The Potential for Hydrogen in Louisiana

Presentation to Clean Hydrogen Task Force
October 1, 2024

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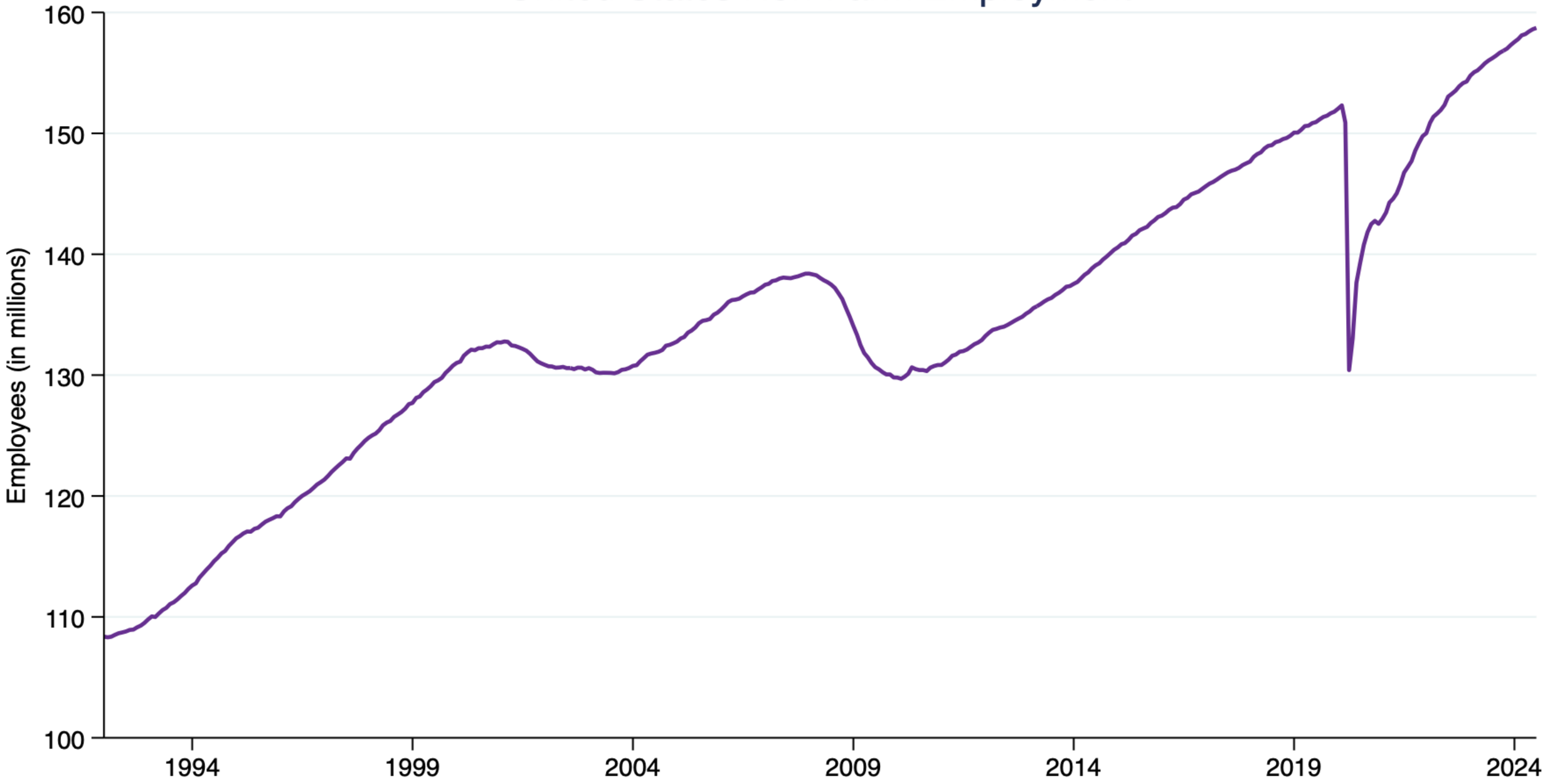
Outline

1. The U.S. and Louisiana Economy
2. The Energy Sector
3. Decarbonization
4. Hydrogen's Potential Role in Decarbonization
5. Current Uses of Hydrogen in Louisiana
6. Potential Markets for Hydrogen
7. Summary and Conclusions

United States Non-Farm Employment



Source: Bureau of Labor Statistics. Current Employment Statistics (CES). Retrieved from FRED.

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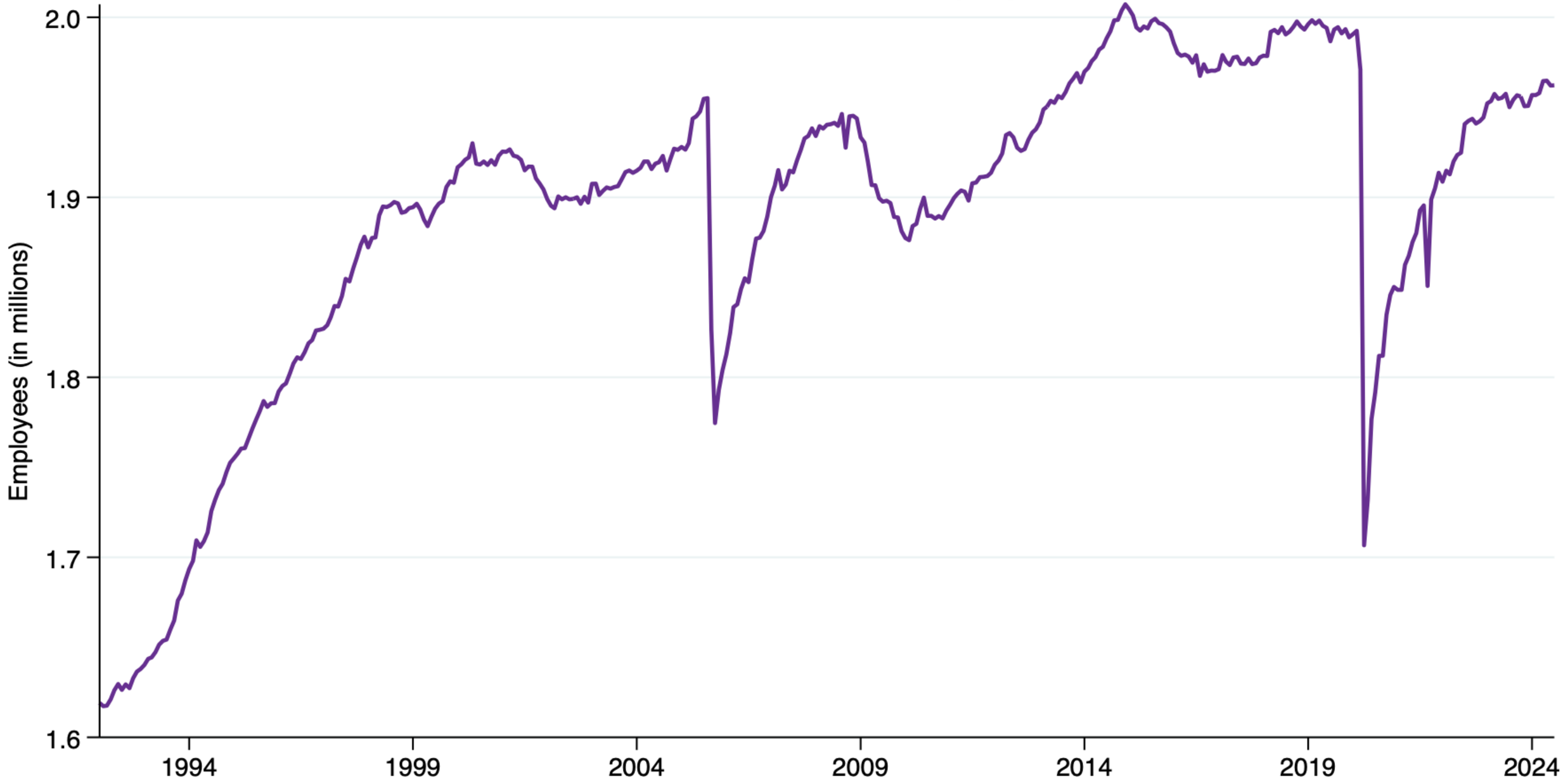
Louisiana Non-Farm Employment



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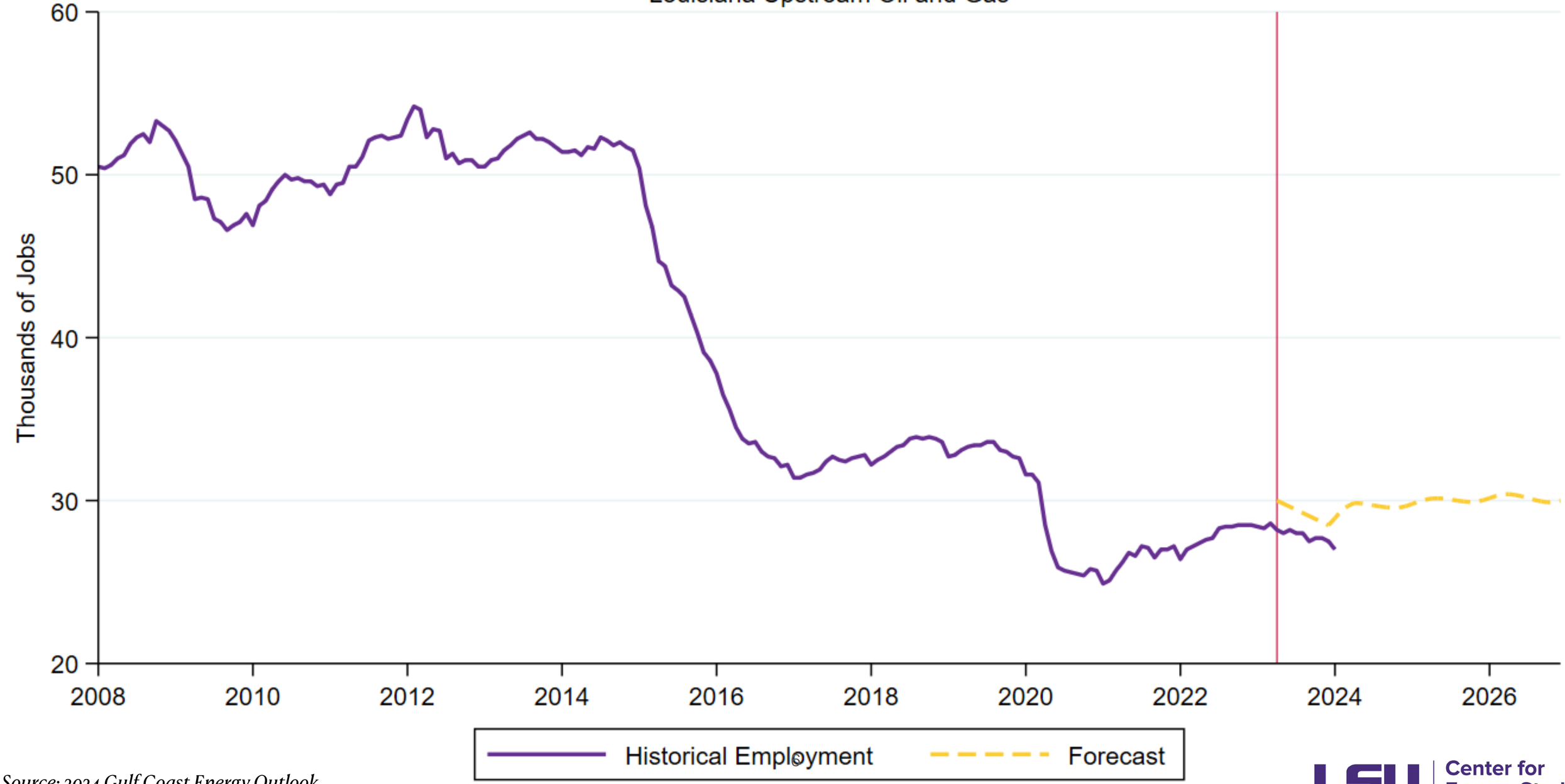
Employment Forecast

Louisiana Upstream Oil and Gas



Source: 2024 Gulf Coast Energy Outlook

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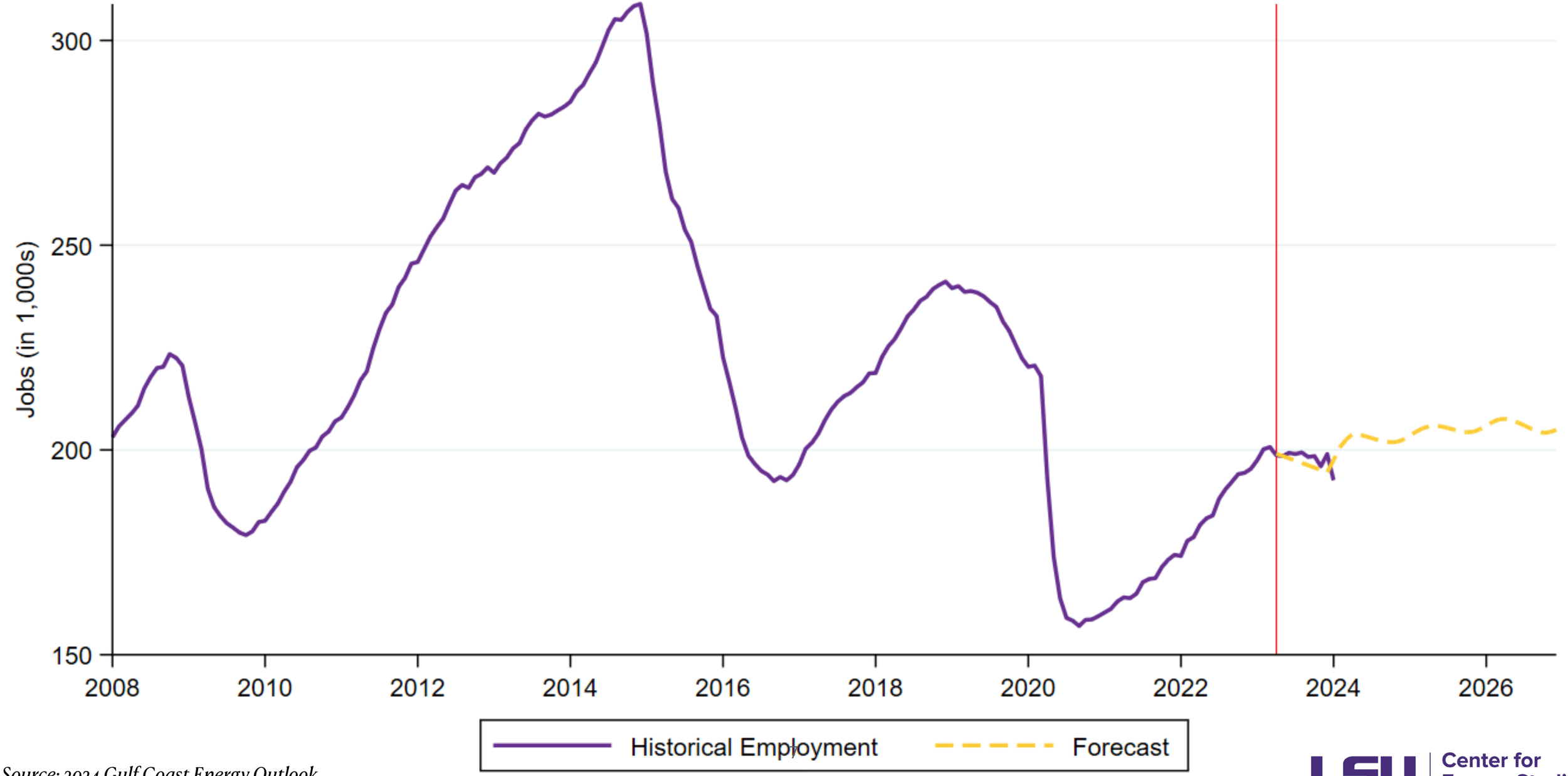
Employment Forecast

Texas Upstream Oil and Gas



Source: 2024 Gulf Coast Energy Outlook

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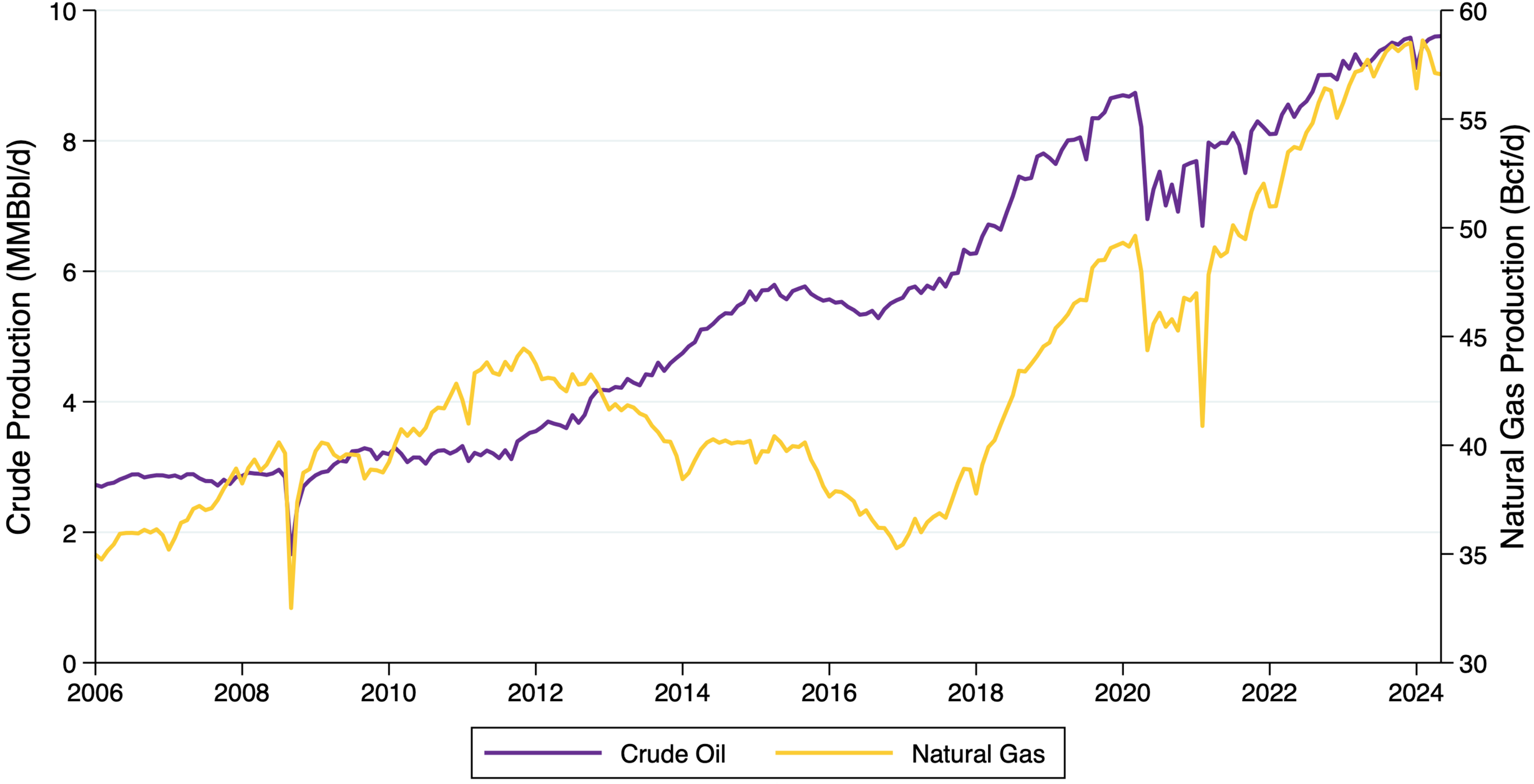
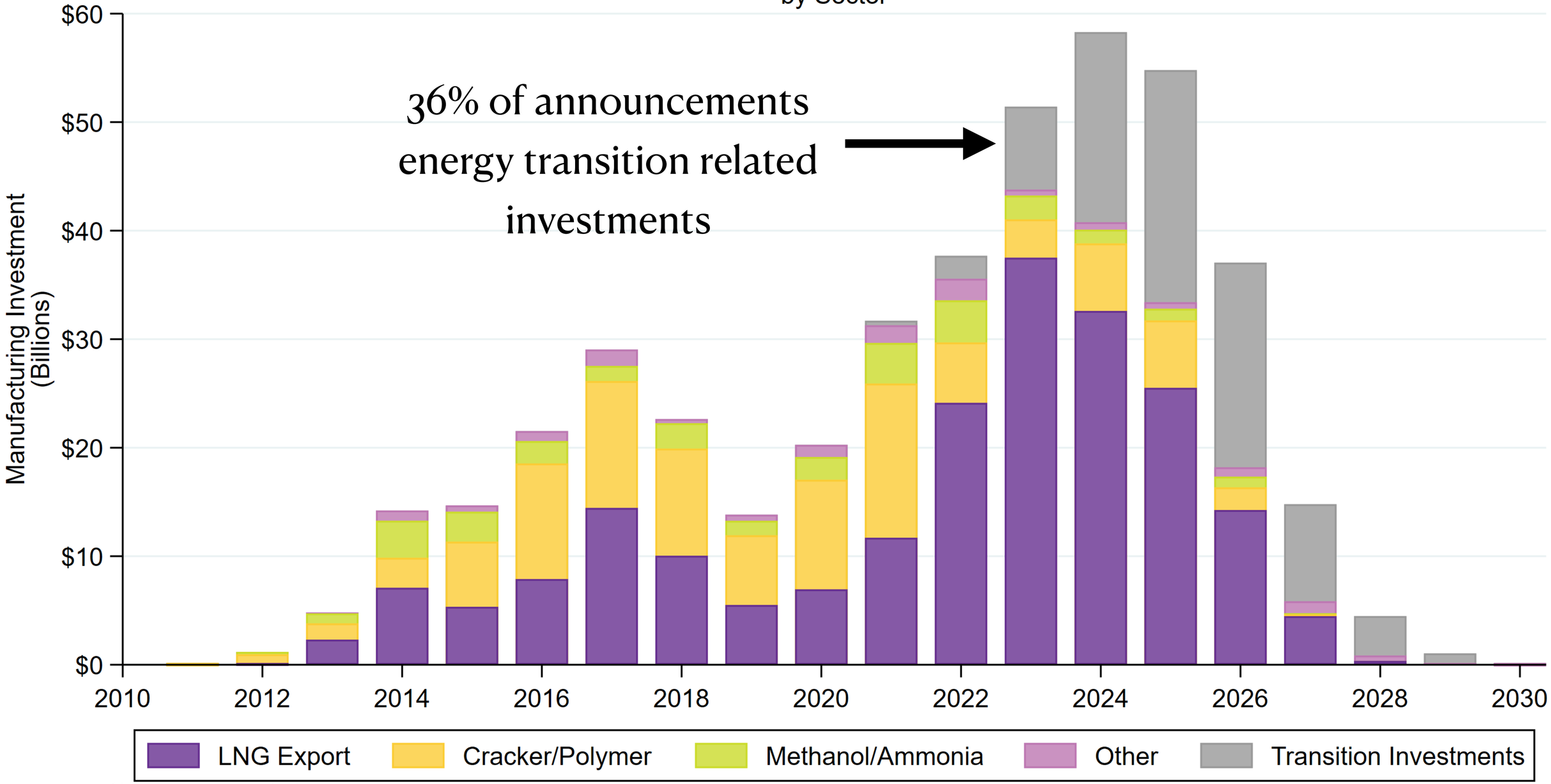
Gulf Coast Crude Oil and Natural Gas Production



Source: Energy Information Administration. U.S. Department of Energy.

Gulf Coast Energy Manufacturing Investments

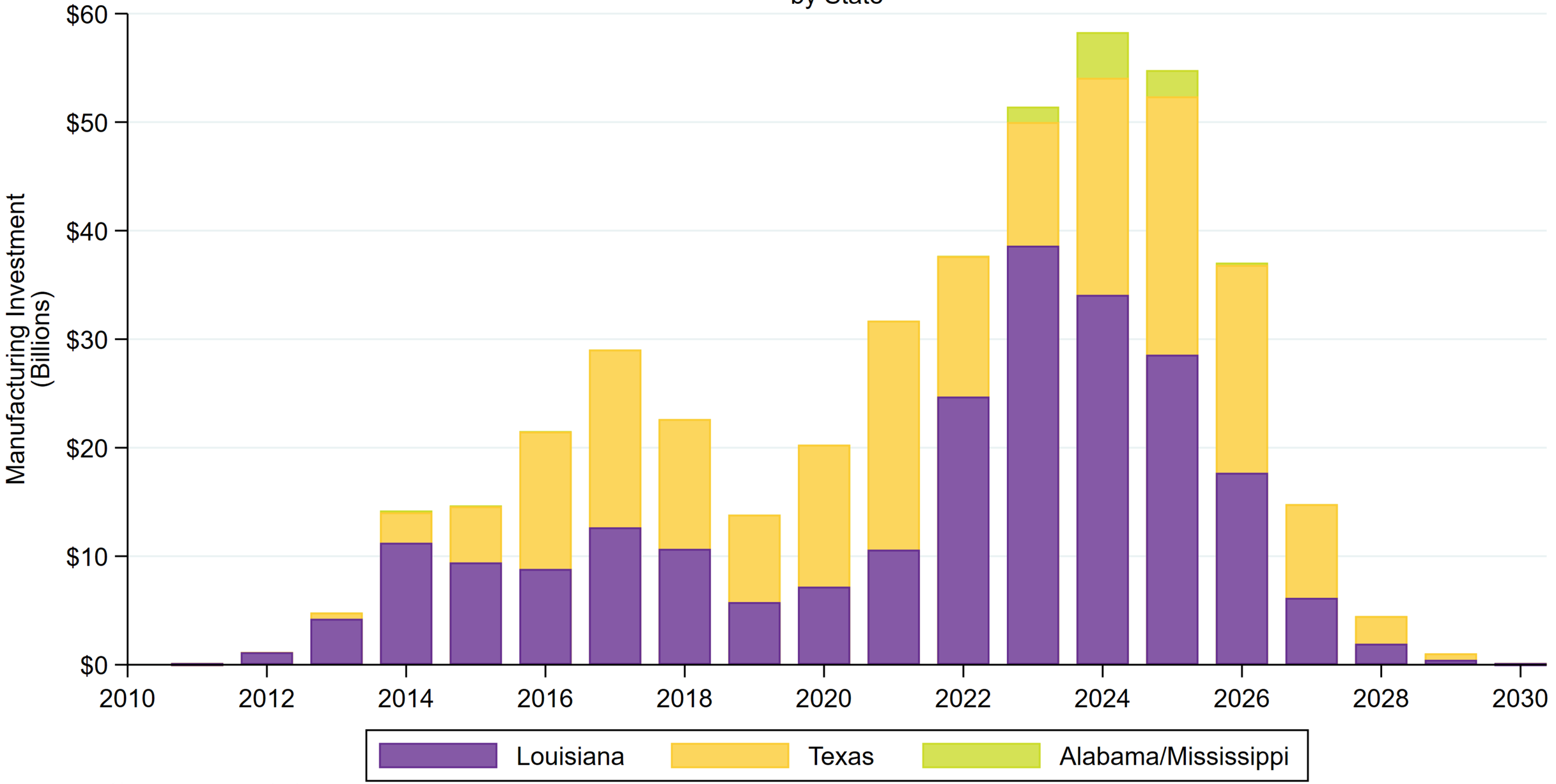
by Sector



Source: 2024 Gulf Coast Energy Outlook

Gulf Coast Energy Manufacturing Investments

by State



Source: 2024 Gulf Coast Energy Outlook

Gulf Coast Manufacturing

- Between 2011 and 2022, there was approximately $212 billion of investment in refining, chemicals, and hydrocarbon export across the Gulf Coast region.
- Approximately $106.5 billion, or 50 percent is within Louisiana.
- Currently, there are an additional $170.5 billion in announcements, with approximately 52 percent of these announcements in Louisiana.

Table 1: Total GOM investments

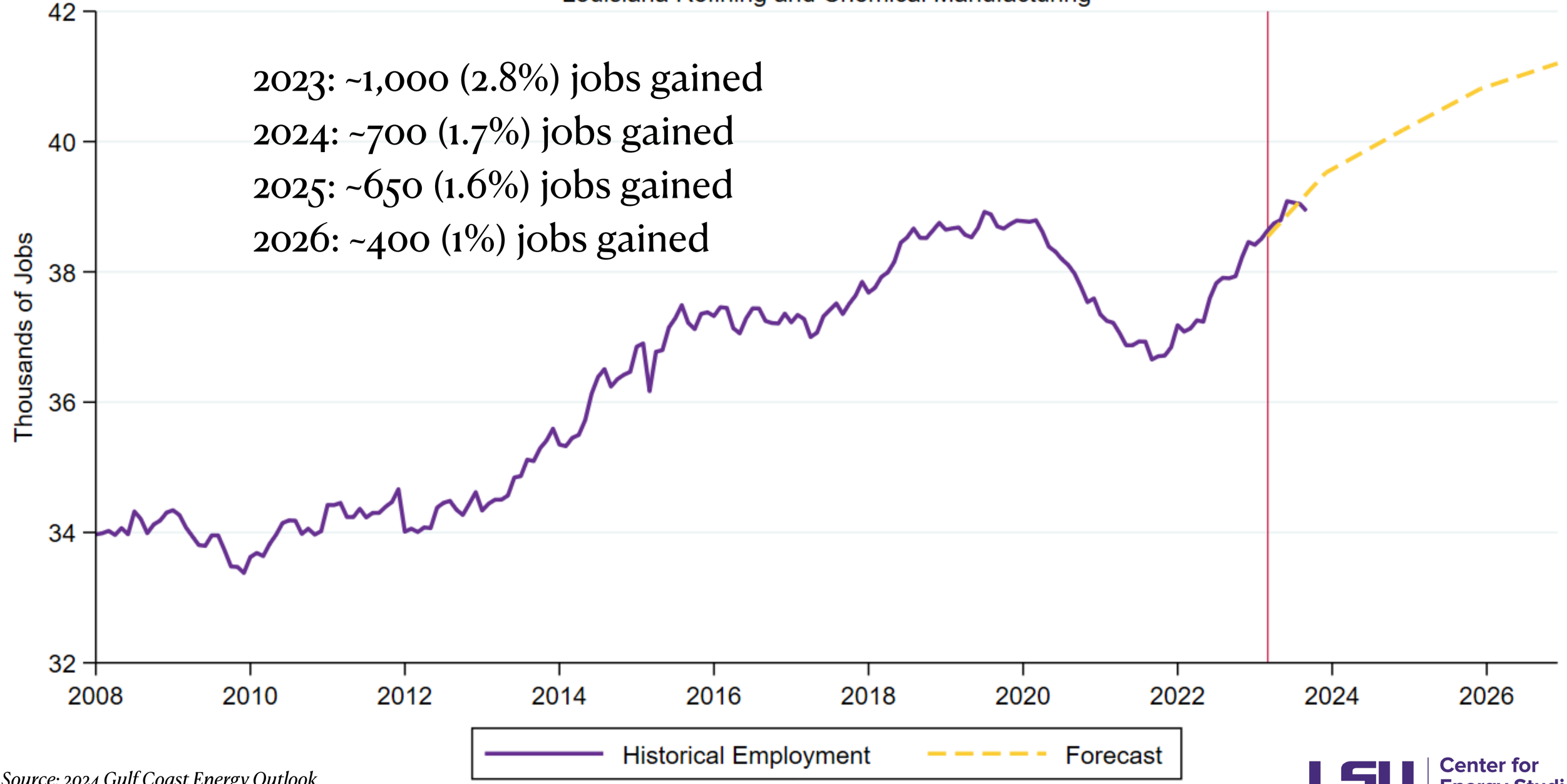
Year	Texas				Louisiana				Other GOM				Total GOM			
	LNG	Non-LNG	Transition	Total	LNG	Non-LNG	Transition	Total	LNG	Non-LNG	Transition	Total	LNG	Non-LNG	Transition	Total
	(million $)															
2023	5,274	2,986	3,133	11,393	30,910	3,190	4,513	38,613	1,321	-	1	1,322	37,506	6,277	7,646	51,429
2024	8,517	5,413	6,066	19,997	20,049	2,609	11,426	34,085	4,038	-	21	4,060	32,604	8,171	17,514	58,290
2025	10,010	4,941	8,851	23,803	13,113	2,946	12,507	28,566	2,394	-	29	2,423	25,517	7,887	21,387	54,791
2026	9,292	1,742	8,116	19,151	4,750	2,200	10,735	17,684	213	-	3	217	14,255	3,942	18,854	37,052
2027	4,103	1,139	3,387	8,629	373	232	5,558	6,163	-	-	-	-	4,477	1,371	8,945	14,792
2028	347	505	1,698	2,550	-	-	1,935	1,935	-	-	-	-	347	505	3,633	4,484
2029	-	118	473	591	-	-	457	457	-	-	-	-	-	118	930	1,048
2030	-	8	30	38	-	-	31	31	-	-	-	-	-	8	61	69
Total	**$37,544**	**$16,852**	**$ 31,754**	**$86,151**	**$69,195**	**$11,177**	**$ 47,161**	**$127,533**	**$7,967**	**$ -**	**$ 55**	**$8,022**	**$114,706**	**$28,279**	**$ 78,970**	**$221,955**

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

Source: 2024 Gulf Coast Energy Outlook

Employment Forecast

Louisiana Refining and Chemical Manufacturing



Source: 2024 Gulf Coast Energy Outlook

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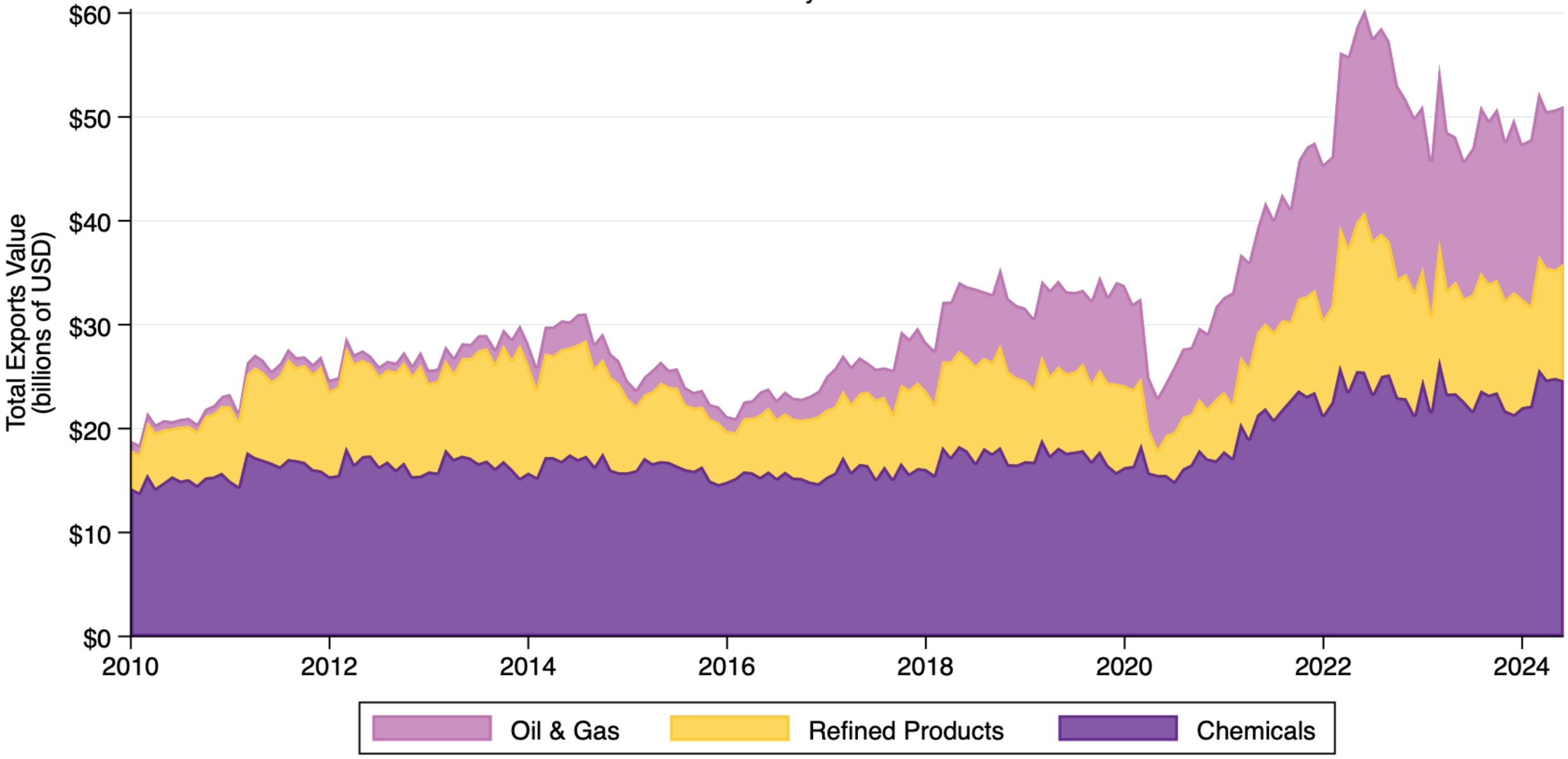
U.S. Exports to World

by NAICS



Source: U.S. Census Bureau: Economic Indicators Division USA Trade Online

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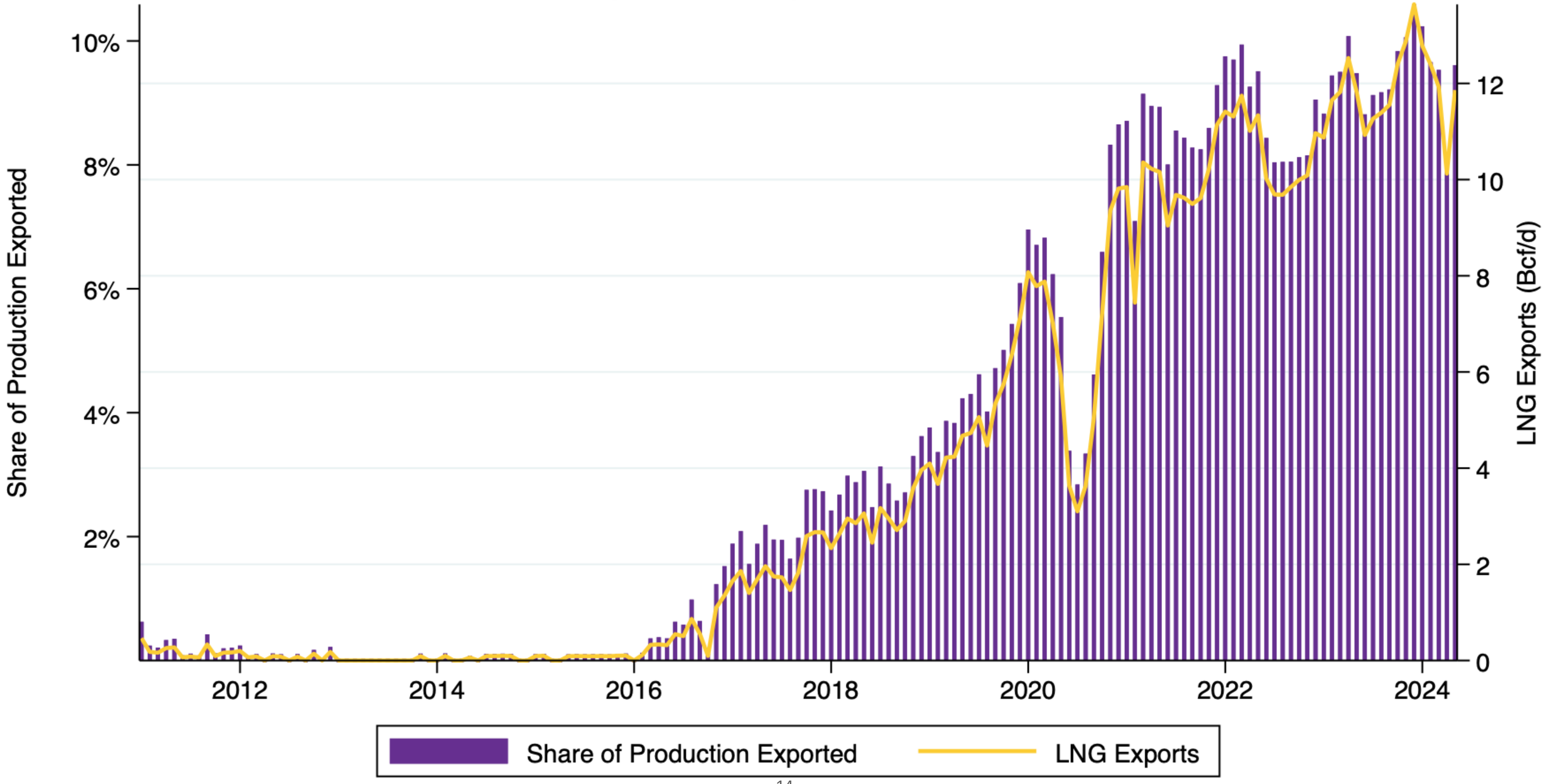
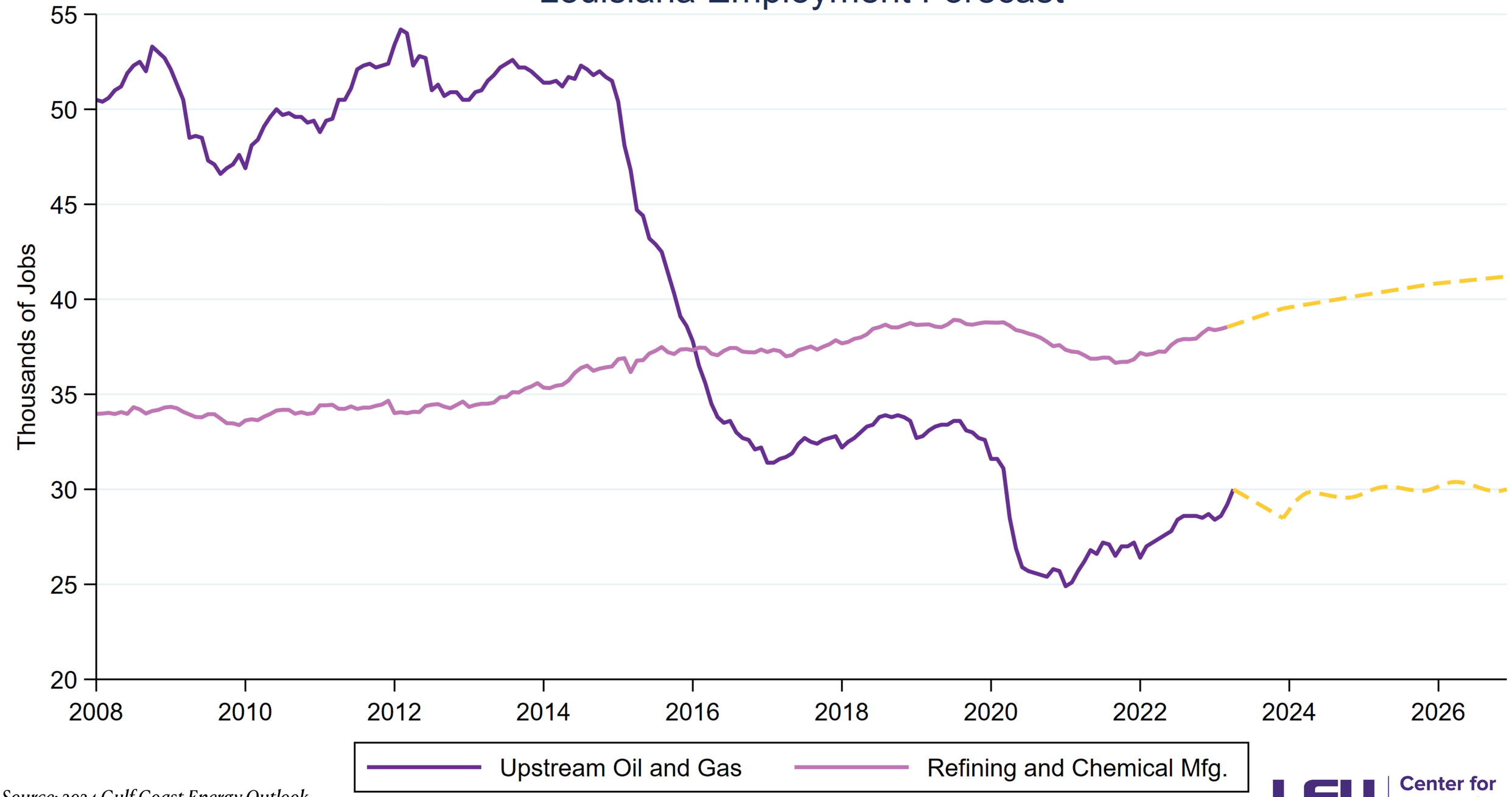
U.S. Exports of Liquefied Natural Gas



Source: U.S. Energy Information Administration

Louisiana Employment Forecast



Source: 2024 Gulf Coast Energy Outlook

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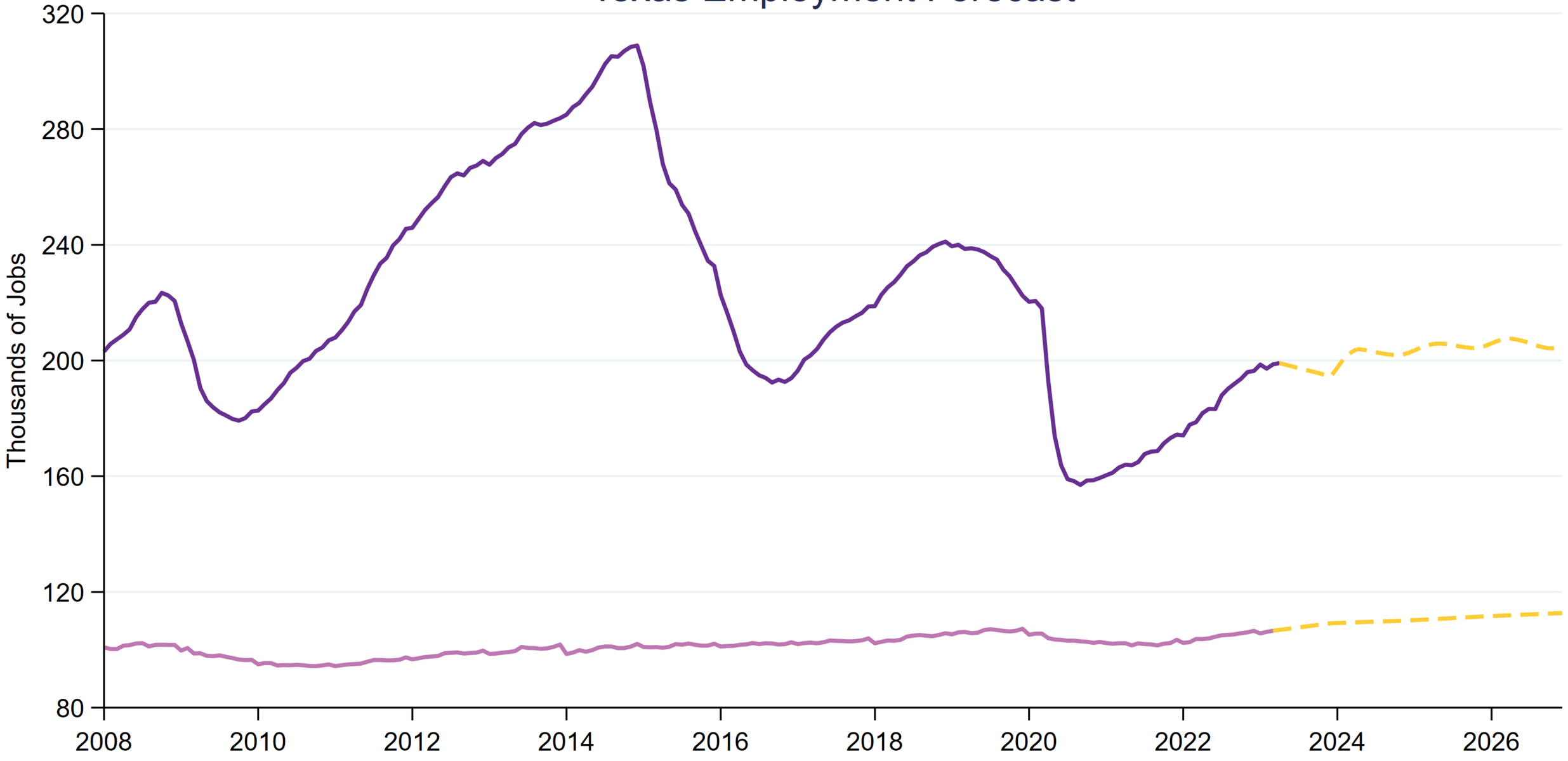
Texas Employment Forecast



Source: 2024 Gulf Coast Energy Outlook

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Stylized Facts about the Louisiana Economy

- Louisiana upstream oil & gas employment **has shrunk in half** over the past seven years or so.
- Refining and chemical manufacturing employment has **increased over this time frame**.
  - Louisiana now **employs more in refining and chemicals** than in **upstream oil and gas**.
  - This is very different than our neighbor, Texas, that still employs ~2 people in upstream for each worker in refining/chemicals.
- The growth in refining and chemicals has been driven by **growth in global demand**, not domestic demand.
  - Unlike the U.S. economy, **Louisiana is a net exporter**.
  - **Louisiana exports ~$3 for every dollar of imports!***

*U.S. Census Bureau. USA Trade.

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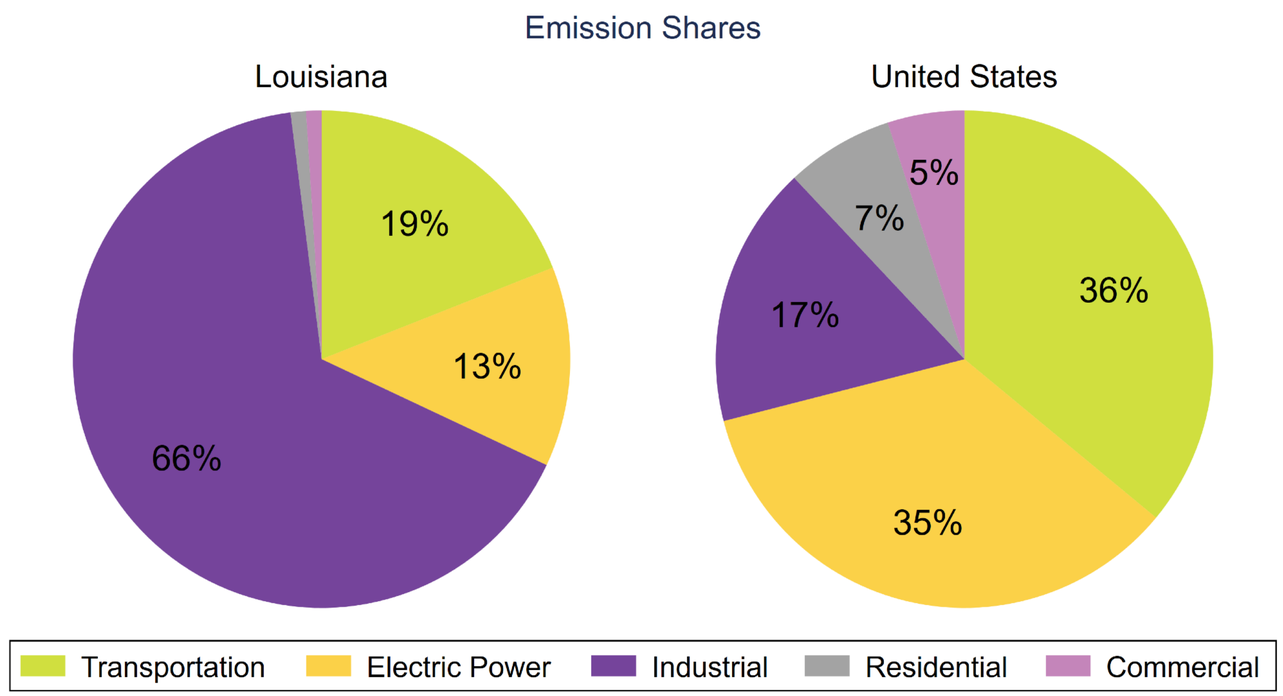
1.2 Decarbonization Efforts: Balancing Cost Competitiveness and Emissions Reductions

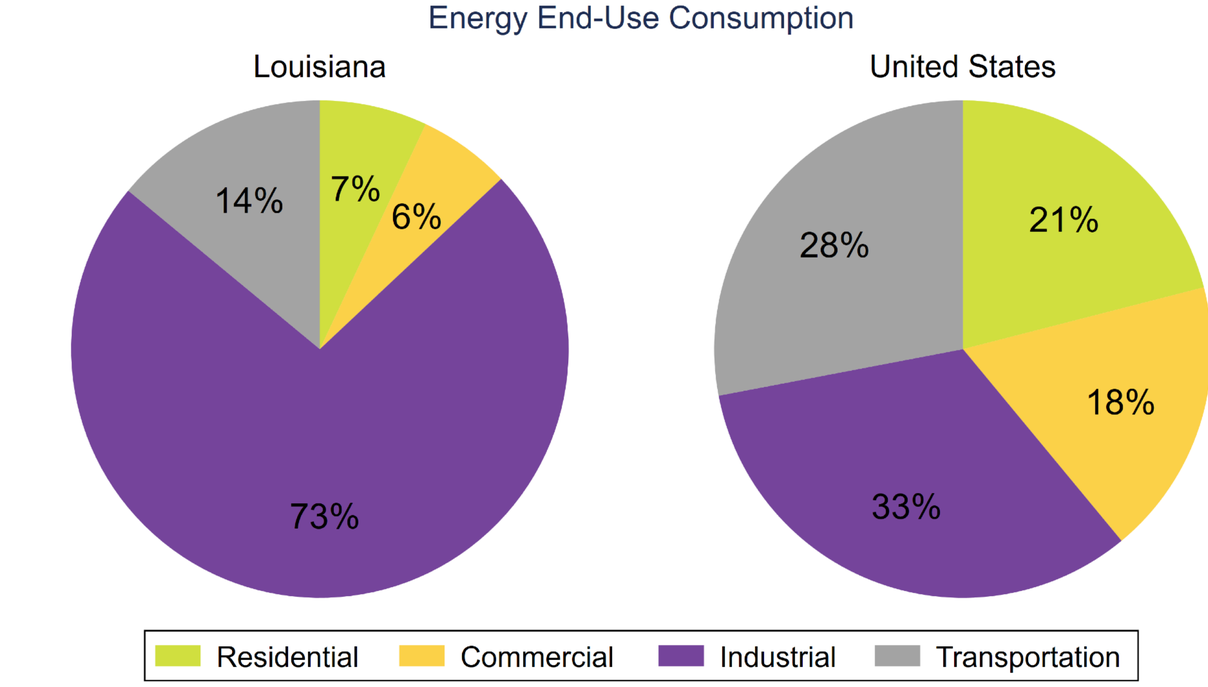
- Decarbonization, particularly industrial decarbonization, continues to take on a new level of importance and urgency each year.
- We are still in the beginning phases of the Inflation Reduction Act's (IRA) 10-years of spending on emissions reductions.
  - IRA signed into law in August of 2022.
  - Energy & climate accounted for 84% of bill's spending.
- Three Stylized Facts:
  1. Energy demand has been flat in the U.S. for a decade, and this is expected to continues.
  2. Energy production has increased over this time period:
     - Oil ↑ 83%; Natural gas ↑ 47%; renewable energy ↑ 51%.
  3. Energy production growth facilitated by exports.

Balancing cost competitiveness and emissions competitiveness at the top of companies minds when making investment decisions.

Source: 2024 Gulf Coast Energy Outlook



Source: Louisiana 2021 Greenhouse Gas Inventory

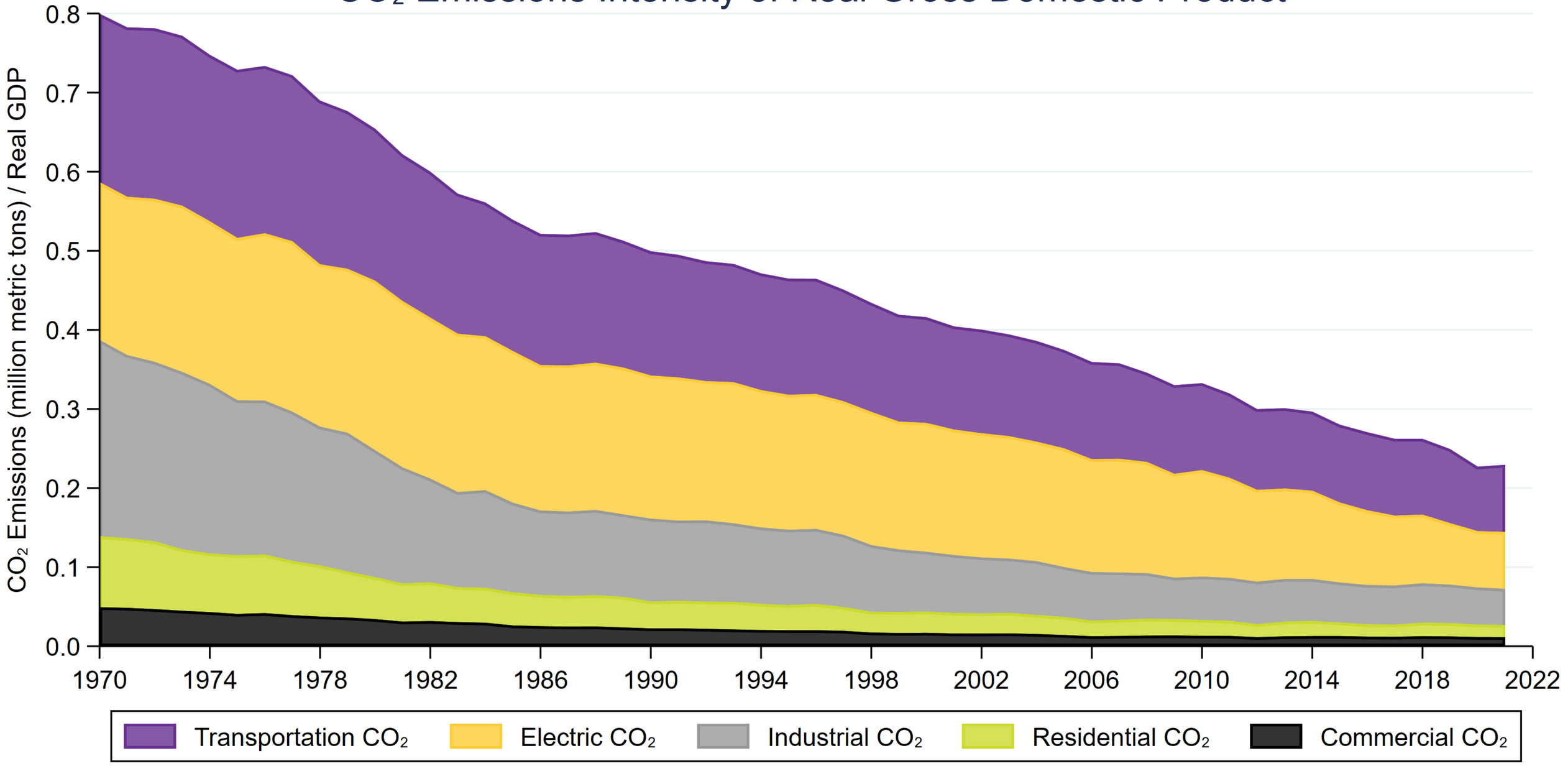


Source: Louisiana 2021 Greenhouse Gas Inventory

Industrial emissions make up ~2/3 of Louisiana's GHG emissions, compared to ~17 percent nationally.

Industrial energy usage makes up approximately ~3/4 of energy usage in Louisiana, compared to ~1/3 nationally.

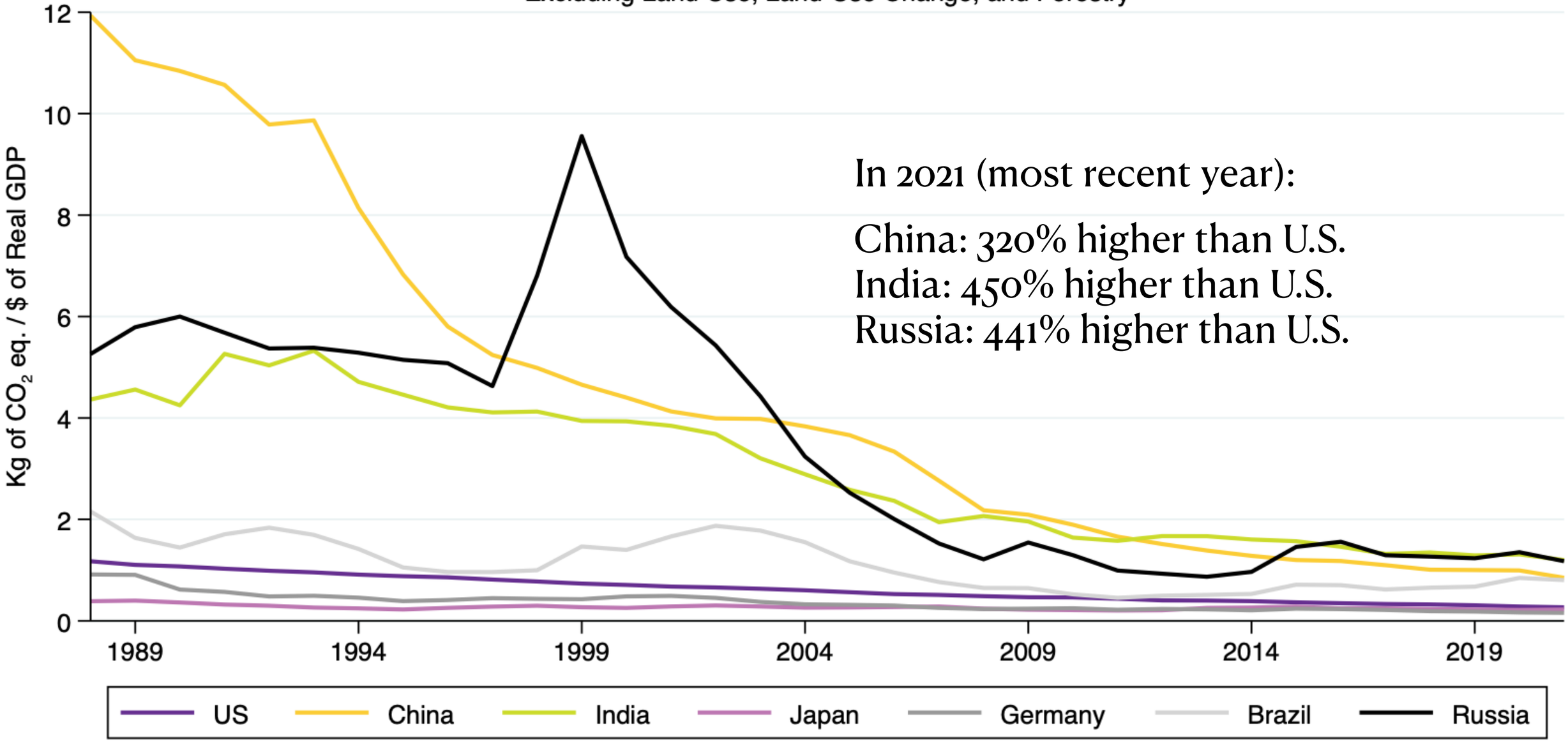
CO_2 Emissions Intensity of Real Gross Domestic Product



Source: U.S. Energy Information Administration
Real GDP is in billions of chained 2017 dollars, not seasonally adjusted

Emissions Intensity of GDP

Excluding Land Use, Land-Use Change, and Forestry



In 2021 (most recent year):

China: 320% higher than U.S.
India: 450% higher than U.S.
Russia: 441% higher than U.S.

Source: GDP data from Bloomberg.
Emissions data from the IMF.

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Risk or Opportunity?

Decarbonization will not only challenge existing Gulf Coast energy manufacturing but also create an opportunity for regional leadership in the development of the production capacity for liquid fuels, chemicals, plastics, fertilizers, and other products historically derived from fossil fuels, with lower, or even net zero GHG emissions. Companies are actively considering the most efficient ways to achieve meaningful emissions reductions given the subsidies that are currently available under the IRA. Over the forecast horizon, the GCEO sees decarbonization creating considerable regional capital investment opportunities. Longer-term effects of decarbonization on the region will be determined by the cost to achieve emissions reductions alongside the global market's willingness to pay a premium for lower emission intensive products.

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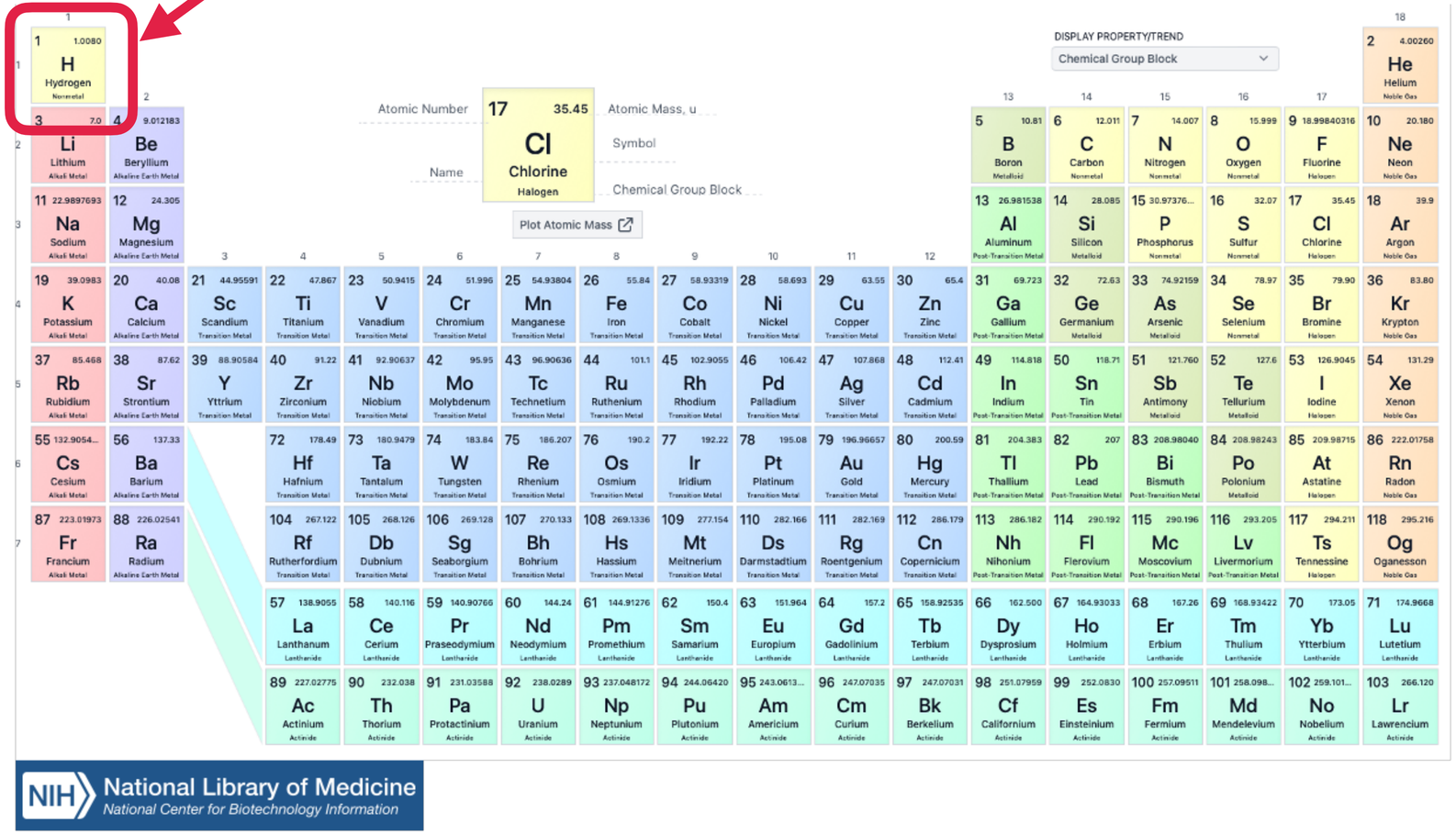
Strategies for Industrial Decarbonization

1. Electrification & Decarbonization of Electric Grid
2. Carbon Capture, Utilization & Storage (CCUS)
3. Hydrogen ⟵
4. Bio-petrochemicals

What is Hydrogen?



NIH National Library of Medicine
National Center for Biotechnology Information

- Hydrogen is the smallest element
  - 12.5% the mass of methane.
- Hydrogen is not generally found in large quantities naturally.
- Thus hydrogen is typically “created” from some process.

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What do we currently use for energy?

- We often use natural gas to generate energy for both industrial uses and electricity.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + energy$$

- Fortunately, natural gas is abundant in geological formations (such as the Haynesville shale).
- Unfortunately, the combustion of natural gas emits CO_2, a greenhouse gas.
- Companies in Louisiana are increasingly considering the emissions intensity of products we produce.
- Combustion of fossil fuels makes up over 80% of all energy used globally and within the United States.*

* Source: International Energy Agency & Energy Information Administration

Why hydrogen?

- One potential pathway is to produce hydrogen.

$$2H_2 + O_2 \rightarrow 2H_2O + energy$$

- Fortunately, we can create energy by adding O_2 (from the air!) with H_2 with no CO_2 emissions.
- Humans have not (yet?) discovered large commercial quantities of naturally occurring H_2.
- But we can create hydrogen through a number of processes. All of these require energy.

Hydrogen can be viewed as a battery in a molecule.

How is Hydrogen Produced?

The hydrogen color spectrum is oftentimes used to specify how hydrogen is produced.

- ~10 million metric tons (MMT) of hydrogen is produced each year in the US.
- ~95% is produced using steam methane reforming (SMR) of natural gas, which is called **grey hydrogen.**
- When grey hydrogen is combined with carbon capture and storage (CCS), this is called **blue hydrogen.**
- When renewable electricity (e.g. solar, wind, etc.)is used for electrolysis of water, this is called **green hydrogen**.
- Naturally occurring hydrogen is called **white hydrogen.**

Whether hydrogen can be used to reduce greenhouse gas emissions depends on the method used to "create" it!

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“Clean” Hydrogen

- The Clean Hydrogen Production Tax Credit is a 10-year incentive up to $3.00 per kg of hydrogen produced.
  - Inflation Reduction Act (IRA) Section 45V.
- Hydrogen production with a maximum carbon intensity of 4 kg of CO_2e/kgH_2 produced qualifies
  - There are different tiers of credits based one carbon intensity.
- Next, we will estimate the amount of hydrogen that would be needed to fulfill certain purposes.

Hydrogen Potential in Louisiana

Current Uses of Hydrogen:

- Crude oil refining
- Ammonia for Fertilizers
- Methanol

Potential Future Uses:

- Export for energy (similar to LNG).
- Manufacturing Energy Consumption
- Electricity Generation

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Ammonia Production

- Ammonia (NH_3) is used primarily as a fertilizer.
  - Produced via the Harber-Bosch process.
  - "Anhydrous ammonia" is a gas at atmospheric pressure, its usually stored under pressure or refrigerated (at -33°C) and can be directly injected into the soil.
  - Ammonia is also converted to other forms such as urea (solid), and UAN solutions (liquid). These have practical benefits.
  - Urea is the most common N fertilizer.*
- Louisiana accounts for 32% of US nitrogen production capacity.
  - 8 plants in Louisiana at 4 different sites.

Photo Source: Adobe Stock

* Source: Pioneer, University of Illinois FarmDocDaily.

Ammonia Production

Analysis

- Annual ammonia production capacity in Louisiana obtained from United States Geological Survey (USGS).*
- Ammonia production capacity in Louisiana was 6.17 million metric tons in 2022.
- We calculated hydrogen consumption based on equations for the Haber-Bosch reaction, with a 90 percent capacity utilization.

Result: We estimate 0.98 MMT of hydrogen per year is used for ammonia production in Louisiana

* Source: US Nitrogen Statistics and Information Minerals Yearbook. Table 4: Domestic Producers of Anhydrous Ammonia

Crude Oil Refining

- Refining of crude oil requires hydrogen for removal of sulfur (***desulfurization***) and the cracking of heavier compounds into lighter ones (***hydrocracking***).
  - This is needed for low-sulfur diesel and production of lower distillates from crude oil.
- Hydrogen is typically generated on site using natural gas at refineries or is supplied by merchant hydrogen producers.
  - Regardless of the producer (refinery or merchant), hydrogen for this purpose today is made almost entirely from SMR.
- The amount of hydrogen needed for this process depends on properties such as density (API gravity) and sulfur content (“sour” or “sweet”).

Photo Source: Adobe Stock

Crude Oil Refining

Analysis

- The annual atmospheric crude oil distillation capacity for 2023 in Louisiana is 3.12 million barrels per stream day.*
  - Converted this to throughput using the 2023 percent utilization of refinery operable capacity of 93.8%.**
  - We calculate hydrogen consumption using estimates to treat a barrel of crude oil: 329 ft^3/bbl.***

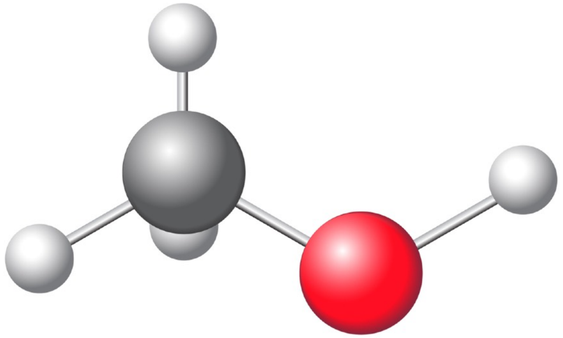
Result: ~0.89 MMT of hydrogen per year is currently used in crude oil refining.

* Source: EIA. Annual operable atmospheric crude oil distillation capacity. ** EIA. Gulf Coast Refining District Percent Utilization of Refinery Operable Capacity. ***Argonne National Laboratory.

Methanol Production

- Methanol is a prominent industrial chemical and solvent.
- It is a precursor for chemicals such as formaldehyde and acet acid.
- Methanol is primarily produced using natural gas (methane).
  - Steam methane reforming of natural gas is used to create synthesis gas.
  - Synthesis gas is reacted with catalyst to produce methanol and water.
- There is additional interest in methanol as a marine fuel to replace maritime diesel.
  - Example: Strategic Biofuels in Caldwell Parish.

Methanol



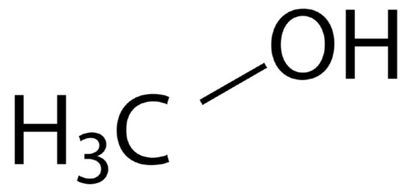


Photo Source: Adobe Stock

Methanol Production

Analysis

- We obtained annual methanol production capacity of **4 MMT per year** from two facilities in Louisiana.*
  - Methanex USA, LLC (Ascension Parish): 2.2 MMT/yr
  - Koch Methanol St. James (St. James Parish): 1.8 MMT/yr.
- We calculate the amount of hydrogen needed for these facilities with a capacity factor of 90%.

Result: ~0.56 MMT of hydrogen per year is currently used in methanol production in Louisiana.

* Source: Company websites.

Hydrogen Potential in Louisiana

Figure 2: Current and potential future estimates of hydrogen usage from multiple applications in Louisiana

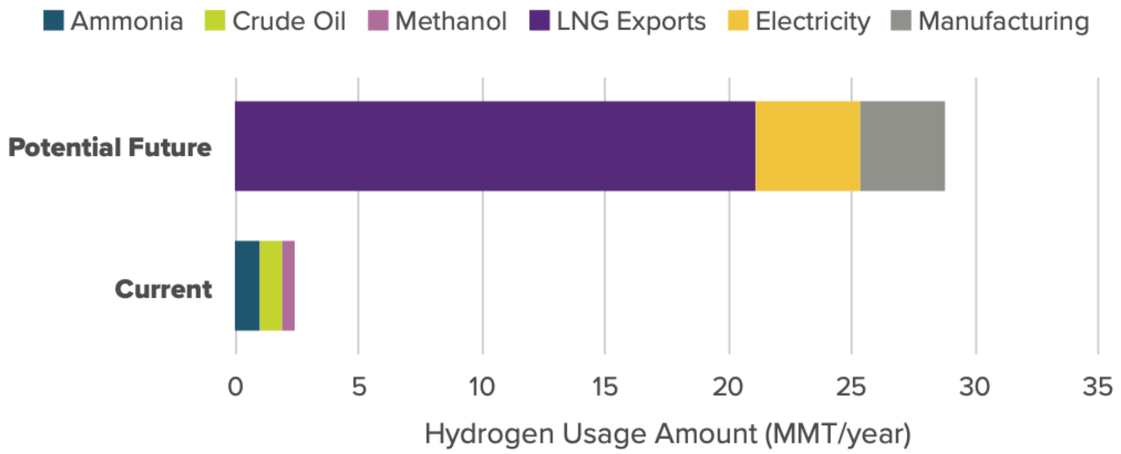


Table 1: Total potential consumption of hydrogen in Louisiana from several applications

Annual Hydrogen Usage Amount in Louisiana (MMT/yr)	
Current Sources	
Production of Ammonia	0.98
Refining of Crude Oil	0.89
Methanol	0.56
Current Total	*2.43*
Potential Future Sources	
Exports of LNG	21.13
Electricity Generation	4
Manufacturing Energy	3.5
Potential Future Total	*28.63*

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LNG Exports

- As mentioned, Louisiana exports energy globally!
- Natural gas is exported in the form of liquified natural gas (LNG).
  - Natural gas is cooled to -162°C (-260°F) for liquefaction.
  - This increases the density by ~600 times making it more efficient for shipping.
  - LNG is loaded into double-hulled tankers on vessels and shipped to other countries.
- Louisiana accounted for 63% of total U.S. LNG exports in 2022.
  - There are currently four operating LNG export terminals in Louisiana.

Photo Source: Adobe Stock

We ask the question: *how much hydrogen would need to be exported to have this same energy content of current LNG exports?*

LNG Exports

Analysis

- Louisiana exported 2.45 trillion cubic feet (Tcf) of LNG in 2022, or about 6.7 Bcf/day.
  - European companies have expressed interest in importing large quantities of hydrogen from the U.S. to meet their energy needs as they wean off of fossil fuels.
  - Hydrogen is included among sectors such as fertilizers, cement, etc., as part of the EU's carbon Border Adjustment Mechanism (CBAM).
  - CBAM seeks to put a "fair price" on carbon-intensive imports into the EU.*
- We calculate the amount of hydrogen required to be equal to the energy content of 2022 LNG exports from Louisiana and compute the mass of hydrogen required to fulfill this energy.
- We repeat this calculation for ammonia assuming that the hydrogen is generated for conversion into ammonia for shipping (instead f shipping hydrogen directly).

Result: ~21.1 MMT of hydrogen would be needed to export the same energy content as LNG in 2022.

24.1 MMT hydrogen would be needed as ammonia.

* Source: European Commission website.

Electricity Generation

- Natural gas accounts for ~69% of electricity generation in Louisiana and ~43% nationwide.
- Nuclear is the second largest electricity generation source, accounting for 15% of generation.
- Hydrogen can be combusted to create electricity, similarly to natural gas.

Electricity Generation

Analysis

- Data on annual natural gas consumption for electricity generation comes from EIA-923.
- The 5-year average natural gas used for electricity generation in Louisiana is about 1.33 Bcf/d.
- We estimate how much hydrogen would be needed to produce the same amount of electricity that is currently produced with natural gas.
  - Calculation assumes conversion efficiency of Btus to electricity is the same for hydrogen and natural gas.

Result: ~4.17 MMT of hydrogen per year would be needed to generate the same amount of electricity that currently comes from natural gas. Note that this would require building electricity generators capable of producing electricity from hydrogen and would require considerable capital investment.

Manufacturing

- Natural gas is also used for non-electricity applications in manufacturing industry for heating applications and other uses.
- This is also referred to as “industrial process heat” and refers to several methods where `heat is used to transform materials into useful products.’
- Examples include removal of moisture, chemical separation, production of process steam, melting of plastics, etc.*
- Includes consumption for:
  - Indirect uses: boiler fuel.
  - Direct uses: Process heating and cooling, refrigeration, etc.
  - Non-process direct uses : facility HVAC, lighting, etc.
- Can account for ~half of onsite energy use and 30% of GHG emissions.*

* Source: U.S. Department of Energy Industrial Efficiency and Decarbonization Office.

Manufacturing

Analysis

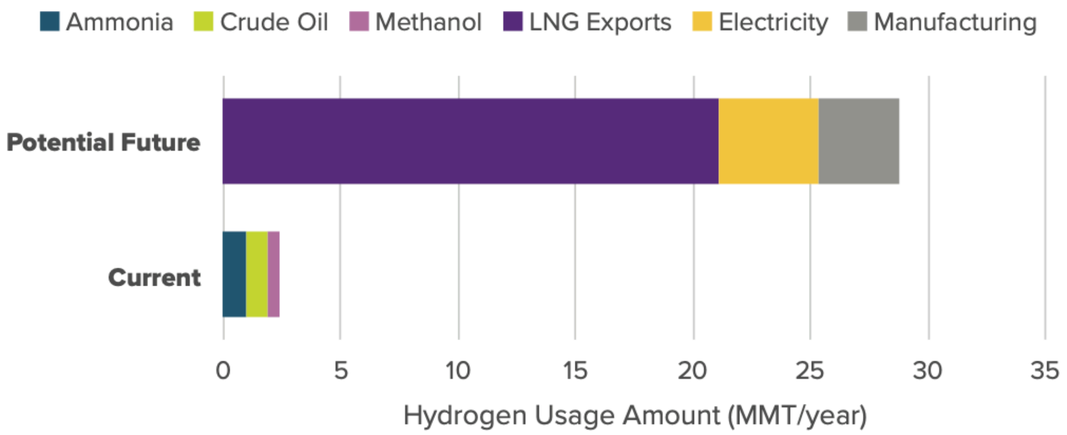
- Obtained industrial energy consumption (non-electricity) statistics for the South Census Region (SCR).*
- The SCR share of manufacturing energy fulfilled using natural gas is 10.1 Quads, per 2018 survey results.
- To filter this data for Louisiana, we estimate Louisiana's share of natural gas consumption in the industrial sector:
  - Louisiana's share of natural gas consumption in the industrial sector is ~23% of that of the SCR.**

Result: ~20.4 MMT of hydrogen would be needed to provide same energy content as natural gas consumed for manufacturing in Louisiana.

* Source: EIA. Manufacturing Energy Consumption Survey (MECS). ** EIA. State Energy Data System (SEDS).

Hydrogen Potential in Louisiana

Figure 2: Current and potential future estimates of hydrogen usage from multiple applications in Louisiana



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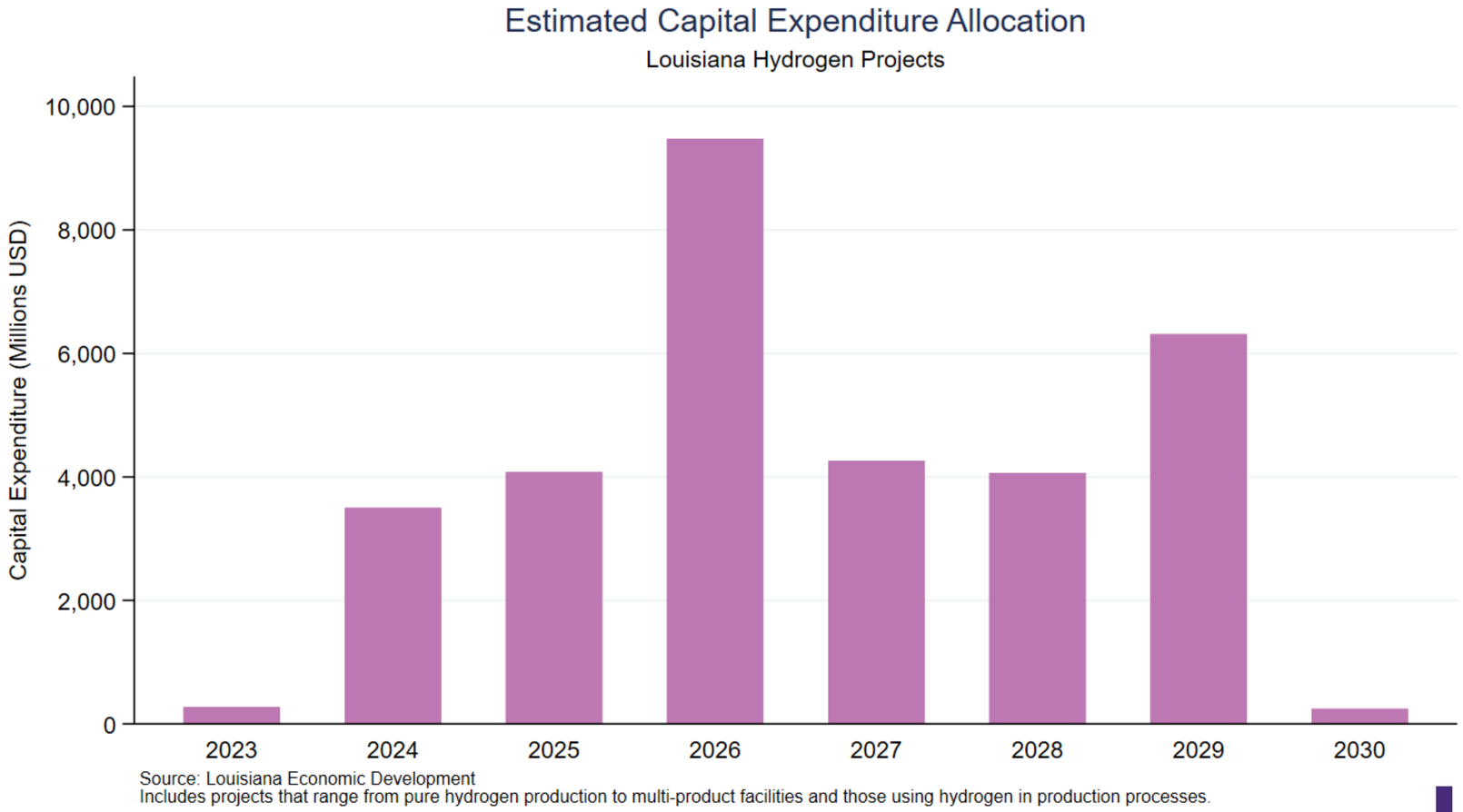
Project Announcements

According to LED, there are currently nine announced hydrogen projects, summing to over $32 billion in Capex.



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Conclusions

- Louisiana's economy is likely to be **impacted by decarbonization policies**, from both governments and multi-national corporations, **regardless of the political actions taken by the state of Louisiana and U.S. federal government**.
- Louisiana has experienced growth in the refining and chemical manufacturing—industries with significant GHG emissions.
- Potential decarbonization strategies for Louisiana include:
  - CCUS
  - Hydrogen
  - Bio-petrochemicals
  - Decarbonize the electric grid

There is ample opportunity for hydrogen to grow significantly in Louisiana. The question is whether companies can make the economics work.

Hydrogen Potential in Louisiana

Figure 2: Current and potential future estimates of hydrogen usage from multiple applications in Louisiana

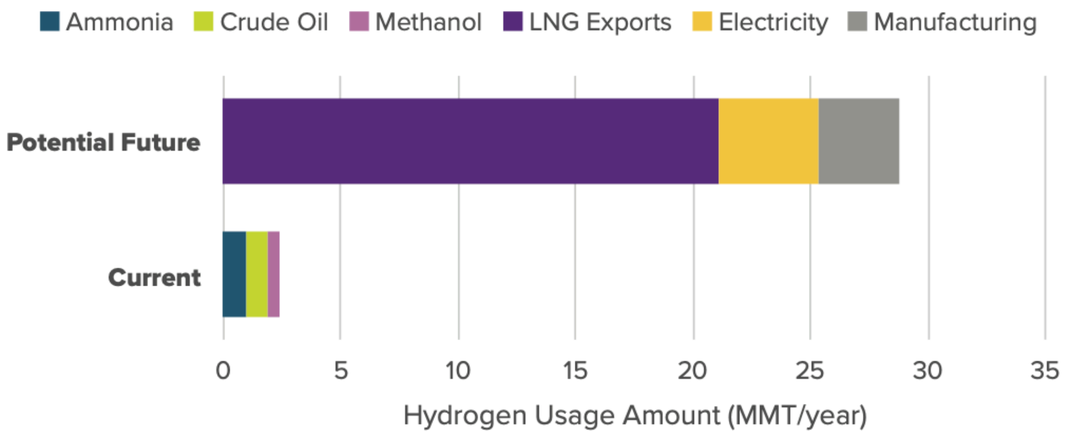

Table 1: Total potential consumption of hydrogen in Louisiana from several applications

Annual Hydrogen Usage Amount in Louisiana (MMT/yr)	
Current Sources	
Production of Ammonia	0.98
Refining of Crude Oil	0.89
Methanol	0.56
Current Total	*2.43*
Potential Future Sources	
Exports of LNG	21.13
Electricity Generation	4
Manufacturing Energy	3.5
Potential Future Total	*28.63*

Questions / Discussion

Photo Source: Adobe Stock

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