Global Gas Study Phase II: The Future of Natural Gas in a Low-Carbon World

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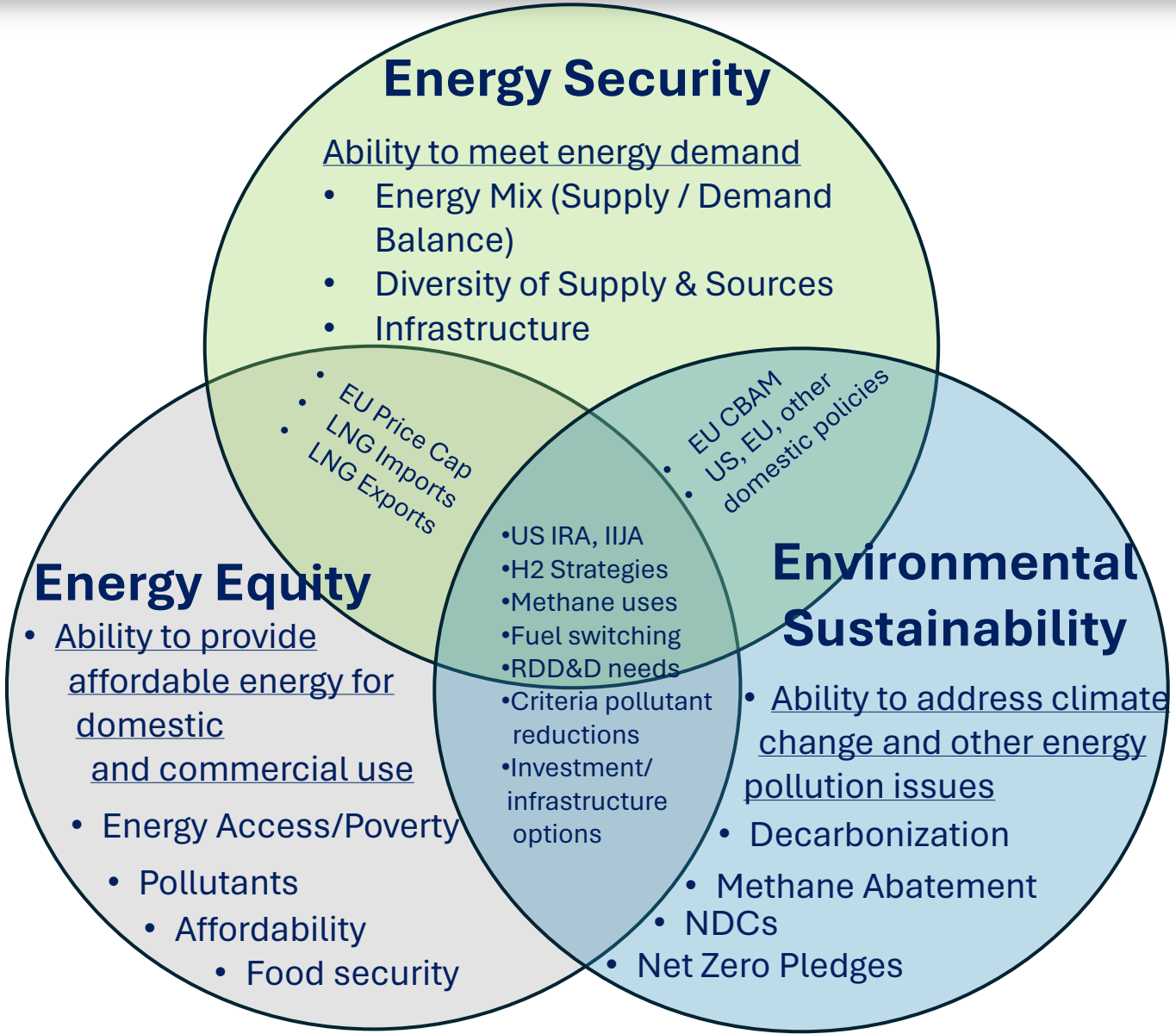
April 30, 2024

The Energy Trilemma and Natural Gas



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.

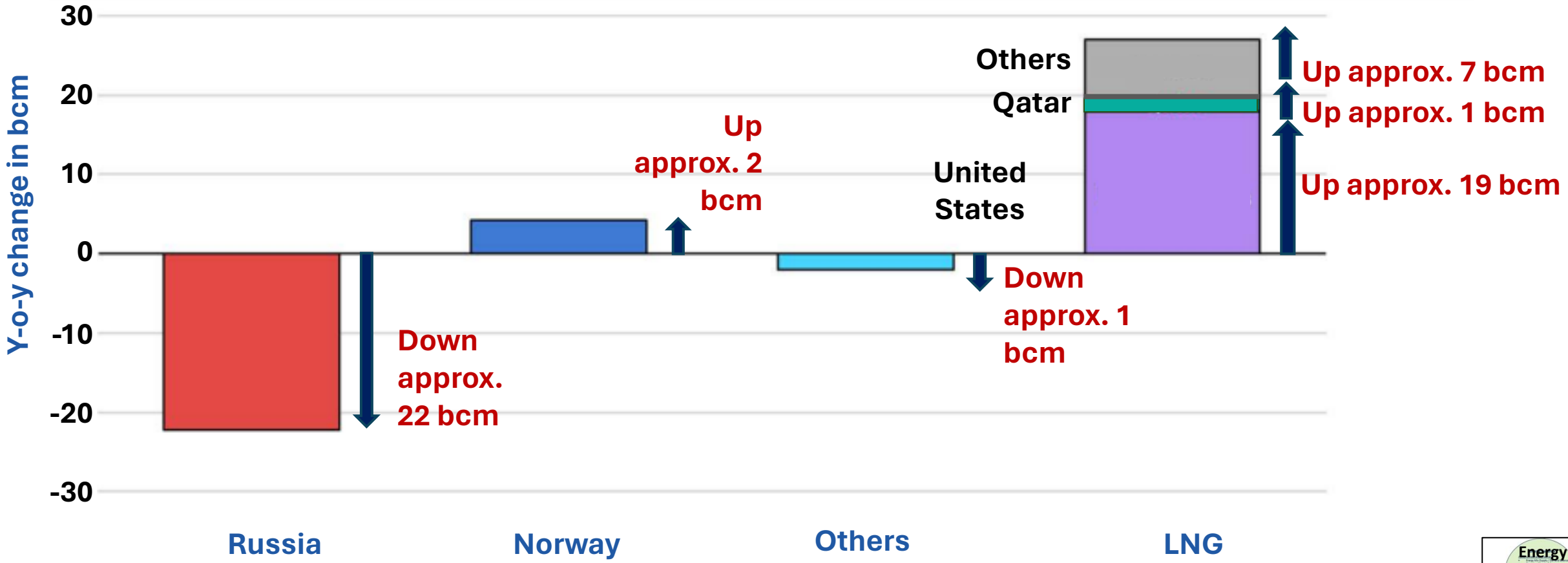
Asian Workshop Report: Key Themes/Findings

There were eight key takeaways from the Asian Roundtable in Singapore

1. Natural gas demand in Asia is expected to be the main driver for global LNG markets in the coming decades.
2. Affordable and reliable energy supply remains a top concern for many Asian countries.
3. Natural gas supply is a key energy security concern for many Asian countries.
4. It is critical to elevate the voices (in international forums) of low- and middle-income countries in Asia in the net-zero context.
5. Natural gas can play an important role in industrial decarbonization.
6. Coal-to-gas fuel switching lowers air pollution and decreases carbon emissions.
7. Large-scale deployment of carbon capture and sequestration (CCS) is critical for natural gas to be utilized while meeting decarbonization goals.
8. Methane leakage is a critical issue that needs to be addressed in the net-zero context.

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

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



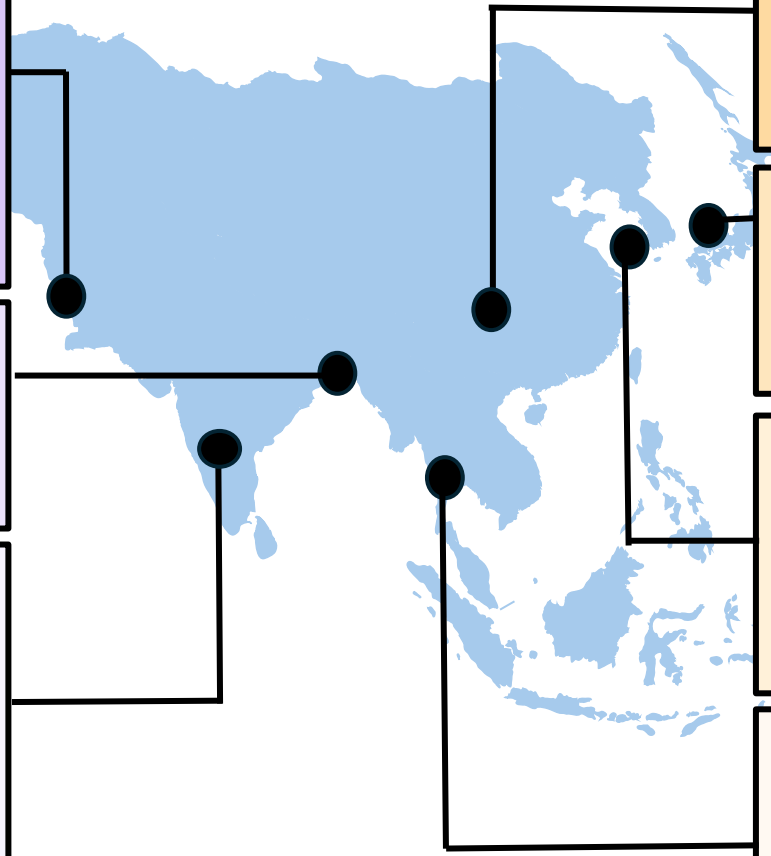
Source: IEA Gas Market Report, q2-2022

Impact of High Spot LNG Prices Across Asia

Pakistan
- Deep energy crisis with economy-wide implications
- **Rolling blackouts of up to 12 hours**
- LNG imports down19% y-o-y in January-August 2022
- Spot LNG purchases down to bare minimum
- Oil-fired generation up fivefold

Bangladesh
- No spot LNG purchases July-August 2022
- Load shedding of 20% in mid-July
- **Mandatory conservation measures**

India
- Power sector gas burn down 28% y-o-y in January-August 2022 (partly replaced with coal)
- **Reduced gas use in refining (down 29%) and chemicals (down 23%) mostly replaced with oil**



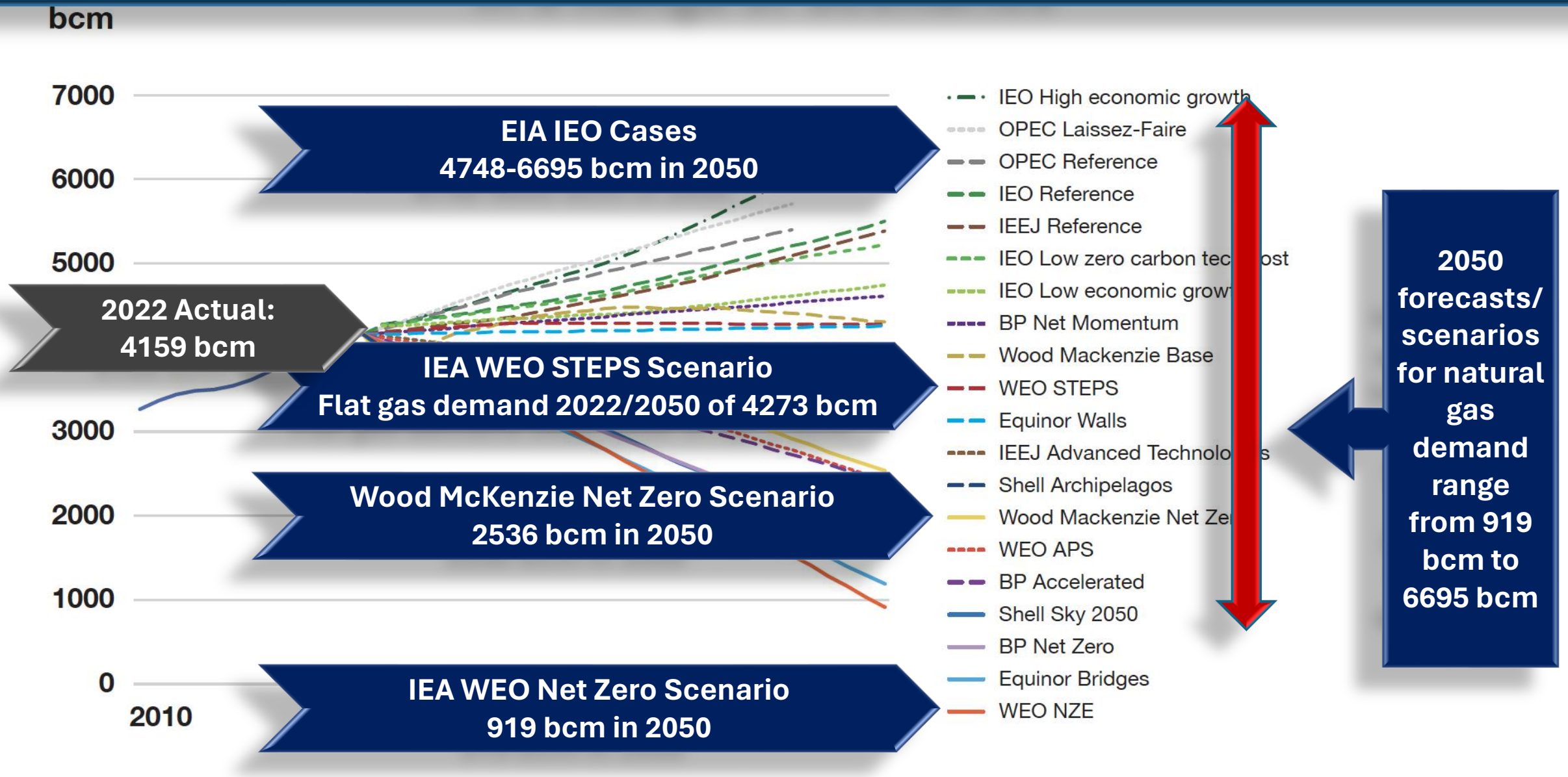
China
- **Power sector gas use down by 9% y-o-y in January-August 2022**
- Evidence of demand destruction in industry and transport

Japan
- **Accelerated restart of 7 nuclear reactors from mid-2023**
- Contingency plan for LNG supply cut scenario

Korea
- **Voluntary coal restrictions suspended for summer 2022**
- accelerated start-up of new coal-fired and nuclear units

Thailand
- Power sector gas burn down by 6% y-o-e in January-July 2022, **diesel generation up 16-fold**
- Buy tenders cancelled or unawarded due to high price

Global Natural Gas Demand in 2050 Differs Greatly in a Range of Scenarios



LNG Import Infrastructure in Operation and Under Construction, Demand Forecasts, Europe/Northeast Asia (MTPA)

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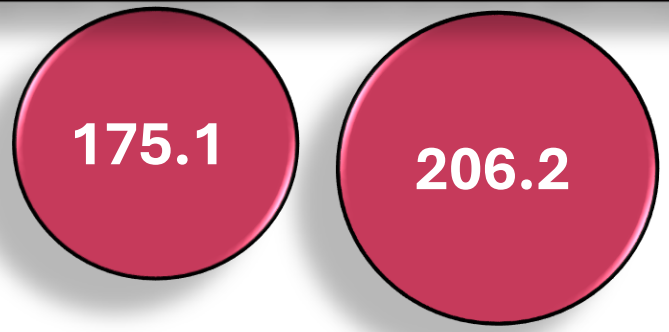
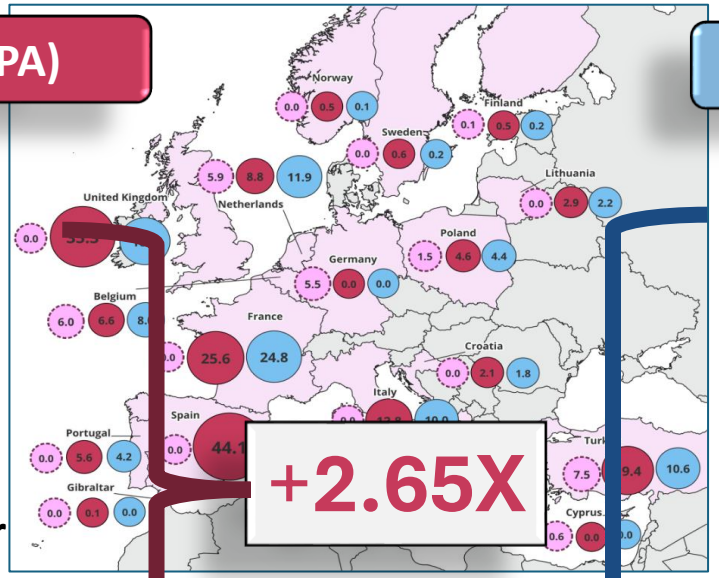
European Import Infrastructure (MTPA)



Operating Capacity

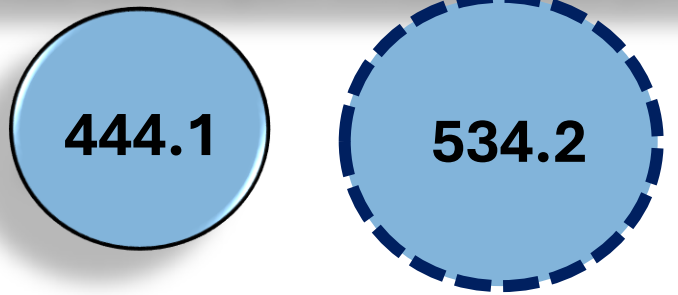
Operating Capacity & Under Construction



+2.65X

+2.85X

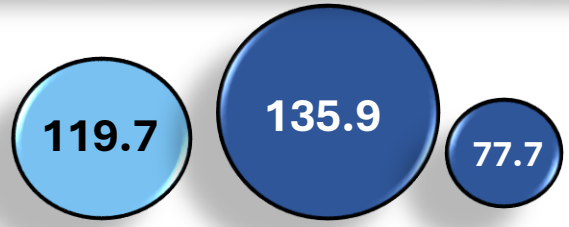
China/NE Asia LNG Import Infrastructure (MTPA)



Operating Capacity

Operating Capacity + Under Construction

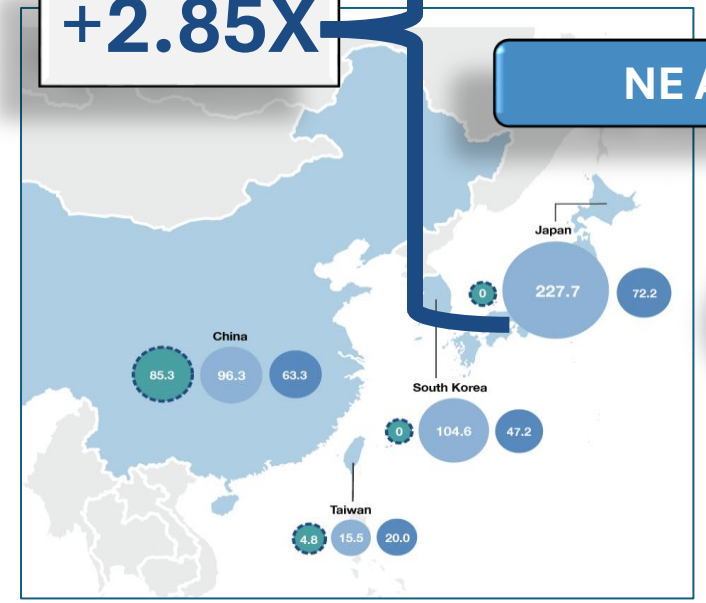
European Forecasted Demand (MTPA)



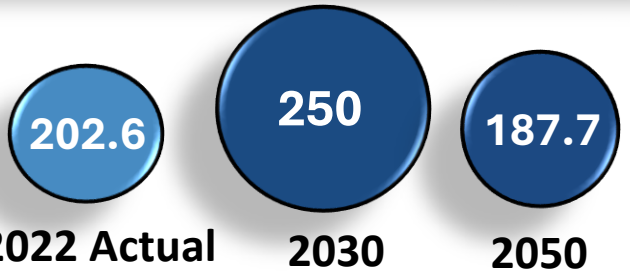
2022 Actual
World Energy Review

2030
Wood McKenzie

2050



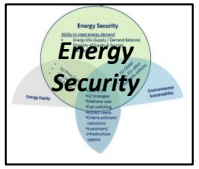
NE Asia Forecasted Demand (MTPA)



2022 Actual
World Energy Review

2030
Wood McKenzie

2050



LNG Import Infrastructure in Operation and Under Construction, Demand Forecasts, Southeast/South Asia (MTPA)

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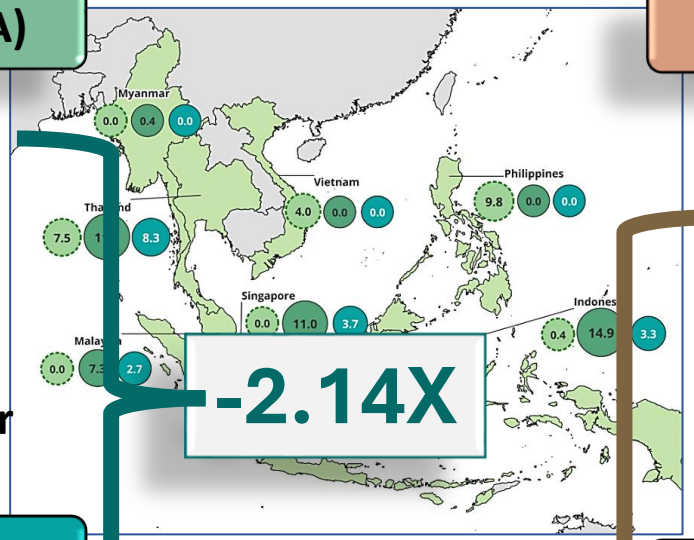
SE Asia LNG Import Infrastructure (MTPA)

45.1

Operating Capacity

66.8

Operating Capacity + Under Construction



-2.14X

South Asia LNG Import Infrastructure (MTPA)

65.2

Operating Capacity

98.2

Operating Capacity + Under Construction

SE Asia Forecasted Demand (MTPA)

18

2022 Actual

World Energy Review

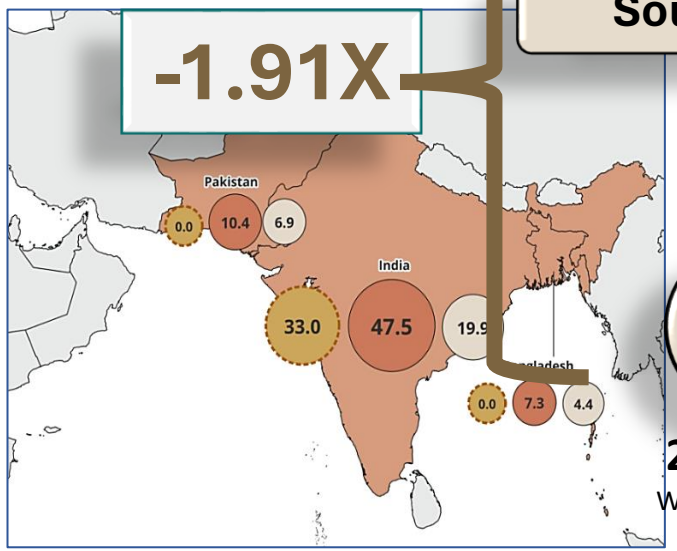
15.8

2030

143.2

2050

Wood McKenzie



-1.91X

South Asia Forecasted Demand (MTPA)

31.2

2022 Actual

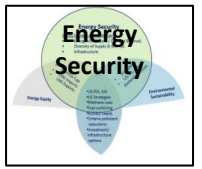
World Energy Review

83

2030

187.7

2050



Natural Gas Power Generation Plants, Announced, Under Construction, Operating, Europe (MW), 02/24

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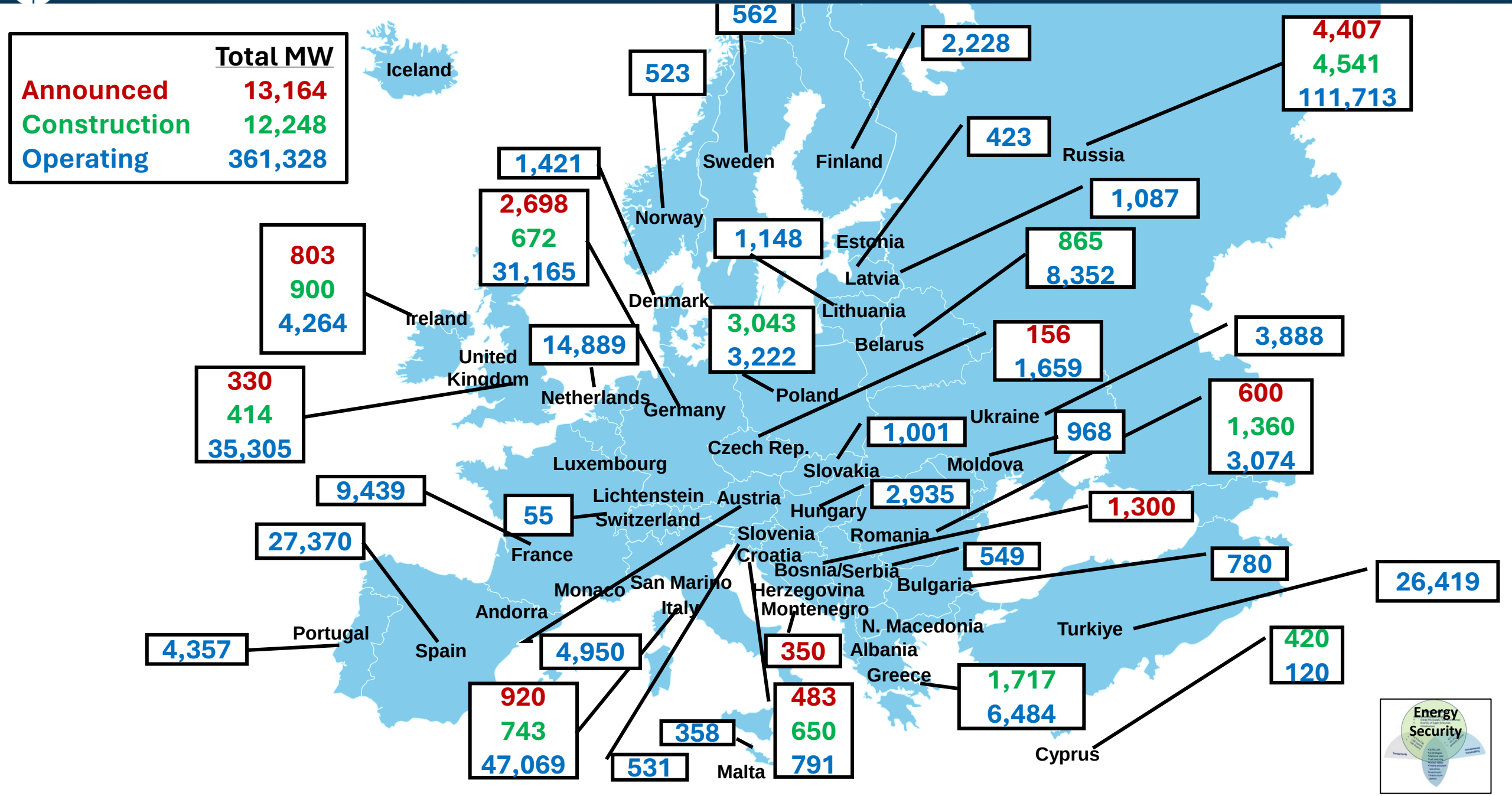
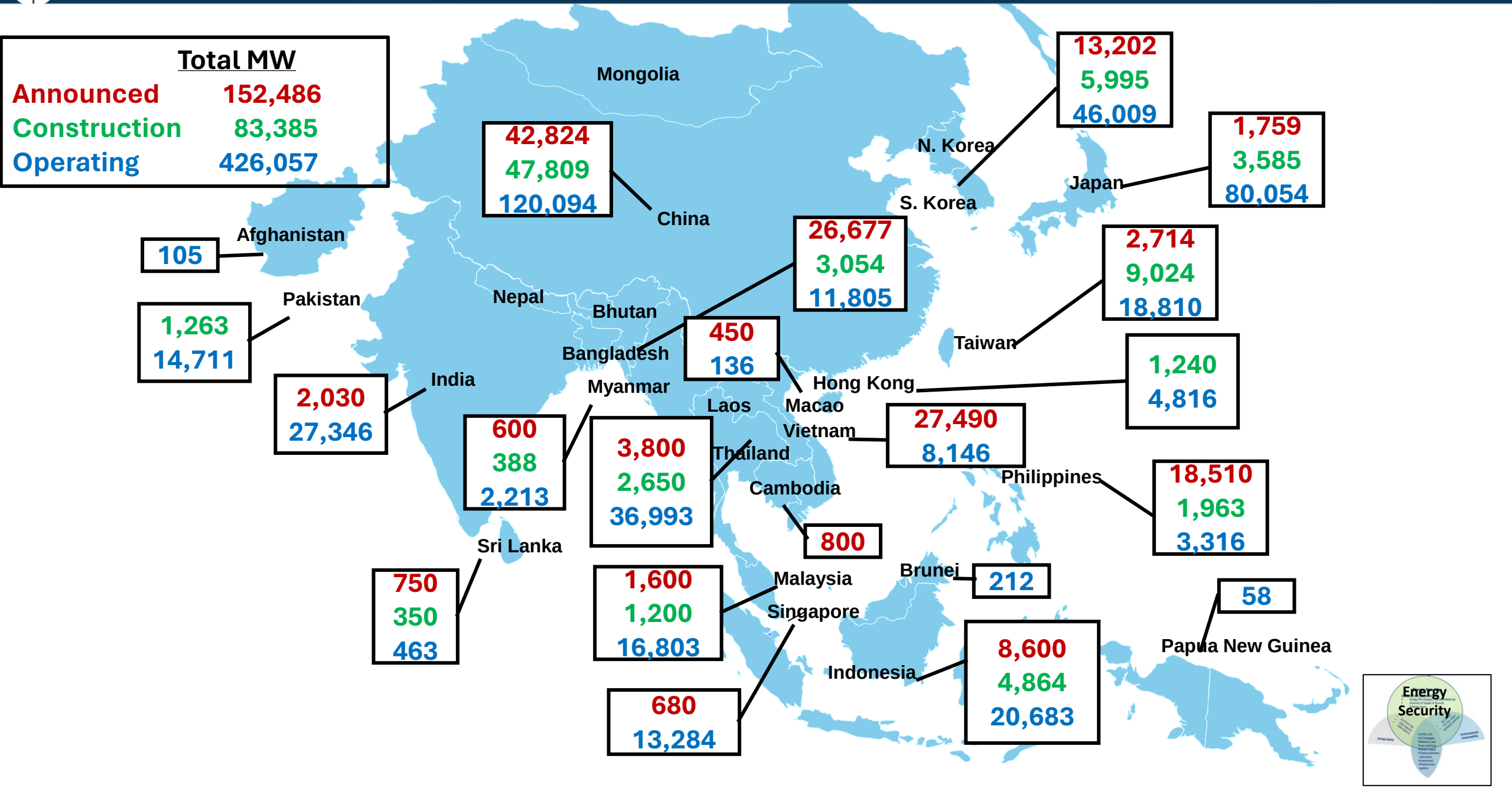
	Total MW
Announced	13,164
Construction	12,248
Operating	361,328



Natural Gas Power Generation Plants, Announced, Under Construction and Operating, Asia, 2/24 (MW)

EFI FOUNDATION

Total MW	
Announced	152,486
Construction	83,385
Operating	426,057



Under the "Pause", Near-term US LNG Export Volumes Would Still Dramatically Increase

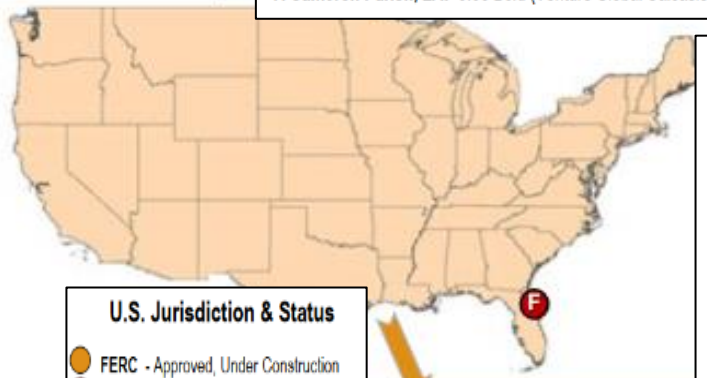
1. **Kenai, AK:** 0.2 Bcfd (Trans-Foreland)
2. **Sabine, LA:** 4.55 Bcfd (Cheniere/Sabine Pass LNG – Trains 1-6)
3. **Cove Point, MD:** 0.79 Bcfd (Dominion–Cove Point LNG)
4. **Corpus Christi, TX:** 2.40 Bcfd (Cheniere – Corpus Christi LNG Trains 1-3)
5. **Hackberry, LA:** 2.06 Bcfd (Sempra–Cameron LNG, Trains 1-3)
6. **Elba Island, GA:** 0.35 Bcd (Southern LNG Company Units 1-10)
7. **Freeport, TX:** 2.38 Bcfd (Freeport LNG Dev/Freeport LNG Expansion/FLNG Liquefaction Trains 1-3)
8. **Cameron Parish, LA:** 1.70 Bcfd (Venture Global Calcasieu Pass Units 1-9)

Existing Export Volumes: 14.43 bcfd

U.S. Jurisdiction
- FERC
- MARAD / U.S. Coast Guard

If all approved volumes are constructed, the US will increase its export capacity by 121.5%

1. **Sabine Pass, TX:** 2.57 Bcfd (ExxonMobil – Golden Pass) (CP14-517, CP20-459)
2. **Plaquemines Parish, LA:** 3.32 Bcfd (Venture Global Plaquemines) (CP17-66)
3. **Calcasieu Parish, LA:** 3.81 Bcfd (Driftwood LNG) (CP17-117)
4. **Corpus Christi, TX:** 1.58 Bcfd (Cheniere Corpus Christi Stage III) (CP18-512)
5. **Port Arthur, TX:** 1.86 Bcfd (Sempra - Port Arthur LNG Trains 1 & 2) (CP17-20)
6. **Brownsville, TX:** 3.73 Bcfd (Rio Grande LNG – NextDecade) (CP16-454)
7. **Cameron Parish, LA:** 0.06 Bcfd (Venture Global Calcasieu Pass) (CP15-550)



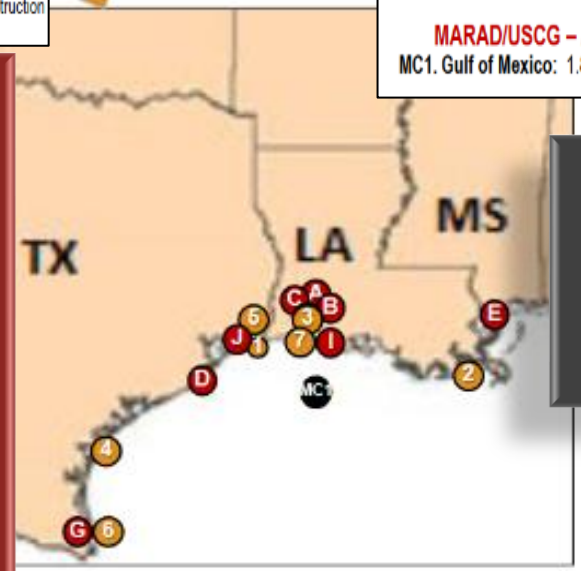
U.S. Jurisdiction & Status
- FERC - Approved, Under Construction
- FERC - Approved, Not Under Construction
- MARAD / U.S. Coast Guard

FERC – APPROVED, NOT UNDER CONSTRUCTION

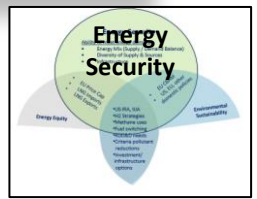
A. **Lake Charles, LA:** 2.27 Bcfd (Lake Charles LNG) (CP14-120)
B. **Lake Charles, LA:** 1.22 Bcfd (Magnolia LNG) (CP14-347)
C. **Hackberry, LA:** 0.93 Bcfd (Sempra - Cameron LNG Train 4) (CP15-560, CP22-41)
D. **Freeport, TX:** 0.74 Bcfd (Freeport LNG Dev Train 4) (CP17-470)
E. **Pascagoula, MS:** 1.50 Bcfd (Gulf LNG Liquefaction) (CP15-521)
F. **Jacksonville, FL:** 0.13 Bcf/d (Eagle LNG Partners) (CP17-41)
G. **Brownsville, TX:** 0.62 Bcfd (Texas LNG Brownsville) (CP16-116)
H. **Nikiski, AK:** 2.76 Bcfd (Alaska Gasline) (CP17-178)
I. **Cameron Parish, LA:** 1.21 Bcfd (Commonwealth LNG) (CP19-502)
J. **Port Arthur, TX:** 1.86 Bcfd (Sempra - Port Arthur LNG Trains 3 & 4) (CP20-55)

MARAD/USCG – APPROVED, NOT UNDER CONSTRUCTION

MC1. **Gulf of Mexico:** 1.8 Bcfd (Delfin LNG)



Approved Export Volumes: 31.97 bcfd



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

EFI FOUNDATION

USC Coal → $82.61
$52.11 | 85%

Combined Cycle → $39.94
$9.36 | 87%

Advanced Nuclear → $88.24
$60.71 | 90%

Battery Storage → $128.55
$64.03 | 10%

Combustion Turbine → $117.86
$53.78 | 10%

Geothermal → $39.82
$22.04 | 90%

Capacity Resource Technologies

Dispatchable

Onshore Wind → $40.23
$29.90 | 41%

Offshore Wind → $136.51
$103.77 | 44%

Solar Standalone → $36.49
$26.60 | 29%

Hydroelectric → $64.27
$46.58 | 54%

Resource Constrained Technologies

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

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

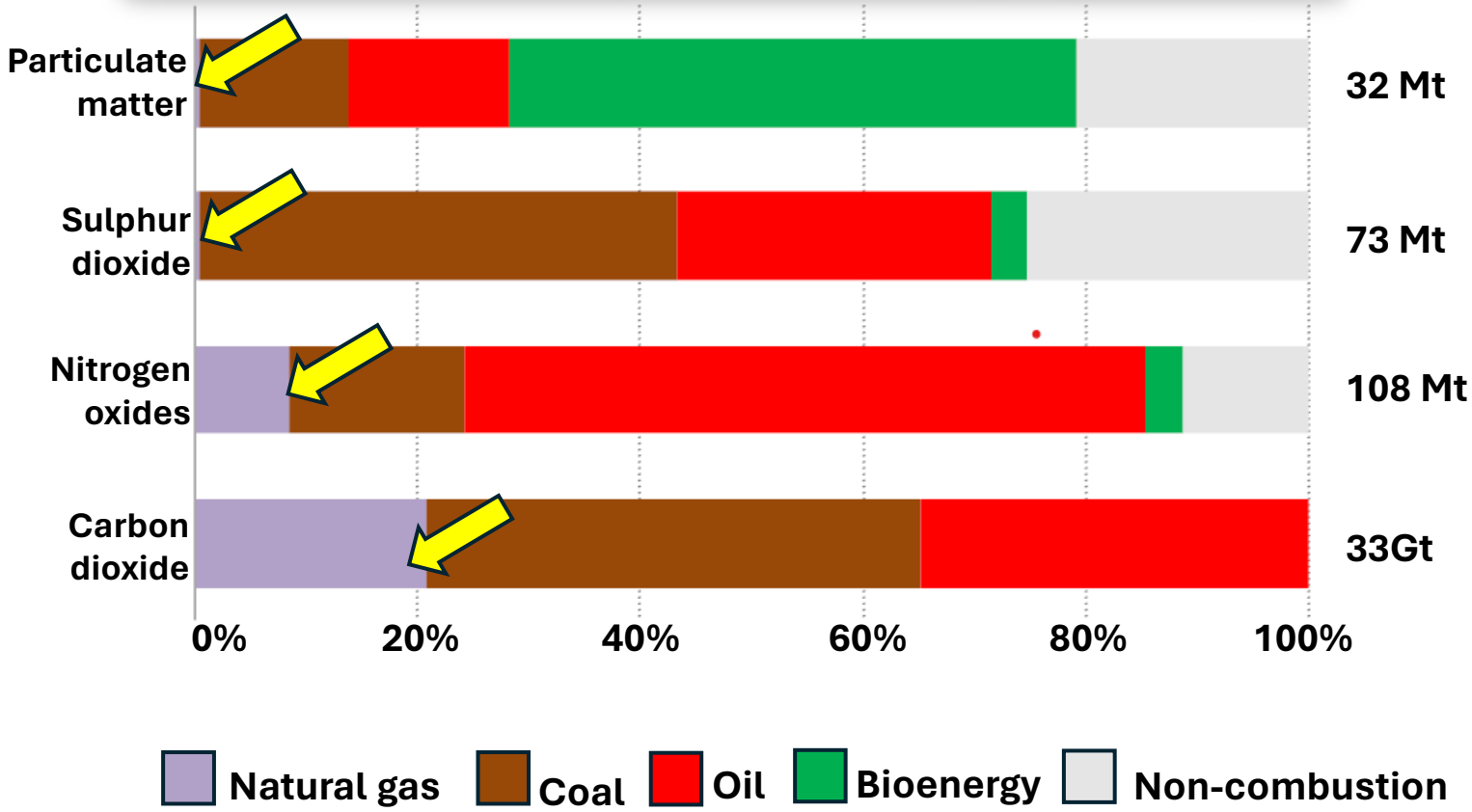
Energy Equity

Natural Gas and Energy Equity

Natural gas has numerous attributes that could enhance energy equity

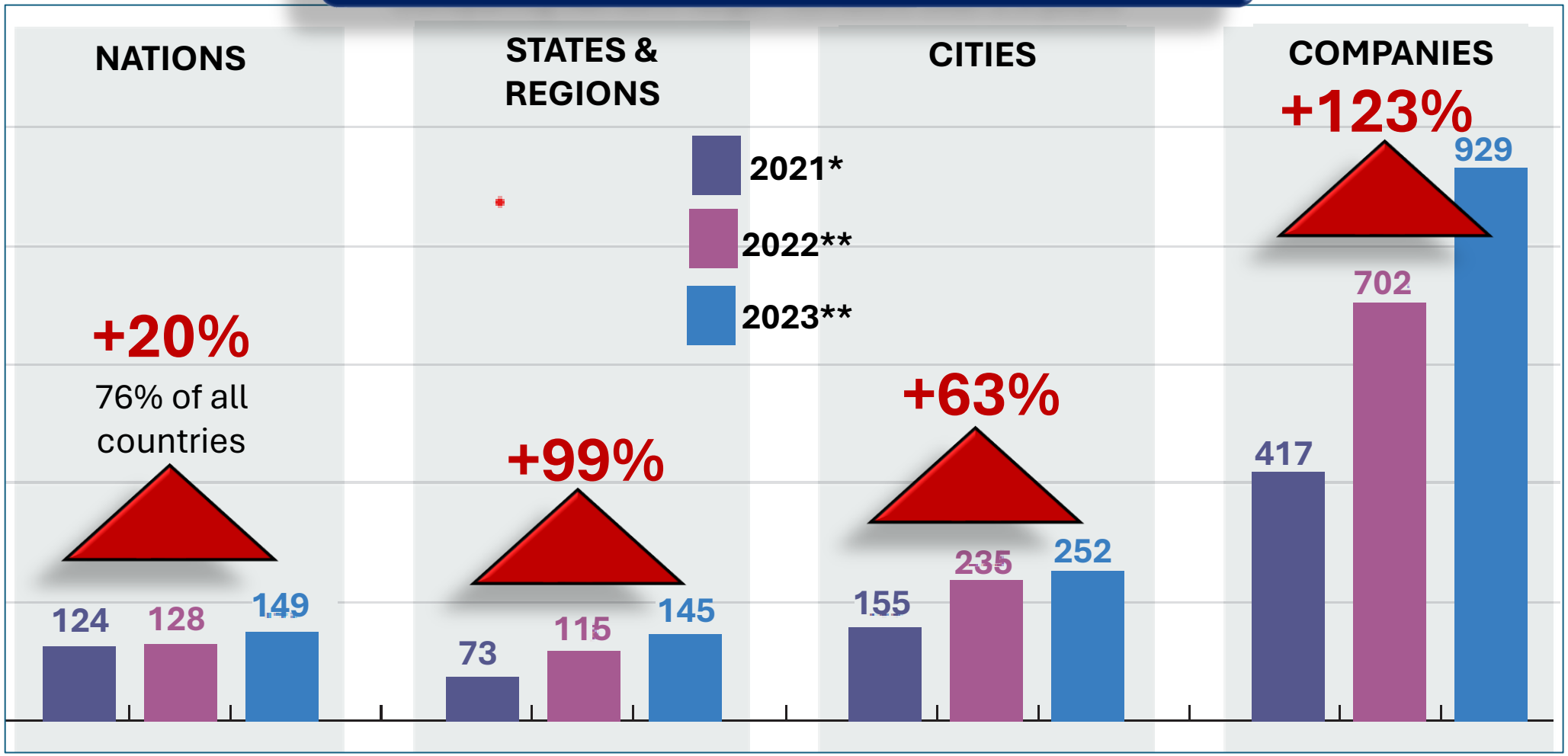
- Provides reliable power generation
- Backup generation for renewables
- Air pollution reduction
- Increased food security
- Associated economic benefits

Share of natural gas in total energy-related emissions of selected air pollutants, including CO_2



Net Zero Target Coverage, June 2023

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



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

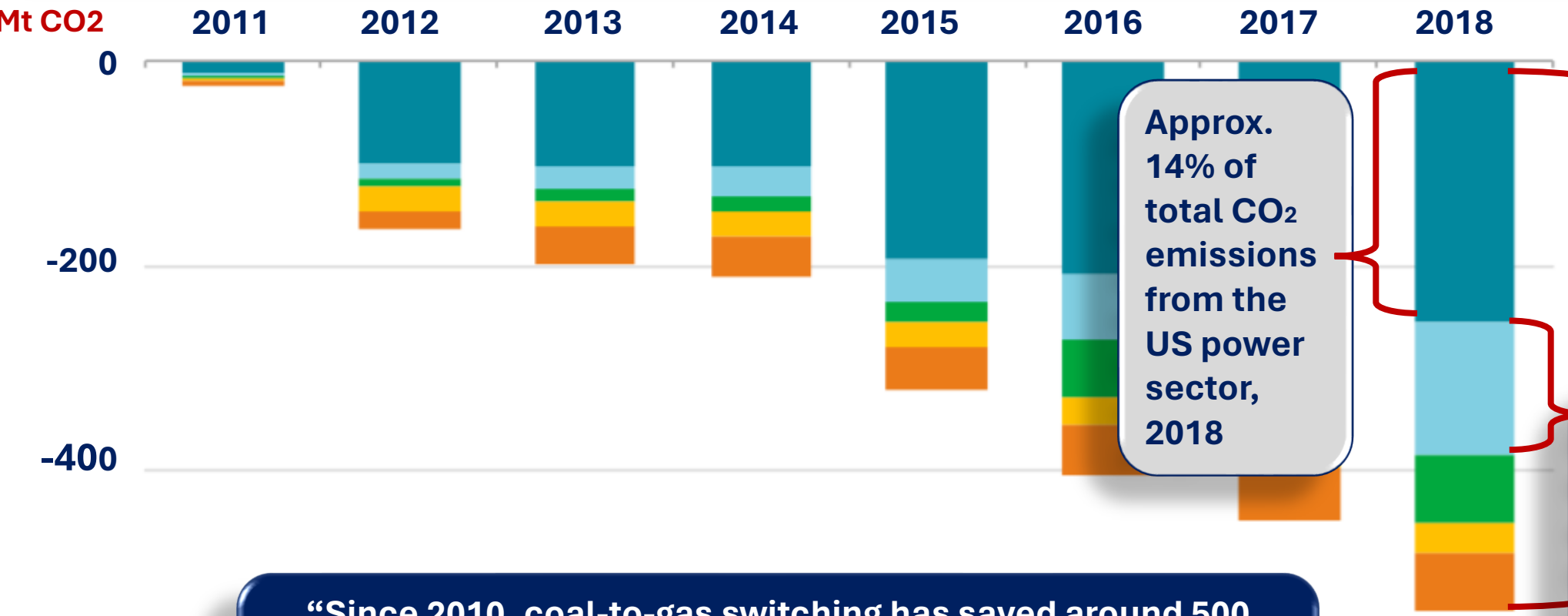
**Net Zero Stocktake 2022, Data: Jume 2022

**Net Zero Stocktake 2023, Data: June 2023

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

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

EFI FOUNDATION



Approx. 14% of total CO_2 emissions from the US power sector, 2018

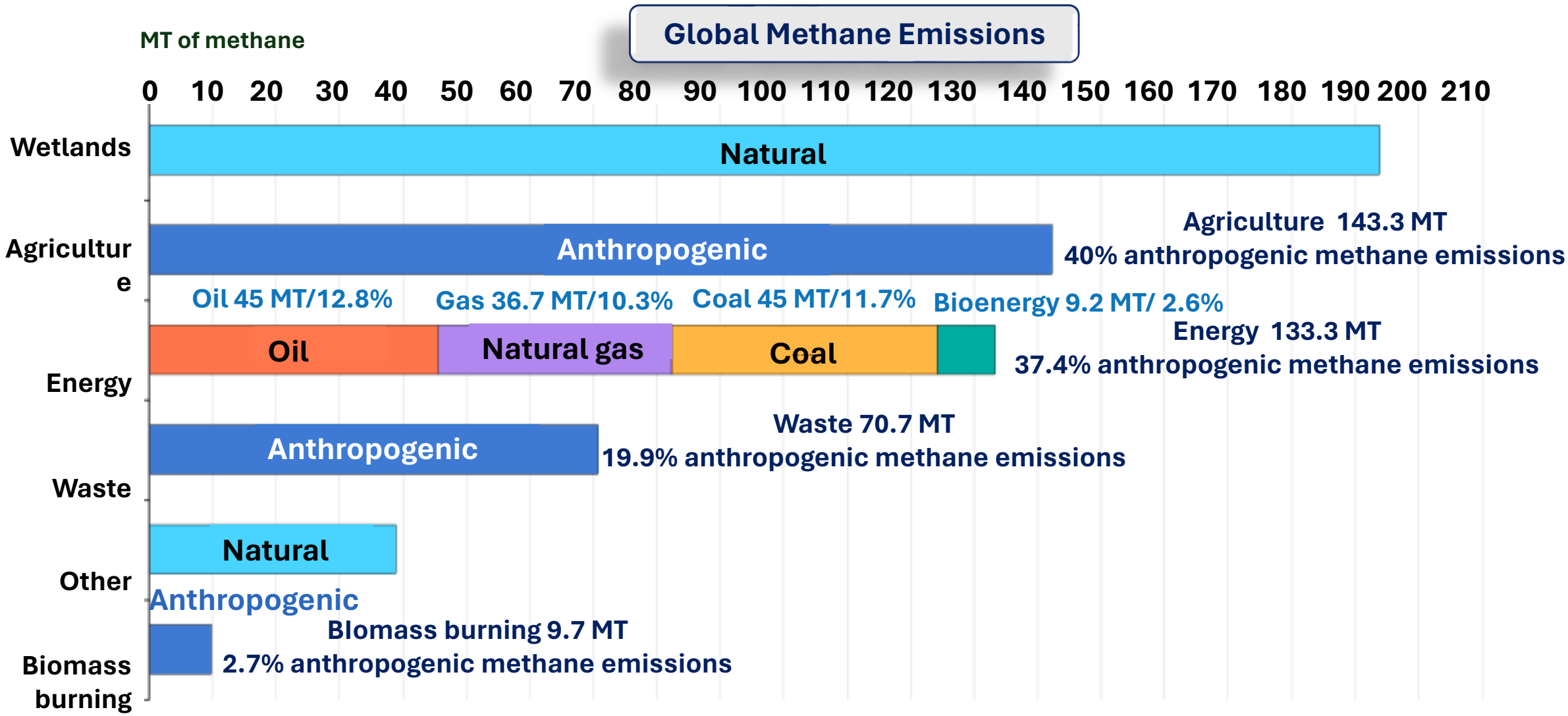
Approx. 4% of total world CO_2 emissions from the power sector, 2018

Approx. 8% of total CO_2 emissions from China's power sector, 2018

"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

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

Amounts/Sources of Global Methane Emissions (2022)



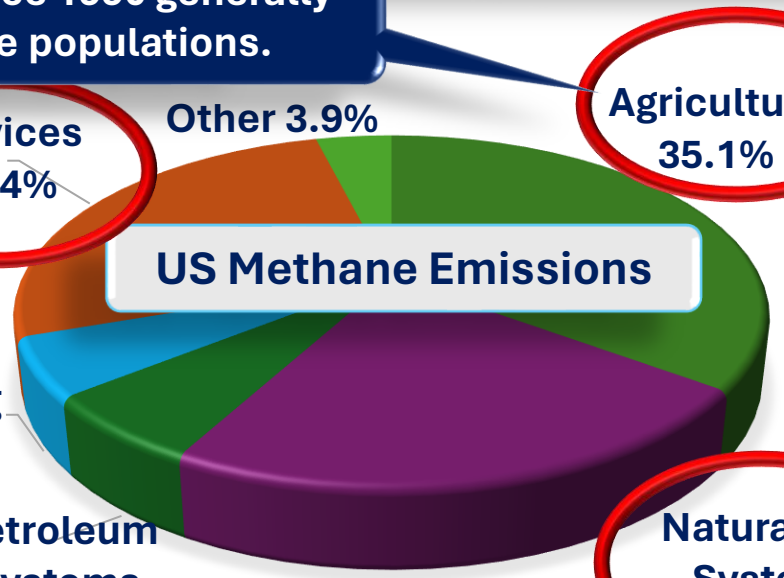
https://www.iea.org/reports/global-methane-tracker-2023/understanding-methane-emissions

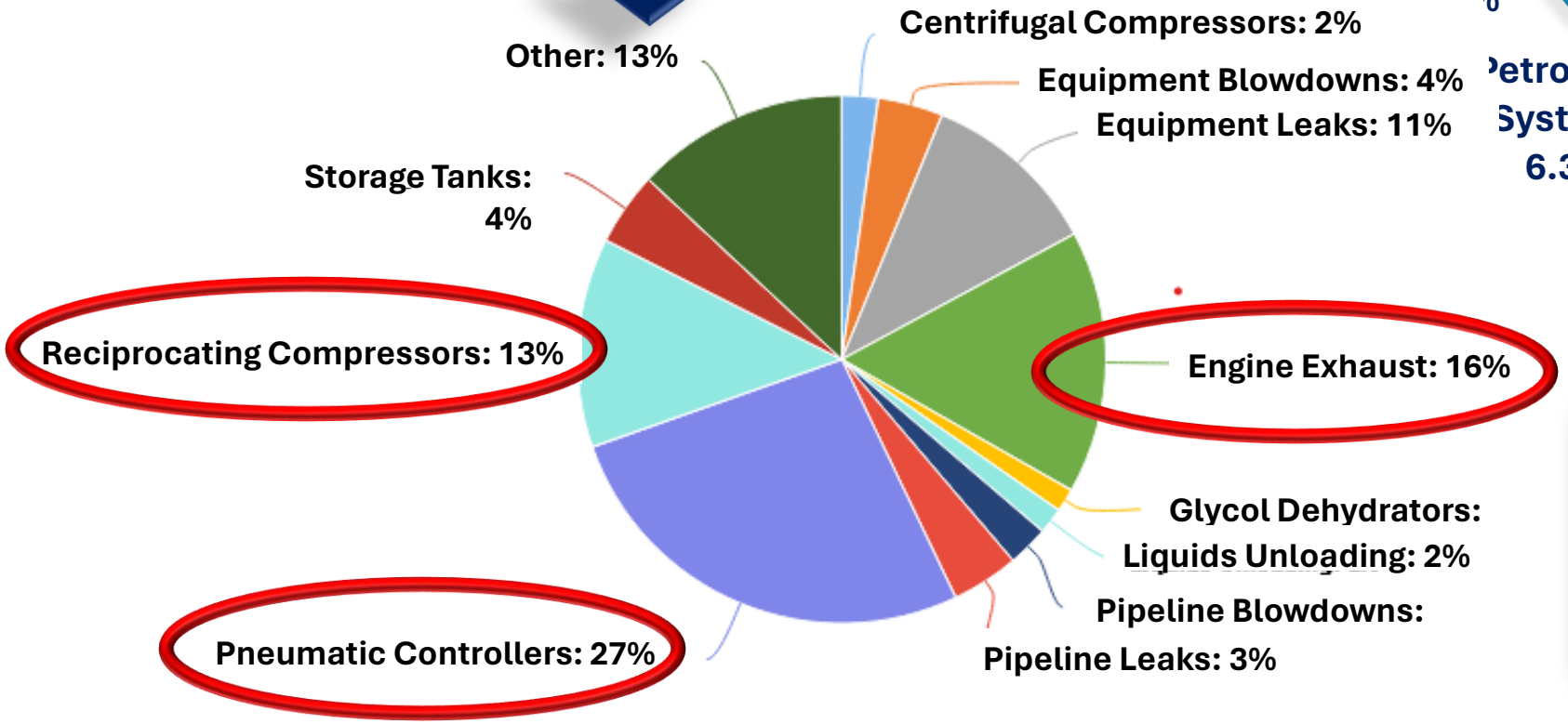
Amounts/Sources of US Methane Emissions (2021)

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

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%***



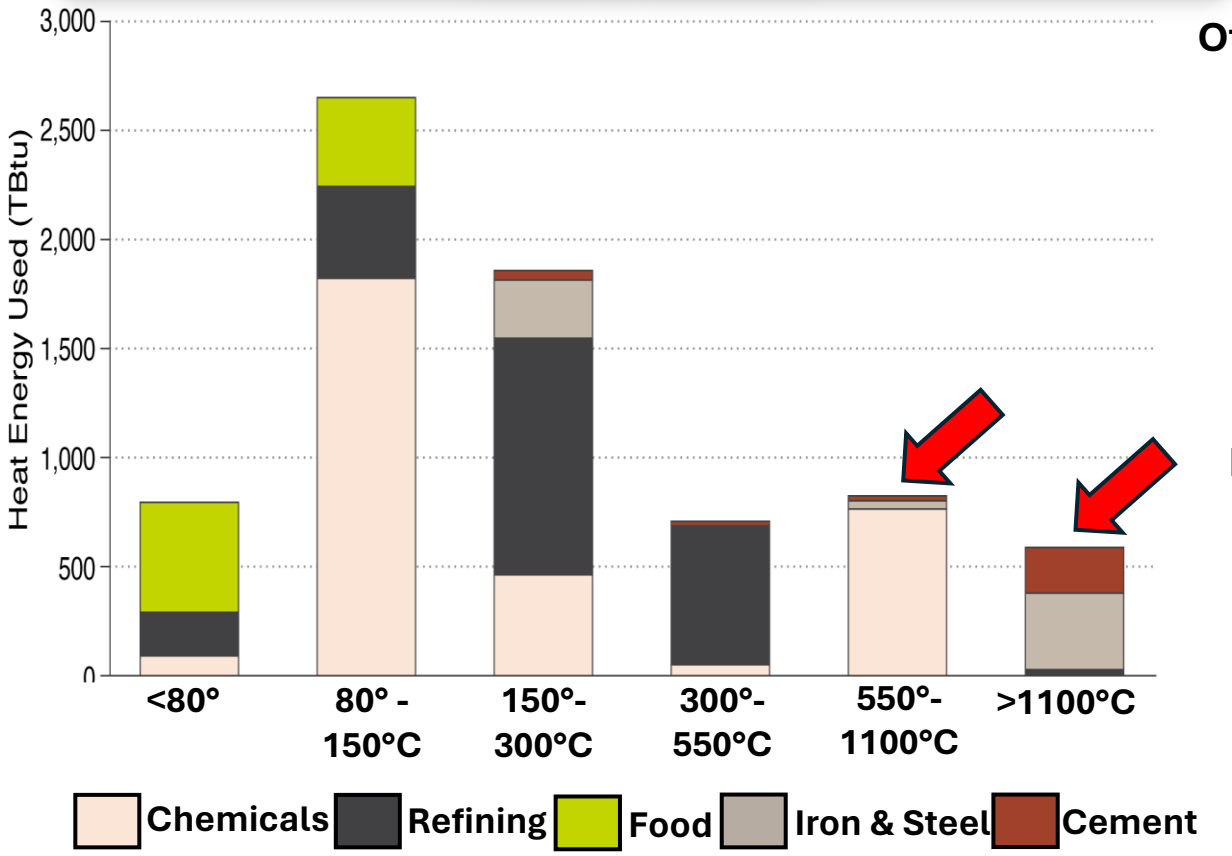


Emissions decreased by 15.7% since 1990 largely due to decreases in emissions from distribution, transmission, and storage.

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

Heat Requirements for Key Industrial Processes

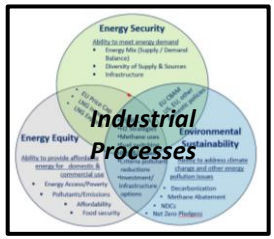
Distribution of process heat temperature ranges by U.S. industrial subsector



% Share of Heat Requirements for Key/Cross-cutting Industrial Processes

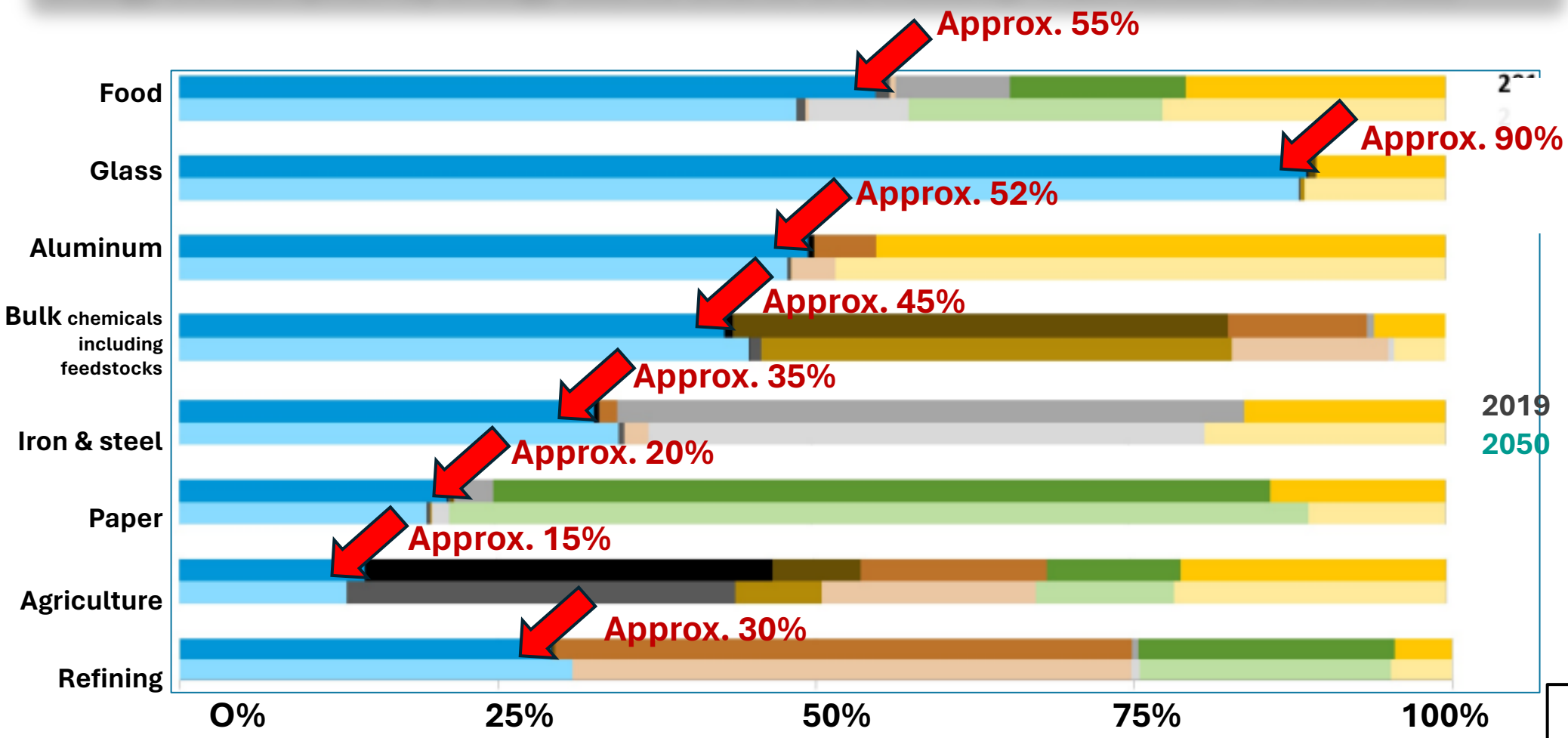
		Examples of process	Technology status
Other (potential not assessed)	19%		
Very high temperature heat (>1000° C)	32%	Melting in glass furnace, reheating of slab in hot strip mill, calcination of limestone for cement production	Research or pilot phase
High-temperature heat (400-1000°C)	16%	Steam reforming and cracking for petrochemical industry	Available today
Medium-temperature heat (100-400°C)	18%	Drying, evaporation, distillation,, activation	Available today
Low-temperature heat (<100°C)	15%	Washing, rinsing, food production	Available today

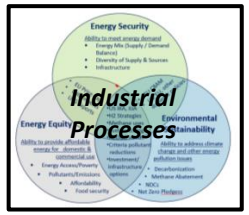
…approximately 32 percent of key industry processes require very high temperatures (>1000 °); another 16% require high temperatures (400-1000 °). Technologies for achieving high heat other than from fuel combustion are still in the research or pilot phases. These processes currently require a fuel such as natural gas to affordably achieve the levels of heat needed.



Natural Gas Supports Significant Industrial/ Economic Activity

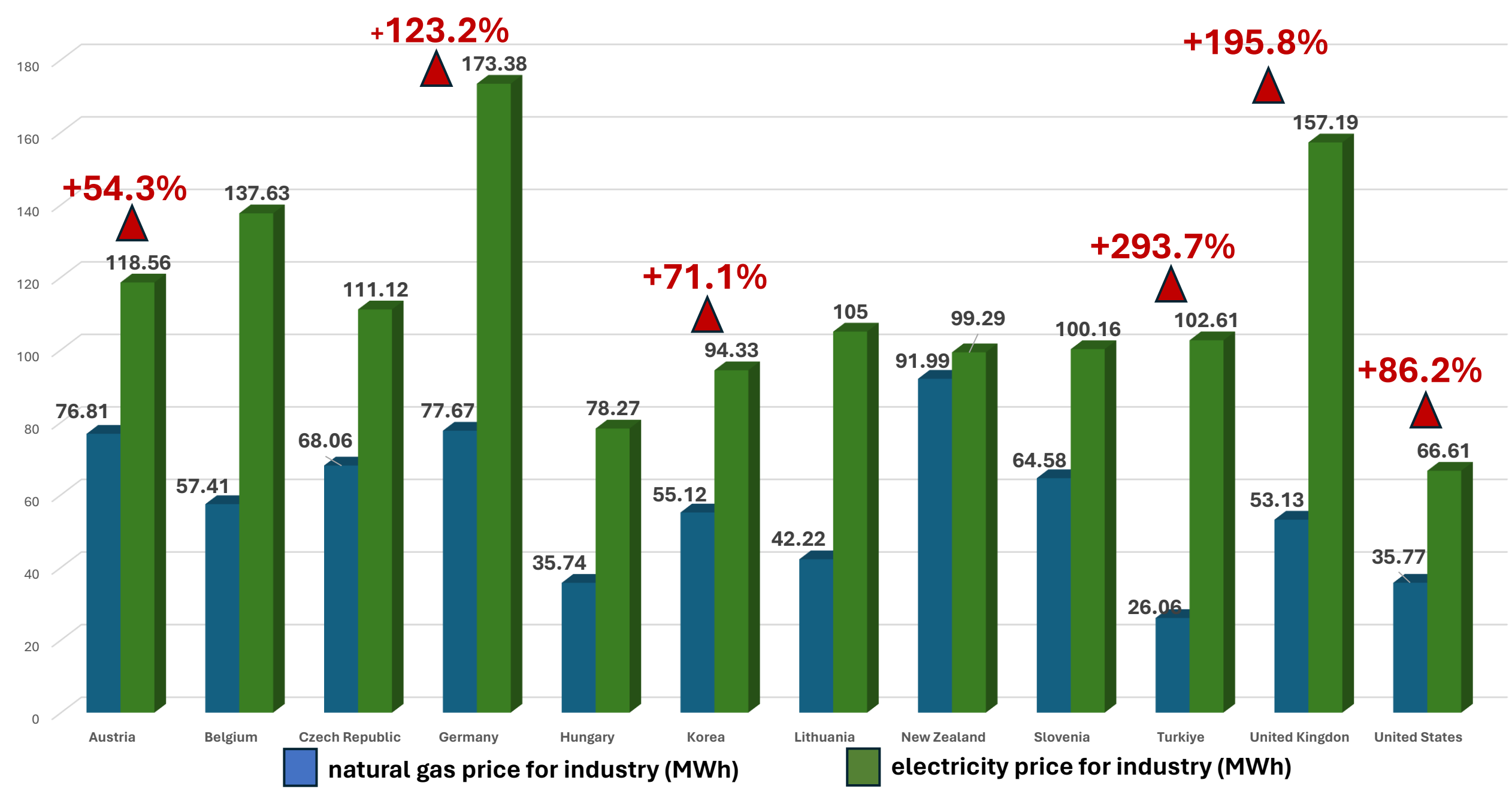
Energy Consumption by Energy Source Shares and Industry, % (EIA AEO2020 Reference Case)





Source: US EIA, 2020 AEO

Natural Gas and Electricity Prices, Select OECD countries, 2021 (mcf)



Case Studies of Key Industrial Sub-sectors: Need for Multiple Decarbonization Pathways

Glass

- Energy intensive, high heat required
- Electrification of furnaces not fully developed
- Need options commercially viable and aligned with technical needs and regulations

Steel

- Challenging to balance emissions reduction with the industry's role in development
- Need to adopt multiple decarbonization options – changes in manufacturing process, fuel switching, and CCUS

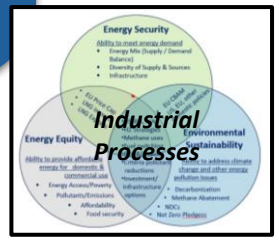
Need for multiple pathways to deep decarbonization

Cement

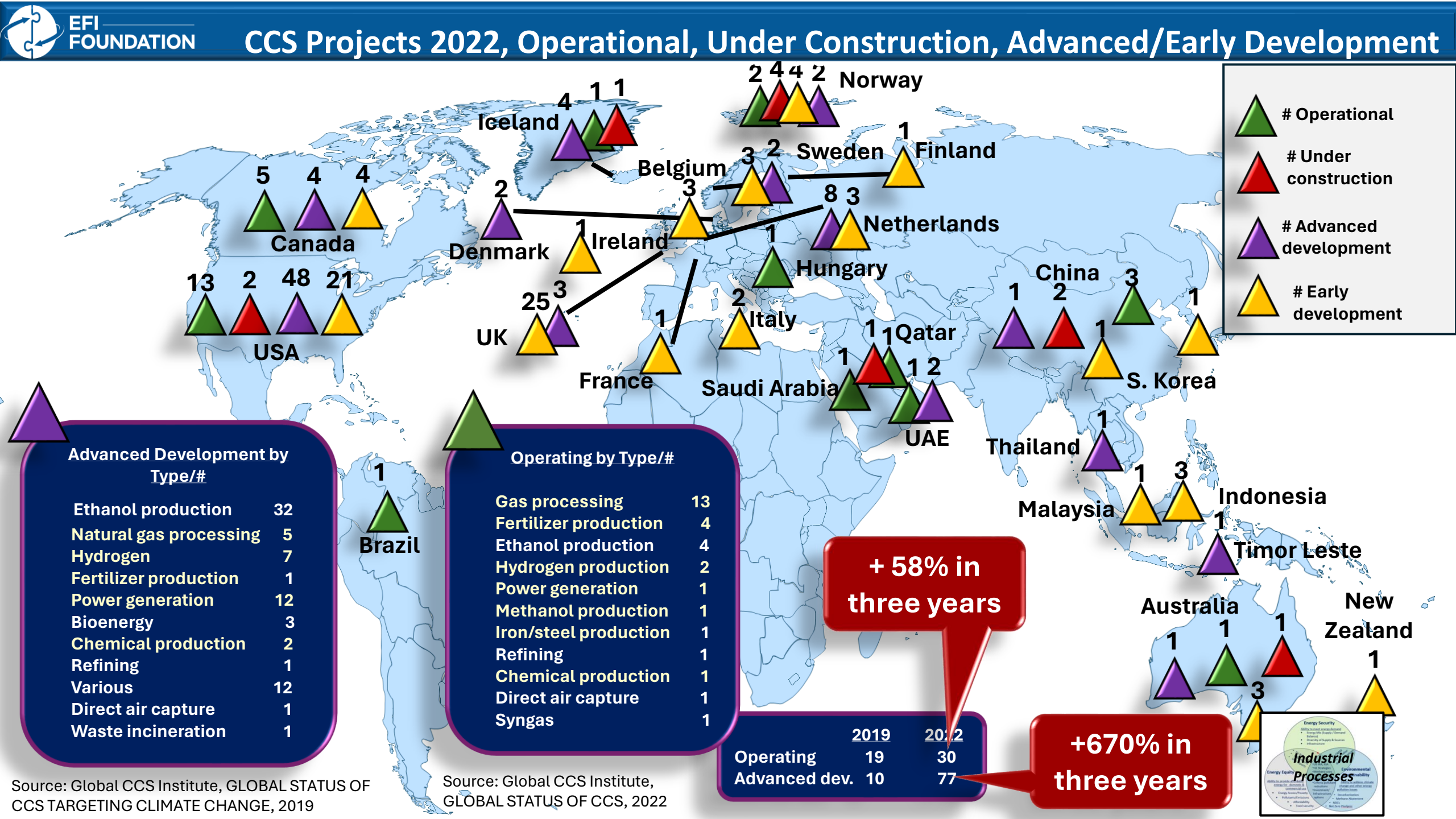
- Mitigation measures are insufficient, expensive, or inadequate
- In addition to electrification, multiple approaches are needed for decarbonization
- Cost-sensitive due to the low-margin nature

Ammonia

- Mostly made from natural gas
- Green ammonia is promising but costly
- Decarbonization options include electrolysis, methane pyrolysis, and CCUS



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



Advanced Development by Type/#

Ethanol production	32
Natural gas processing	5
Hydrogen	7
Fertilizer production	1
Power generation	12
Bioenergy	3
Chemical production	2
Refining	1
Various	12
Direct air capture	1
Waste incineration	1

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

Operating by Type/#

Gas processing	13
Fertilizer production	4
Ethanol production	4
Hydrogen production	2
Power generation	1
Methanol production	1
Iron/steel production	1
Refining	1
Chemical production	1
Direct air capture	1
Syngas	1

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

	2019	2022
Operating	19	30
Advanced dev.	10	77

+ 58% in three years

+670% in three years

Recommendations

Energy Security

- Establish a collective action mechanism to develop energy security strategies for natural gas
- Include an "Energy Security Determination" as a key component of the public interest determination for approving U.S. LNG export permits to non-Free Trade Agreement (FTA) countries
- Ensure ongoing global leadership role for the U.S. in meeting global energy security objectives
- Continue to maintain destination flexibility of U.S. LNG
- Establish U.S. information-sharing requirements and a convening authority to harmonize federal, state, local, and tribal permitting requirements.
- Further analyze supply needs and operational implications of announced and under construction natural gas-fired power plants and associated infrastructure in Europe and Asia

Energy Equity

- Enhance international support for the clean energy transition in developing countries.
- Support additional public and private sector funding for the implementation of the ALTÉRRA fund, or similar private funds.
- Expand MDBs' financing of methane emissions reduction projects in natural gas operations.
- Re-establish a multilateral development bank CCUS trust fund
- Support developing countries in securing reliable and affordable natural gas supplies, mitigation technologies, and infrastructure.
- Perform an analysis of the Asia-Pacific region to develop a comprehensive energy security roadmap for the region through 2050.

Recommendations, contd.

Environmental Sustainability

- Build international consensus on GHG disclosure requirements for LNG supply chain
- Assess the potential for ,methane emissions associated with additional gas supplies and provide policy/technology support for mitigation
- Task CEQ with clarifying and routinizing the assessment criteria and guidance for emissions from U.S. LNG projects
- Accelerate the implementation of the Global Methane Pledge
- Assess and quantify methane emissions from LNG shipping and ships
- Enhance cooperation on developing national and regional industrial decarbonization pathways
- Incentivize and accelerate R&D to reduce the cost of electrifying industrial heat
- Incentivize industry to switch to low-carbon hydrogen to meet existing demand for industrial feedstocks

Cross-cutting

- Identify an international entity to develop consistent, transparent, and accurate methodologies for calculating Scope 1, 2 and 3 emissions
- Establish and maintain accurate and comprehensive methodologies for GHG accounting across energy systems and supply chains
- IEA should accommodate economic development metrics in its modeling
- Under the auspice of the UNFCCC, complete a price-based climate policy economic analysis
- Accelerate international collaboration on deployment of CCUS technologies