By 2025	By 2030	By 2050
26 - 28% Of 2005 levels	40 - 50% Of 2005 levels	Net Zero

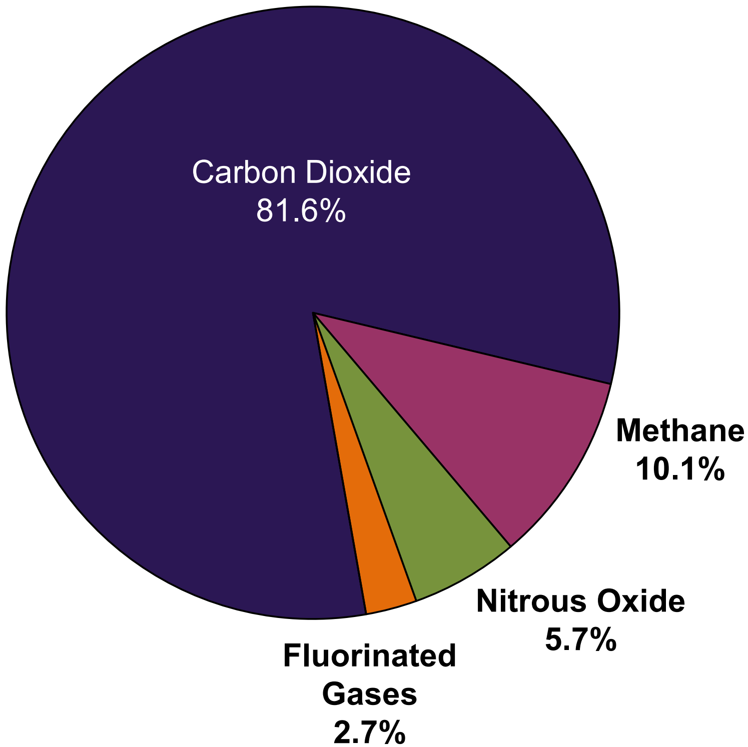
Source: Louisiana Climate Action Plan, February 2022.

Greenhouse gas ("GHG") emissions

Carbon dioxide (CO_2) enters the atmosphere **through the burning of fossil fuels** (oil, natural gas, and coal), solid waste, trees and wood products, and also as a result of other chemical reactions (e.g., manufacture of cement).

Nitrous oxide (N_2O) is emitted during agricultural and industrial activities, **as** well as during **combustion of fossil fuels and solid waste.**

Total U.S. Greenhouse Gas Emissions, 2016 (CO_2 eq.)
(naturally-occurring and anthropogenic sources)

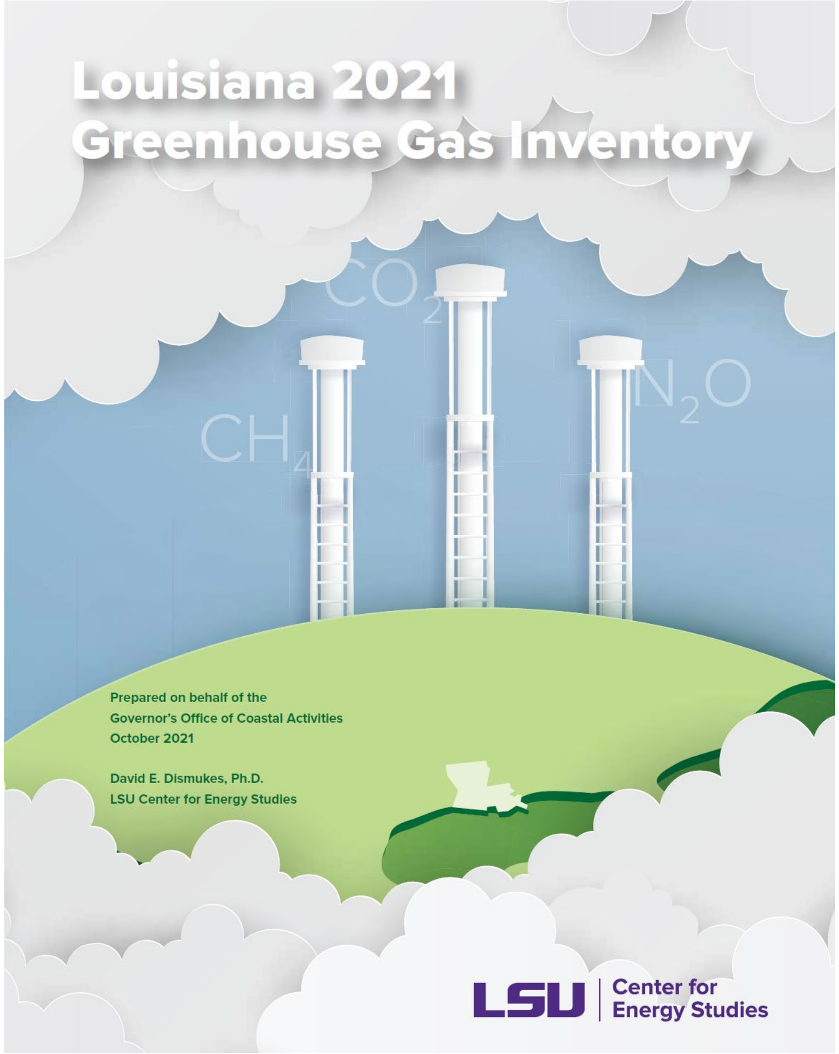


Methane (CH_4) is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills.

Source: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2009. April 2011.*

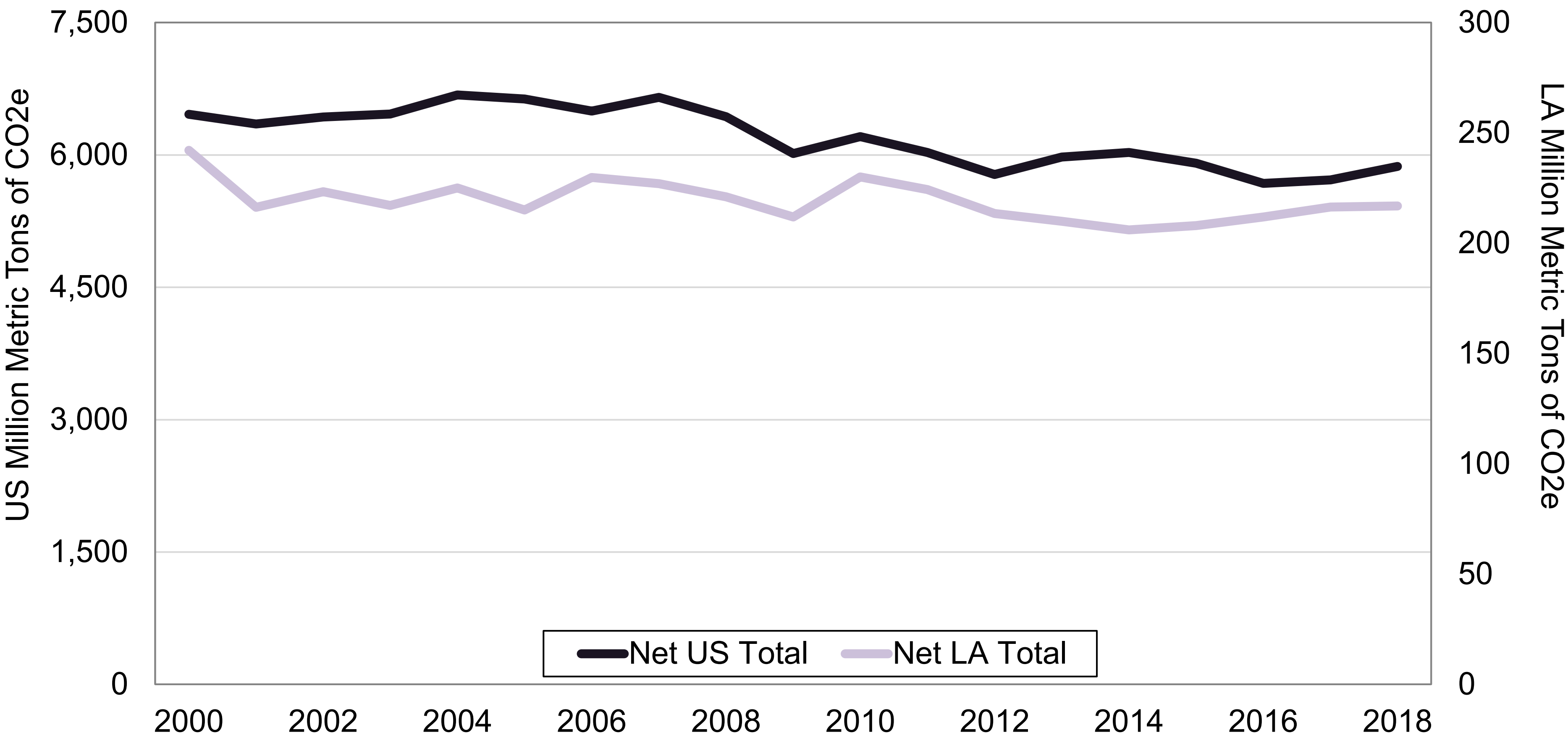
Louisiana GHG emissions inventory

- In January 2021, the **Governor's Office of Coastal Activities** ("OCA") contracted with the LSU **Center for Energy Studies** ("CES") to update prior statewide GHG emission estimates.
- CES' prior work includes **publishing estimates of the state's greenhouse gas ("GHG") emissions in 2000 and 2010**.
- Study goal: provide the state with an updated GHG emissions inventory that **could be used as a policy making tool by the Governor's Clean Climate Initiatives Task Force**.
- **Scholarly and subject-matter input, guidance, and peer review has been provided by the Scientific Advisory Group ("SAG")**.



Total US vs LA emissions

Total GHG emissions for the **U.S. and LA have trended down since 2000**. LA emissions are down relative to 2000, but flat since 2001.

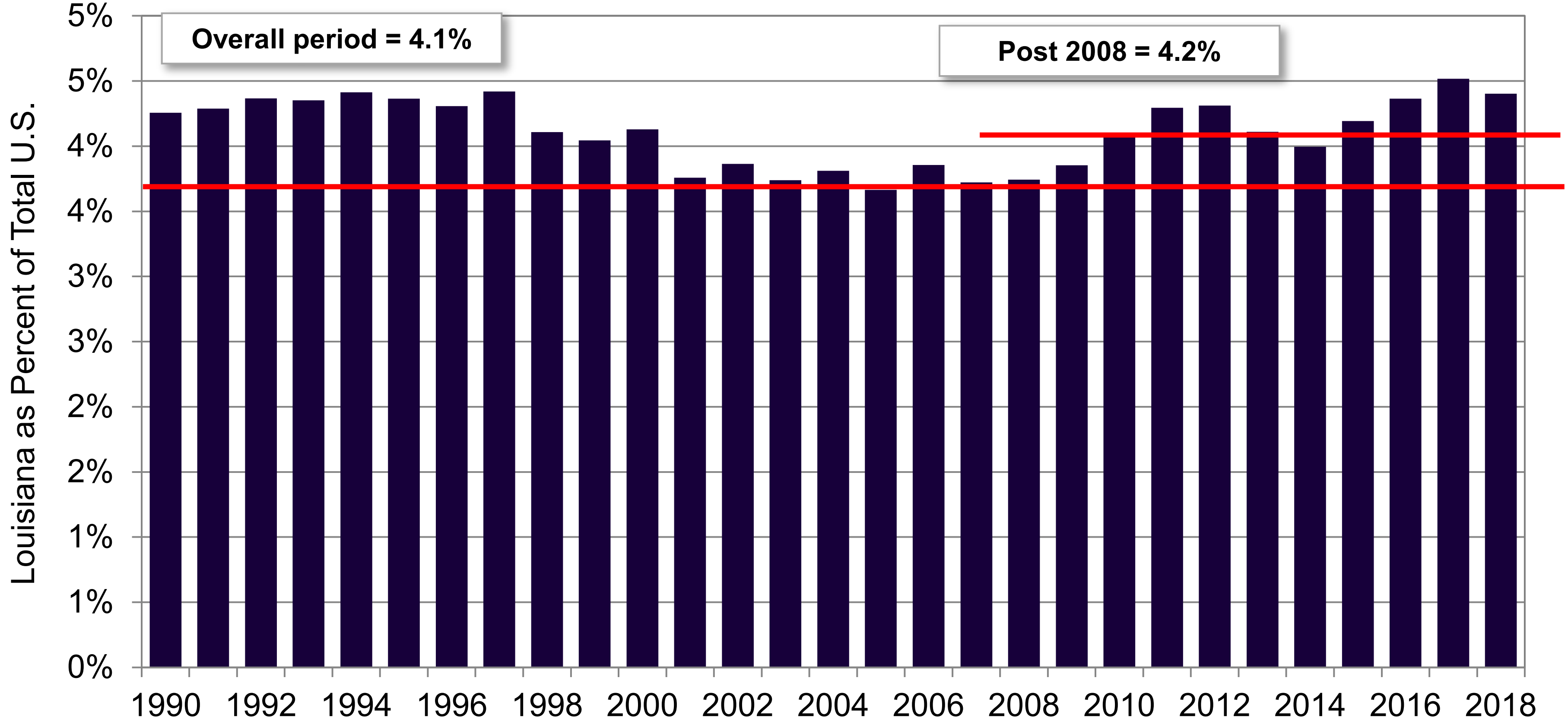


Note: CO_2 emissions are net of sinks.

Source: U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018; and State CO_2 Emissions from Fossil Fuel Combustion.

Louisiana share of total U.S. CO_2 emissions

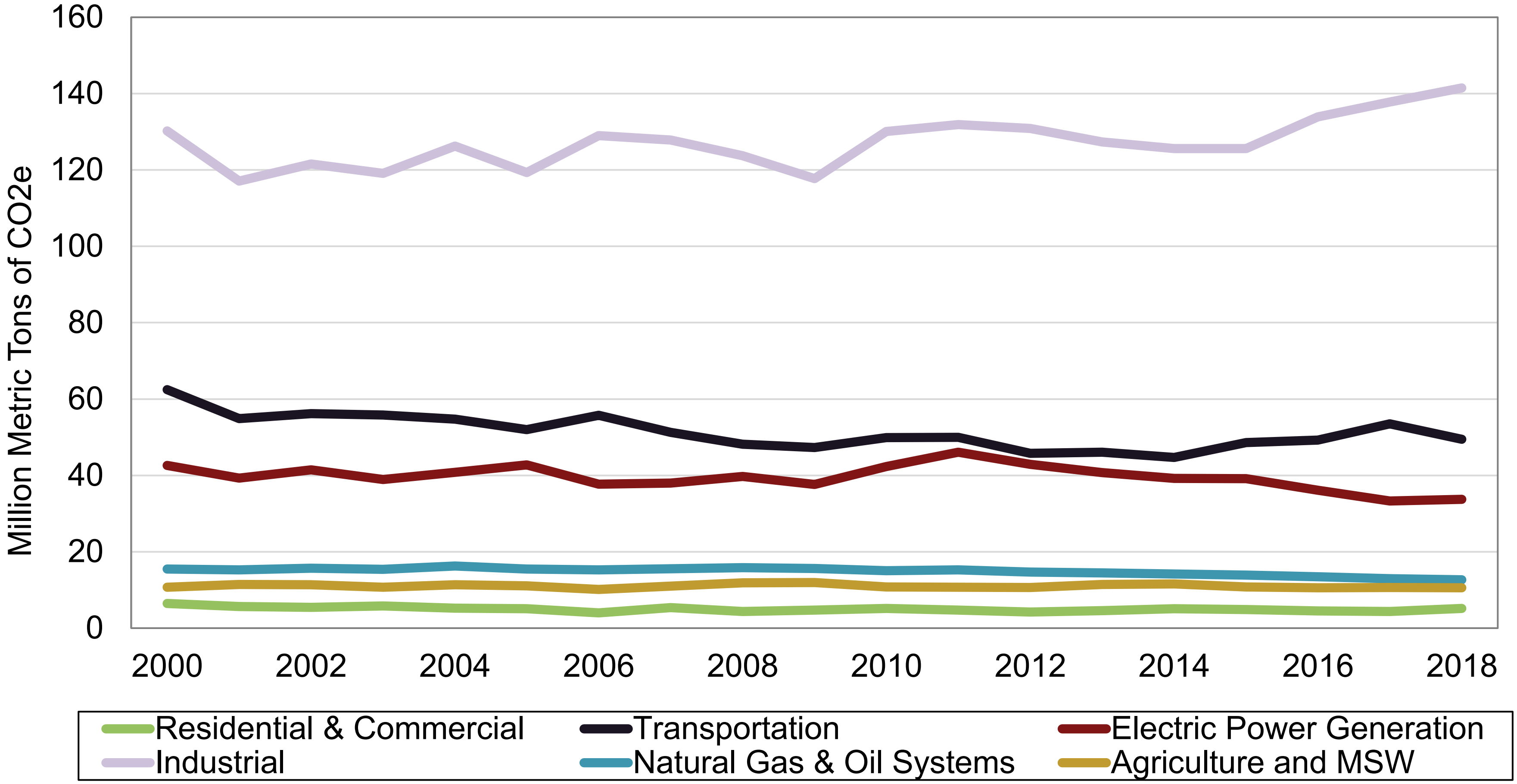
Louisiana's share of total U.S. GHG emissions has been between three and four percent. Louisiana now accounts **for just over four percent of all U.S. carbon emissions.**



Source: U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018; and State CO_2 Emissions from Fossil Fuel Combustion.

Louisiana CO_2 emissions per sector

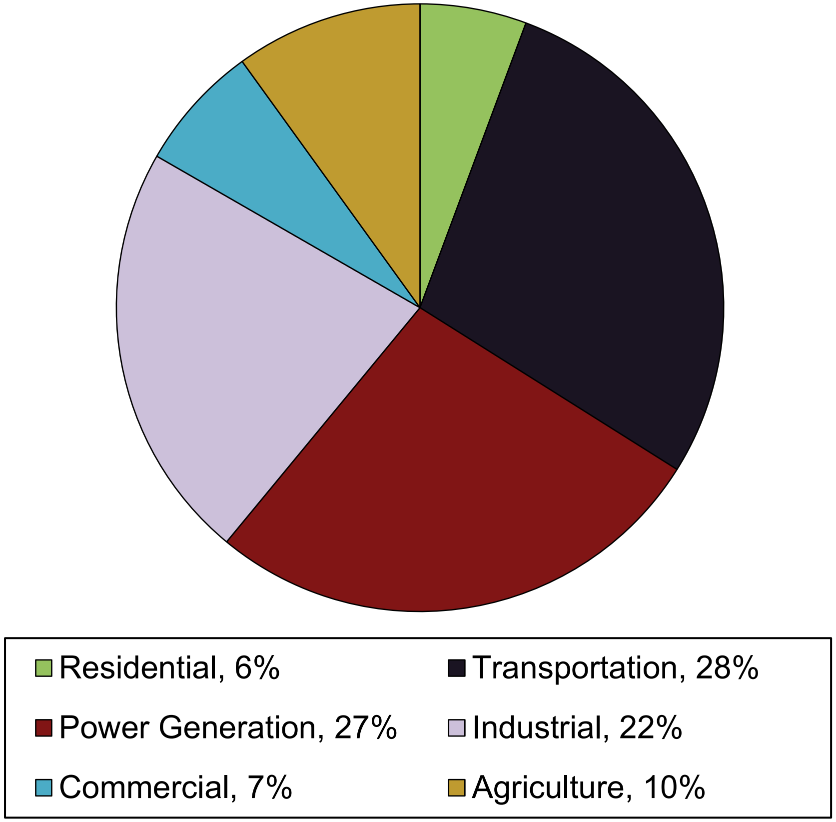
Louisiana GHG emissions are **dominated by the industrial sector**.



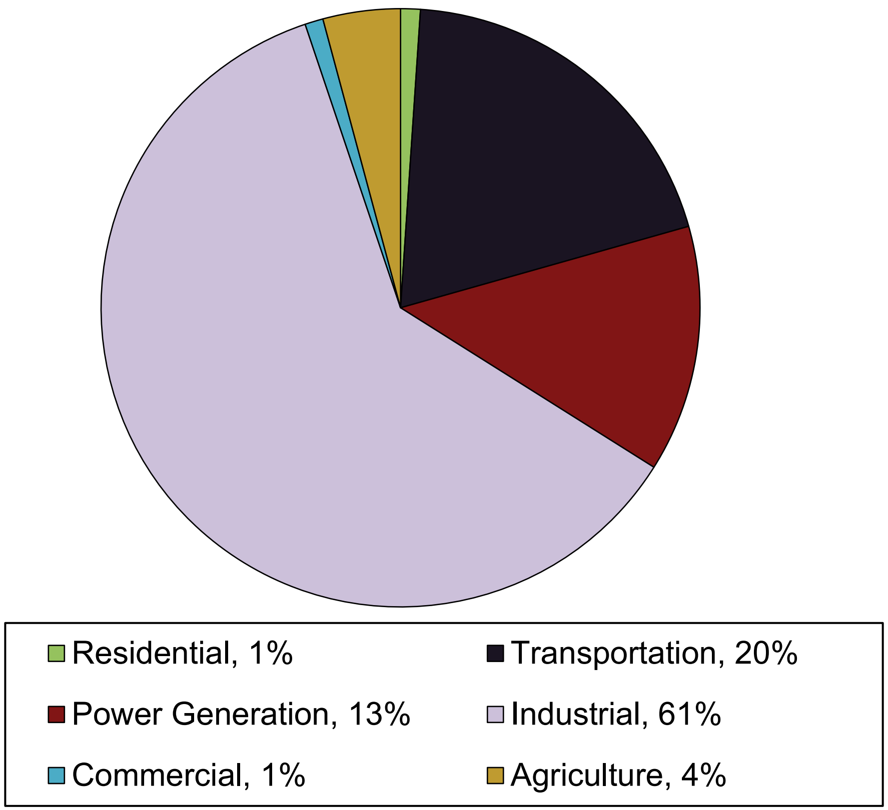
Note: CO_2 emissions are from fossil fuel combustion only.
Source: U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018; and State CO_2 Emissions from Fossil Fuel Combustion.

U.S. and Louisiana CO_2 emissions per sector, 2018

In the U.S., **power generation comprises about 35 percent** of overall national emissions.



In Louisiana, **power generation comprises about 17 percent of overall state emissions**. Louisiana's primary source of CO_2 emissions comes from **industrial sources**.



Note: CO2 emissions are from fossil fuel combustion only, adjusted for feedstock use.
Source: U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018; and State CO_2 Emissions from Fossil Fuel Combustion.

Industrial decarbonization

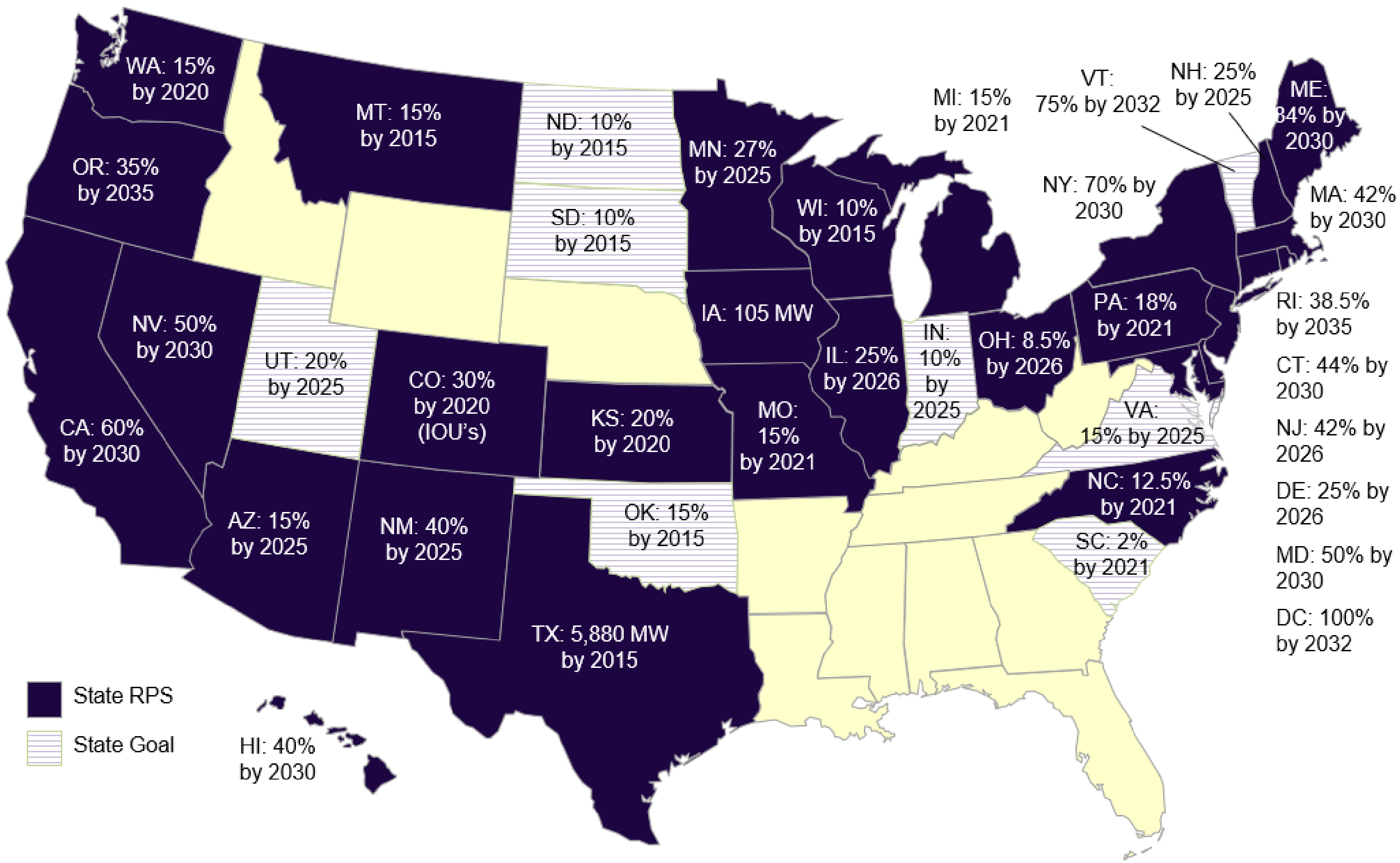
Big picture, this is all about finding **pathways for industrial decarbonization**. There are a **variety of approaches** that include, and are not limited to:

- Renewables
- Carbon capture, utilization and storage (“CCUS”)
- Industrial fuel switching – electrification
- Industrial fuel switching – hydrogen

Renewables

RPS States

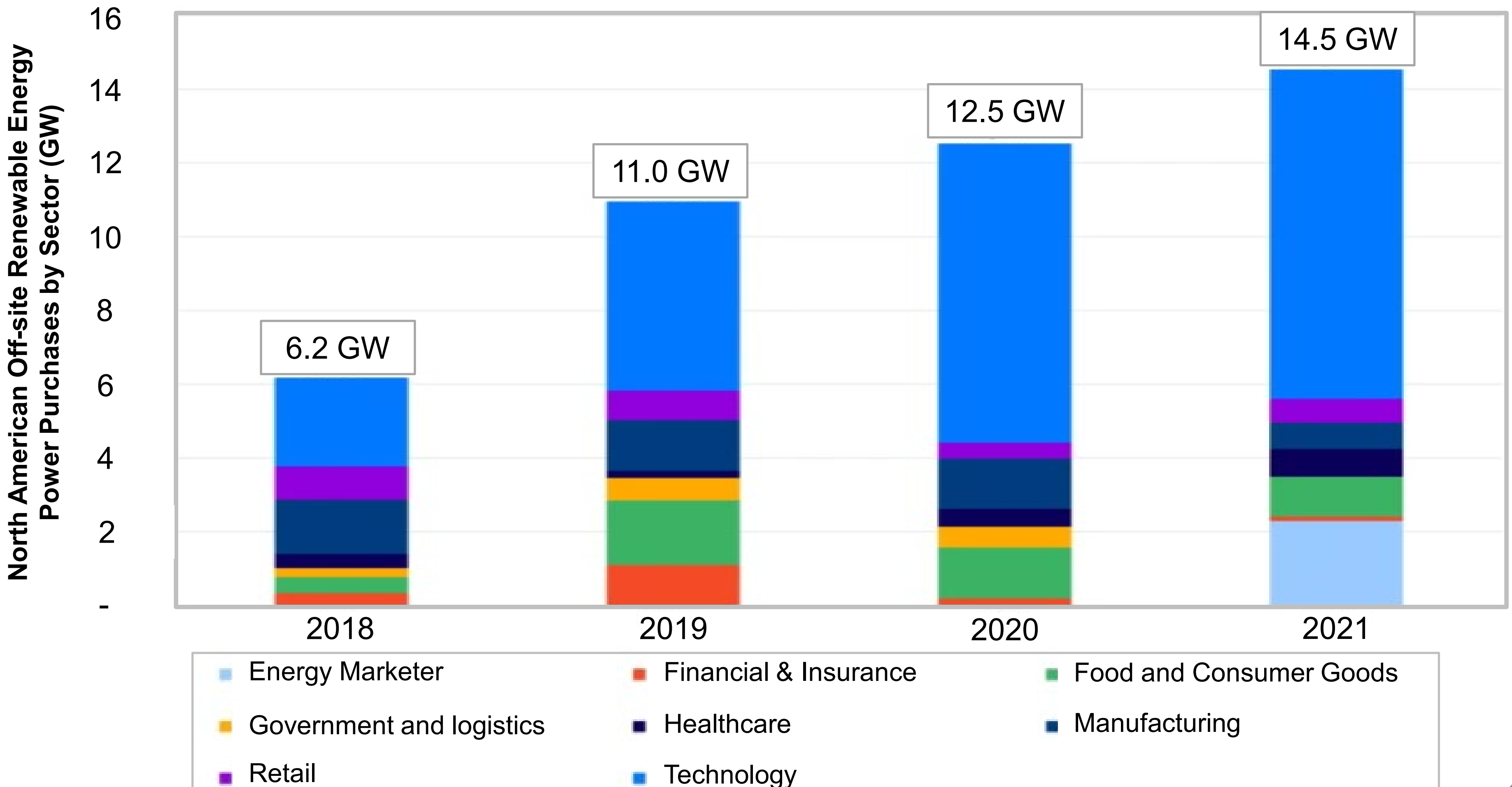
Currently 37 states have RPS policies in place. Together these states account for over **75 percent of electricity sales** in the U.S.



Source: Berkeley Lab, Renewables Portfolio Standards Resources.

Corporate off-site renewable energy purchases (2018-2021)

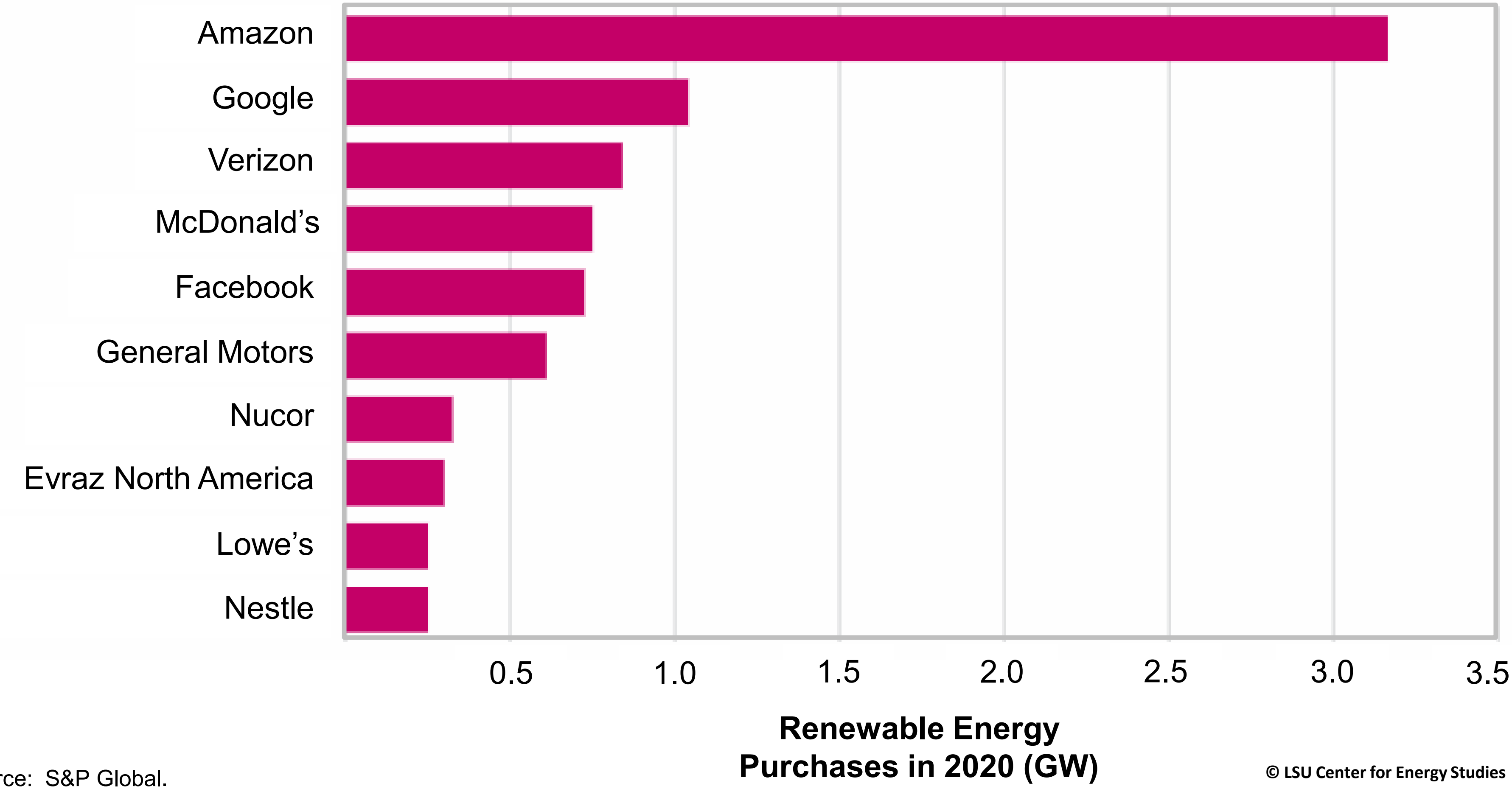
Numerous corporations, across all industries, are now making **large voluntary renewable energy purchases** to meet their internal corporate climate goals.



Source: Edison Energy

Top 10 U.S. Corporate Renewable Energy Buyers (2020)

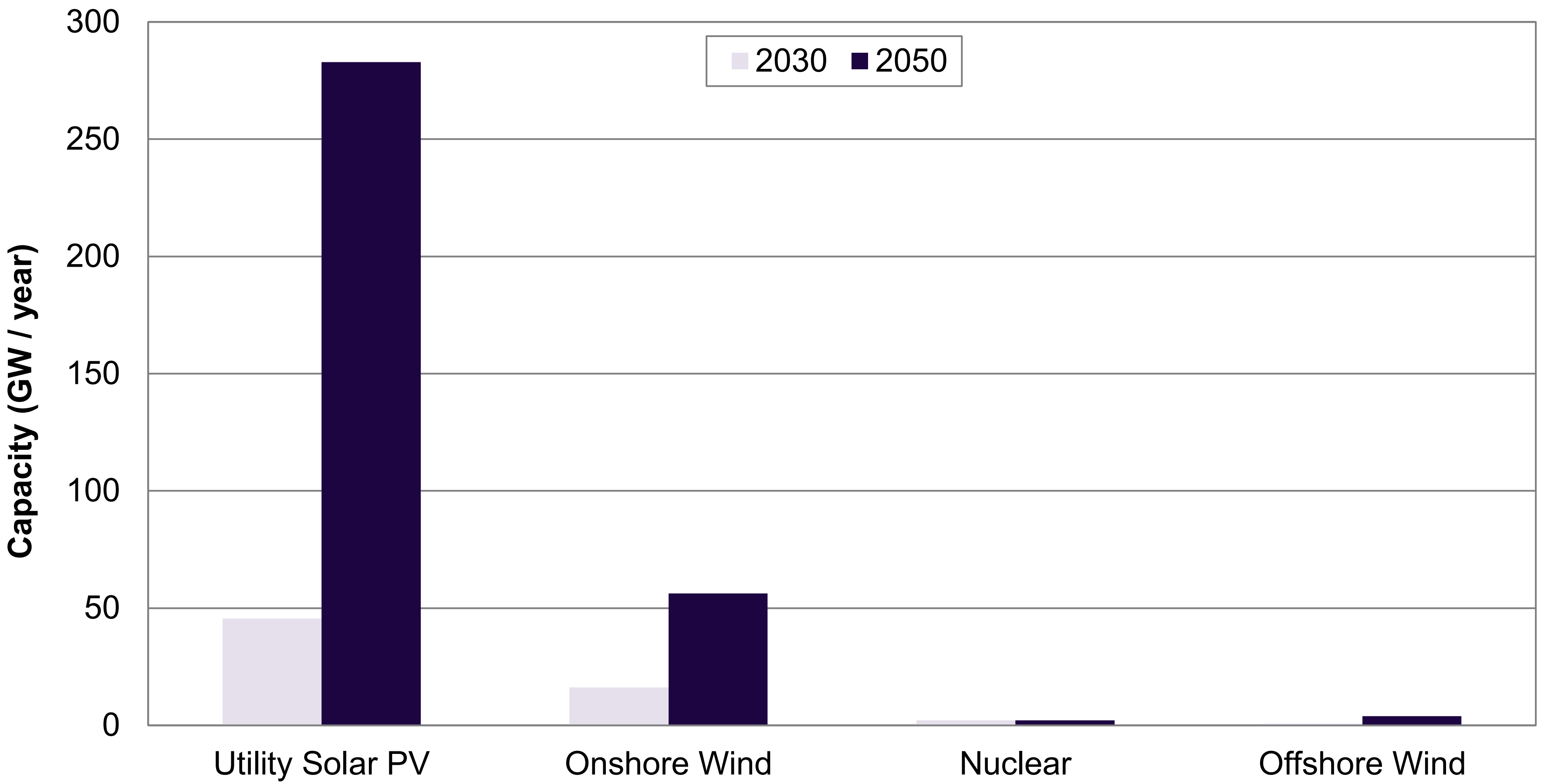
Numerous corporations, across all industries, are now making **large voluntary renewable energy purchases** to meet their internal corporate climate goals.



Source: S&P Global.

Louisiana electric capacity requirements (Governor's Climate Plan)

Over **350 GW of new generating resources** (mostly renewable) will be needed to meet the Governor's electrification goals.

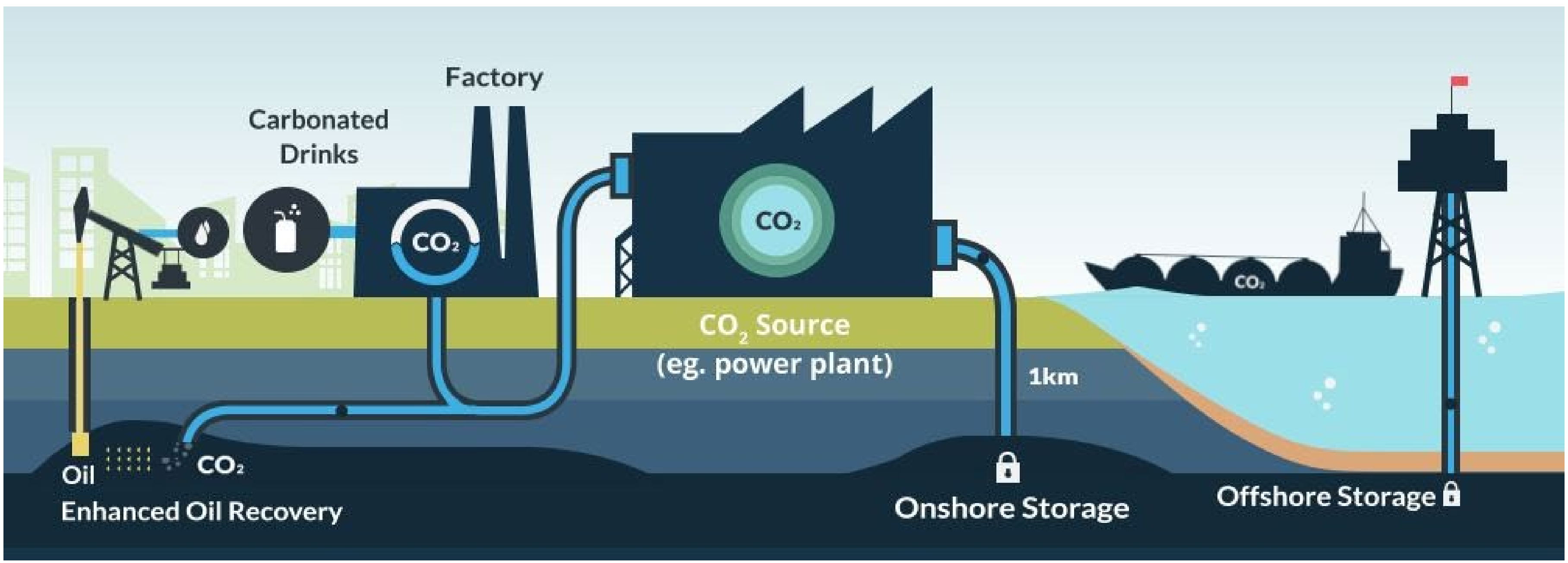


Source: Louisiana Energy Policy Solutions tool.

Carbon capture, utilization and storage

CCUS application (industry/power)

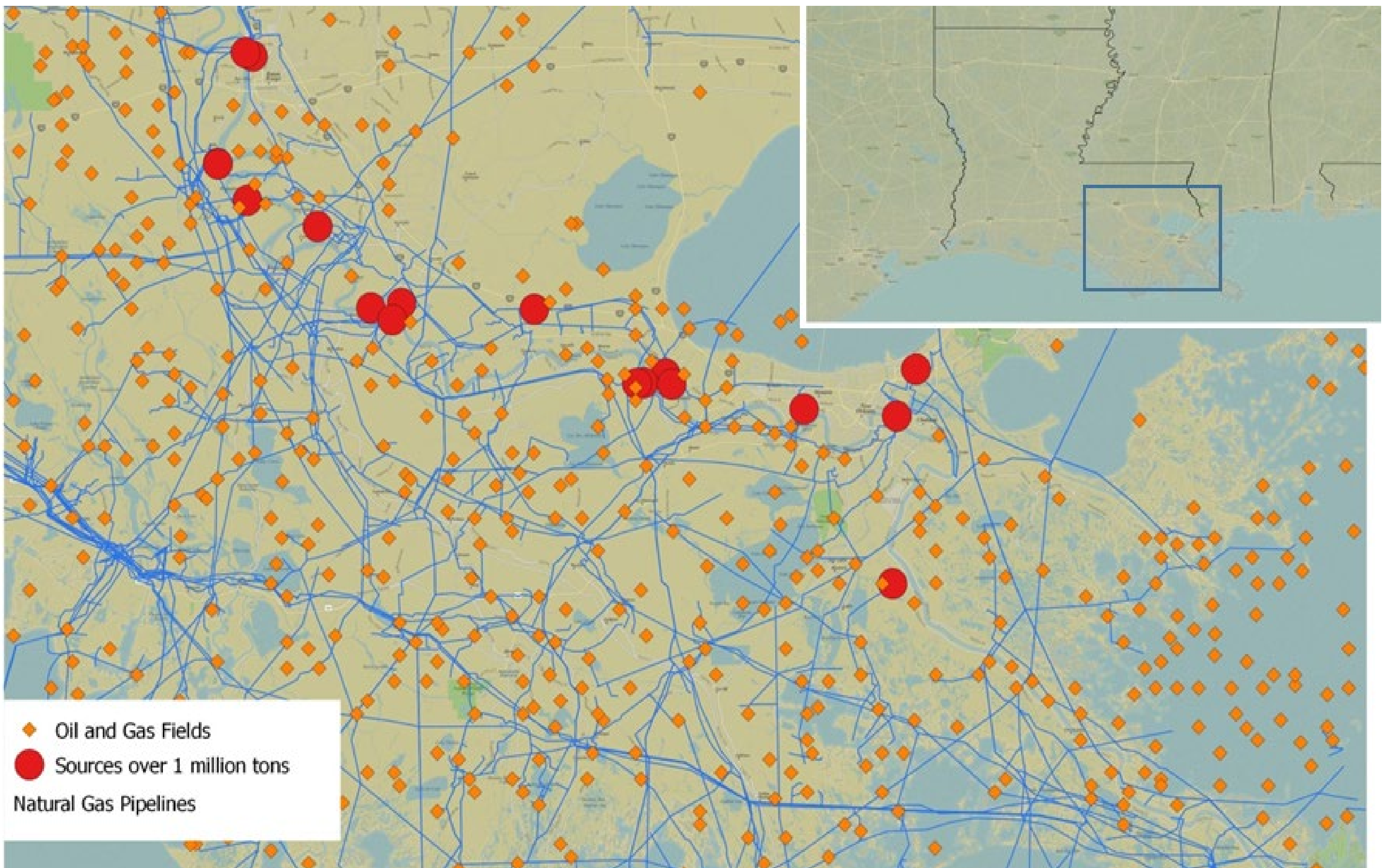
Carbon capture and sequestration ("CCS") involves the **capture of CO_2** from power plants and other large industrial sources, its **transportation to suitable locations**, **and injection into deep underground geological formations** for long-term sequestration.



Source: Global CCS Institute, CCS features at European Sustainable Energy Week, June 15, 2015.

Potential sinks and transportation alternatives

There are **several oil and gas reservoirs**, some of which are depleted, that could be used as sources with **considerable co-located transport infrastructure**.



Source: Author’s construct.

Operational U.S. CCUS projects (2021)

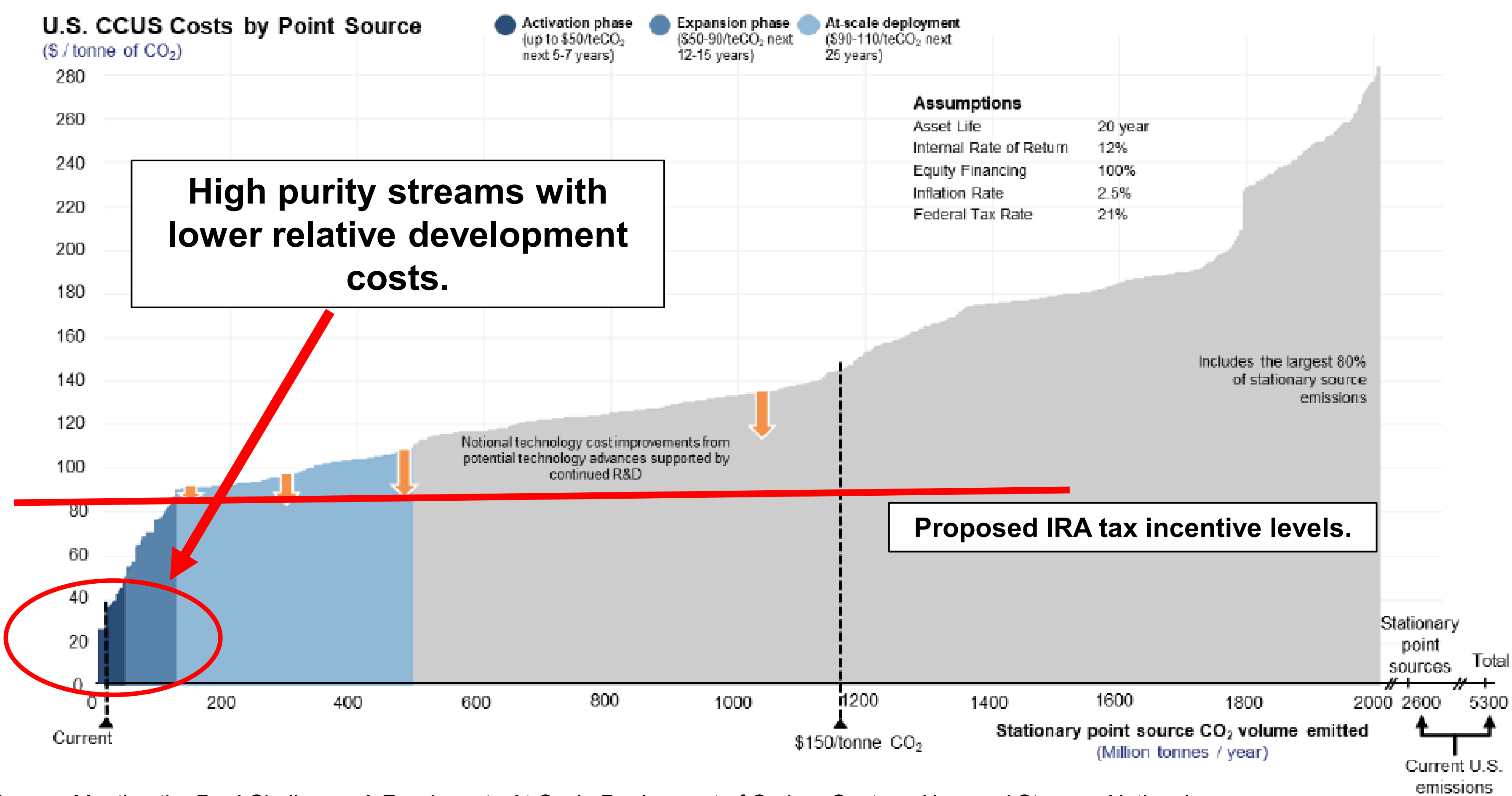
Twelve active projects in the U.S. close to **20 mtpa** in capture capabilities.

Plant Name	Start up Year	State	Capital Operator	Capacity (mtpa)	CO2 Source	CO2 Sink
Terrell Gas Processing	1972	TX	Occidental Petroleum	0.50	Natural gas processing	EOR
Enid Fertilizer	1982	OK	Koch Nitrogen Company	0.20	Fertilizer production	EOR
Shute Creek Gas Processing Plant	1986	WY	ExxonMobil	7.00	Natural gas processing	EOR
Great Plains Synfuels	2000	ND	Dakota Gasification	3.00	Coal gasification	EOR
Core Energy CO_2-EOR	2003	MI	Core Energy	0.35	Natural gas processing	EOR
Arkalon CO_2 Compression Facility	2009	KS	Southwest Regional Partnership	0.29	Ethanol production	EOR
Century Plant	2010	TX	Occidental Petroleum	5.00	Natural gas processing	EOR
Bonanza BioEnergy CCUS EOR	2012	KS	Conestoga Energy Partners	0.10	Ethanol production	EOR
Air Products SMR	2013	TX	Air Products	1.00	Hydrogen production	EOR
Coffeyville Gasification	2013	KS	Coffeyville Resources	0.90	Fertilizer production	EOR
PCS Nitrogen	2013	LA	PCS Nitrogen	0.30	Fertilizer production	EOR
Illinois Industrial CCS	2017	IL	ADM	1.00	Ethanol production	Saline
Total Capacity				**19.64**		

Source: Global CCS Institute, Global Status Report 2021, December 1, 2021.

U.S. CCUS cost curve (2019 NPC Study)

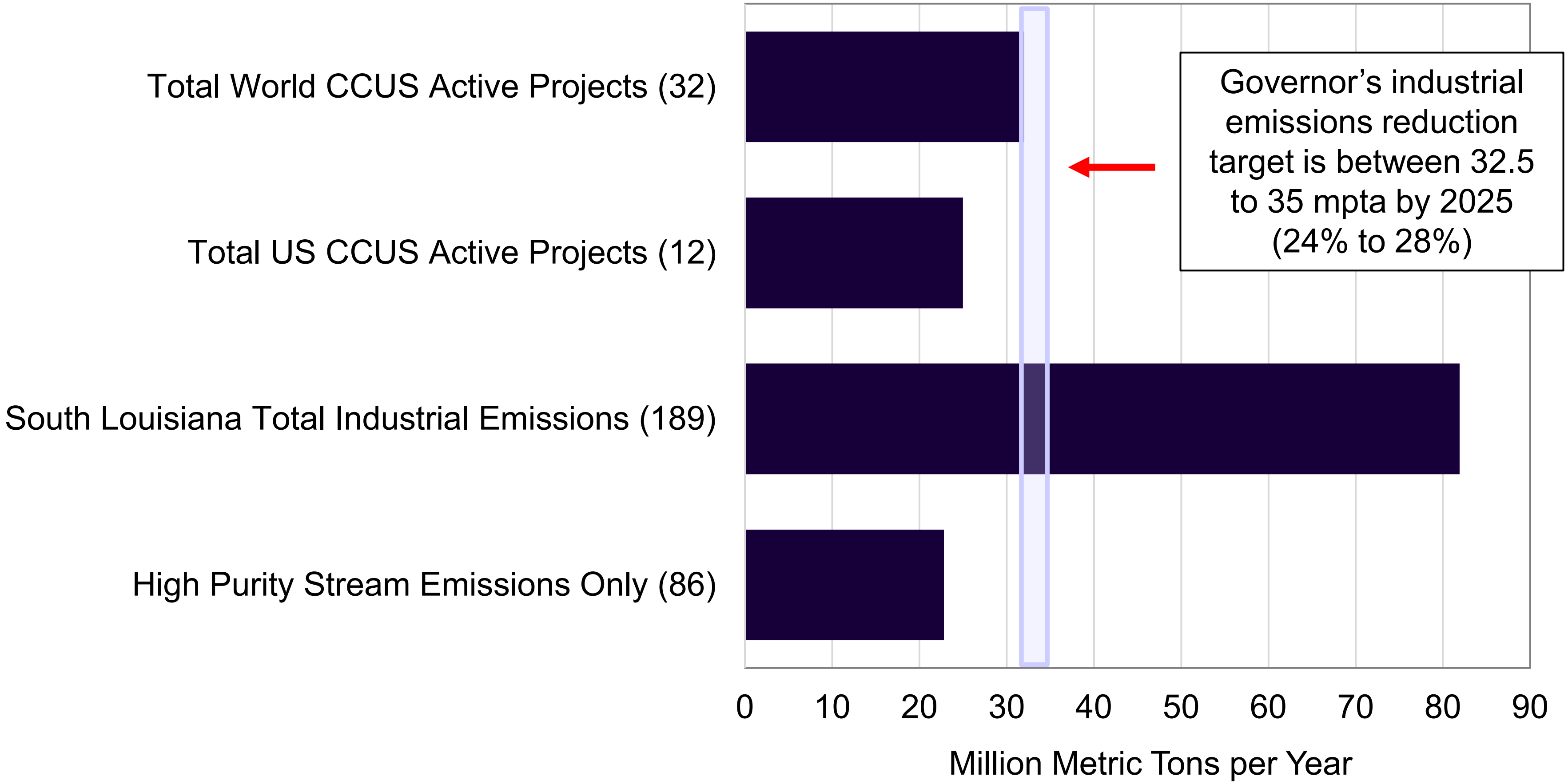
Costs are an important challenge. **High purity streams could be in a relatively economic range, particularly with 45(Q) or other enhanced tax incentives.**



Source: Meeting the Dual Challenge, A Roadmap to At-Scale Deployment of Carbon Capture, Use, and Storage. National Petroleum Council.

Louisiana high purity streams of CO_2

The opportunities for development in Louisiana are rich. There is **in excess of 20 mpta in high quality (90 percent plus) streams** in Louisiana alone: a level comparable to all the active U.S. CCUS facilities.



Source: Author's construct.

Fuel substitution: electricity

Changing end uses

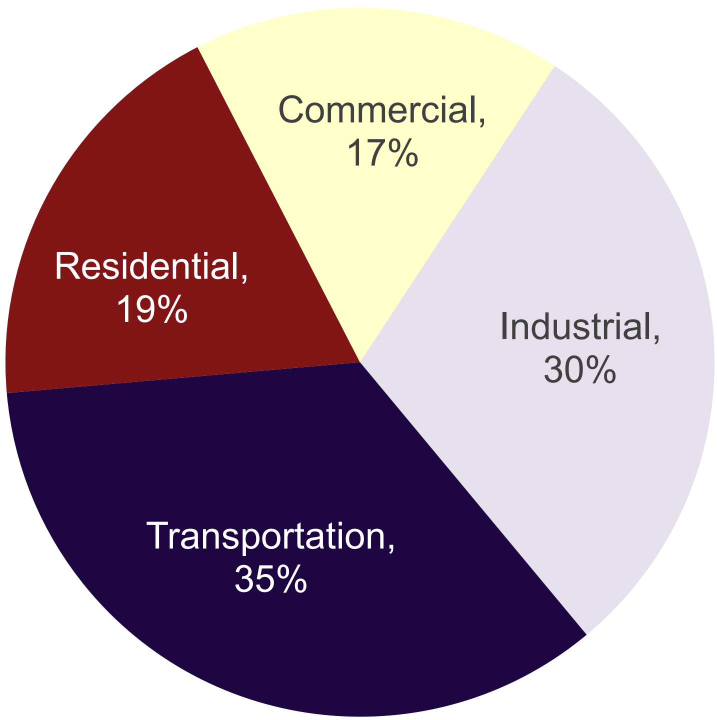
Industry has been **moving more and more towards electrical end-uses** over several decades, arguably dating back to the CAAA of 1990.

Examples in the natural gas midstream industry include **moving compression fuel from pipeline gas to electricity** – which had considerable implications in during **Winter Storm Uri in 2021.**

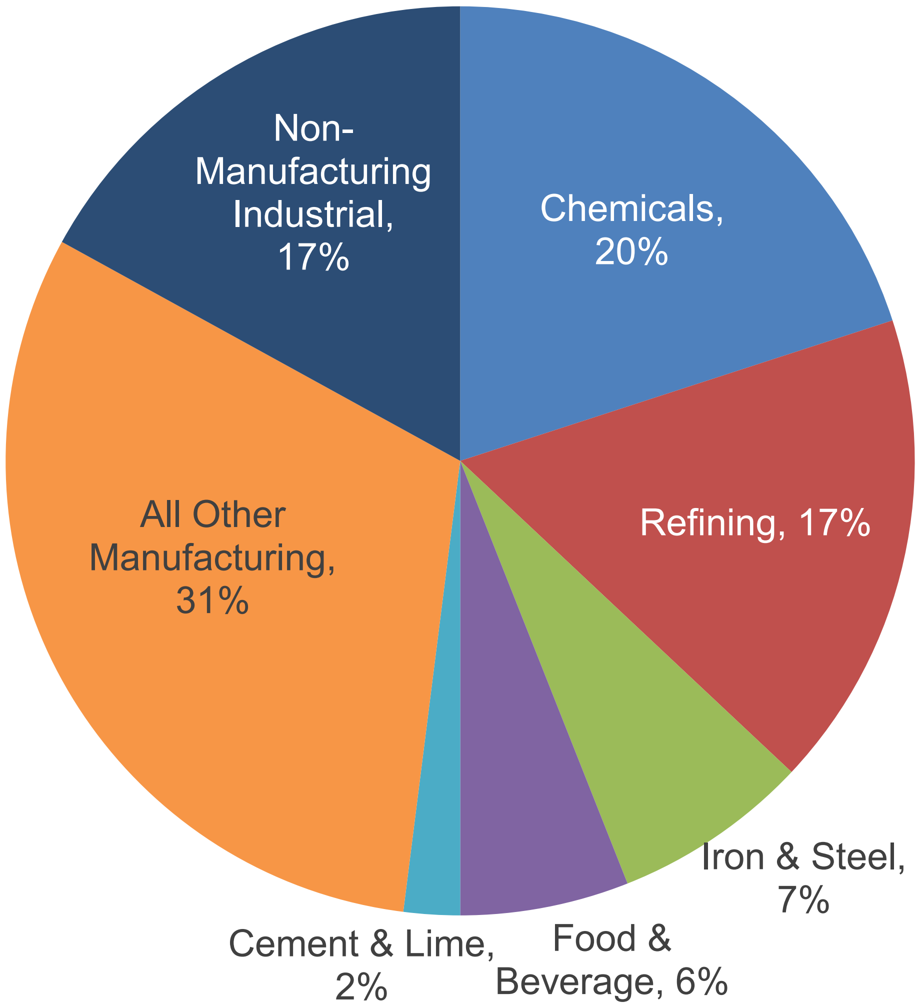
Other examples include moving other forms of **compression, motors, pumps, and other forms of mechanical energy** and using electricity rather than **natural gas, waste fuels, and other fossil-based options.**

U.S. industrial energy use & GHG emissions.

Industrial GHG emissions are **concentrated in a six sectors.**



→



Source: Energy Central; EIA.

US industrial sector GHG emissions

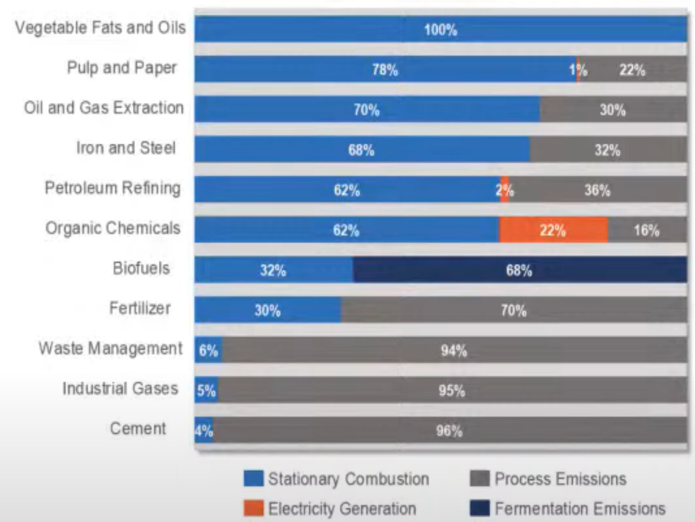
Industries are heterogenous in their GHG with some having far more percentages dedicated to just **stationary combustion than process GHG emissions**.

Industrial Process Emissions

- Process emissions result from the manufacture of products
- Not strictly related to energy use
- Often the result of chemical processes that release CO_2
- Hard to decarbonize without carbon capture or new techniques

Emissions	Reduction Strategy
On-site combustion:	Electrification & Fuel Switching
Process Emissions:	Carbon Capture; R&D and New Technology
Indirect Emissions:	Decarbonizing Electric Grid

Direct Emissions: U.S. Midcontinent Facilities

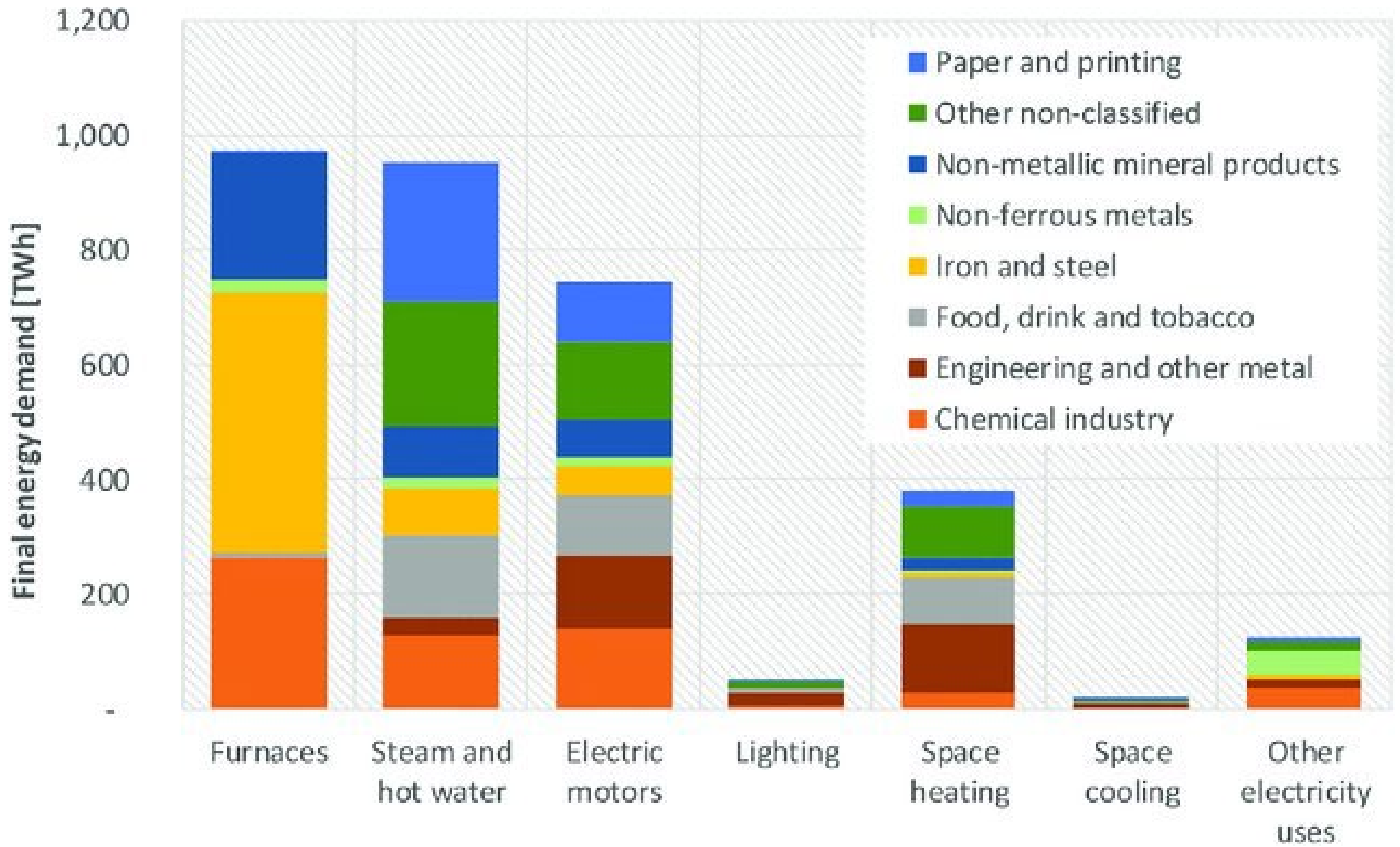


Figures authored by Elizabeth Abramson, Great Plains Institute, 2020
Source: EPA 2018

Source: CTF October Special Meeting on Industrial Decarbonization Part 2; Great Plains Institute; Dane Mcfarlane

U.S. industrial final energy use (2015)

Heat, steam and electric motors are largest industrial end uses. Steam and heat are difficult to replace with electricity.

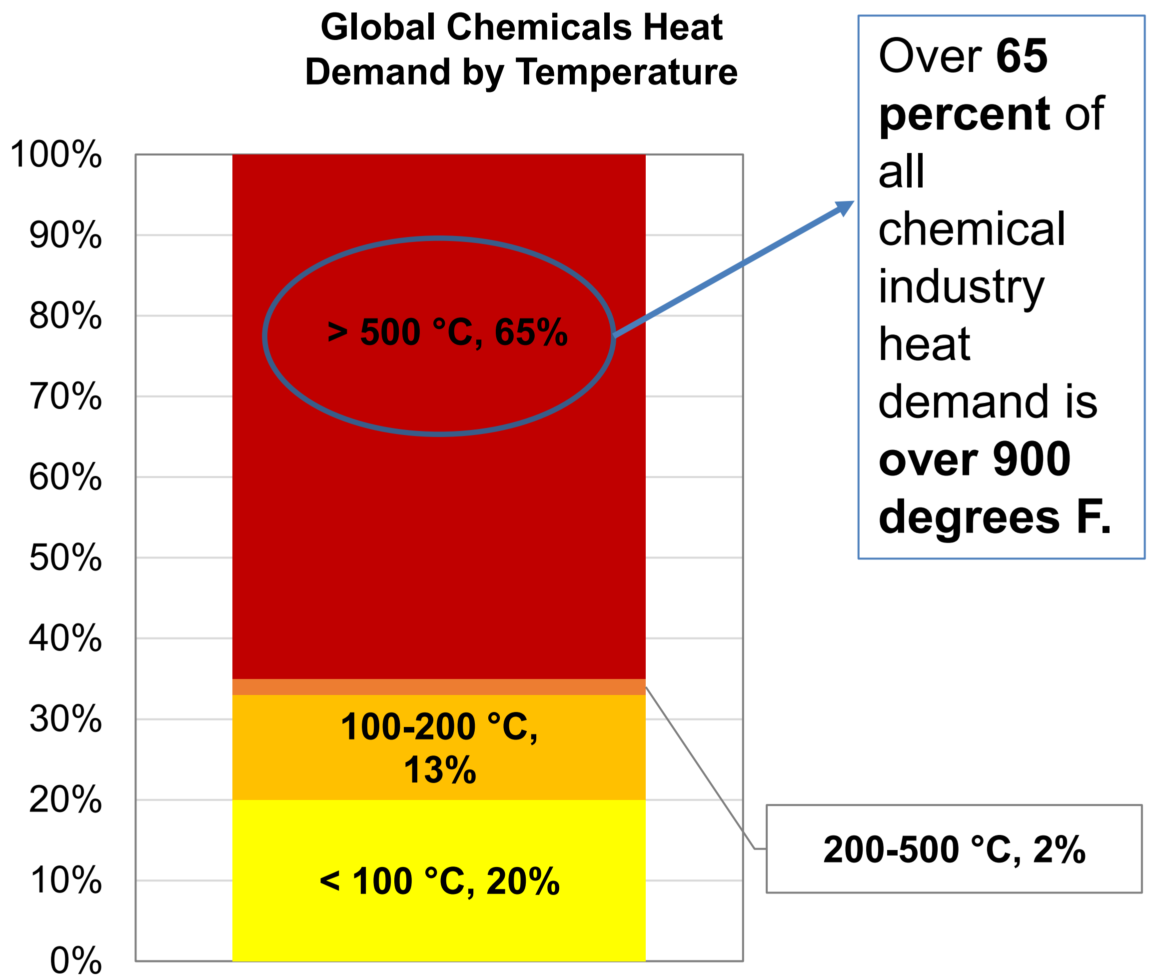


Source: U.S. Energy Information Administration.

Chemical industry use

Over **40 percent** of chemical industry energy use is for **non-feedstock purposes**.

Energy Source	Global Chemical Non-Feedstock Energy Use (%)
Natural Gas	29%
Purchased Electricity	23%
Coal	23%
Petroleum	13%
Purchased Heat / Steam	12%
Bioenergy	>1%



Over **65 percent** of all chemical industry heat demand is **over 900 degrees F.**

Source: Jeff Rissman. "Decarbonizing Chemicals and other Industries in Louisiana." CTI Presentation. October 8. 2021.

Fuel substitution: hydrogen

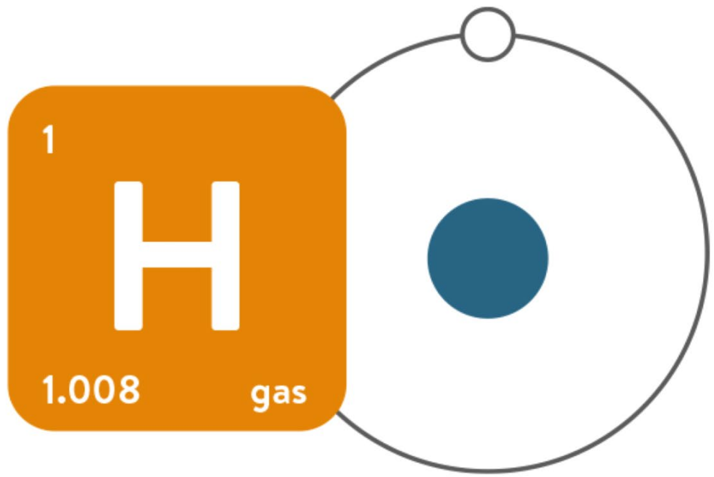
Hydrogen

Hydrogen

Simplest and most abundant element with an estimated 90% of the visible universe being composed of hydrogen

Despite the massive abundance, pure hydrogen is rarely found on earth, instead it is combined with other elements such as hydrocarbons, acids, and hydroxides

Today use is dominated by the industry sector, with growing potential in the energy sector



Characteristics:

Non-toxic, Colorless,

Odorless, Tasteless,

Flammable, Gaseous Substance

Source: Tiffany Aucoin and Madison Menou. (2021) “Hydrogen: Fuel of the Future?”

The hydrogen rainbow

Grey Hydrogen: The most common type of hydrogen made today. It is made through "steam reformation" – heating fossil fuels under pressure – particularly natural gas.

Brown Hydrogen: Produced from lignite coal. It may not surprise you to learn that it is highly polluting.

Black Hydrogen: Also made from coal, but in this case bituminous coal.

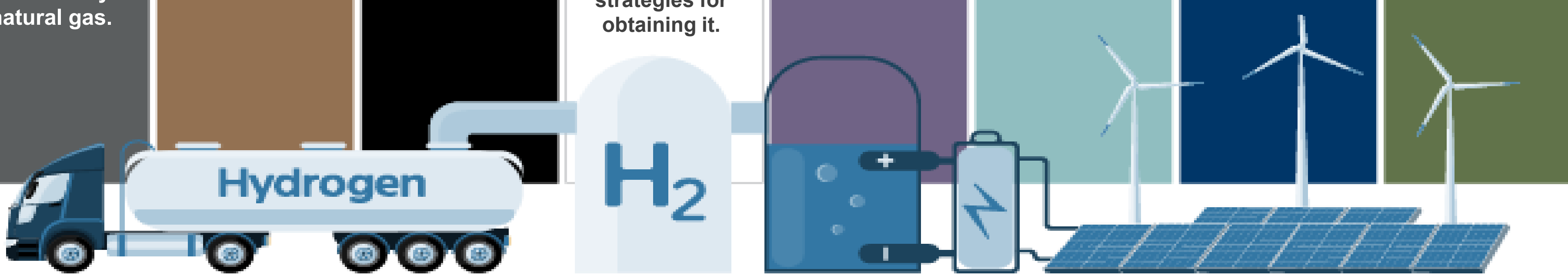
White Hydrogen: Naturally occurring "white" hydrogen is found underground and can be captured through fracking. However, there are no proven strategies for obtaining it.

Purple/Pink/Red Hydrogen: These are created from various forms of nuclear power.

Turquoise Hydrogen: Hydrogen can be extracted from natural gas. But there are problems with methane.

Blue Hydrogen: As with grey hydrogen, blue hydrogen is extracted from fossil fuels – but its producers then attempt to capture and store carbon emissions.

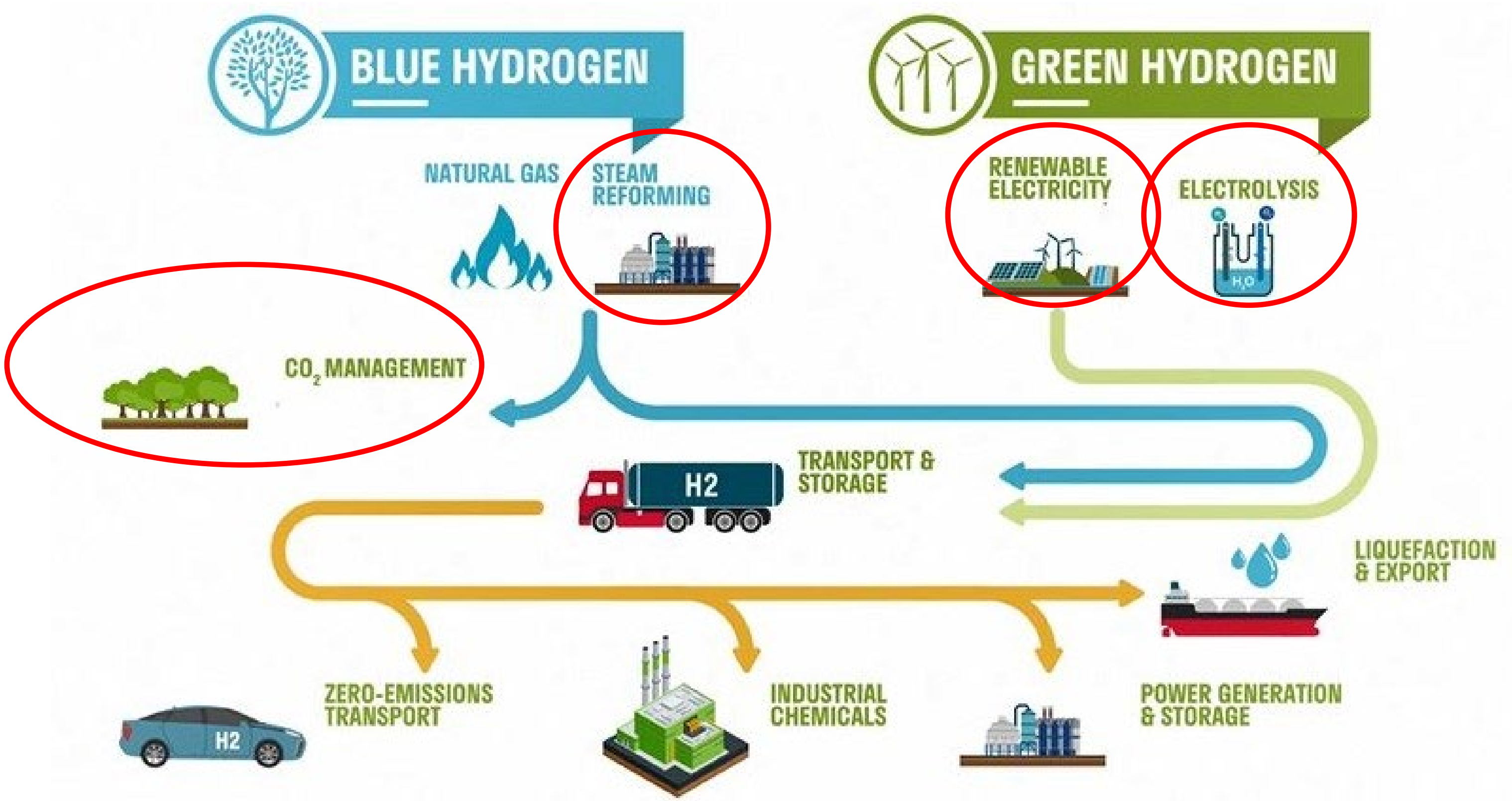
Green Hydrogen: Uses an electrical current obtained from renewable energy sources to separate the hydrogen from the oxygen in water.



Source: Goddin, Neal. Artemis Investments. January 12, 2022

Blue v. green hydrogen

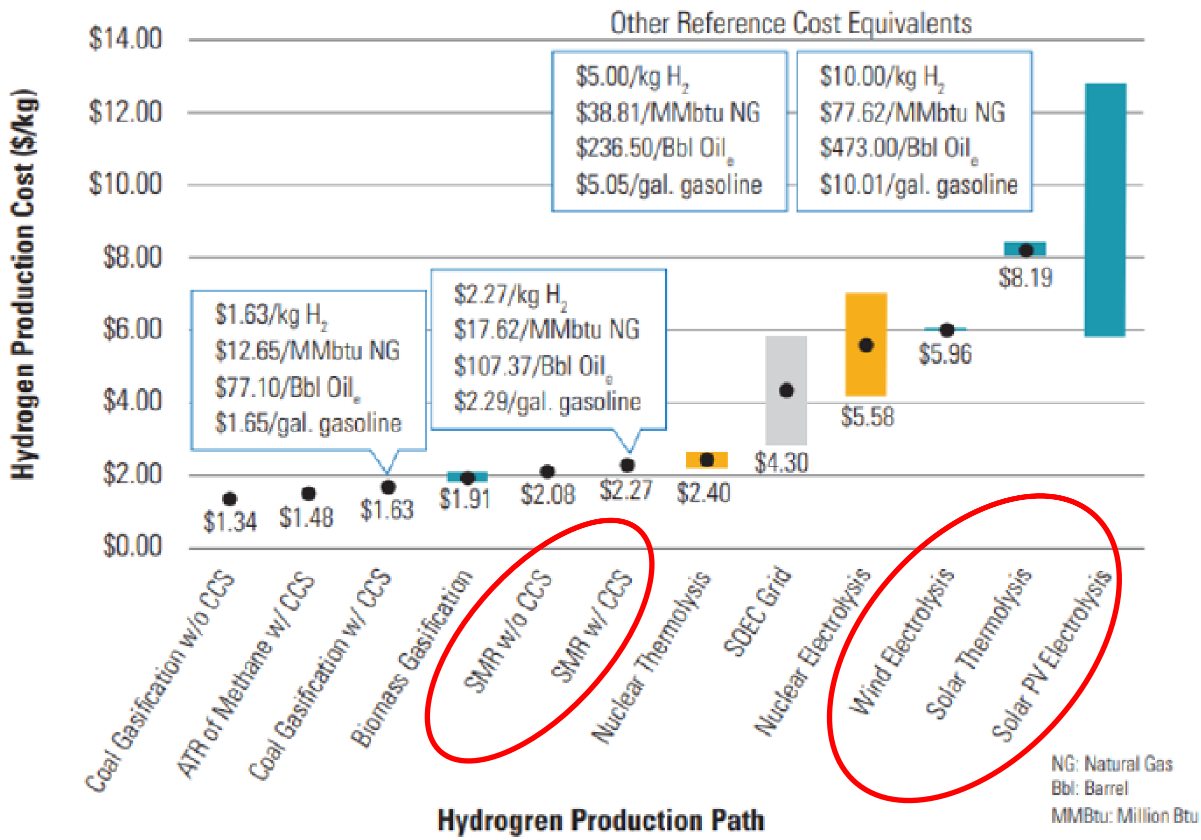
How the hydrogen is made, matters.
Blue uses SMR and CCS;
Green uses RE and electrolysis



Source: Energy Tracker Asia.https://energytracker.asia/hydrogen-oil-green-vs-blue-whats-the-difference

Hydrogen Cost Ranges

Natural gas-based production methods with CCUS are the more likely cost-effective transition methods.



USDOE, 2020. Hydrogen Strategy, Enabling a Low-Carbon Economy: https://www.energy.gov/sites/prod/files/2020/07/f76/USDOE_FE_Hydrogen_Strategy_July2020.pdf

Source: Frank Frey, GHD; “Hydrogen and CCUS”

Salt Cavern Storage Constraints

GHD US Hydrogen Storage	Hydrogen Blend 5%	10%	20%	50%
Energy Equivalent Consumption (BCF)[1,2]	31,533	32,659	35,172	45,723
Volume Hydrogen Req'd (BCF)	1,577	3,266	7,034	22,862
Hydrogen Working Gas Capacity (BCF)[3]	249	517	1,113	3,617
Approximate Salt Cavern Facilities[4]	19	40	85	277
Salt Caverns[5]	62	129	278	904

NOTES
1. Consumption based on 2020 natural gas consuption of 30,482 BCF per EIA
2. Energy Equivalency assumes H2 energy density is 33% of natural gas
3. Hydrogen Storage Capacity based on ratio of total storage to total consumption for natural gas per EIA (2019)
4. Cavern Facilities based on average work gas per Salt Cavern facility per EIA
5. Salt Caverns assumes average 4 BCF working gas per cavern

Existing Natural Gas Storage Facilities (US, 2019)

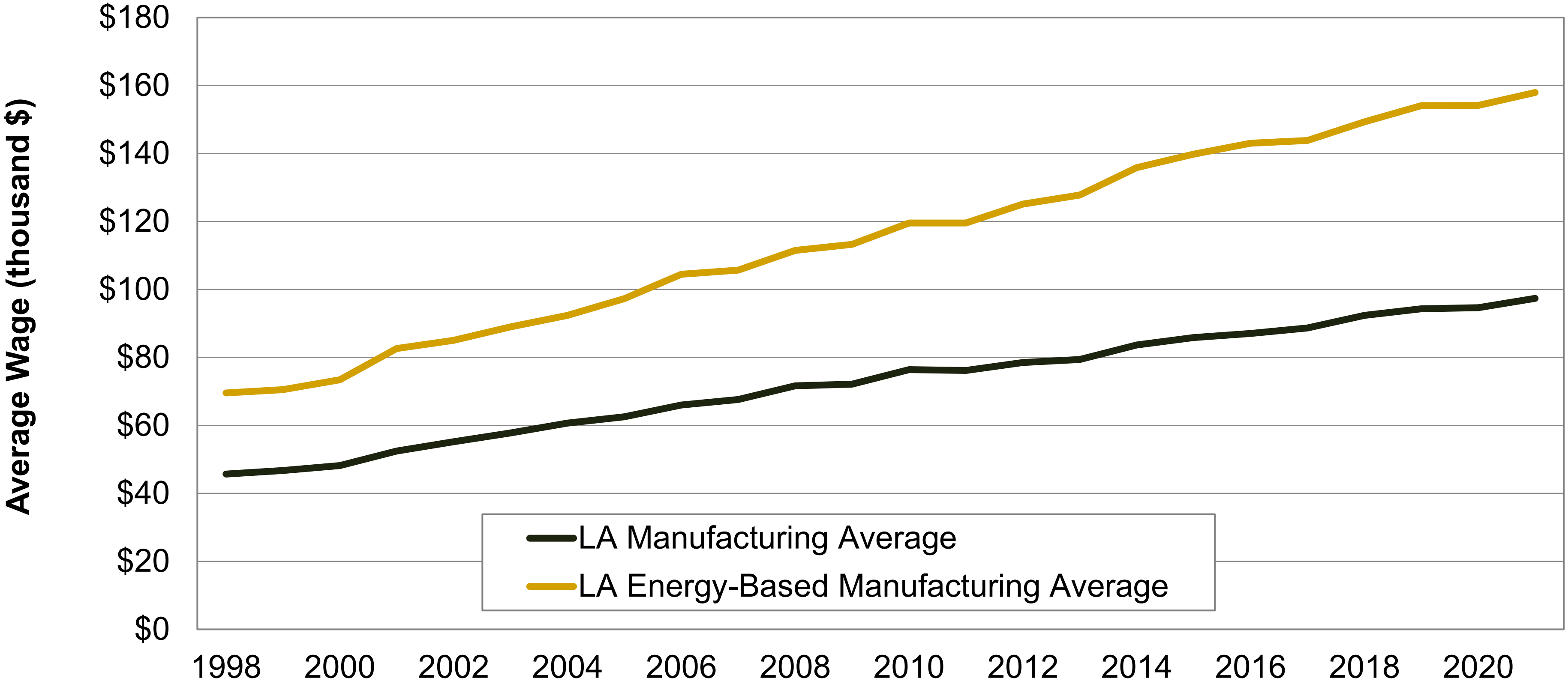
Storage Type	Facilities	Working Gas (BCF)	Avg Working Gas (BCF)	% of Annual Consumption
Aquifer	47	403.81	8.59	1%
Depleted Field	328	3,935.13	12.00	13%
Salt Dome	37	483.17	13.06	2%
TOTAL	412	4,822.11	11.70	16%

Source: Frank Frey, GHD; "Hydrogen and CCUS"

Louisiana importance

Average wage comparison, Louisiana manufacturing and energy-based manufacturing

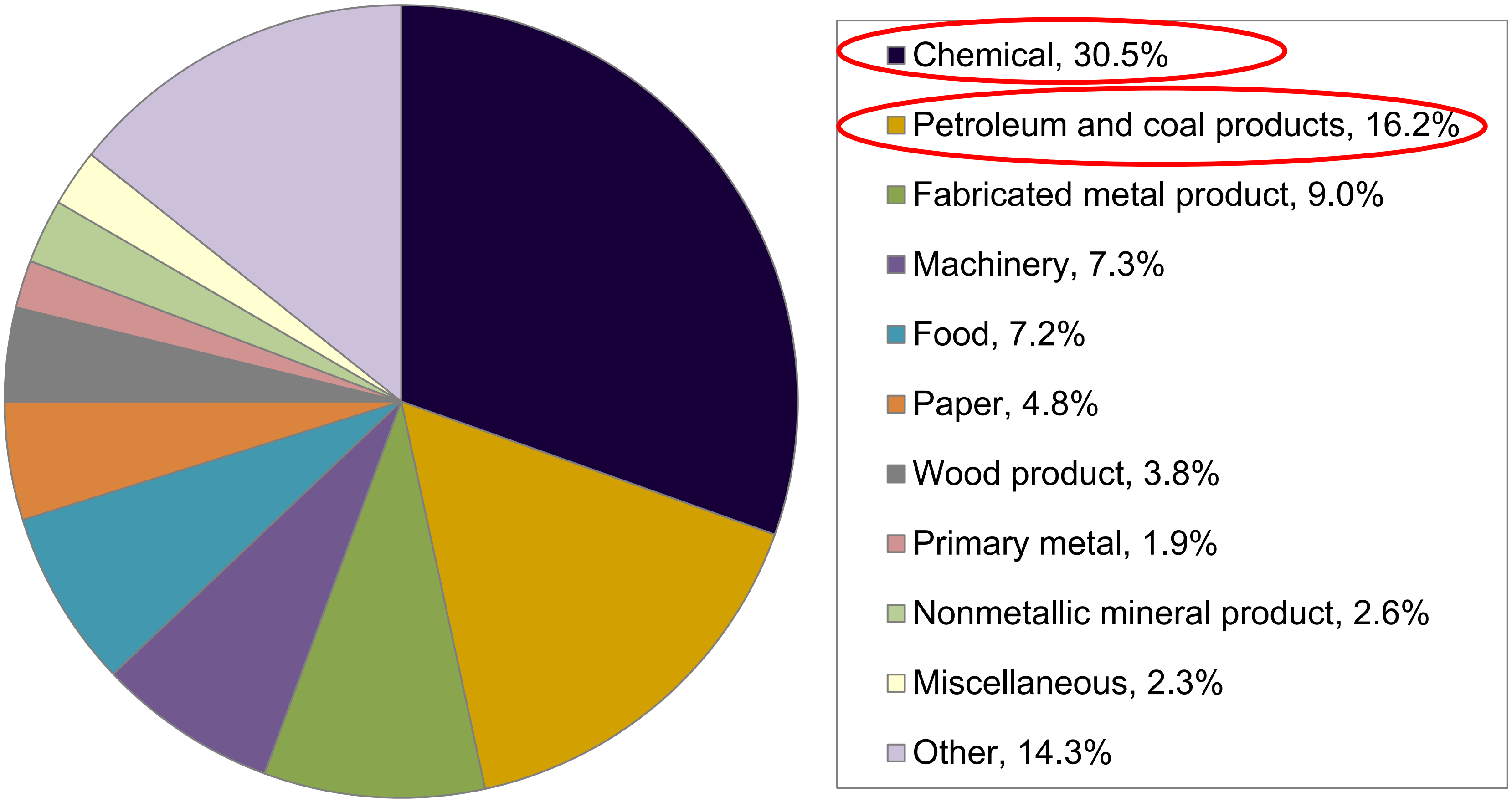
The premium of energy-based manufacturing to total manufacturing is more pervasive in Louisiana. In 2021, **Louisiana energy-based manufacturing wages were 1.62 times traditional manufacturing** and have increased at an average annual rate of 5.5 percent (compared to the manufacturing average of 4.9 percent)



Note: Energy-based manufacturing includes: petroleum and coal products; chemical; and plastics and rubber products manufacturing.
Source: Bureau of Economic Analysis, U.S. Department of Commerce.

Manufacturing wages by sector, Louisiana (2021)

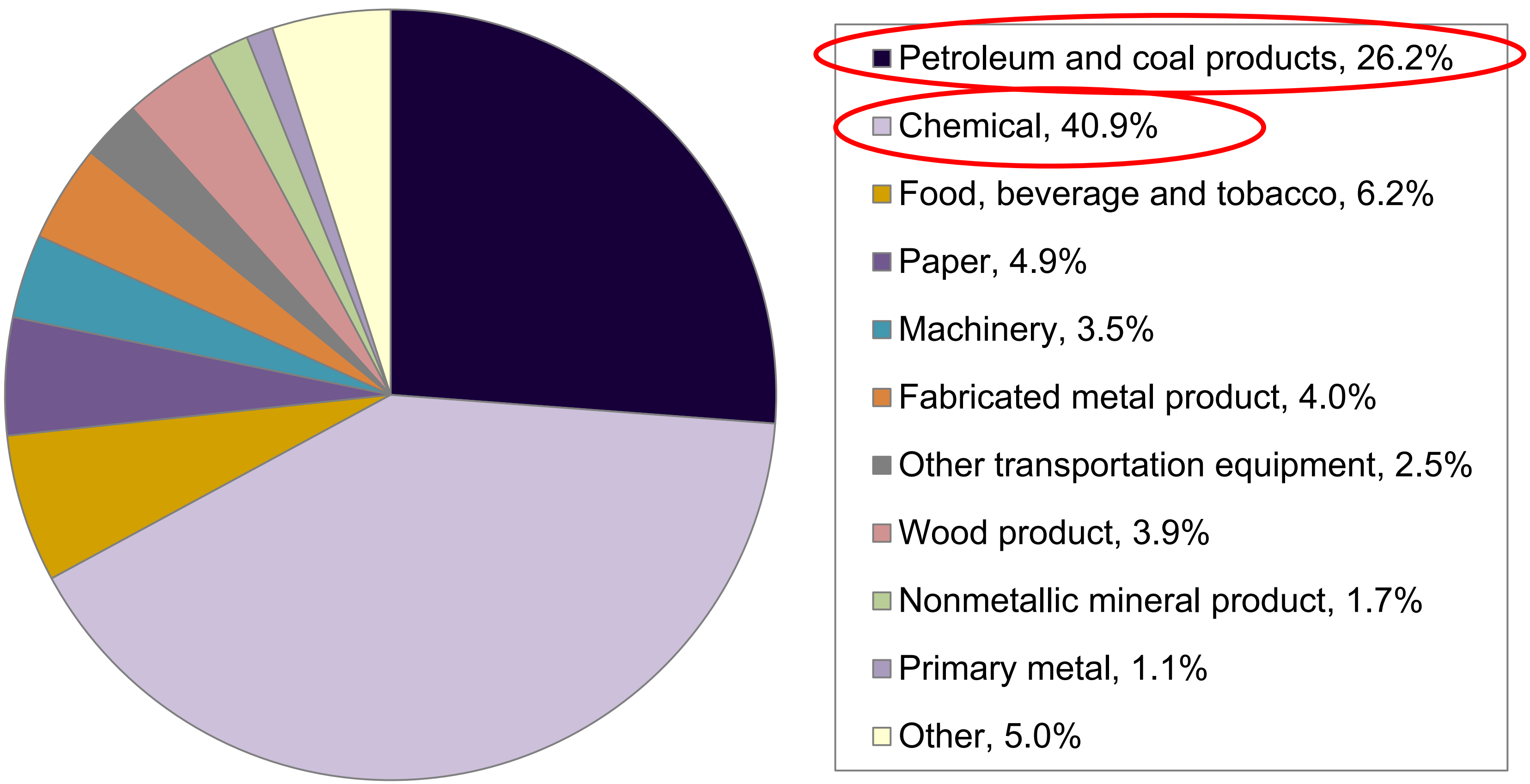
In Louisiana, manufacturing sector wages totaled $13.6 billion in 2021. **Energy manufacturing accounts for 46 percent of total manufacturing wages ($6.7 billion)**.



Note: Energy-based manufacturing includes: petroleum and coal products; chemical; and plastics and rubber products manufacturing.
Source: Bureau of Economic Analysis, U.S. Department of Commerce.

GDP by sector and share of Louisiana manufacturing total (2021)

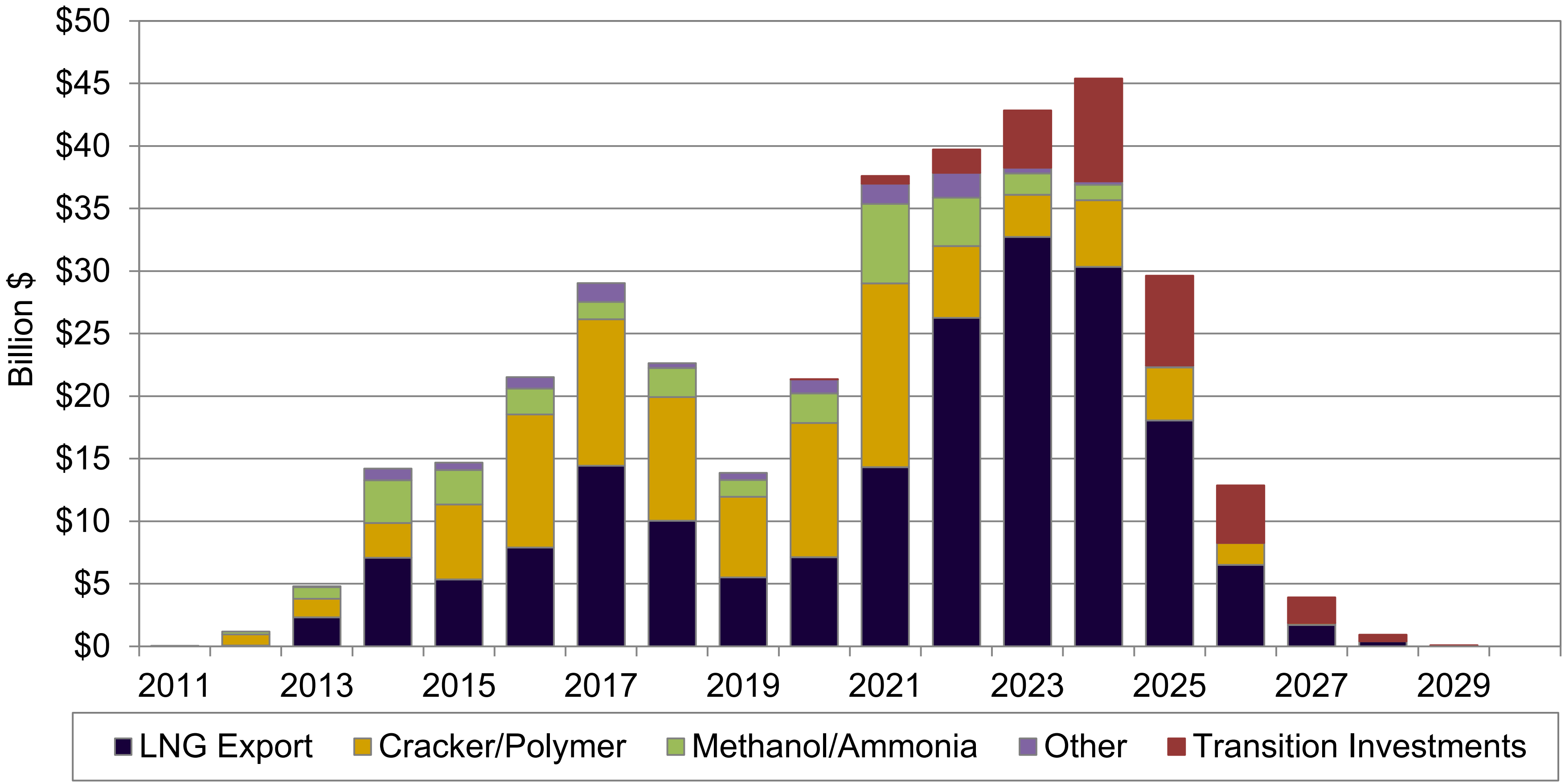
In terms of total economic contributions, **manufacturing accounts for 16 percent of Louisiana's state GDP. Energy-related industries account for 67 percent of total state manufacturing GDP ($40.3 billion), or 11 percent of total state GDP ($258.6 billion)**.



Note: Energy-based manufacturing includes: petroleum and coal products; chemical; and plastics and rubber products manufacturing.
Source: Bureau of Economic Analysis, U.S. Department of Commerce.

GOM energy manufacturing investments by sector.

Large number of future investments tied to energy transition. Note the Inflation Reduction Act has **$3.2 billion in additional CCS tax credits** and **$7.8 billion in clean hydrogen**.



Source: Authors Construct; capex for announced projects with missing information were estimated using available data from average/typical facility type/cost.

Total GOM Investment, All Project Announcements.

GOM looking at **$29 billion in total energy transition investments**, most of which are announced to be in Louisiana (~**$23 billion**).

	Texas					Louisiana					Other GOM					Total GOM				
Year	LNG	Non-LNG	Transition	Other	Total	LNG	Non-LNG	Transition	Other	Total	LNG	Non-LNG	Transition	Other	Total	LNG	Non-LNG	Transition	Other	Total
	(million $)																			
2022	5,529	4699.1638	54	1,762	12,044.0	20,687	4915.7122	1,815	225	27,642.5	33	-	-	-	33.4	26,248.9	9,614.9	1,869.4	1,986.6	39,719.8
2023	5,241	2375.9201	743	228	8,588.3	26,171	2685.1846	3,834	136	32,826.5	1,321	-	-	101	1,422.3	32,733.6	5,061.1	4,576.5	465.9	42,837.1
2024	7,142	4335.14	2,720	-	14,196.6	19,155	2227.0785	5,507	117	27,005.5	4,038	-	-	149	4,187.1	30,335.3	6,562.2	8,226.3	265.4	45,389.2
2025	3,825	3490.7157	1,930	-	9,245.9	11,836	894.02991	5,251	15	17,996.0	2,394	-	-	-	2,393.9	18,055.1	4,384.7	7,181.0	14.9	29,635.8
2026	336	1005.1731	424	-	1,764.9	5,963	745.30632	4,180	-	10,888.9	213	-	-	-	213.3	6,512.6	1,750.5	4,604.1	-	12,867.1
2027	-	68.096455	44	-	112.0	1,716	88.197118	1,995	-	3,799.8	-	-	-	-	-	1,716.2	156.3	2,039.3	-	3,911.8
2028	-	0	187	-	187.3	412	0	336	-	748.2	-	-	-	-	-	412.2	-	523.3	-	935.5
2029	-	0	45	-	44.9	29	0	15	-	44.2	-	-	-	-	-	28.8	-	60.2	-	89.0
2030	-	0	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	$ 22,073	$ 15,974	$ 6,146	$ 1,990	$ 46,184	$ 85,970	$ 11,556	$ 22,934	$ 493	$ 120,951	$ 8,000	$ -	$ -	$ 250	$ 8,250	$ 116,043	$ 27,530	$ 29,080	$ 2,733	$ 175,385

Source: Authors Construct; capex for announced projects with missing information were estimated using available data from average/typical facility type/cost.

Conclusions

Conclusions

- **Industrial carbon emissions are high** in energy producing states, particularly those along the Gulf Coast.
- These industries, however, are **important components of many regional economies**. Their loss could be devastating.
- **Industrial decarbonization will be important** over the next several years in order to meet many state's clean energy and climate goals.
- Further, **industrial decarbonization** will be important for future industrial development since, at the margin, a good share of this development is **tied to international trade**.
- **CCUS is a critical component of industrial decarbonization** and is also a critical component of managing the negative impacts of the clean energy/climate transition.

Questions, comments and discussion.

David E. Dismukes
Professor and Executive Director
Center for Energy Studies
Email: dismukes@lsu.edu

Phone: 225-578-4343

URL: www.enrg.lsu.edu

