Global Gas Phase II: The Climate, Economic, and National Security Roles of U.S. Natural Gas Uses and Exports

Melanie Kenderdine

NASEO Annual Meeting, Portland Oregon

October 17, 2023

Global Gas Phase I Study: Cross-cutting Issues From All Workshops

In all regions, workshop participants expressed ***strong commitments to reducing greenhouse gas emissions*** and each region had a distinct approach to mitigation

There is ***shared agreement that there may be a continued role for natural gas in a decarbonized global economy***, although there may be significant regional differences and conflicts with local decarbonization goals

Workshop participants stated that ***global emissions reductions may fall far short of what would be necessary*** to prevent the worst outcomes of climate change

Participants found that ***impacts of COVID-19 on decarbonization efforts vary widely across regions***

Innovations in clean energy technologies are needed

The cost of natural gas relative to alternative sources of energy, including clean energy technologies, will ***factor heavily into regional gas use***

Innovative business models and project financing mechanisms are needed to build out energy infrastructures.

Infrastructure investor and financial institutions are shifting their focus to low carbon solutions

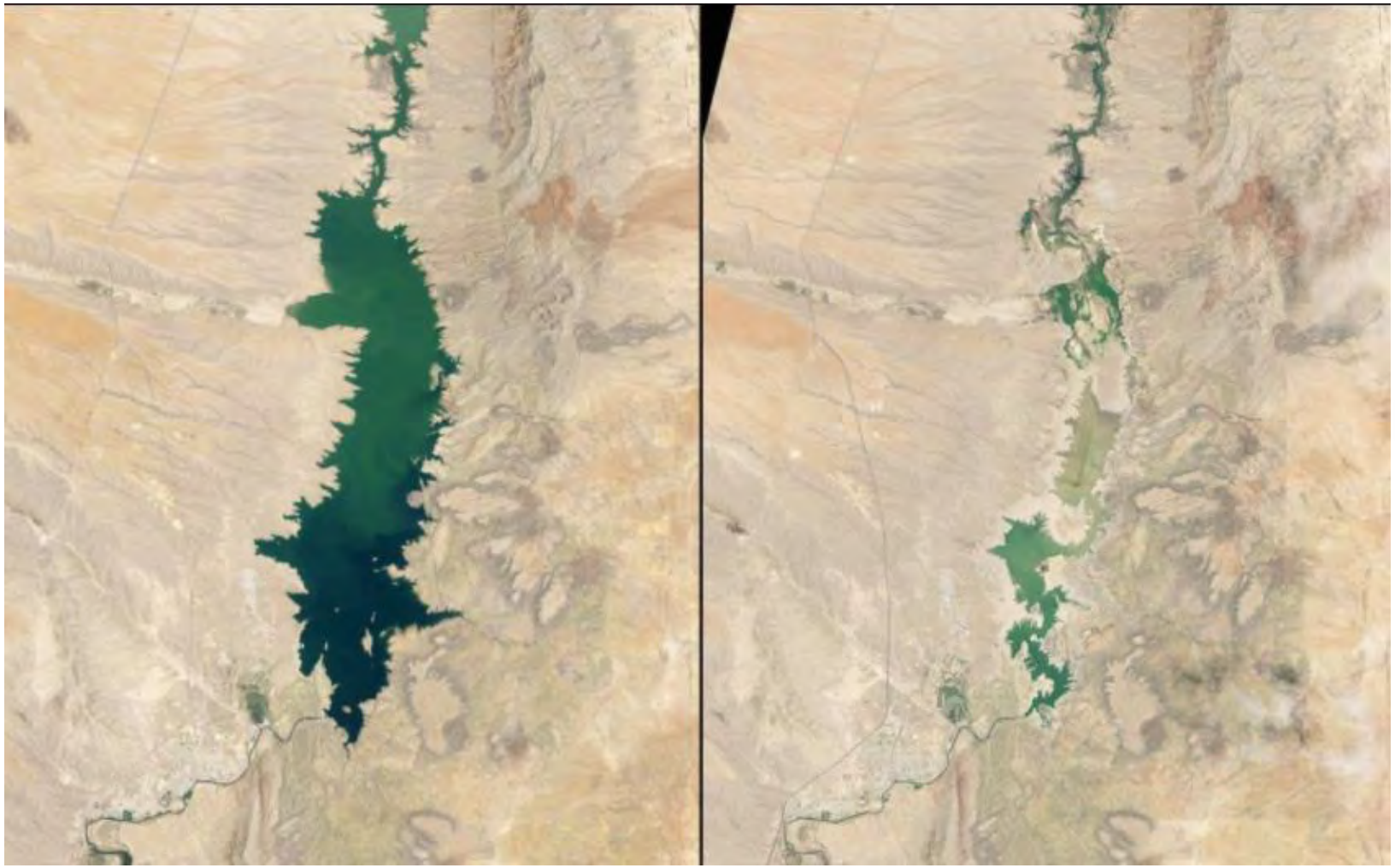
The need for resilient, reliable, secure energy systems is growing in importance as climate risks increase.

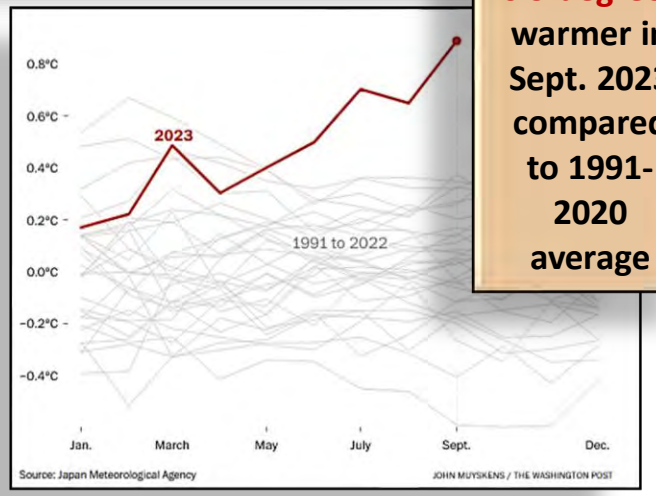
North America's significant domestic natural gas supply presents opportunities and challenges for gas use in the region and the world going forward.

NASA Satellite Photos, Elephant Butte Reservoir, New Mexico, My Home State

1994

2013





0.9 degrees warmer in Sept. 2023 compared to 1991-2020 average

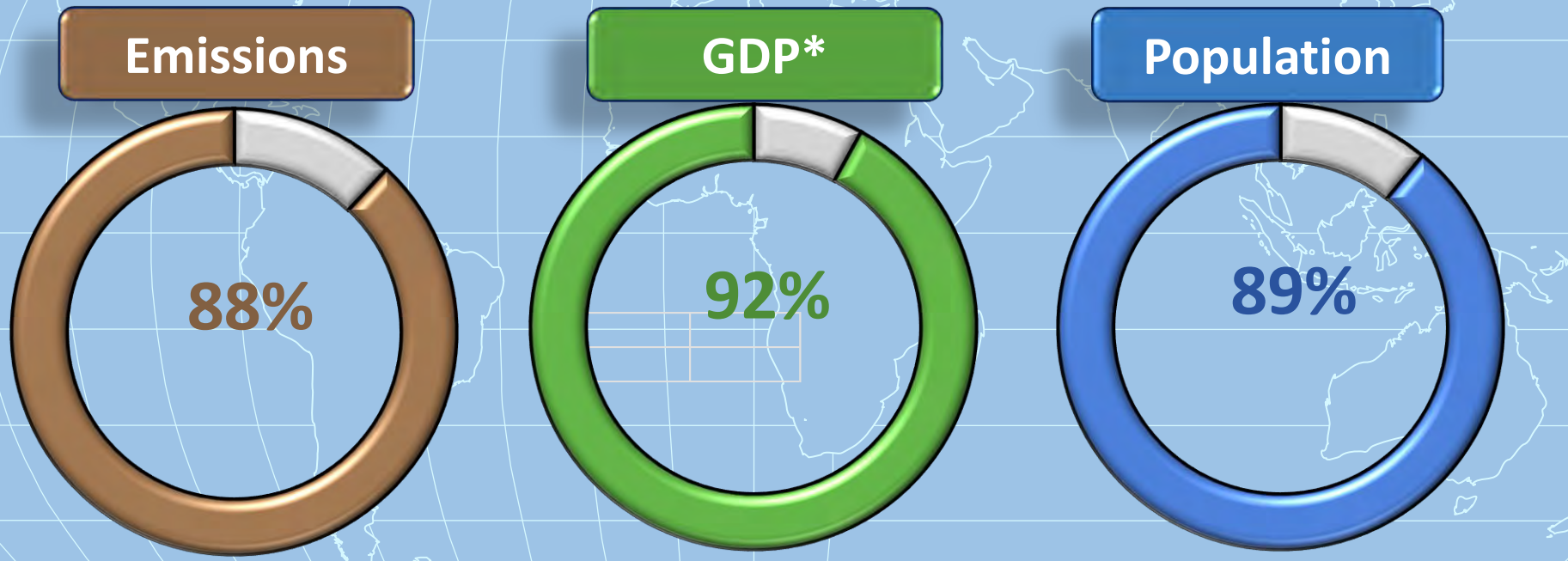
On the ground at Elephant Butte, 2019

Need for Decarbonization

Net Zero Target Coverage, June 2023

*purchase power parity

Net Zero commitments cover --



*Black et al. 2021, Data: Dec. 2020

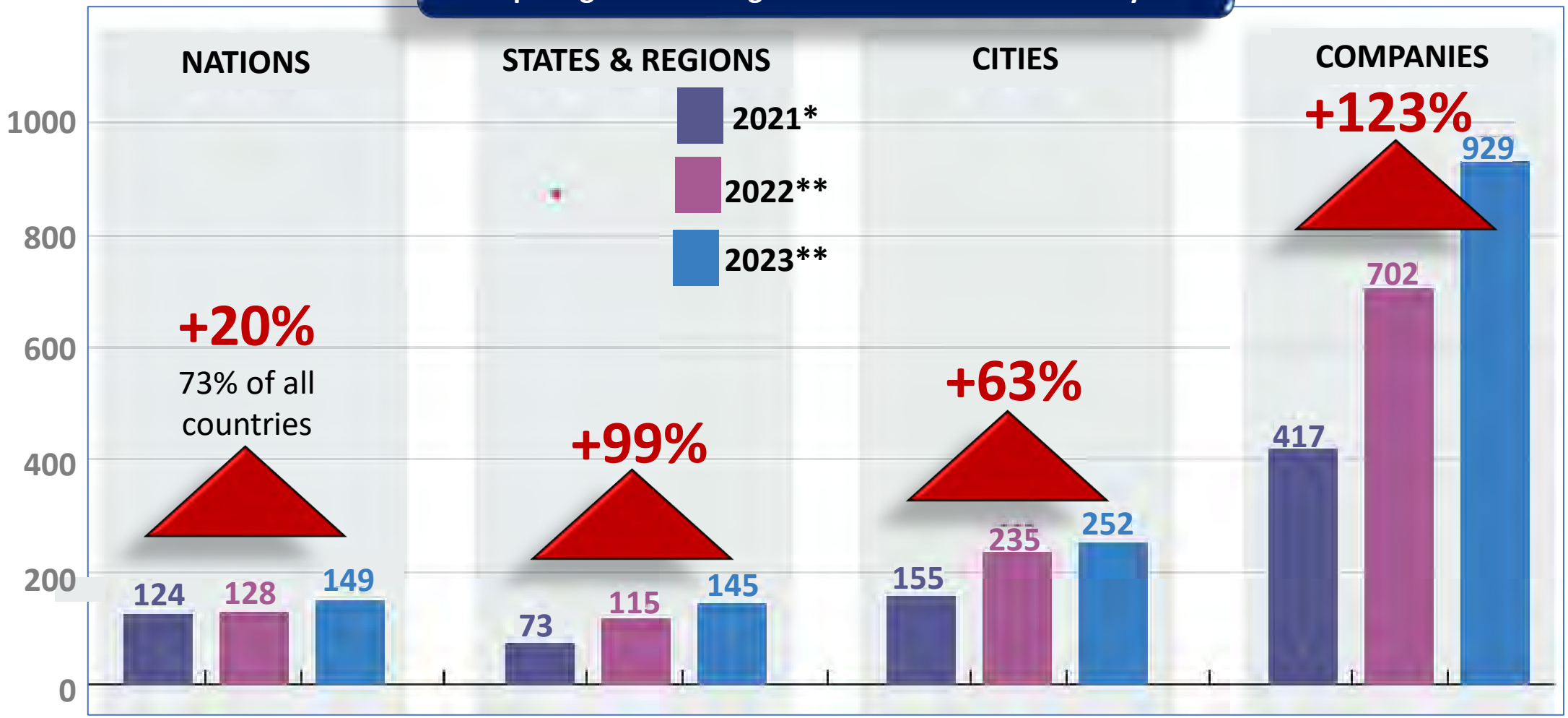
**Net Zero Stocktake 2022, Data: Jume 2022

**Net Zero Stocktake 2023, Data: Jume 2023

https://zerotracker.net/analysis/net-zero-stocktake-2022

Net Zero Target Coverage, June 2023

Net Zero Target Setting
Comparing net zero target numbers over the last 2.5 years



*Black et al. 2021, Data: Dec. 2020

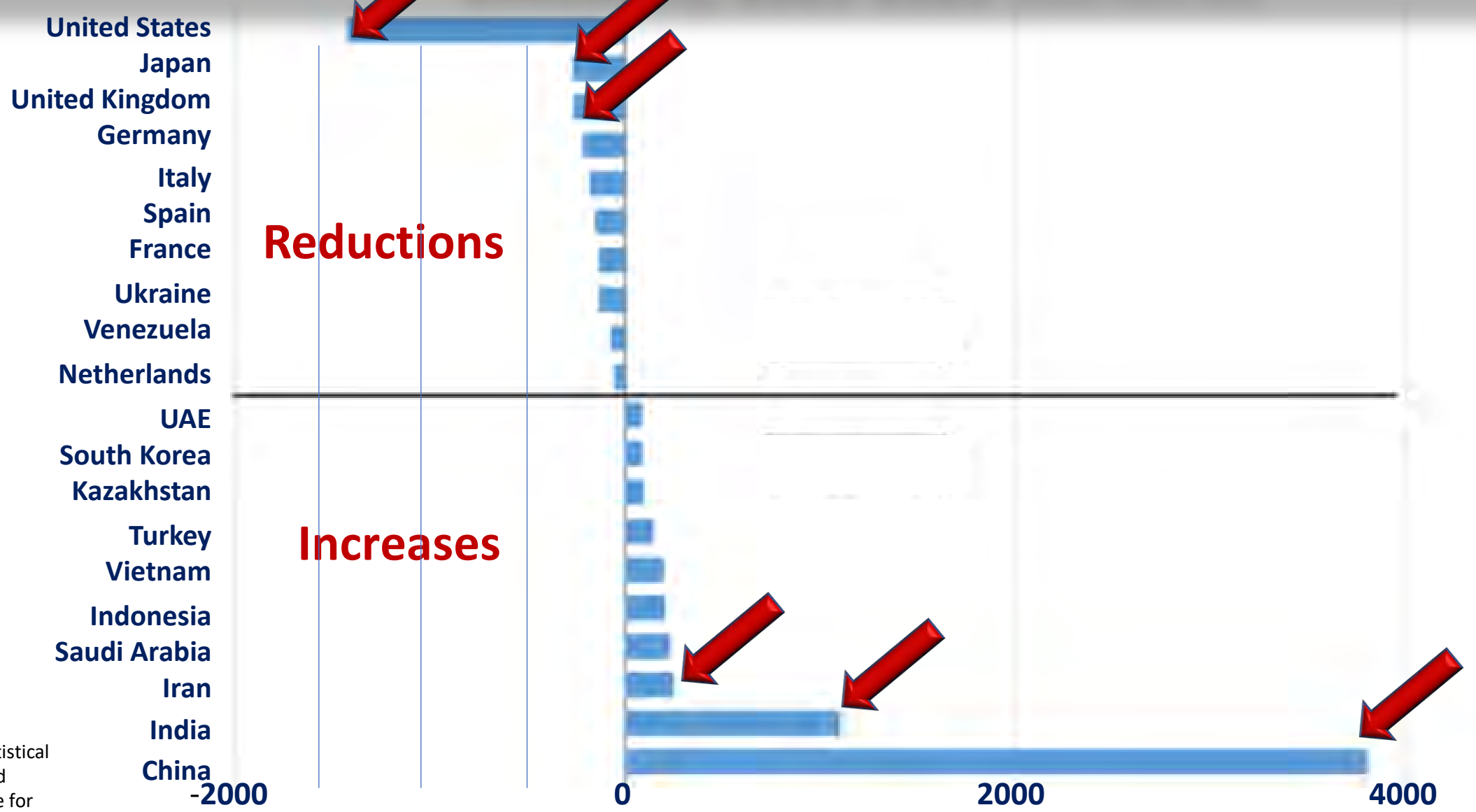
**Net Zero Stocktake 2022, Data: June 2022

**Net Zero Stocktake 2023, Data: June 2023

https://zerotracker.net/analysis/net-zero-stocktake-2022

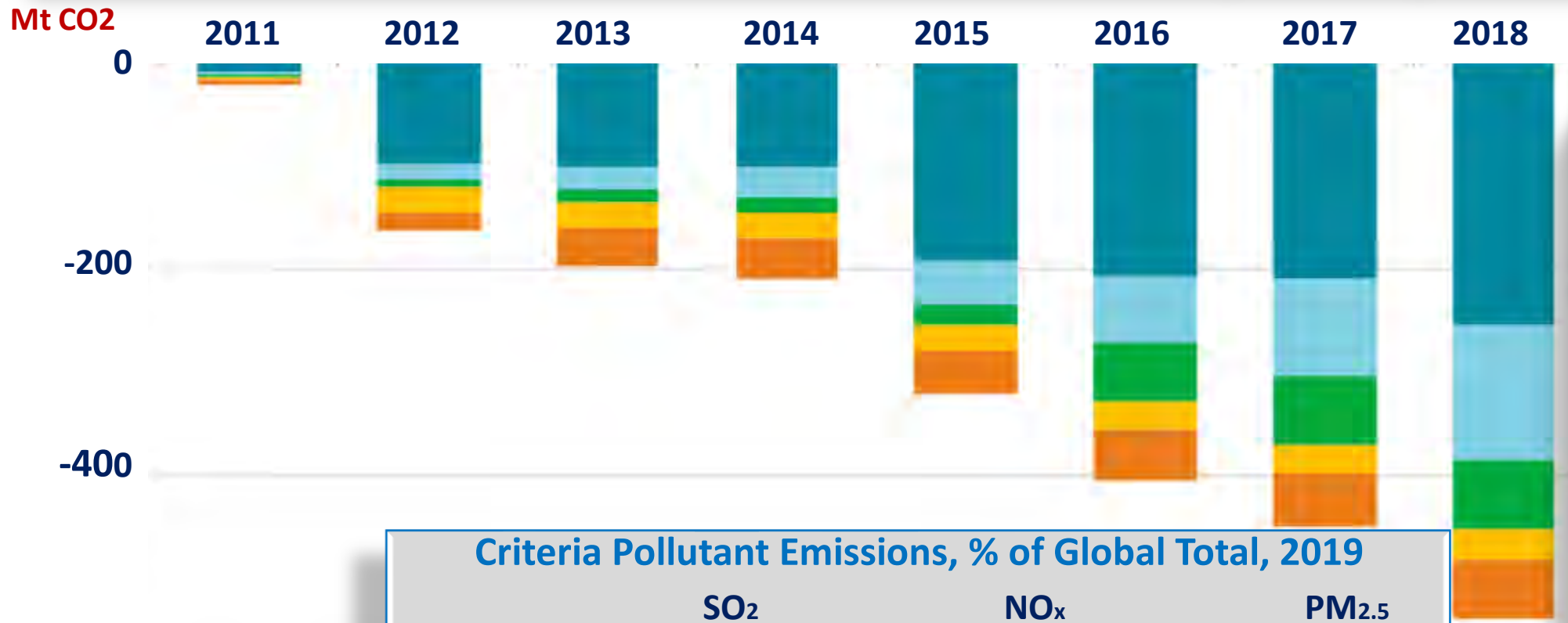
Global Trends/Issues

10 Countries with Largest Reductions and Increases in CO2 Emissions, 2005-2020 (million metric tons)



Sources: BP Statistical Review of World Energy, Institute for Energy Research

Regional CO_2 Savings from Coal to Gas Fuel Switching, Since 2010 ($MtCO_2$)



Since 2010, coal-to-gas switching has saved around 500 million tonnes of CO2 - an effect equivalent to putting an extra 200 million EVs running on zero-carbon electricity on the road over the same period.

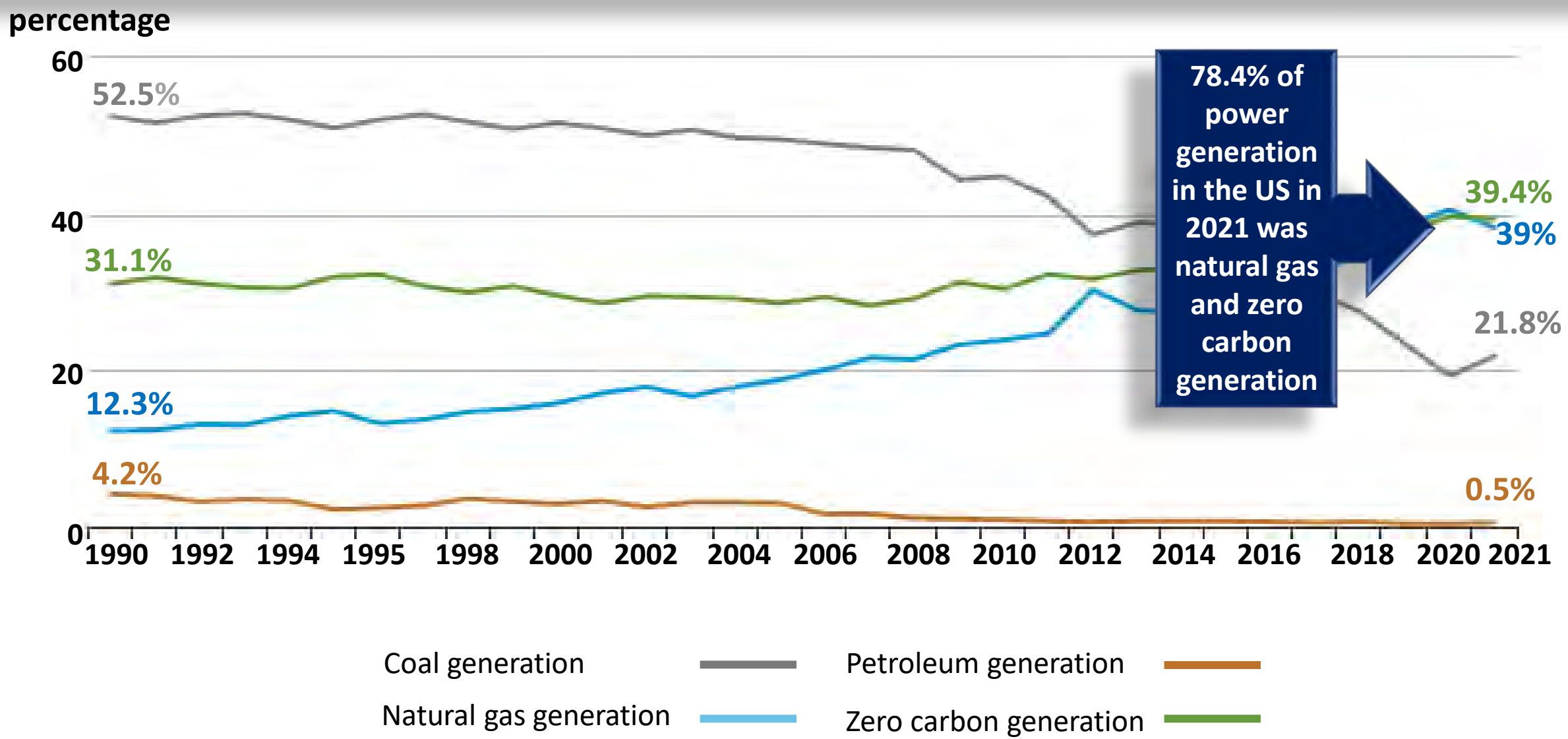
IEA

Criteria Pollutant Emissions, % of Global Total, 2019

	SO_2	NO_x	$PM_{2.5}$
Coal	58%	14%	16%
Oil	37%	72%	20%
Natural Gas	0.7%	10%	4%
Bioenergy	5%	4%	63%

https://www.iea.org/reports/the-role-of-gas-in-todays-energy-transitions

US Annual Percentage of Power Generation by Source, 1990-2021



Source: EIA website

CO_2 Emissions Reductions Caused by Change in Fuel Mix for US Power Generation, 2005-2021

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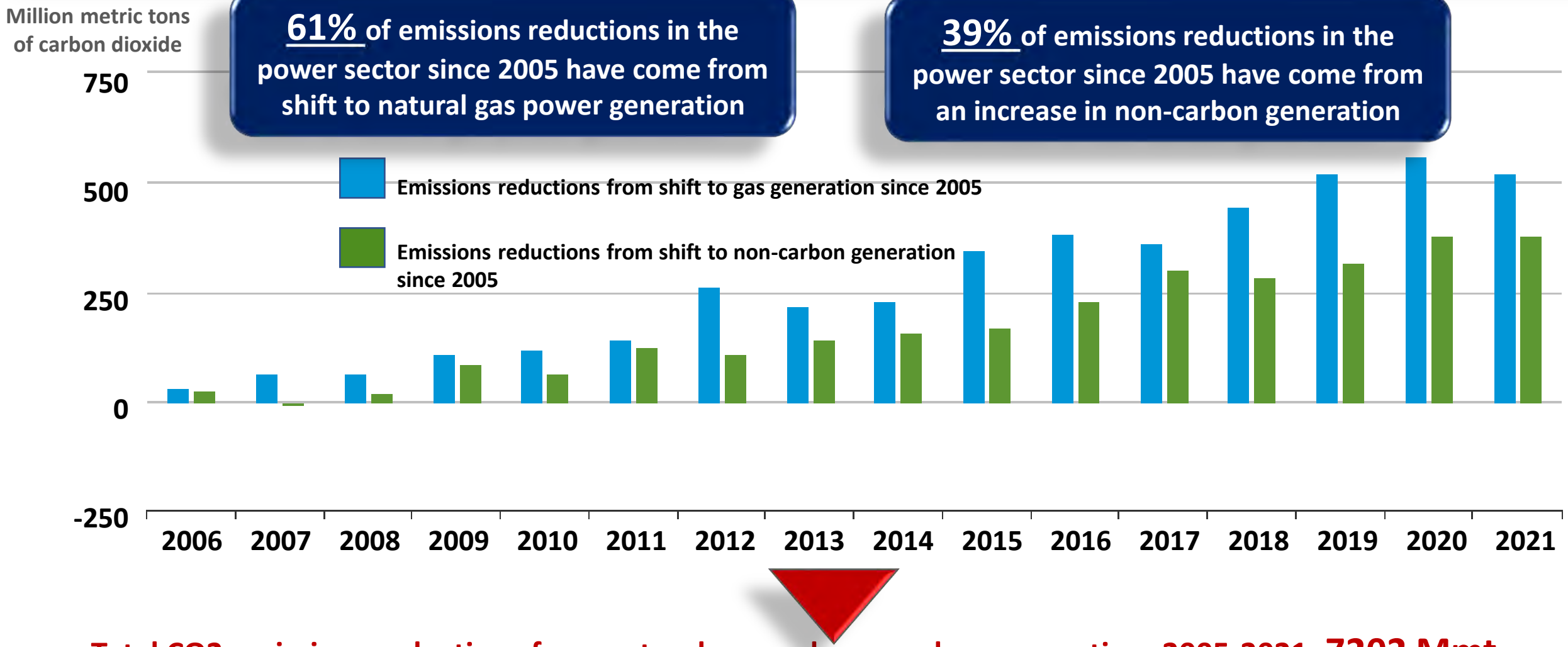
61% of emissions reductions in the power sector since 2005 have come from shift to natural gas power generation

39% of emissions reductions in the power sector since 2005 have come from an increase in non-carbon generation



Total CO2 emissions reductions from natural gas and non-carbon generation, 2005-2021: 7202 Mmt

https://www.eia.gov/environment/emissions/carbon/index.php/pd/pdf/2019_co2analysis.pdf

Levelized Cost of Electricity (LCOE) & Storage (LCOS) for Plants Entering Service in 2027

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USC Coal → $82.61
$52.11 — 85%

Combined Cycle → $39.94
$9.36 — 87%

Advanced Nuclear → $88.24 / $81.71
$60.71 — 90%

Battery Storage → $128.55
$64.03 — 10%

Combustion Turbine → $117.86
$53.78 — 10%

Capacity Resource Technologies

Geothermal → $39.82 / $37.62
$22.04 — 90%

Dispatchable

Onshore Wind → $40.23
$29.90 — 41%

Offshore Wind → $136.51 / $105.38
$103.77 — 44%

Solar Standalone → $36.49 / $33.83
$26.60 — 29%

Hydroelectric → $64.27
$46.58 — 54%

Resource Constrained Technologies

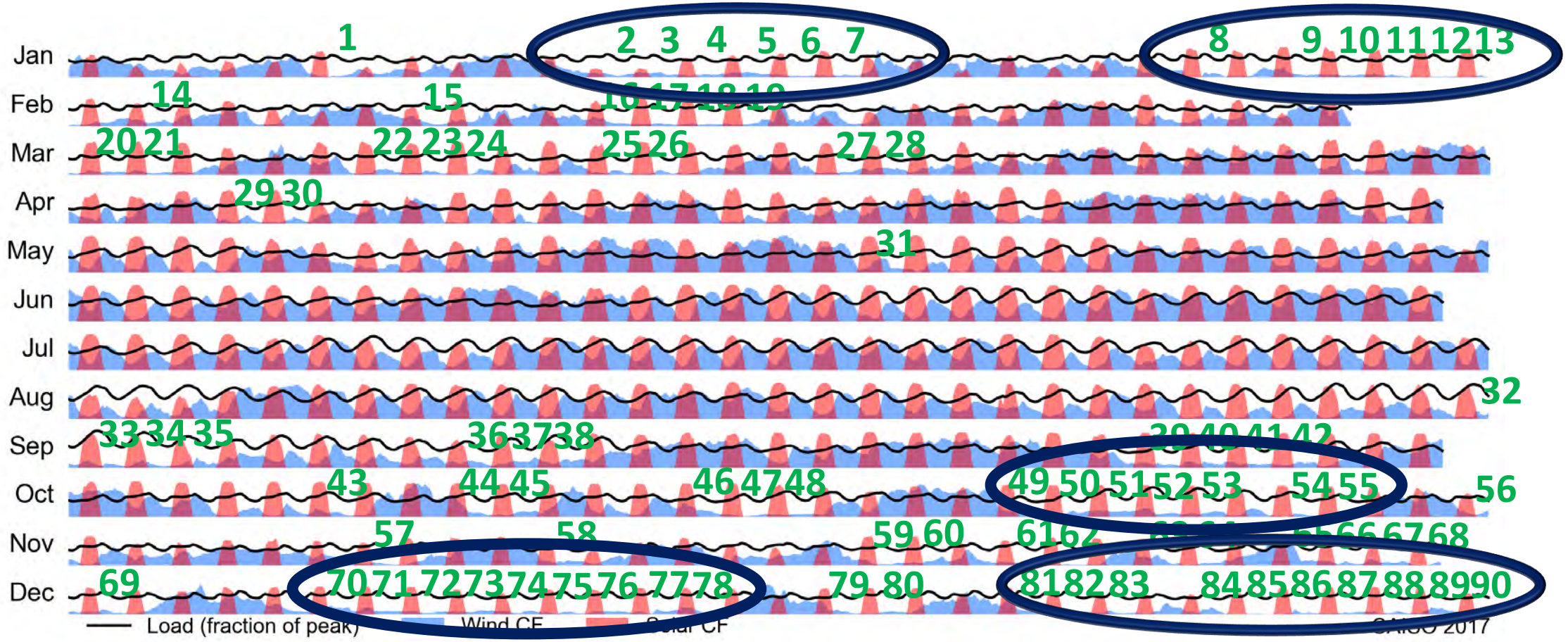
Total system LCOE or LCOS (2020 $/MWhr) w/tax credit
Total system LCOE or LCOS (2020 $/MWhr)
Levelized capital cost
Capacity factor

Electricity

https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

The Challenges of Integrating Intermittent Renewables

Over the course of a year large-scale dependence on both wind and solar will result in significant periods requiring very large-scale back-up options



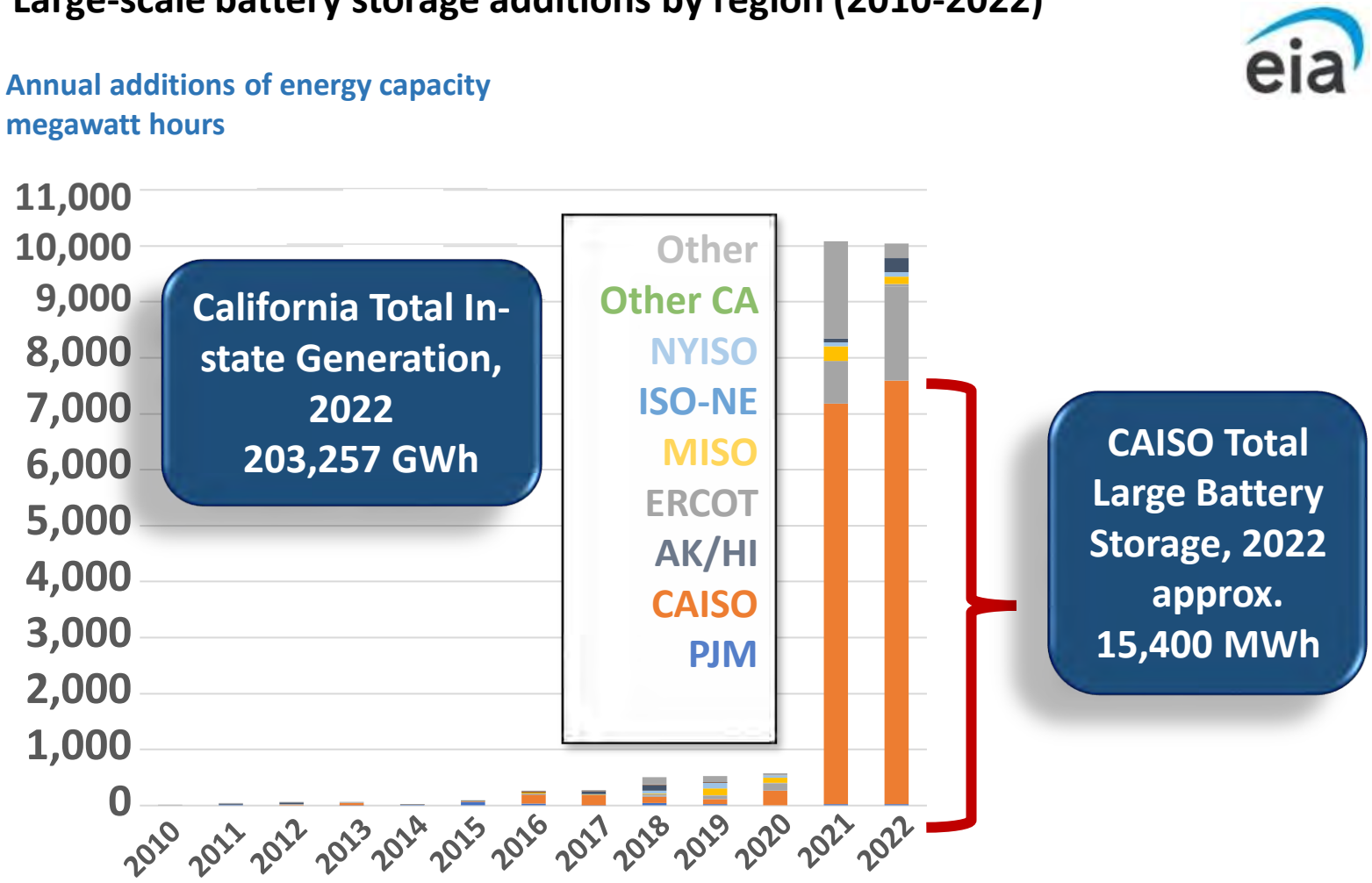
Hourly trends in solar and wind capacity factors in CA for 2017 aligned to normalized variation in hourly load relative to peak daily load

Source: CAISO data, EFI analysis

Source: EIA, 2020

The Challenges of Integrating Intermittent Renewables

Large-scale battery storage additions by region (2010-2022)



Data source: U.S. Energy Information Administration, *2022 Form EIA-860 Early Release, Annual Electric Generator Report*

Source: EIA, 2020

Source: CAISO data, EFI analysis

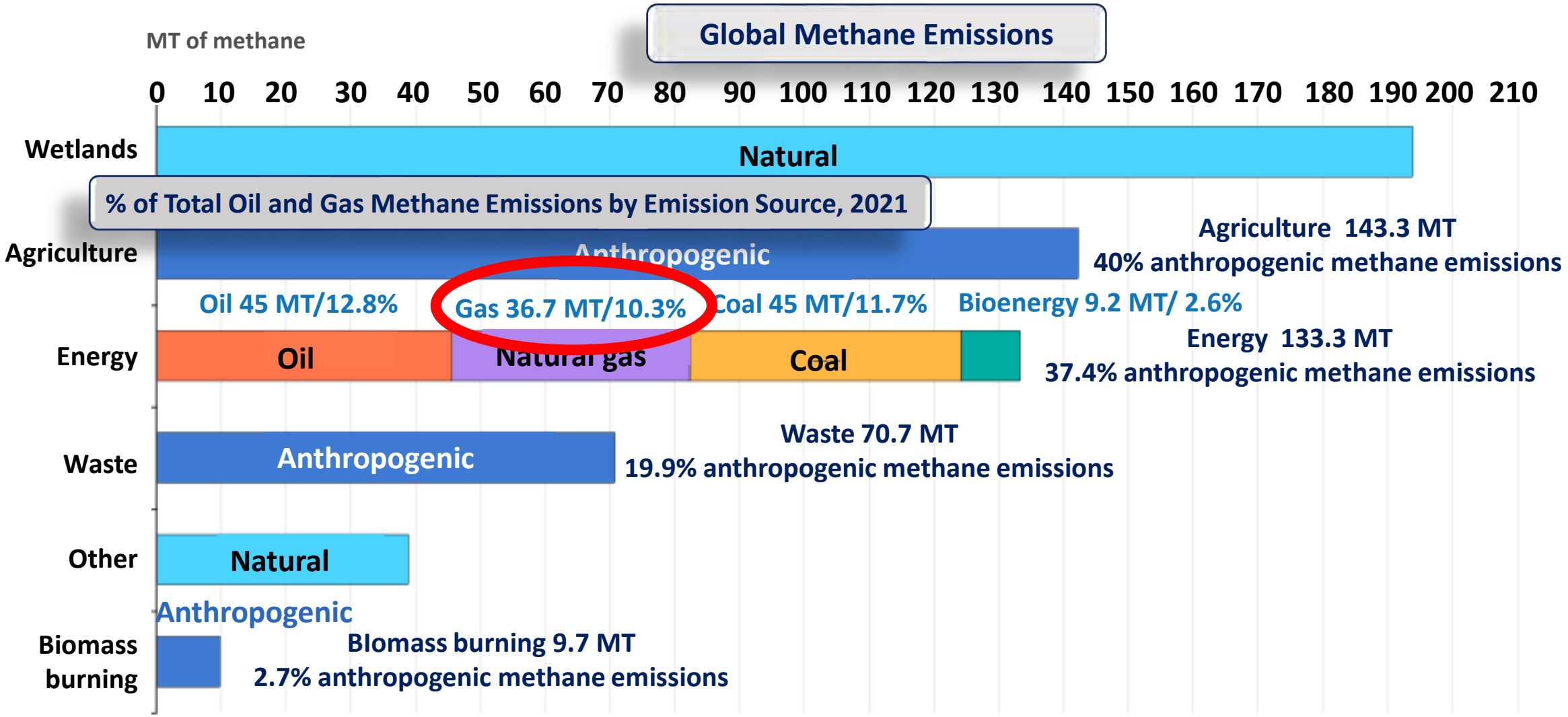
US Workshop Report: Key Themes/Findings

There were nine key takeaways from the US workshop in Washington, DC

1. Climate goals and energy security – both affordability and availability of supply – need to be addressed in the same conversation.
2. Natural gas will continue to be crucial for fulfilling global goals for decarbonization, energy security, economic development, and food security.
3. The deployment of current technologies and additional regulations are needed for the natural gas industry to address its GHG emissions including methane.
4. Federal, state, and local government permitting issues are a major challenge to meeting global energy security and decarbonization needs.
5. The timelines for financing and building energy infrastructure may not be sufficient to meet global energy security and decarbonization needs.
6. Natural gas prices in the U.S. are affected by the dynamics of global energy markets, as well as domestic politics and concerns.
7. The U.S. must shape its role in supplying natural gas while enabling global decarbonization goals.
8. Although Europe needs gas in the near term, it may not be a long-term market for U.S. exports.
9. In Asia, developing nations are primarily concerned about affordability of gas, while developed nations worry more about the reliability of supply.

Amounts/Sources of Global/US Methane Emissions (Global 2022, US 2021)

The deployment of current technologies and additional regulations are needed for the natural gas industry to address its GHG emissions including methane.



https://www.iea.org/reports/global-methane-tracker-2023/understanding-methane-emissions

Amounts/Sources of Global/US Methane Emissions (Global 2022, US 2021)

EFI FOUNDATION

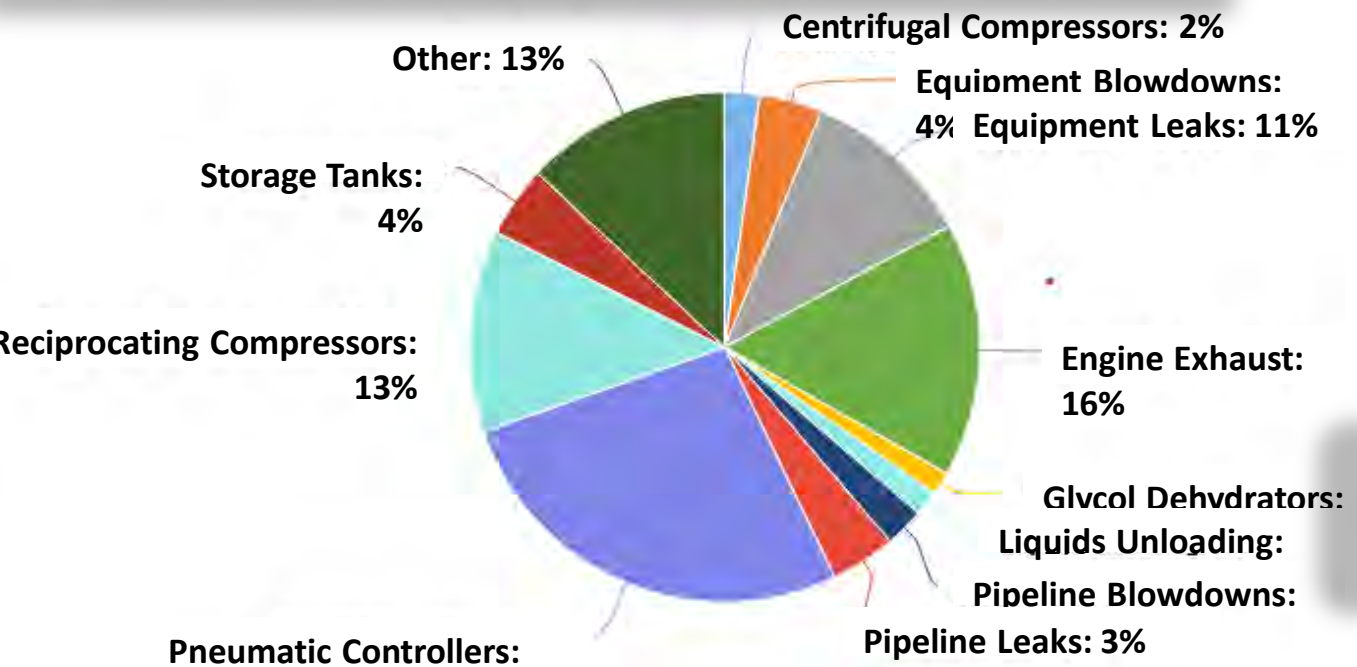
The deployment of current technologies and additional regulations are needed for the natural gas industry to address its GHG emissions including methane.

Between 2008 and 2021, **methane emissions from oil and gas systems declined by 13.4%***

Between 2008 and 2021, **US natural gas consumption rose by 38.7%***

% of Total Oil and Gas Methane Emissions by Emission Source, 2021

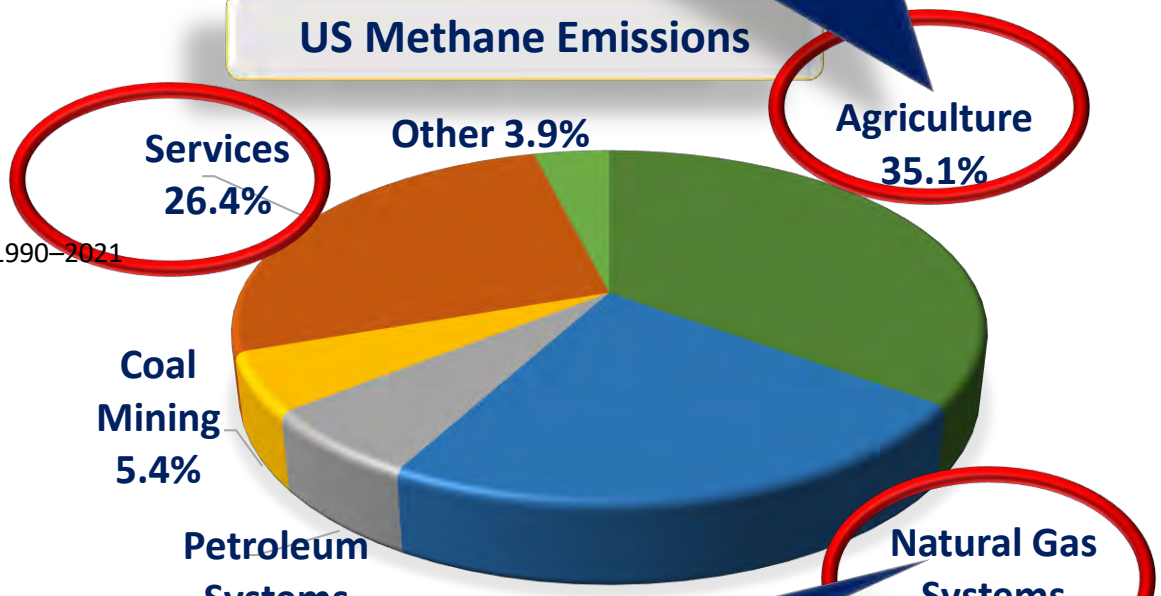
DRAFT Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021



https://www.epa.gov/natural-gas-star-program/methane-mitigation-technologies-platform

Emissions increased by 6.5% since 1990 generally following the increase in cattle populations.

US Methane Emissions



Emissions decreased by 15.7% since 1990 largely due to decreases in emissions from distribution, transmission, and storage.

EPA DRAFT Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021

https://www.northeastgas.org/nat_gas_climate_change.php

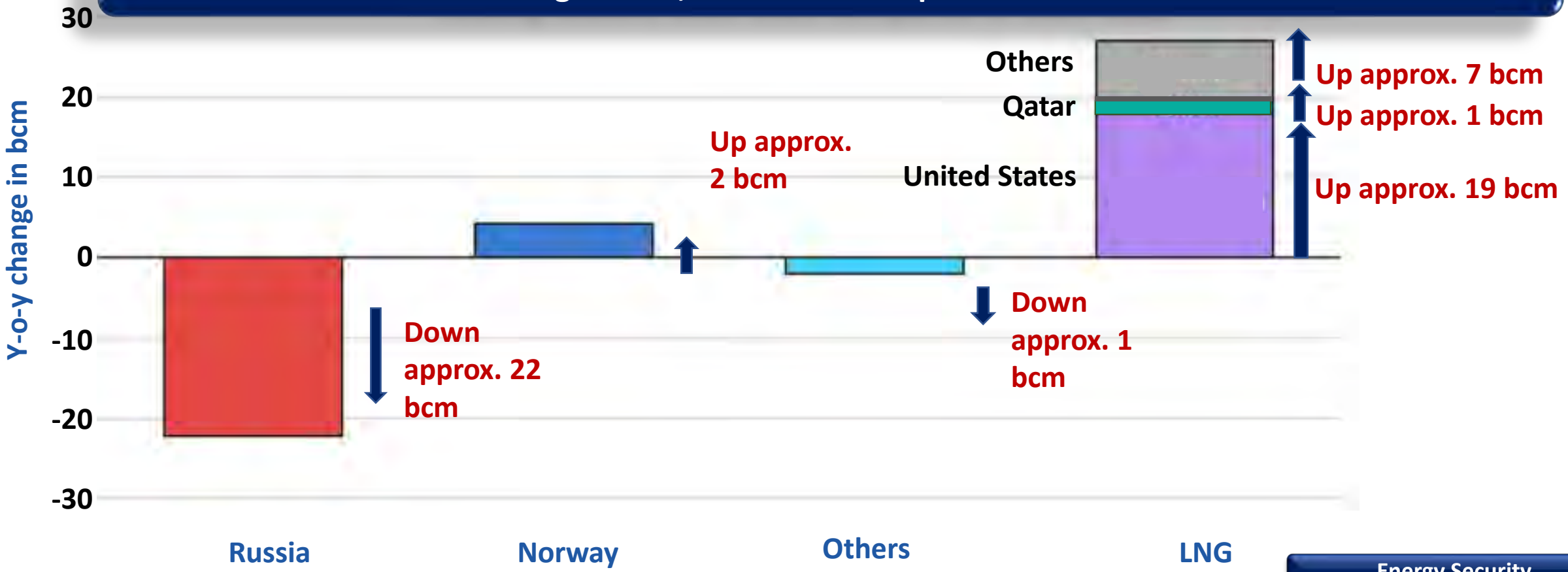
Climate Change Mitigation

Lower Russian Piped Gas Flows to Europe Largely Compensated by Record Levels of LNG Inflow, 2021-2022

Climate goals and energy security – both affordability and availability of supply – need to be addressed in the same conversation.

The U.S. must shape its role in supplying natural gas while enabling global decarbonization goals.

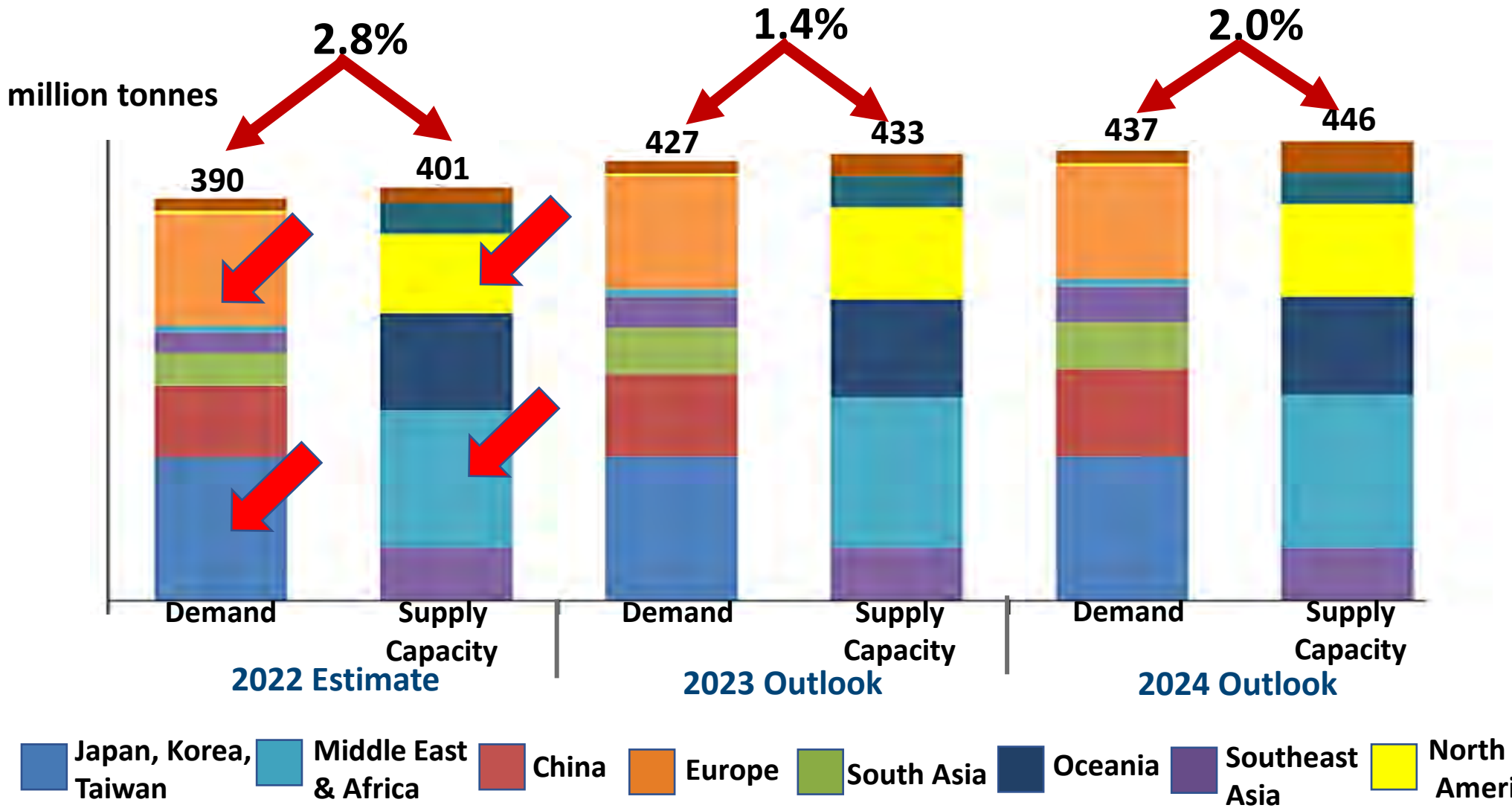
Year on year change in European natural gas imports and deliveries from Norway during the heating season, 2020-2021 compared to 2021-2022



Source: IEA Gas Market Report, q2-2022

LNG Supply/Demand Balances, 2022-2023-2024

Natural gas prices in the U.S. are affected by the dynamics of global energy markets, as well as domestic politics and concerns.



https://globallnghub.com/natural-gas-prices-down-by-over-40-across-key-gas-markets.html

Source: Global LNG Hub, LNG markets and increasing importance of stable procurement

LNG Supply/Demand Balances, 2022-2023-2024

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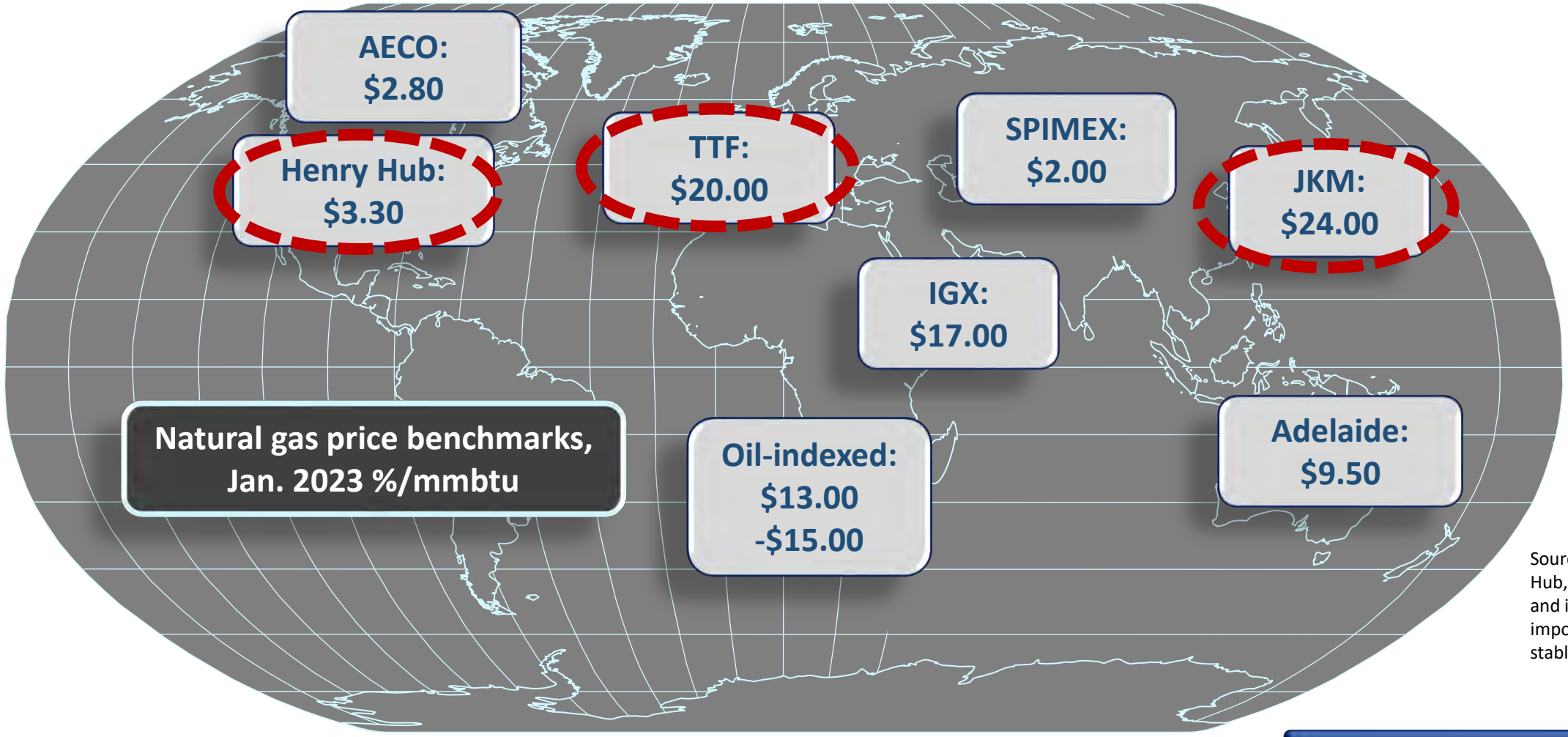
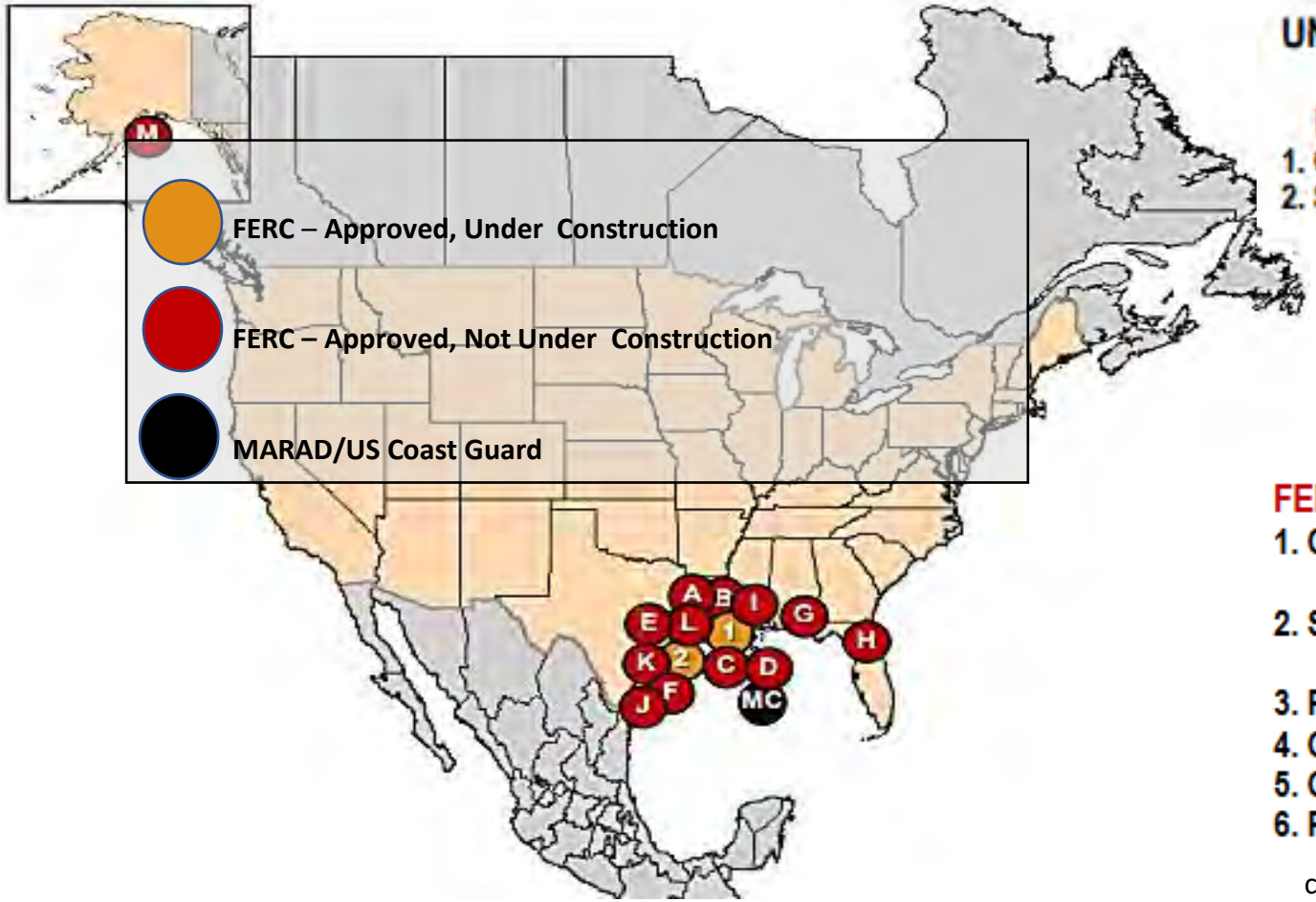


Source: Global LNG Hub, LNG markets and increasing importance of stable procurement

Approved North American LNG Export Terminals*

Natural gas will continue to be crucial for fulfilling global goals for decarbonization, energy security, economic development, and food security



Export Terminals

UNITED STATES

2022 — **3.6 Bcfd**

FERC – APPROVED, UNDER CONSTRUCTION

1. **Cameron Parish, LA:** 1.41 Bcfd (Venture Global Calcasieu Pass) (CP15-550)
2. **Sabine Pass, TX:** 2.26 Bcfd (ExxonMobil – Golden Pass) (CP14-517, CP20-459)

2023 — **13.7 Bcfd****

FERC – APPROVED, UNDER CONSTRUCTION

1. **Cameron Parish, LA:** 0.61 Bcfd (Venture Global Calcasieu Pass Units 7-9) (CP15-550)
2. **Sabine Pass, TX:** 2.57 Bcfd (ExxonMobil – Golden Pass) (CP14-517, CP20-459)
3. **Plaquemines Parish, LA:** 3.32 Bcfd (Venture Global Plaquemines) (CP17-66)
4. **Calcasieu Parish, LA:** 3.81 Bcfd (Driftwood LNG) (CP17-117)
5. **Corpus Christi, TX:** 1.58 Bcfd (Cheniere Corpus Christi Stage III) (CP18-512)
6. **Port Arthur, TX:** 1.86 Bcfd (Sempra - Port Arthur LNG Trains 1 & 2) (CP17-20)

cms.**ferc**.gov/sites/default/files/**2022/LNG** Maps

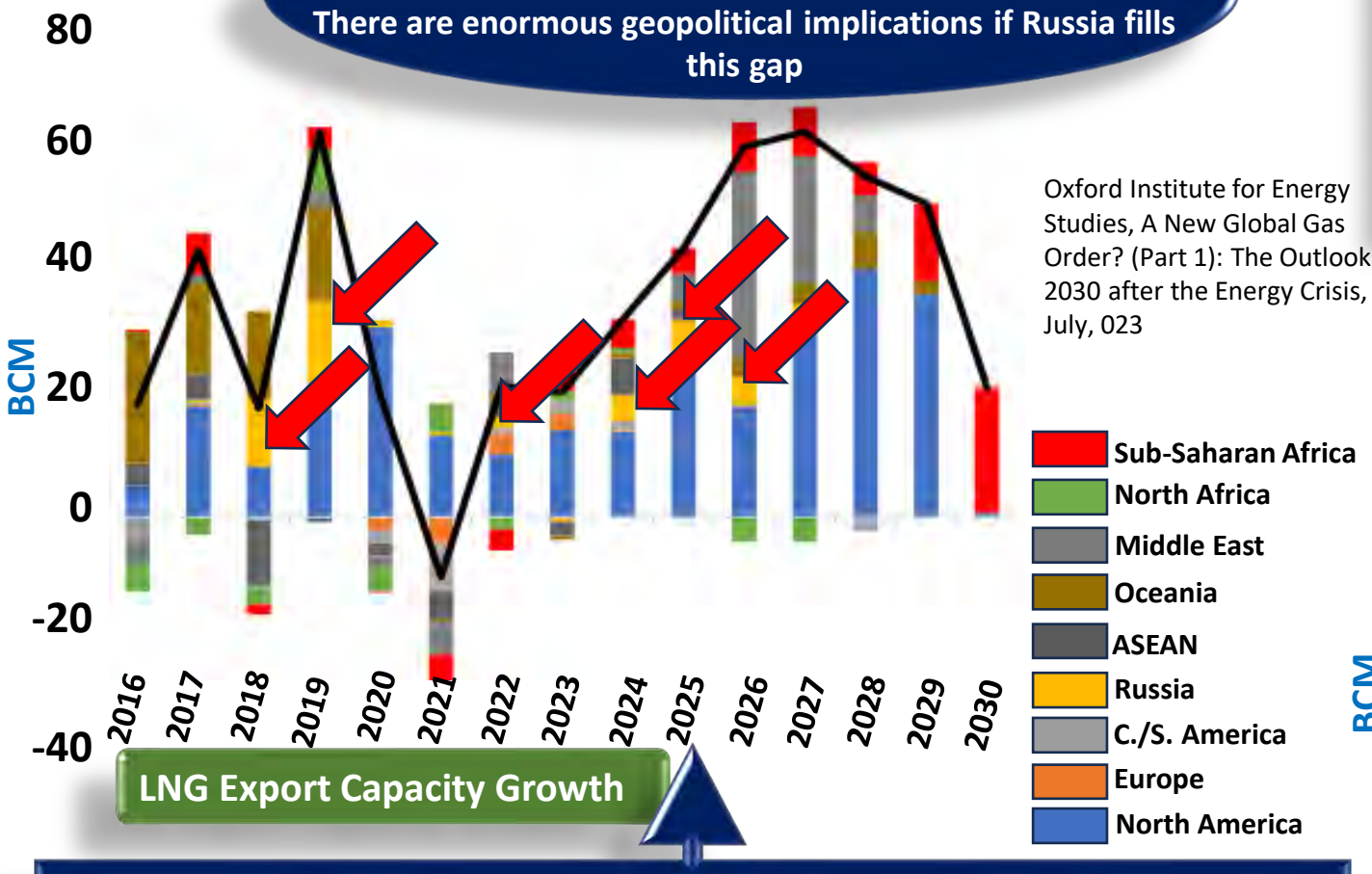
*as of February 16, 2022

**as of October 3, 2023

LNG Export/Import Capacity Growth to 2030

Natural gas will continue to be crucial for fulfilling global goals for decarbonization, energy security, economic development, and food security

ALERT!
Import Capacity Additions by 2030: 550 bcm
Export Capacity Additions by 2030: 350 bcm
There are enormous geopolitical implications if Russia fills this gap



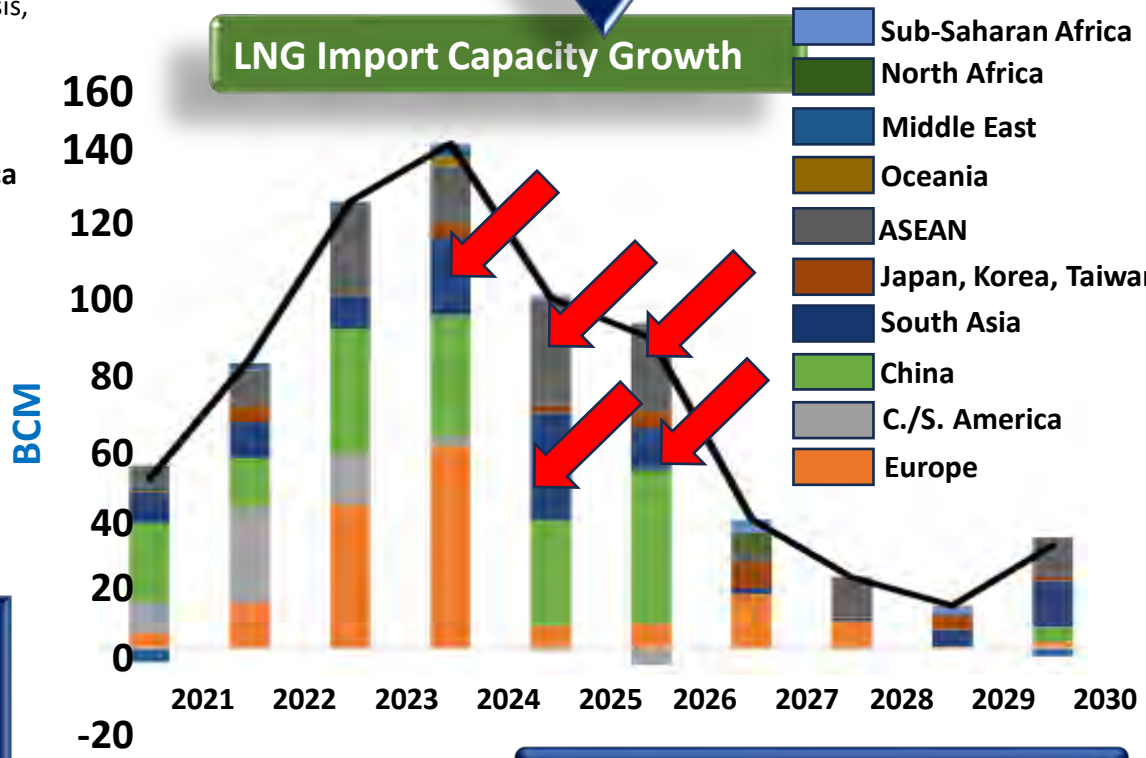
LNG Export Capacity Growth

Oxford Institute for Energy Studies, A New Global Gas Order? (Part 1): The Outlook to 2030 after the Energy Crisis, July, 023

Global LNG export capacity is expected to grow by over 350 bcm between 2022 and 2030, a rise of 60 per cent over the 2022 average . 80 per cent of this rise has already taken FID, and over half the increase is from North America. Six projects have already taken FID and will come on-line before 2030.

Global LNG import capacity is expected to grow by some 550 bcm between 2022 and 2030. China and Europe lead the way with 145 bcm and 135 bcm, respectively, followed by ASEAN (120 bcm) and South Asia (95 bcm). Europe's growth, predominantly in 2023 and 2024, in response to the Russian invasion of Ukraine, is heavily focused in Northwest Europe, especially Germany.

LNG Import Capacity Growth



European Workshops Report: Key Themes/Findings

There were seven key takeaways from the European roundtables in Sofia, Bulgaria and Brussels, Belgium

1. Views on the role of natural gas in Europe's energy transition, and as a vehicle for energy security, differed greatly between participants in Western and Eastern European economies.
2. Western European countries plan to use low- and zero-carbon hydrogen to meet industrial demand.
3. Eastern European participants viewed natural gas as a critical transition fuel and key to industrial development.
4. Concerns were raised by participants representing the Western European economies about LNG currently being too expensive and emissions-intensive to be considered for the EU's long-term decarbonization strategies.
5. The time it will take to deploy and scale up alternatives must be considered when setting realistic decarbonization targets.
6. A recovery of natural gas demand in Asia will make it even more challenging for Europe to secure an ample supply of natural gas for industrial and winter heating needs.
7. Concerns were raised that policies such as the CBAM and REPowerEU could weaken European industrial competitiveness and increase economic risks.

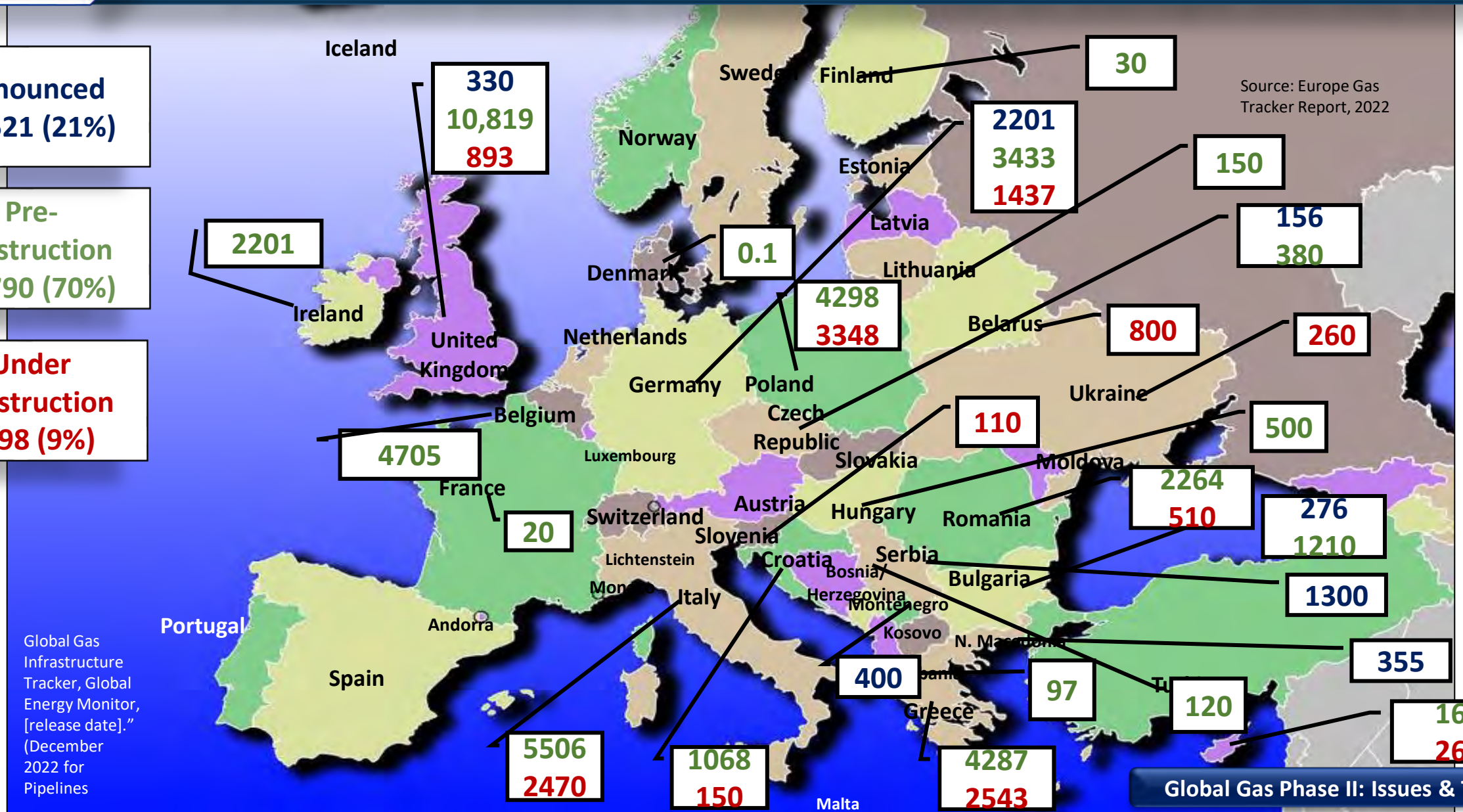
Gas Plants by Country, Under Construction, Pre-Construction, Announced, All of Europe (MW), 02/23

ENERGY FUTURES INITIATIVE

Announced
12,521 (21%)

Pre-construction
41,790 (70%)

Under Construction
5398 (9%)



Source: Europe Gas Tracker Report, 2022

Global Gas Infrastructure Tracker, Global Energy Monitor, [release date]." (December 2022 for Pipelines

Reference Frame: High Voltage Transmission Line Materials Needed by 2050

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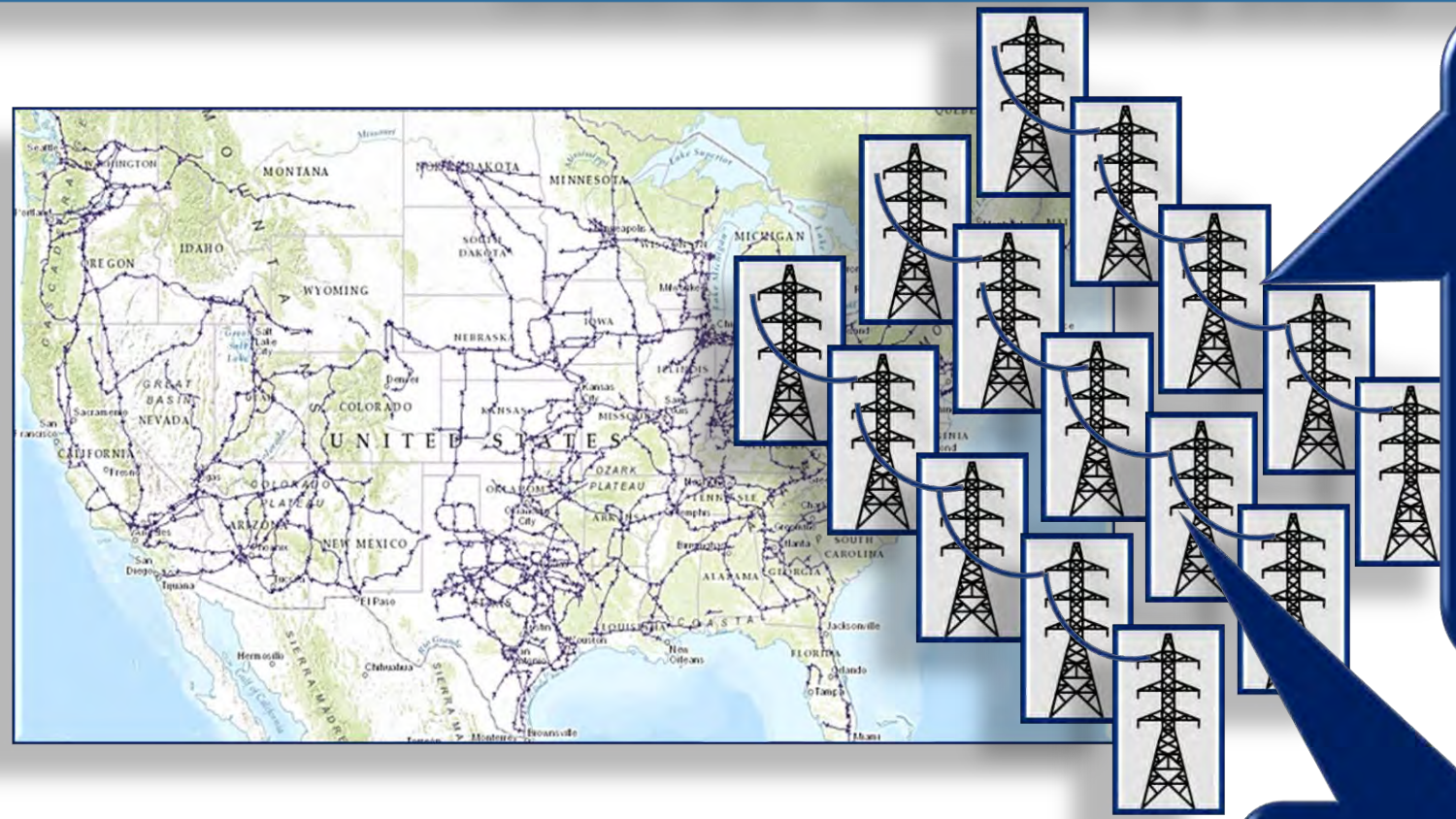
EIA: In 2016, there were 160,000 miles of high voltage transmissions lines

Princeton NZA (E+RE pathway with base land availability): The US will need a 75% increase in transmission capacity by 2030 to meet net zero targets

Assume 60% of that capacity is achieved by adding new miles (the other 40% is met with technology improvements)

60% of 96,000 translates to 72,000 miles of new high voltage transmission lines by 2030

There are between 5 and 5.6 towers per mile on a high voltage transmission line
(credible numbers range from 5 to 5.6)



Transmission towers are made of steel, aluminum and copper., among other materials. So are transmission lines. So are wind turbines. So are cell towers. So are EVs. So are EV charging stations

At 5 towers/mile, we will <u>need 360,000 transmission towers by 2030</u>

https://www.eia.gov/todayinenergy/detail.php?id=27152

Electricity Inadequate for Key Industrial Processes

Metallurgical and ceramic processes require high heat… 99.5% aluminum melts at 1,214°F (657 °C), and carbon steel begins melting at 1,425°F (734°C). Ceramics require kiln temperatures from 2,124°F to 2,264°F (1,162°C to 1,240°C).

At a high level, glass is sand that's been melted down and chemically transformed. To make sand melt, you need to heat it to roughly 1700°C (3090°F)

Concentrated solar collectors: approx. 32 - 400 degrees
Deep geothermal energy: approx. 175 - 380 degrees
Woody biomass: approx. 32 - 400 degrees

The ideal temperature for forging steel typically falls between 2,000°F (1,093°C) and 2,300°F (1,260°C), although different steels may require slightly different temperatures.

https://www.powerblanket.com/blog/types-of-industrial-process-heating-and-applications/

https://theforgehub.com/measuring-forge-and-steel-temperatures-tips-and-tools/

https://theforgehub.com/measuring-forge-and-steel-temperatures-tips-and-tools/

https://www.epa.gov/rhc/hot-water-heating-technologies-and-applications-text-version-diagram

Natural Gas Supports Significant Industrial/ Economic Activity

https://www.aluminum.org/economy

https://www.globaldata.com/data-insights/macroeconomic/market-value-of-steel-industry-in-united-states-of-america-1090750/

Source: US EIA, 2020 AEO
https://www.ngsa.org/industrial-uses-of-natural-gas/

Fertilizers: In 2020, the US fertilizers market was valued at USD 18,602.0 million in 2020, and it is estimated to reach USD 20,520.5 million by 2026

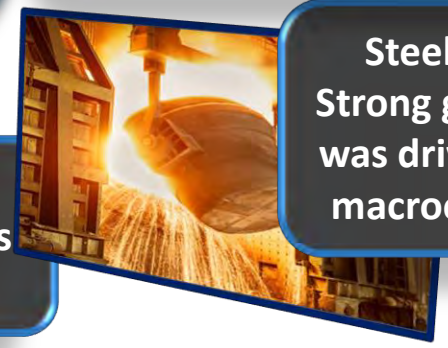
Aluminum: In the U.S., in 2022, the aluminum industry supported $176 billion in economic activity and more than 634,000 direct, indirect, and induced jobs.

Chemicals: in 2022, the chemical industry had $614 billion in final sales and supported 4.1 million direct, support, and induced jobs

2020 Size & Impact Report": Plastics Industry Association

Plastics: The US plastics industry accounted for an estimated $432 billion in shipments and more than one million jobs in 2019

Glass: supported $30.5b in economic activity in 2023, employs almost 80,000 people



Steel: $108 billion in 2021. Strong growth in 2017 and 2018 was driven by consistent robust macroeconomic performance.

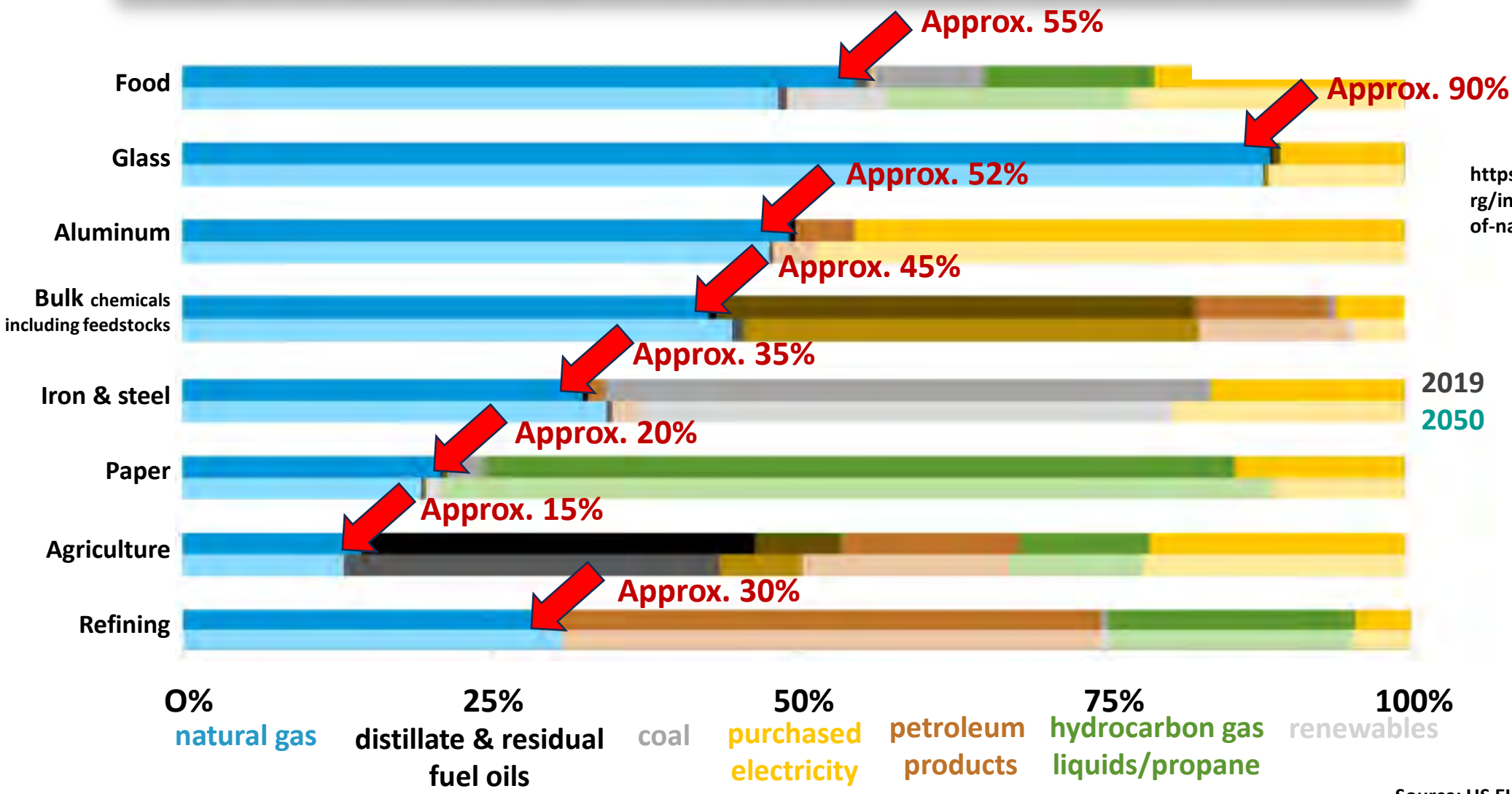
https://www.americanchemistry.com/chemistry-in-america/data-industry-statistics

Source: Fertilizer.org website, how fertilizers are made, accessed 10

https://www.ibisworld.com/united-states/market-research-reports/glass-product-manufacturing-industry/#IndustryStatisticsAndTrends

Natural Gas Supports Significant Industrial/ Economic Activity

Energy Consumption by Energy Source Shares and Industry, % (EIA AEO2020 Reference Case)



https://www.ngsa.org/industrial-uses-of-natural-gas/

Source: US EIA, 2020 AEO

Source: Fertilizer.org website, how fertilizers are made, accessed 10

https://www.ibisworld.com/united-states/market-research-reports/glass-product-manufacturing-industry/#IndustryStatisticsAndTrends

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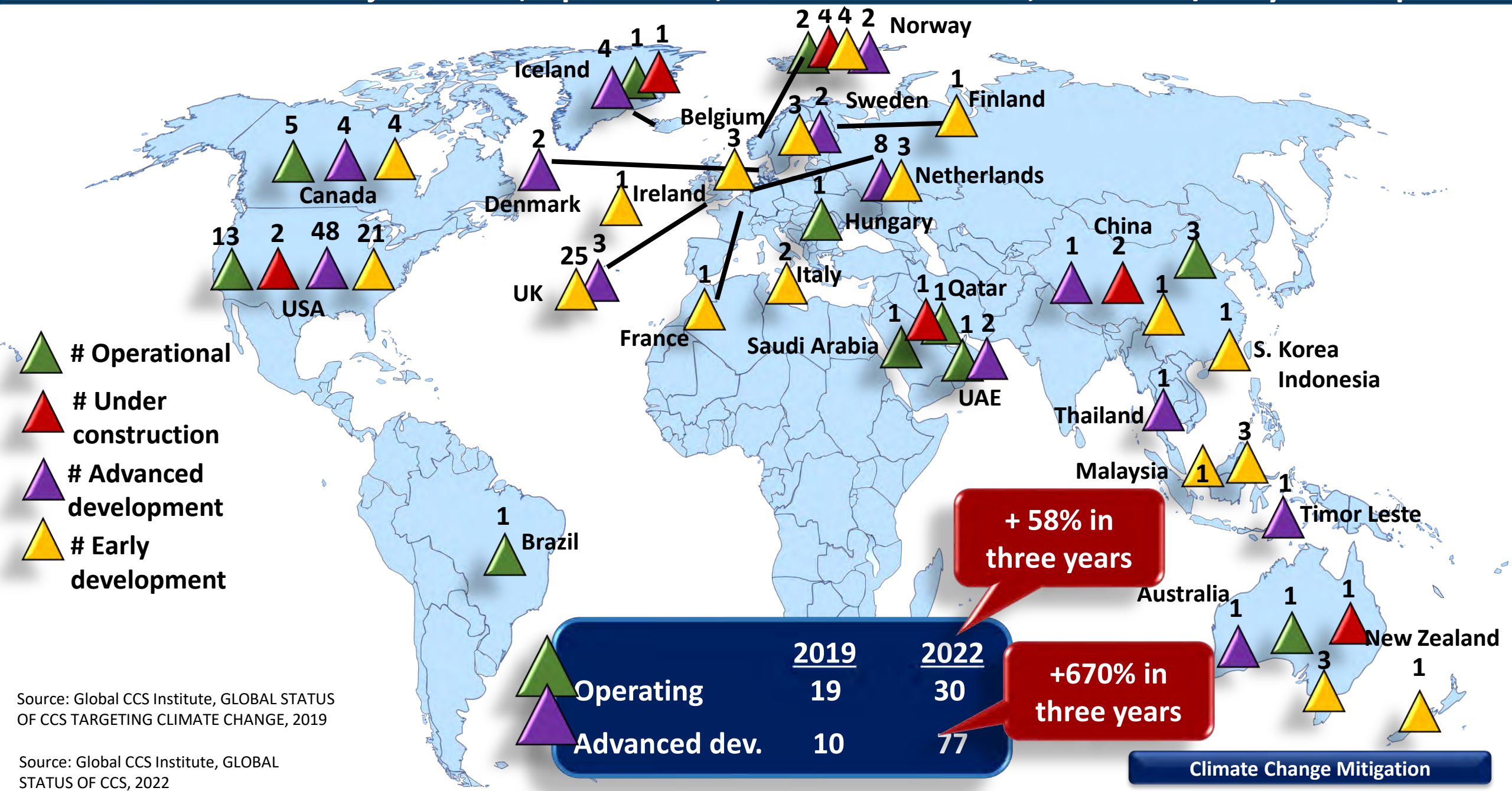
CCS Projects 2022, Operational, Under Construction, Advanced/Early Development



Source: Global CCS Institute, GLOBAL STATUS OF CCS TARGETING CLIMATE CHANGE, 2019

Source: Global CCS Institute, GLOBAL STATUS OF CCS, 2022

Climate Change Mitigation

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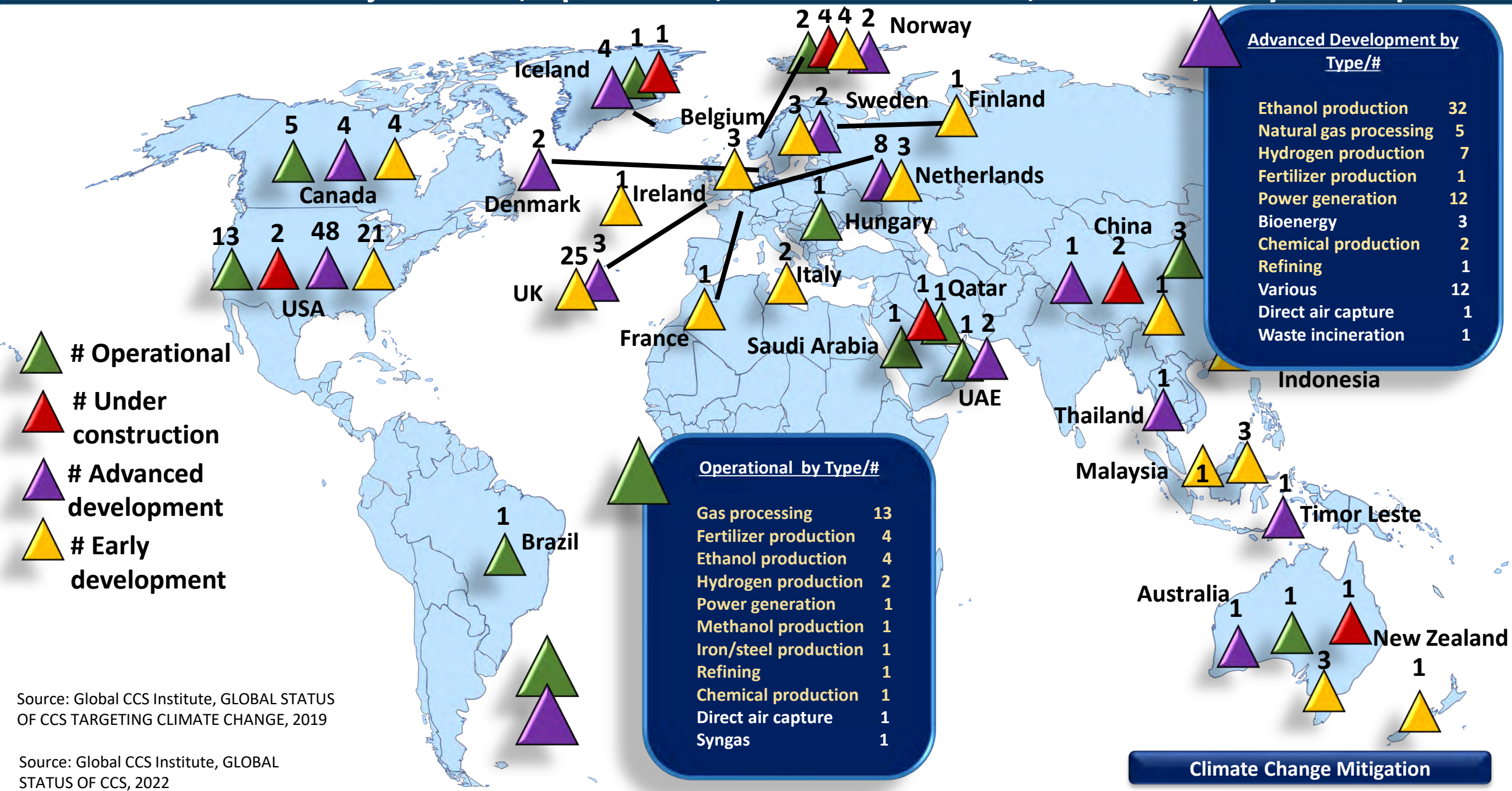
CCS Projects 2022, Operational, Under Construction, Advanced/Early Development



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Source: Global CCS Institute, GLOBAL STATUS OF CCS, 2022

Climate Change Mitigation