

Electricity Energy Supply

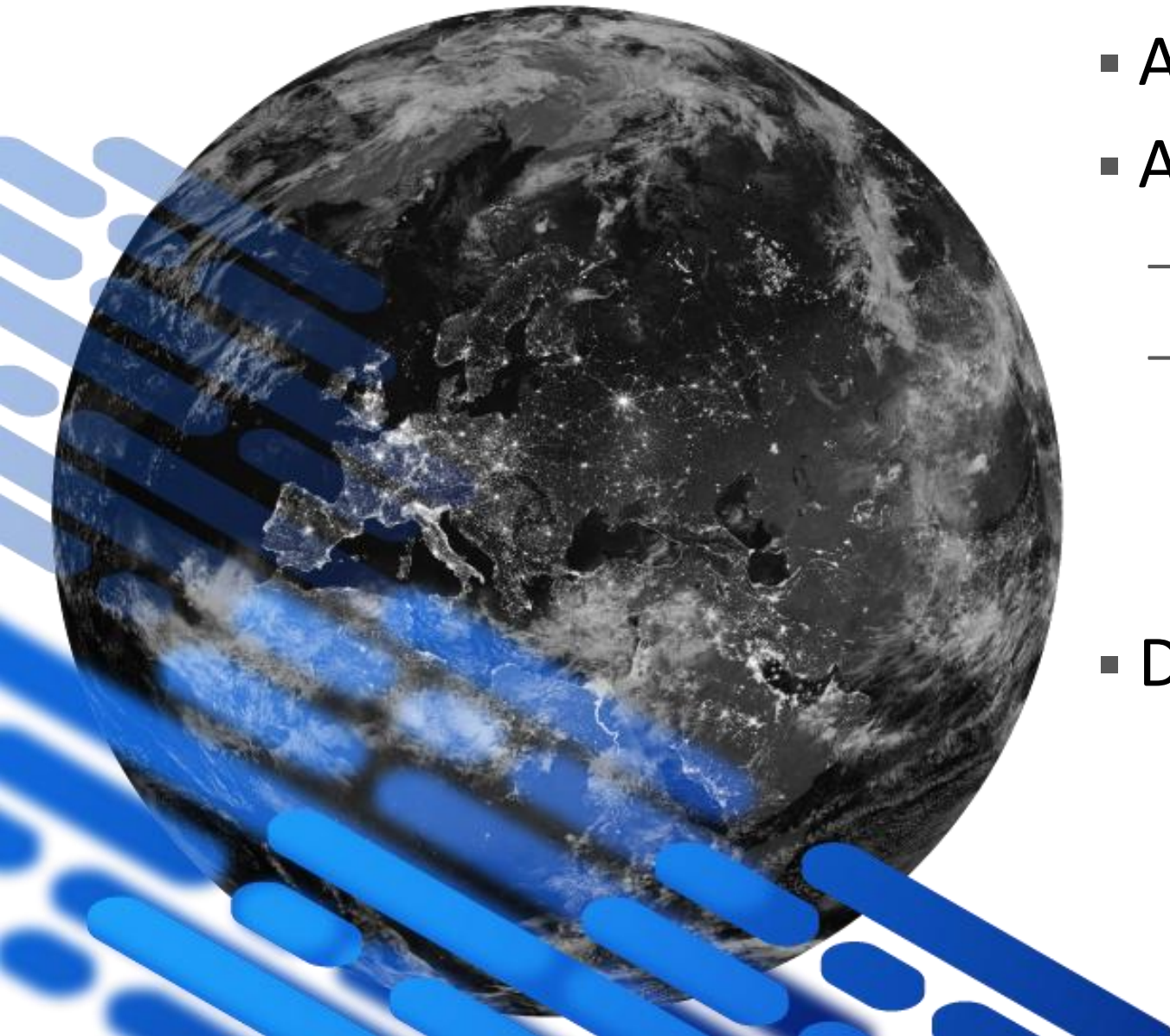
State of the Industry 2025-Q3



October 2025

Mike Caravaggio
Vice President – Energy Supply
Reliability

Agenda



- A little on EPRI
- A look at Electricity Energy Supply
 - Capacity
 - Generation
 - Siting and permitting, the future of generation, workforce development, reliability, supply chain ...
- Discussion

EPRI

Leading Collaborative Energy R&D Around the World

EPRI advances energy technologies and informs decision-making through ~\$420M in collaborative annual research involving nearly 400 entities in ~40 countries - spanning the generation, delivery, and use of electricity.



ENGAGING

- Utilities
- Academia
- OEMs
- Regulators



LISTENING

- Financial Community
- Policy Makers
- Consumer Advocates
- Media

www.EPRI.com

The Future of Energy

~10-15 years

~15-30 years

Decarbonization

Accelerate economy-wide, low-carbon solutions

- Electric sector decarbonization
- Transmission and grid flexibility: storage, demand, EVs
- Efficient electrification

Achieve a net-zero clean energy system

- Ubiquitous clean electricity: renewables, advanced nuclear, CCUS
- Negative-emission technologies
- Low-carbon resources: hydrogen and related, low-carbon fuels, biofuels, and biogas

Clean



Transformation

Drive affordability of a clean and resilient energy system through digital transformation

- Power system modernization: pervasive sensors, monitoring, advanced analytics using AI
- Upgraded and expanded communications infrastructure and control systems

Affordable

Resilience

Mitigate climate impacts and cyber/physical risks

- System and asset hardening
- Improved response
- Faster recovery
- Cybersecurity

Future proof energy system design basis

- Resilient power system design
- Advanced asset design and strategic undergrounding
- Smart integration of energy carriers

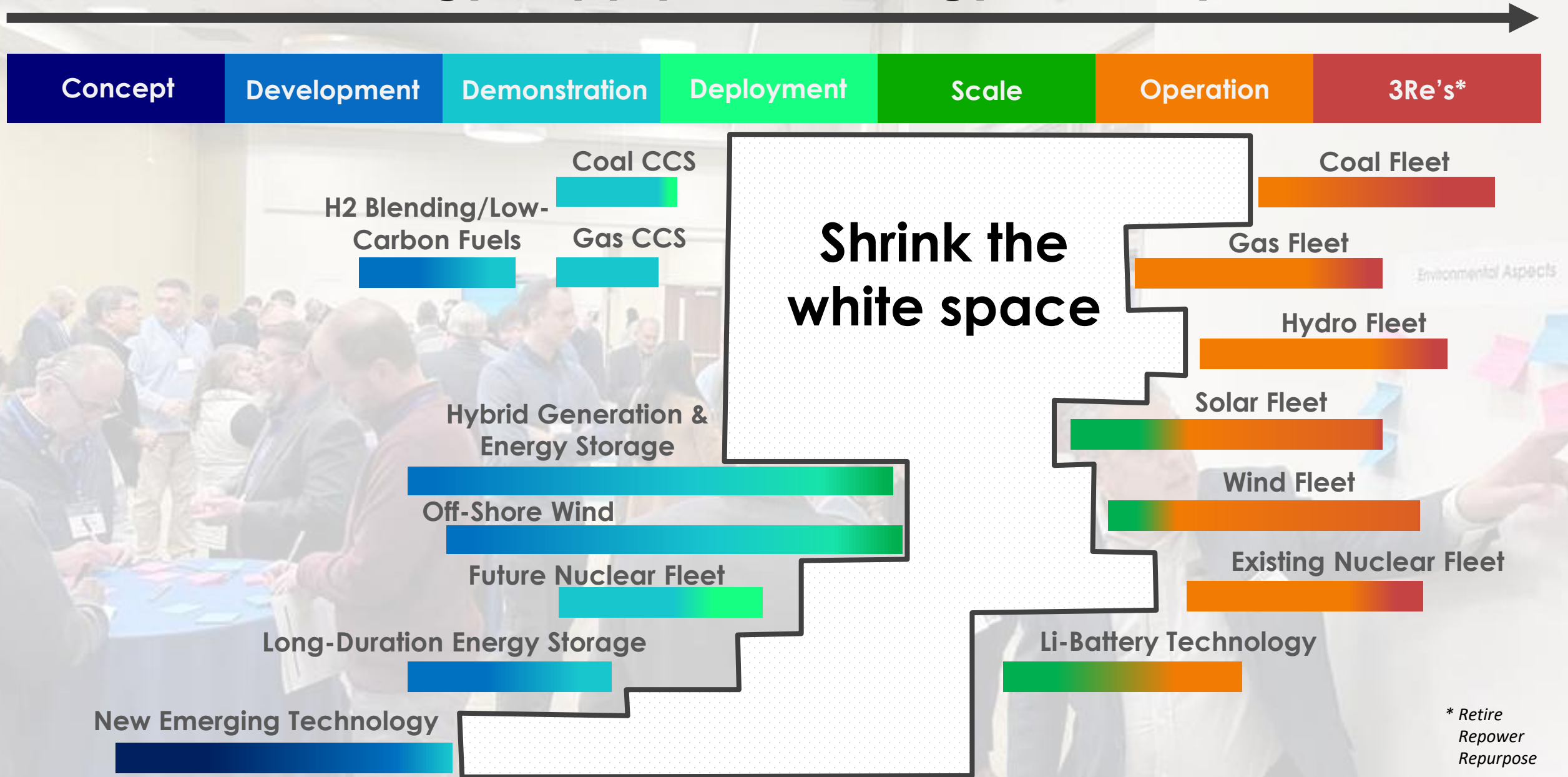
Reliable

~10-15 years

~15-30 years

Making Energy More

Energy Supply Technology Maturity



2025 Generation Portfolio

ARP Program
Supplemental Program
Strategic Supplemental Project



THERMAL FLEET

- 214:** Boiler Life and Availability Improvement
- 215:** Power Plant Piping
- 216:** Gas Turbine Life Cycle Management
- 217:** Gas Turbine Advanced Components and Technologies
- 218:** Heat Recovery Steam Generators
- 219:** Steam Turbines and Auxiliary Systems
- 220:** Generators and Auxiliary Systems

THERMAL OPTIMIZATION & EMISSIONS CONTROLS

- 223:** Heat Rate and Flexibility: Generation Fleet Optimization
- 232:** SCR Performance Issues
- 233:** Continuous Emissions Monitoring and Measurements
- Combustion and Carbon Control Issues (SP254)*
- Emissions Controls (SP253)*

RENEWABLE FLEET

- 206:** Wind Generation
Environmental Aspects of Wind (SP250)
Offshore Wind (SP249)
- 207:** Solar Generation
Environmental Aspects of Solar (SP252)
- 208:** Hydropower Generation
Geothermal

WATER & LAND MANAGEMENT

- 238:** Water Treatment Technologies
- 239:** Aquatic Resource Protection
- 240:** Water Quality and Effluent Guidelines
- 241:** Byproducts Management and Market Development
- 242:** Groundwater and Land Management

AIR QUALITY & HEALTH

- 235:** Air Quality Assessments and Multimedia Characterization
- 236:** Air Quality, Health, and Communities

NEXT-GENERATION FLEET

- 221:** Bulk Energy Storage
- 222:** Advanced Generation and Carbon Capture and Storage
Generation Transitions (SP248)
Low-Carbon Resources Initiative
Net-Zero Industrial Clusters

FLEET MANAGEMENT & OPERATIONS

- 224:** Integrated Asset Management
- 225:** Plant Management Essentials
- 226:** Boiler and Turbine Steam and Cycle Chemistry
Plant Decommissioning and Site Redevelopment (SP255)

DIGITALIZATION

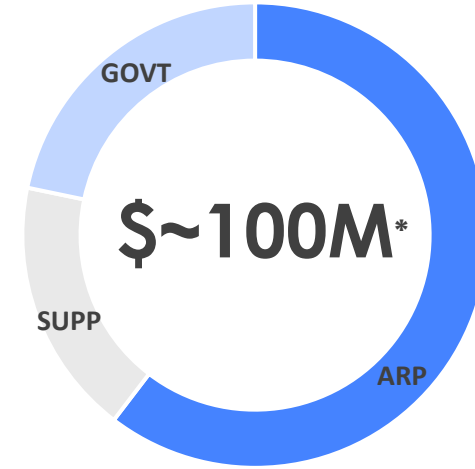
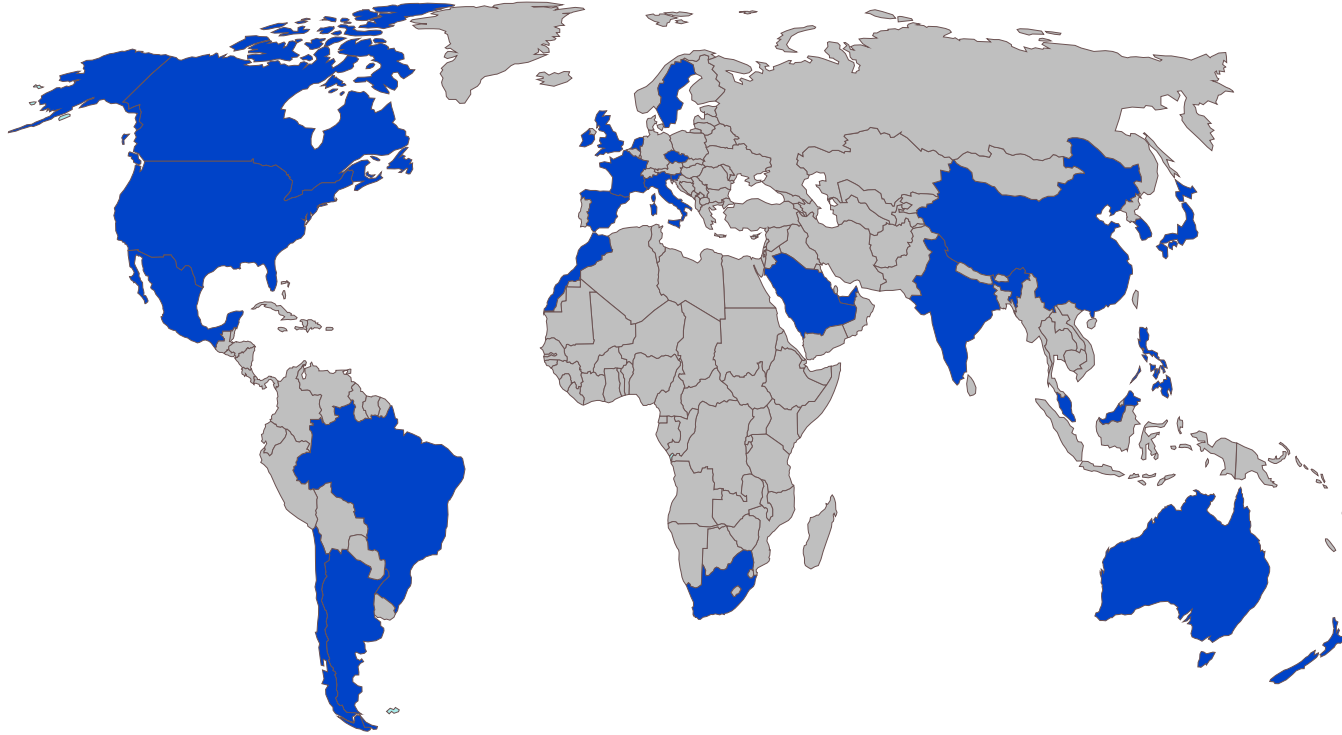
- 209:** Cyber Security for Generation Assets
- 227:** Process Control and Automation
- 228:** Monitoring and Advanced Data Analytics
Digital Transformation Research Initiative

MATERIALS

- 229:** Materials
Advanced Manufacturing

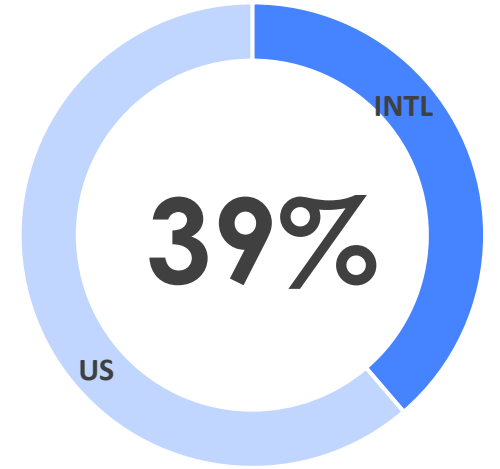


Generation and LCRI at a Glance



GENERATION SECTOR RESEARCH PORTFOLIO SCOPE

***2024 Funding**



INTERNATIONAL OVERALL PARTICIPATION

29 COUNTRIES REPRESENTED

62 ORGANIZATIONS ACROSS THE SUPPLY CHAIN

79 INTERNATIONAL PARTICIPANTS

204 TOTAL US AND INTERNATIONAL PARTICIPANTS



OUR TEAM

**~150 TECHNICAL
GENERATION STAFF**

**2,000+ YEARS OF INDUSTRY
EXPERIENCE**

**Power Companies – OEMs – Suppliers
Engineering Firms – Academia –
Government**

A Perfect Storm

**This Decade
Represents a
Perfect Storm of
Challenges and
Opportunities.**

2020

2021

2022

2023

2024

2025

2026

2027

2028

2029

2030



Demand Growth Accelerates



Weather Events Continue



Aggressive Carbon Goals in Place



Technologies Needed Not Ready



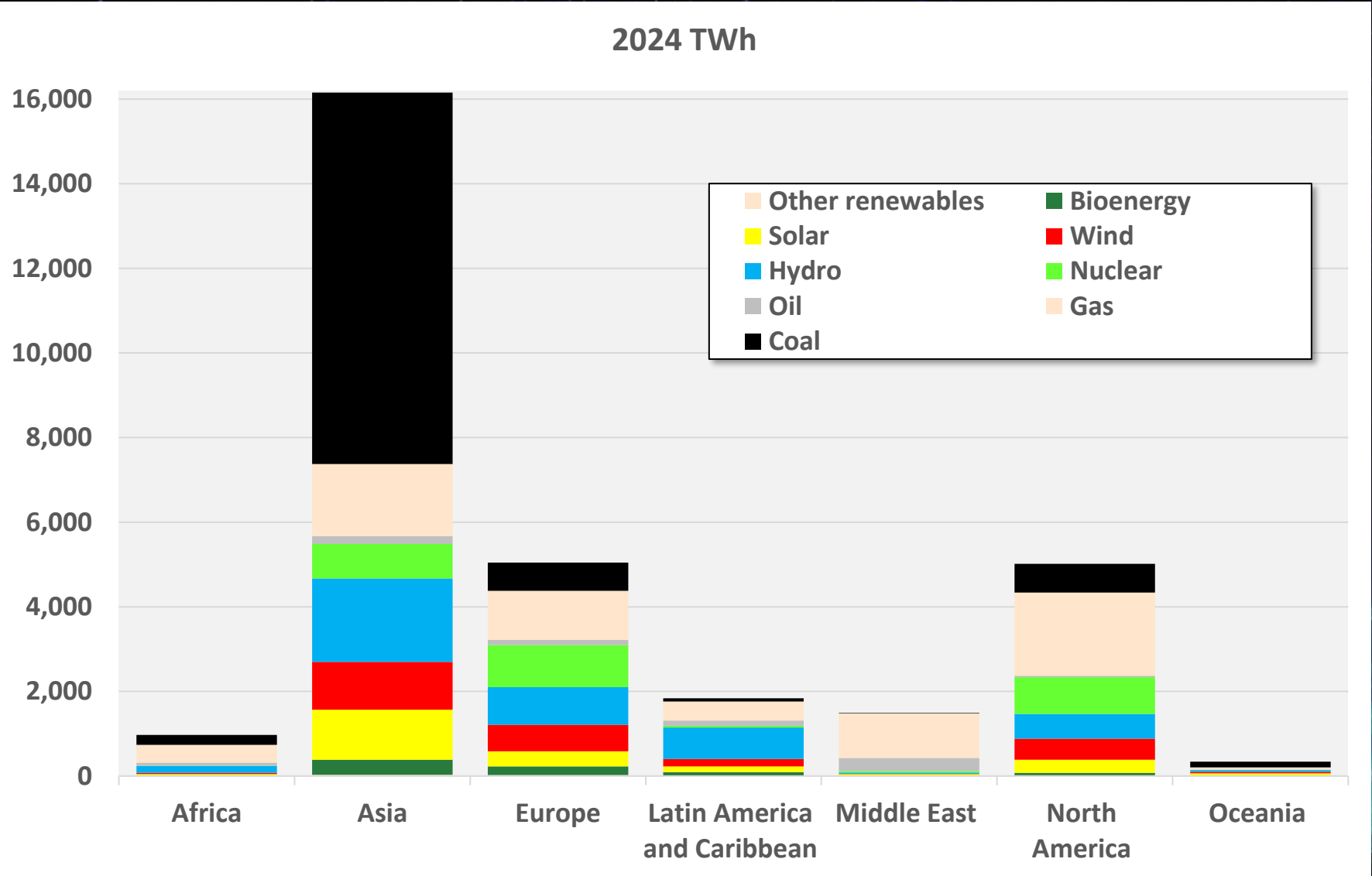
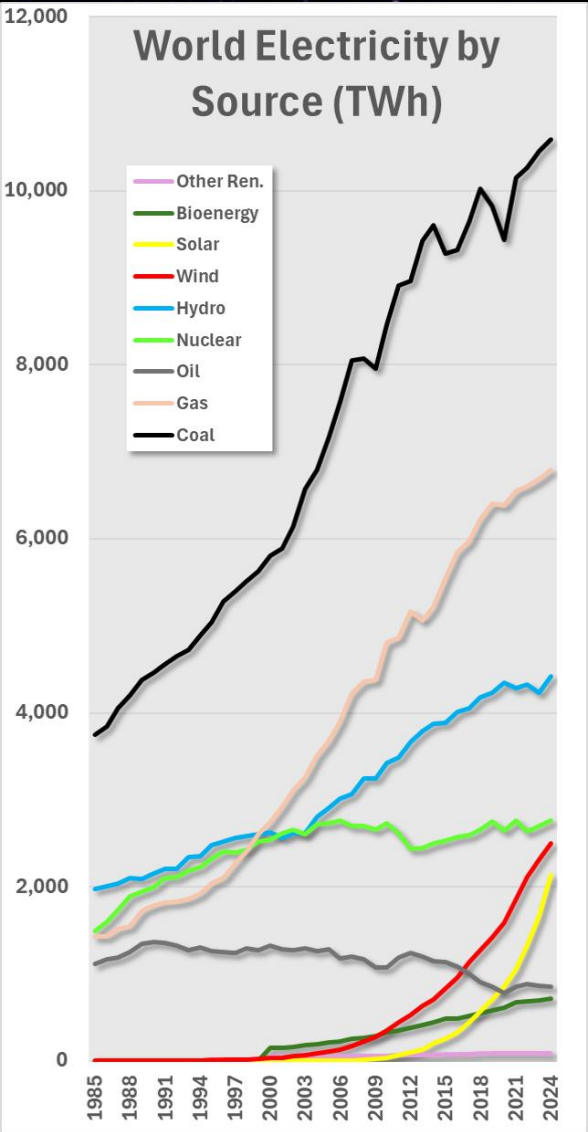
Affordability & Reliability Critical

GLOBAL ENERGY TRANSITION IS TODAY

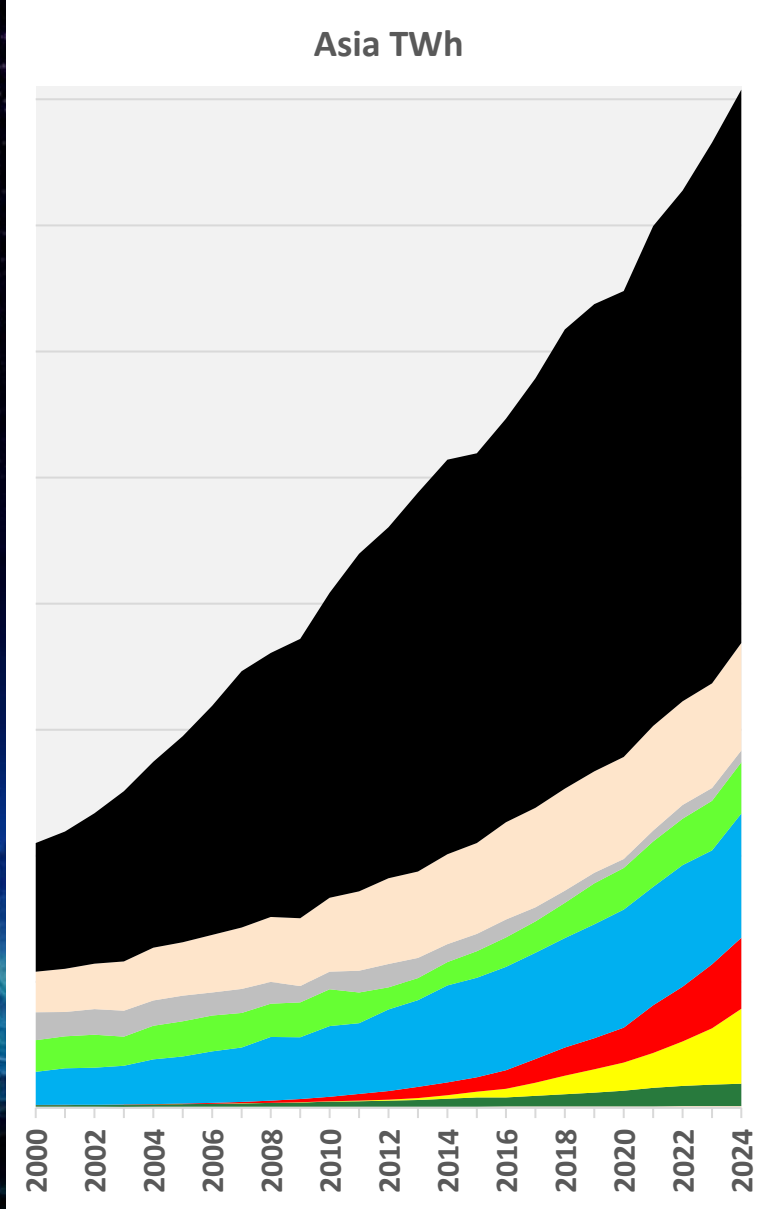
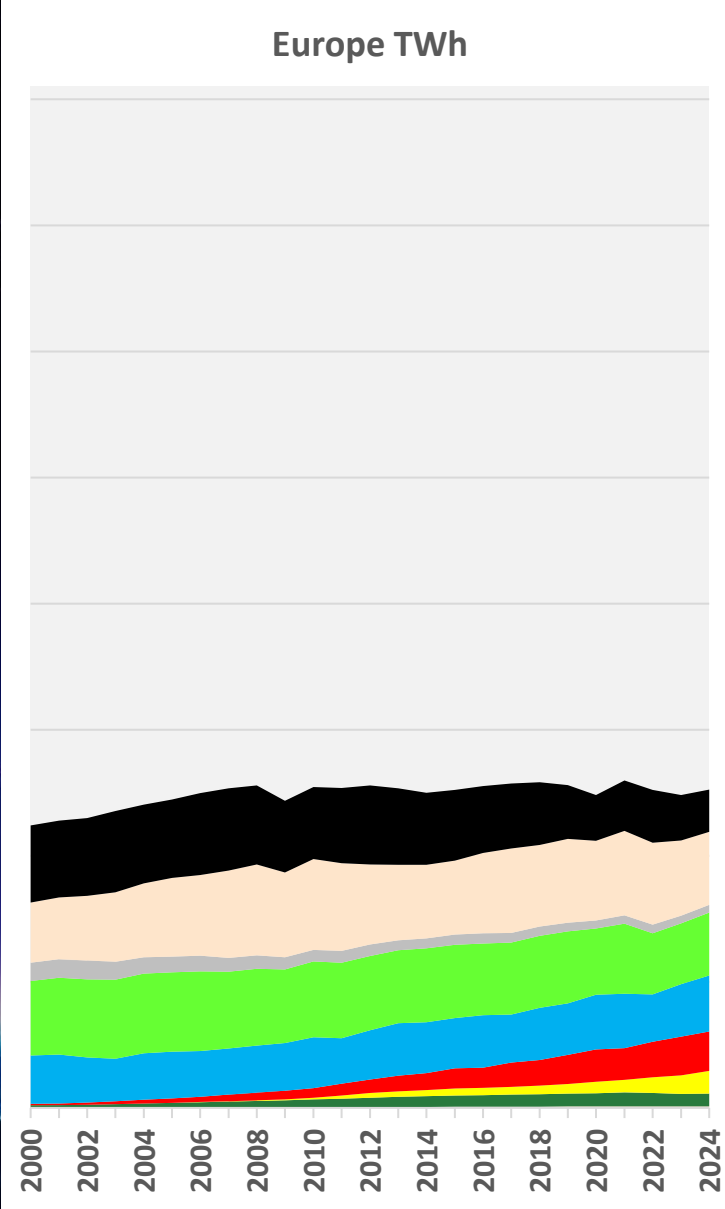
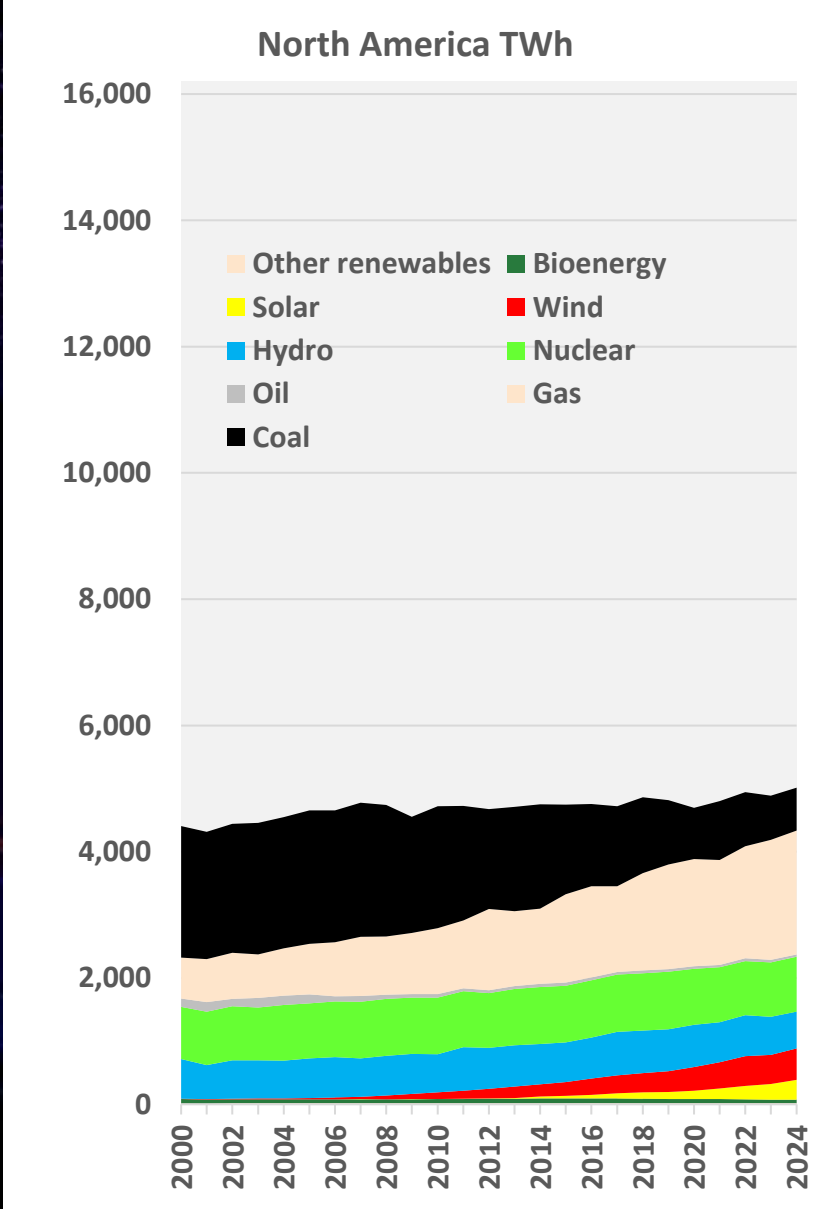


Global

Global Supply



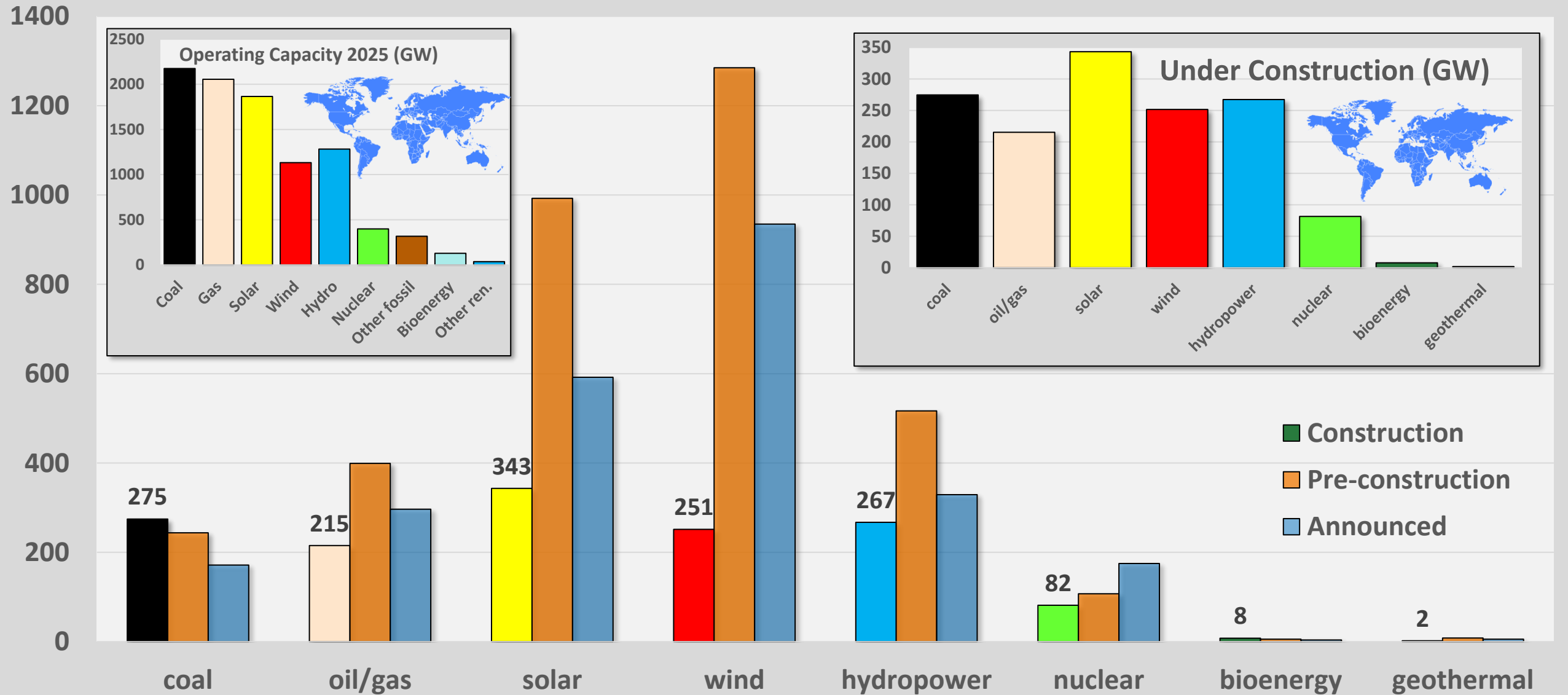
Global Supply



Global Capacity

Capacity (GW)

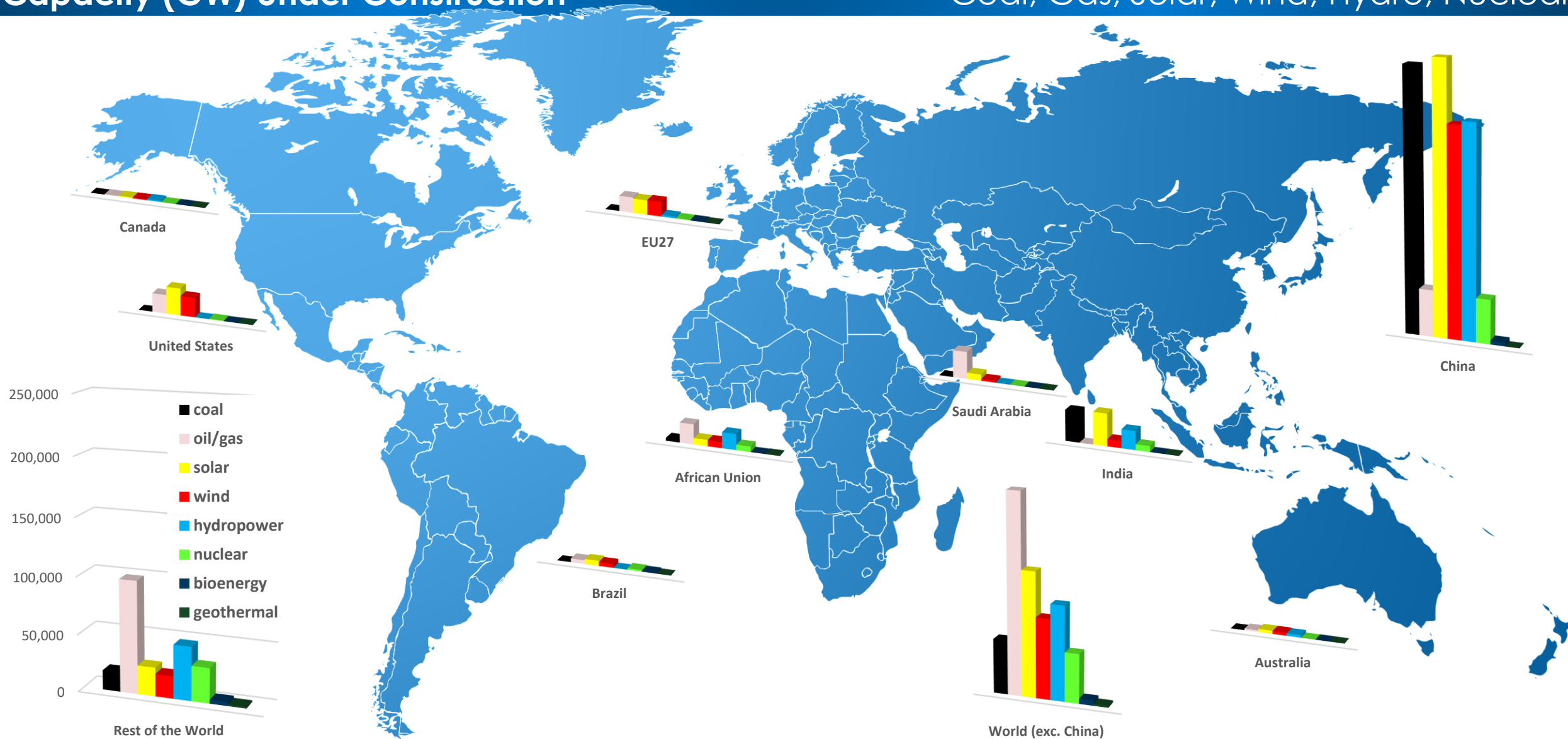
All of the Above
Coal, Gas, Solar, Wind, Hydro, Nuclear



Global Capacity

Capacity (GW) Under Construction

All of the Above
Coal, Gas, Solar, Wind, Hydro, Nuclear

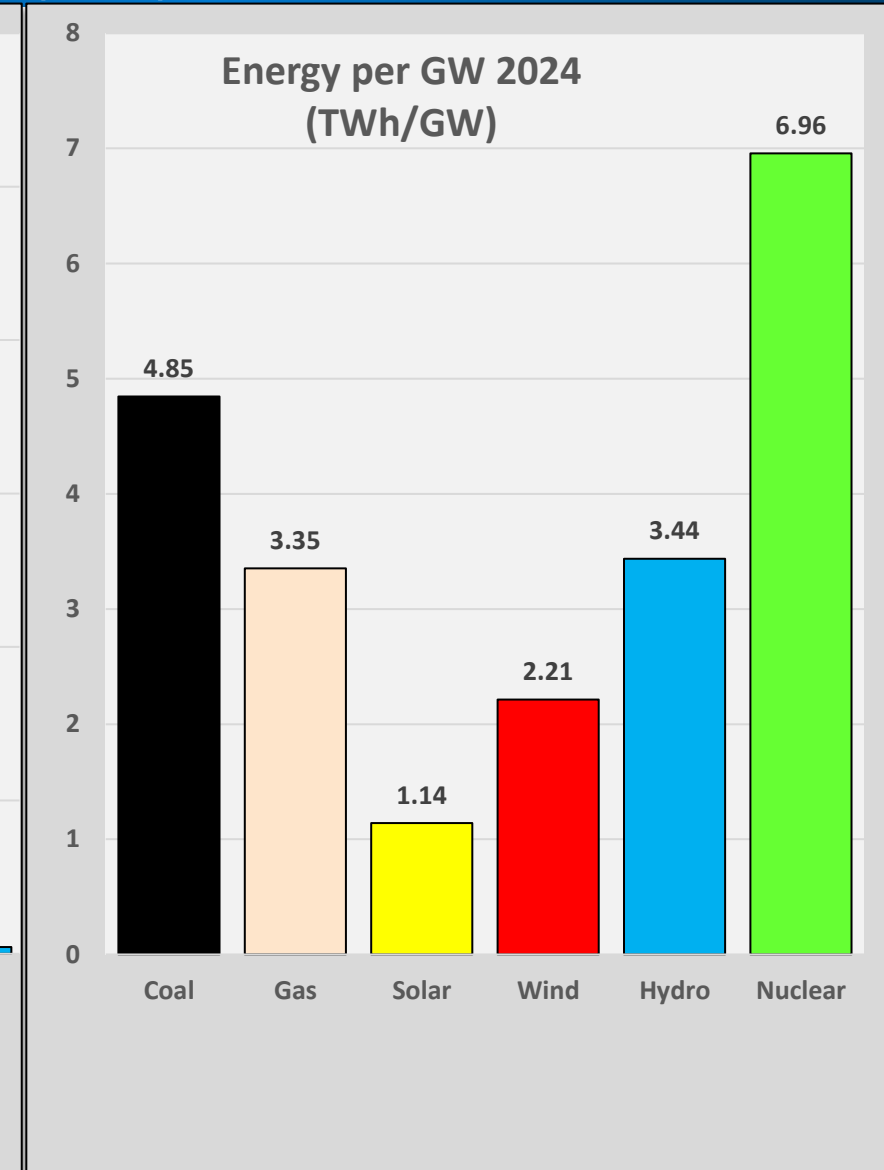
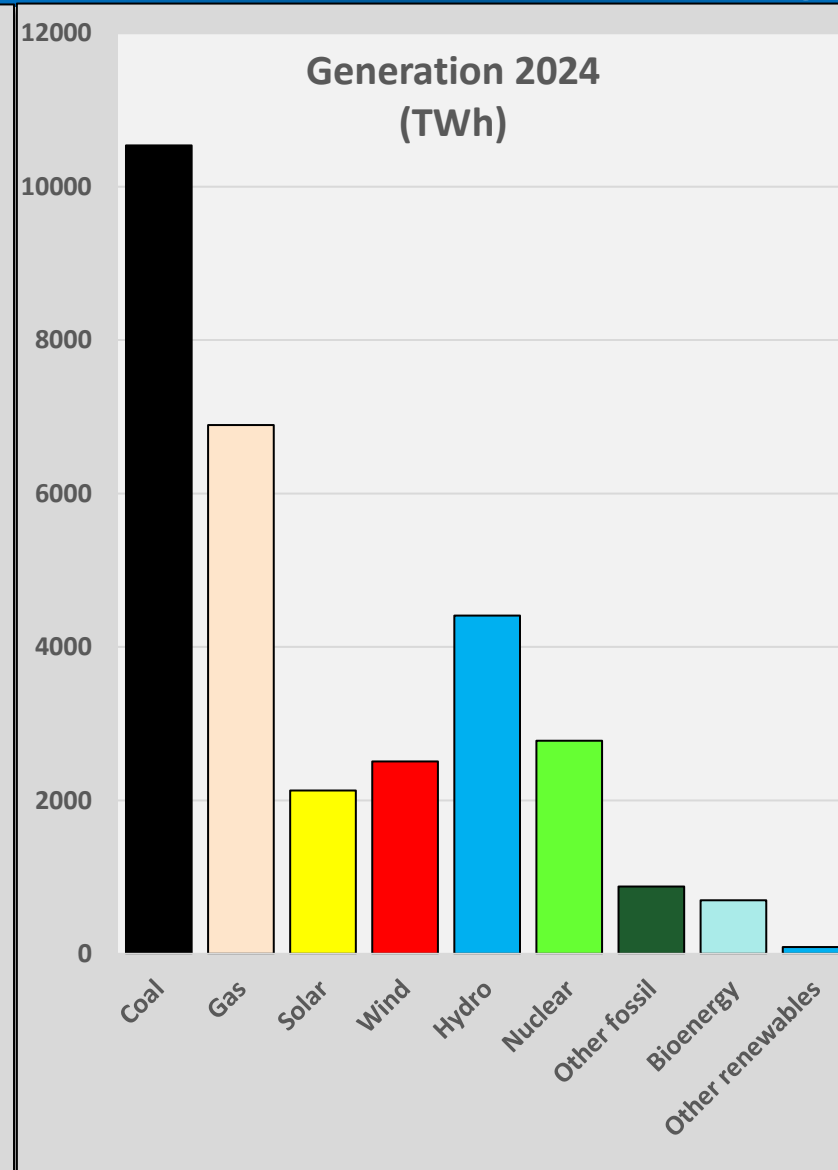
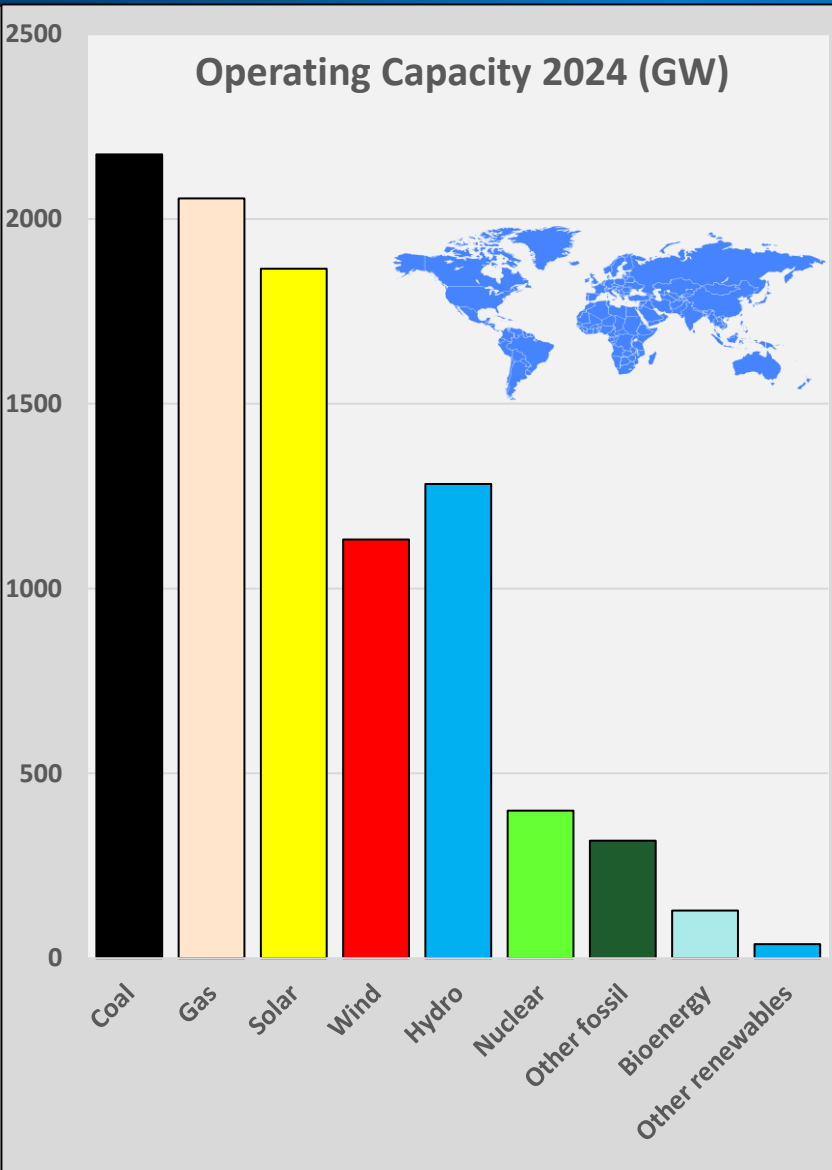


Capacity & Generation

Global 2024

A GW is not a GW is not a GW

Annual Energy (TWh) per GW Installed Capacity

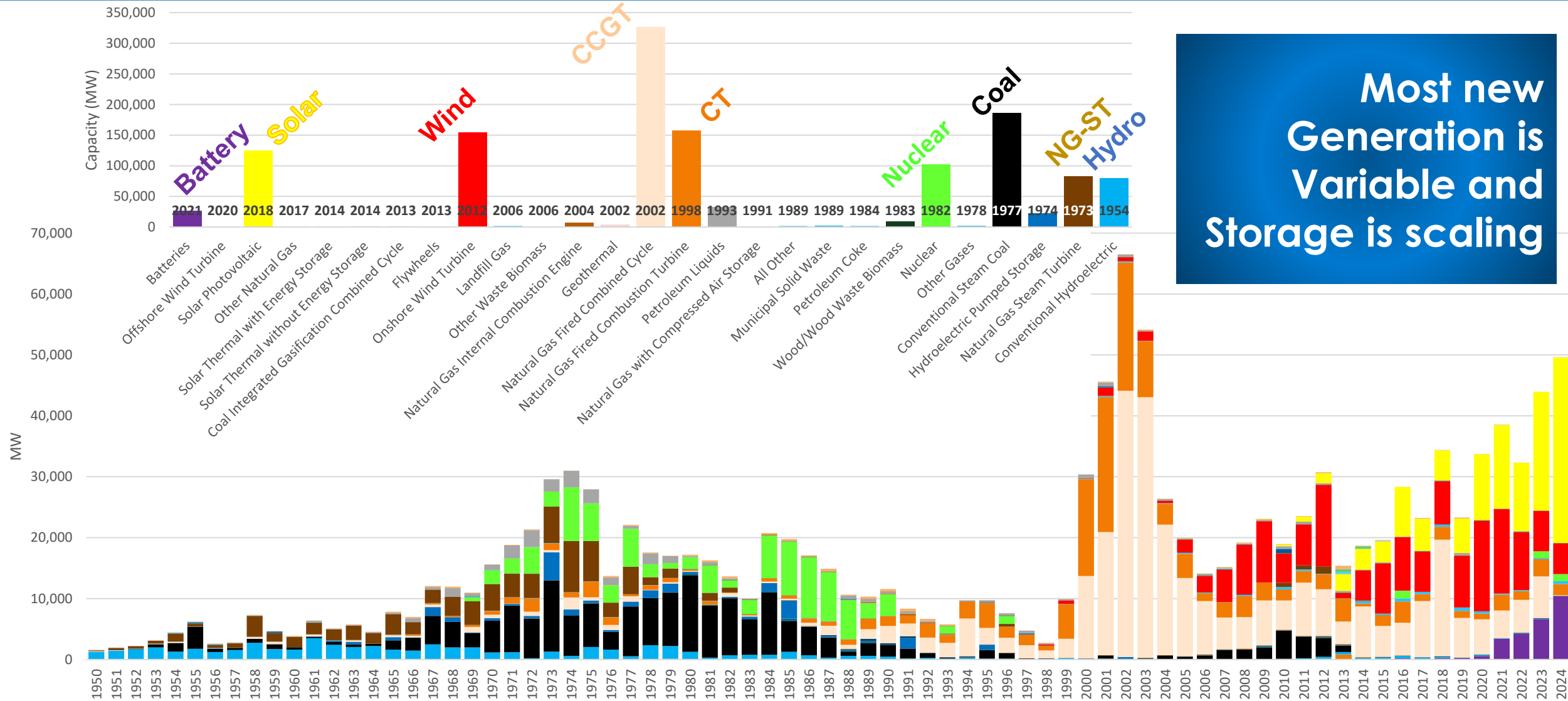




USA

US Capacity Detail

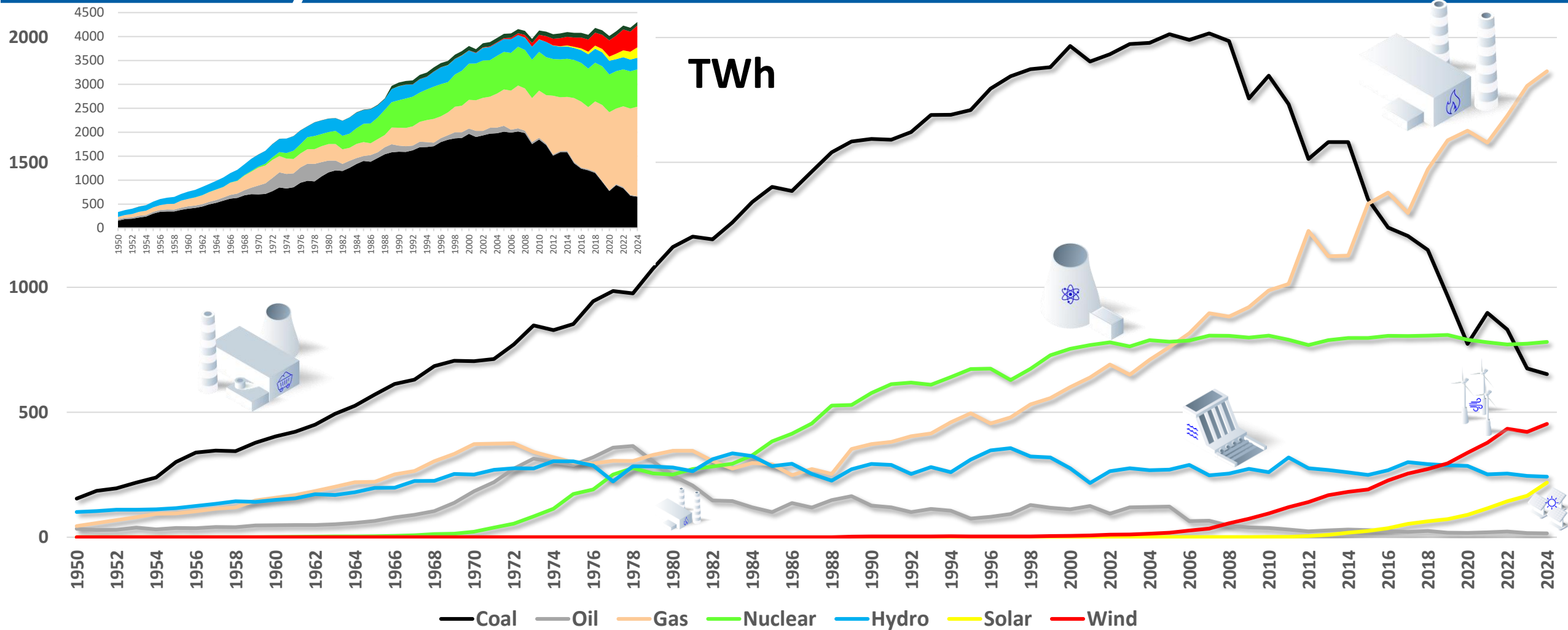
Few New Dispatchable Aging



US Electricity Generation last 70+ years ...



Electricity Evolution



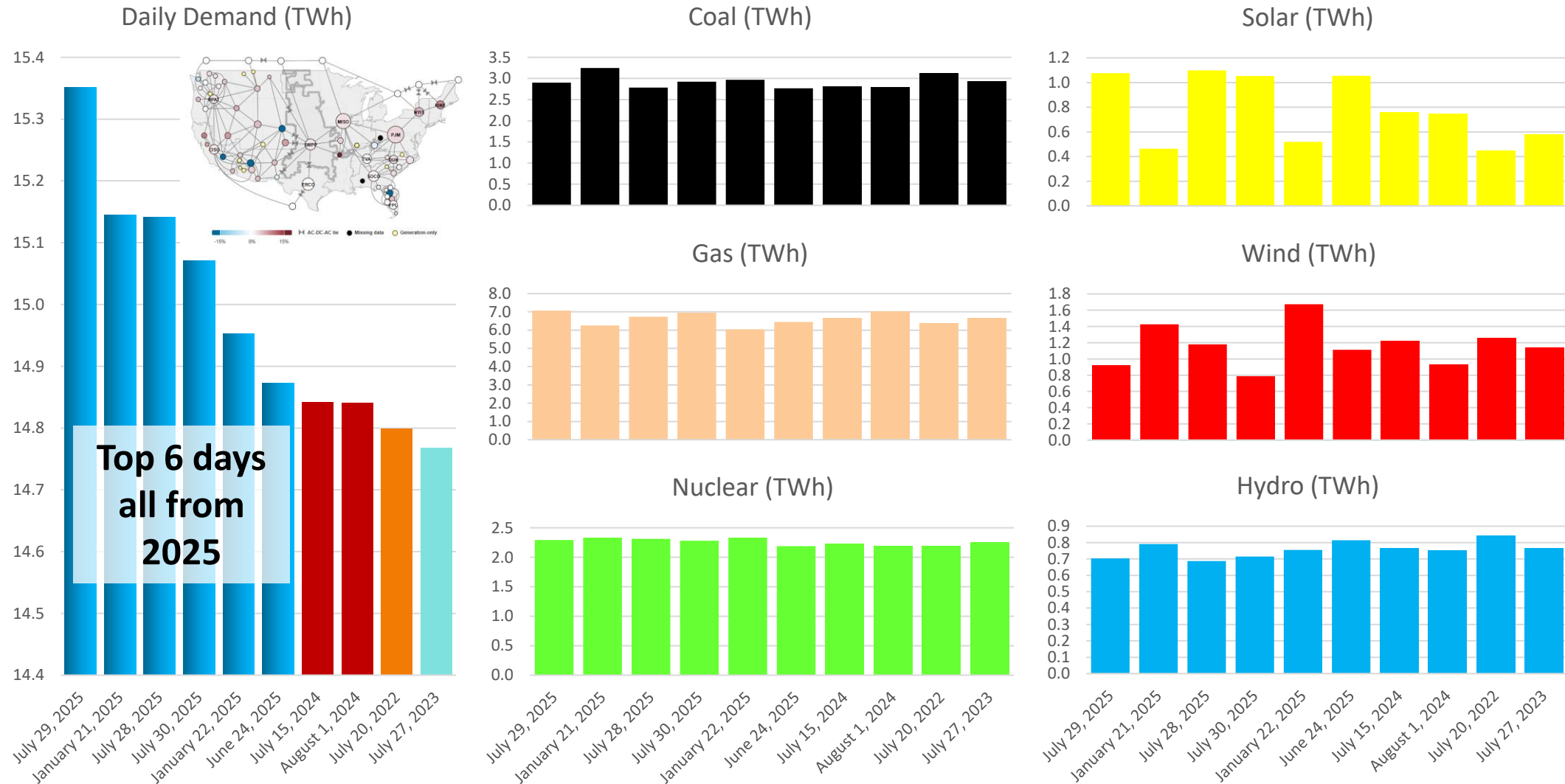
Gas, Solar, and Wind continue to Grow

US48 Peak Days

Includes Winter peak days in 2025

2025 Peak Days

500 GWh greater than 2024 (20 GW baseloaded)



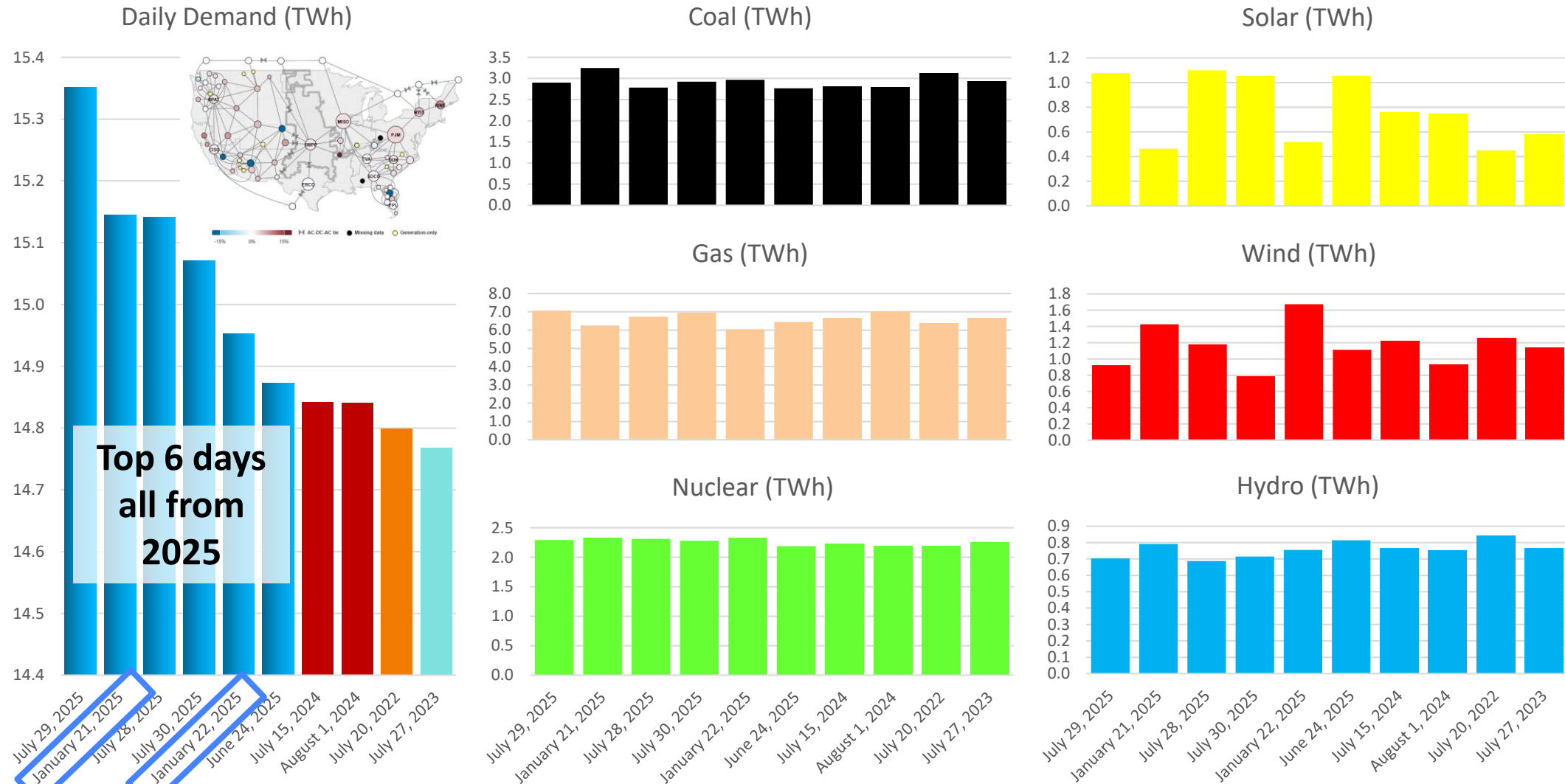
Six of the Top 10 days were this year

US48 Peak Days

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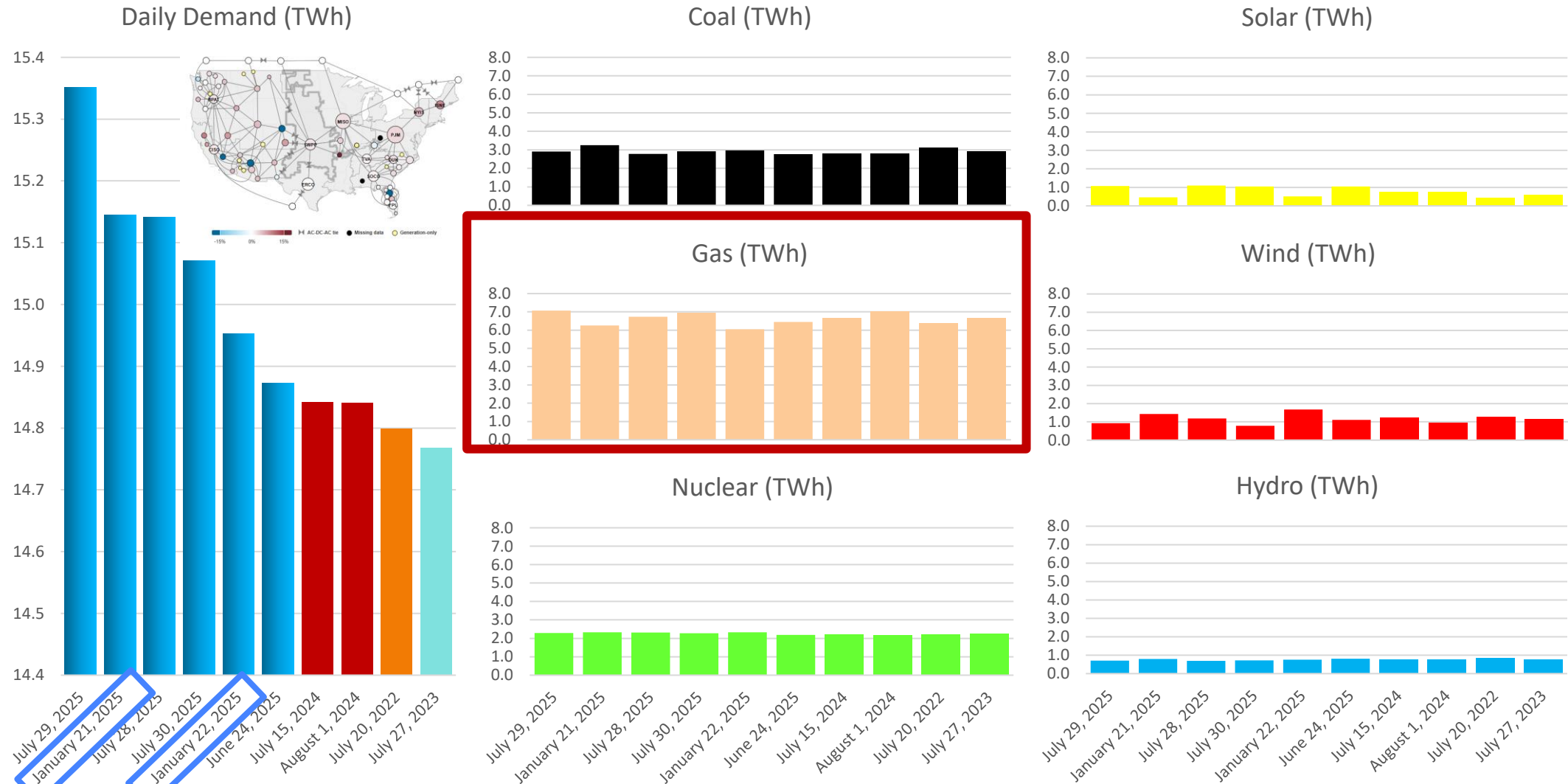
Six of the Top 10 days were this year

US48 Peak Days

Gas Generation Critical

Gas Dependence

Gas, Coal, Nuclear provide majority of Energy



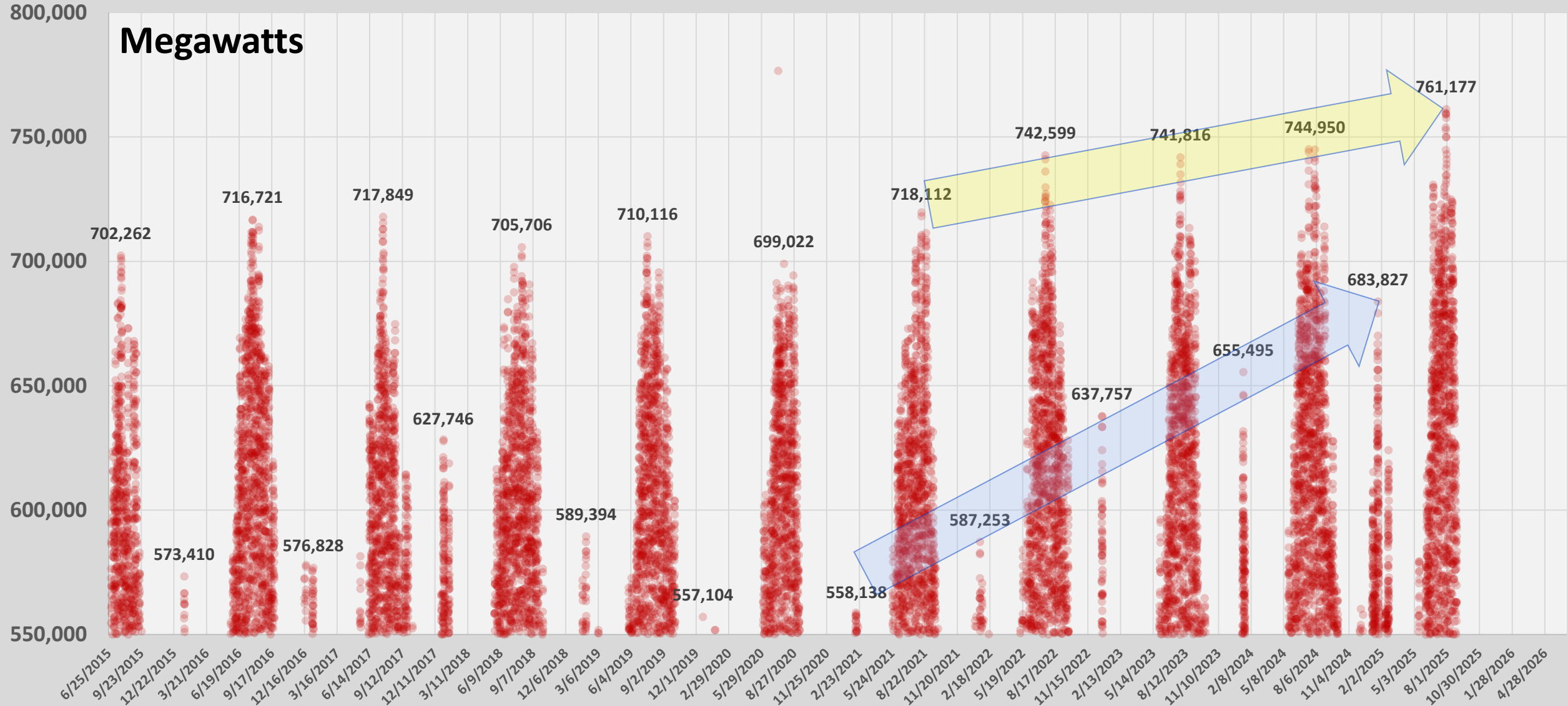
Six of the Top 10 days were this year

US48 Hourly Demand

Winter Hourly Peaks Increasing

Rapid Winter Peak Growth

This Winter 125 GW Greater than 2021



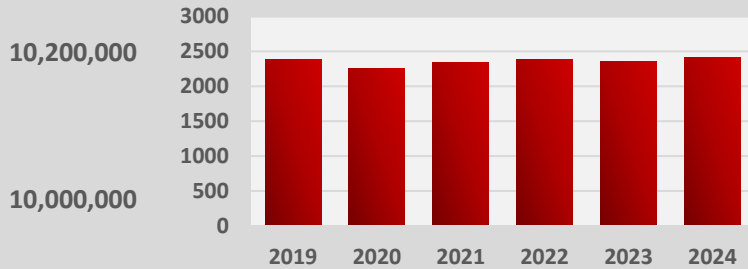
Coal and Gas Reliance

Daily Peaks Increasing

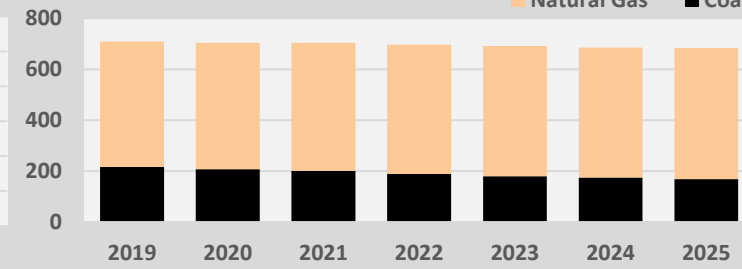
Growing Reliance

Shrinking Capacity (Down >20GW)

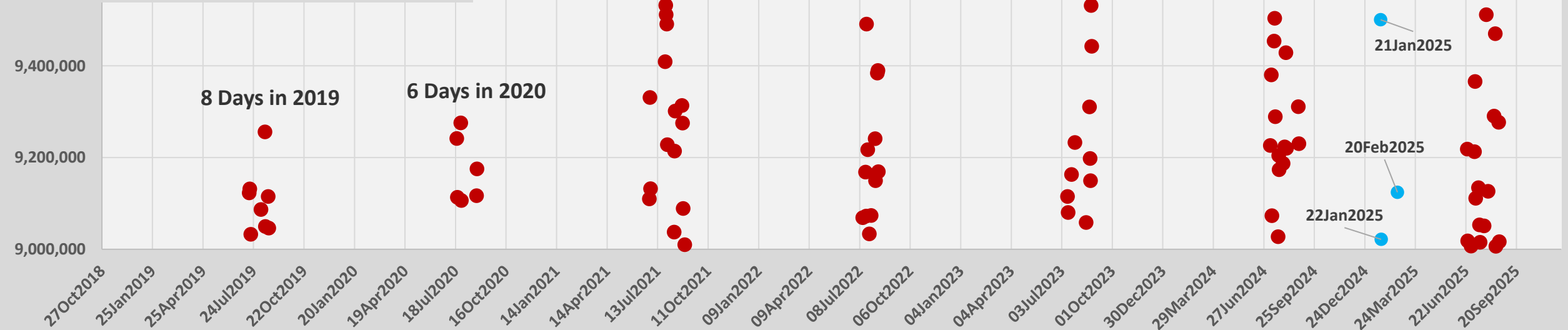
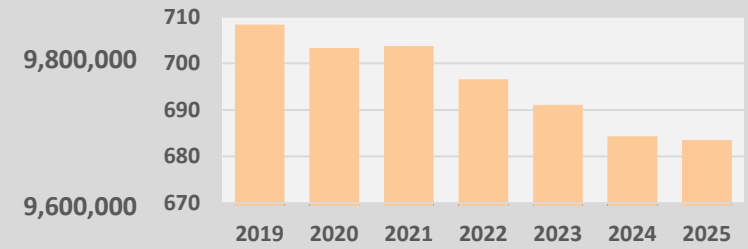
Annual Coal + Gas TWh



Installed Capacity Coal + Gas (GW)



Coal + Gas Days Greater than 9 TWh



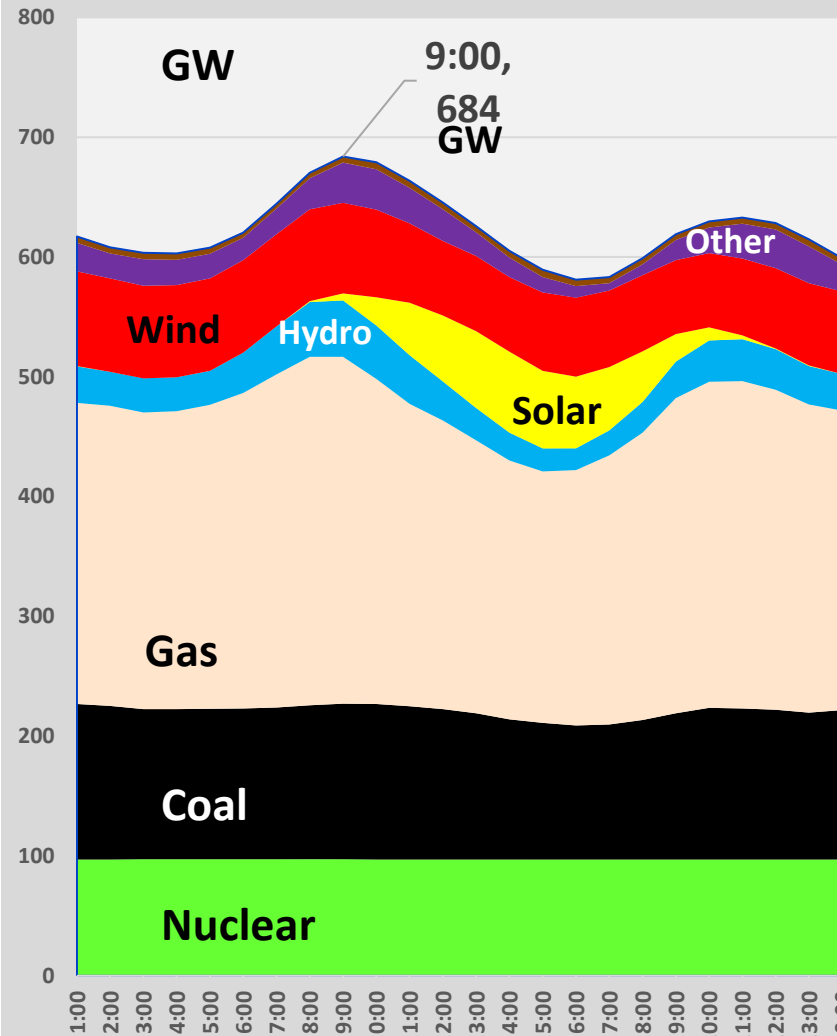
US48 Seasonal Peaks

Winter and Summer (Peak Hourly Days)

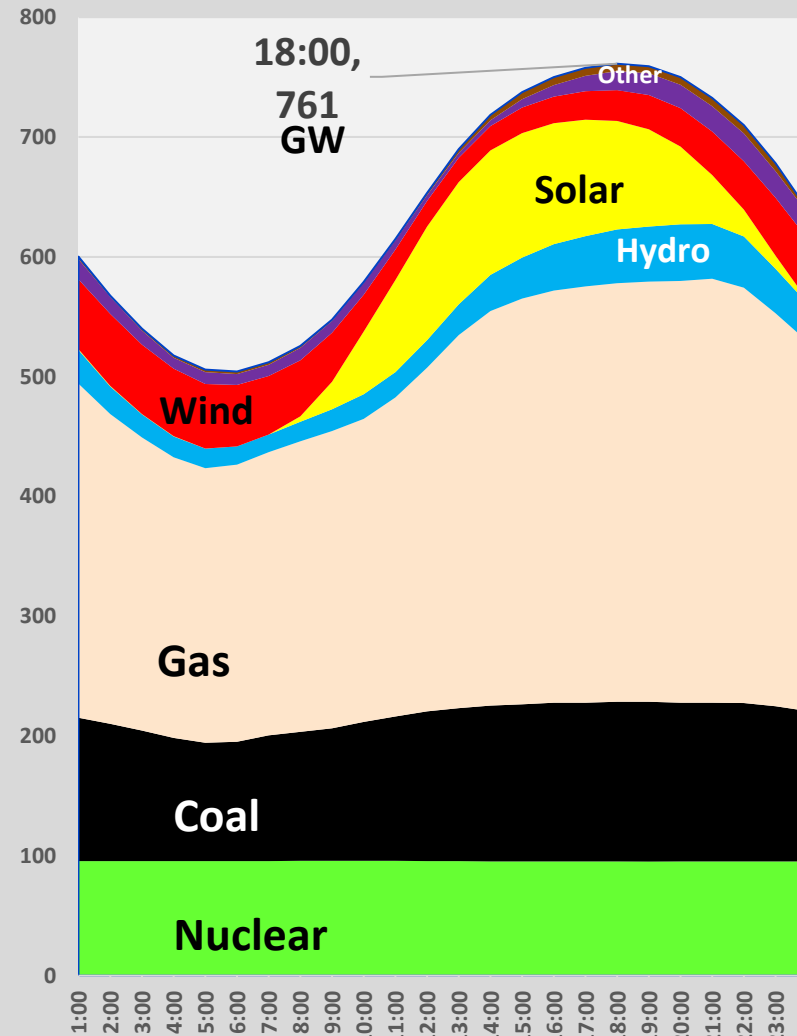
Different Resources

Peak Hour and Daily Energy vs Installed

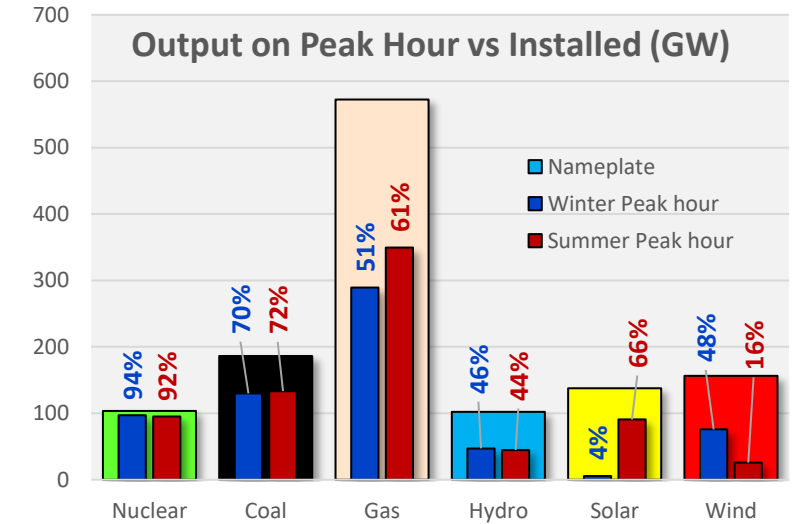
January 22, 2025



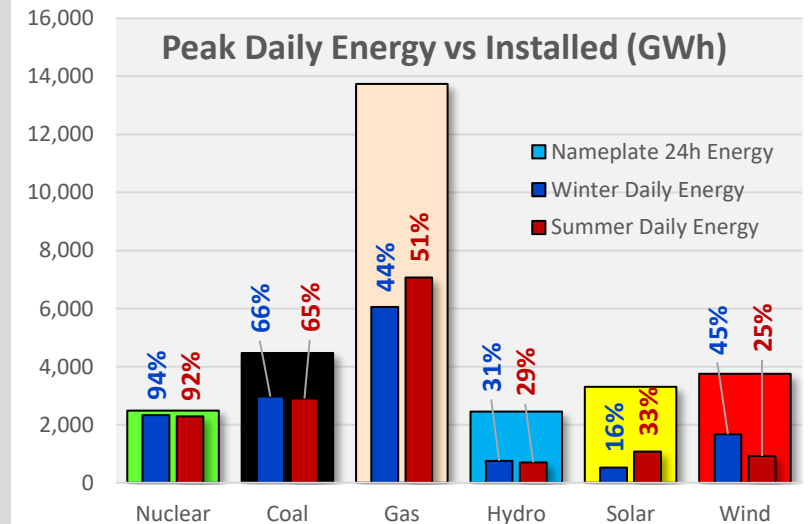
July 29, 2025



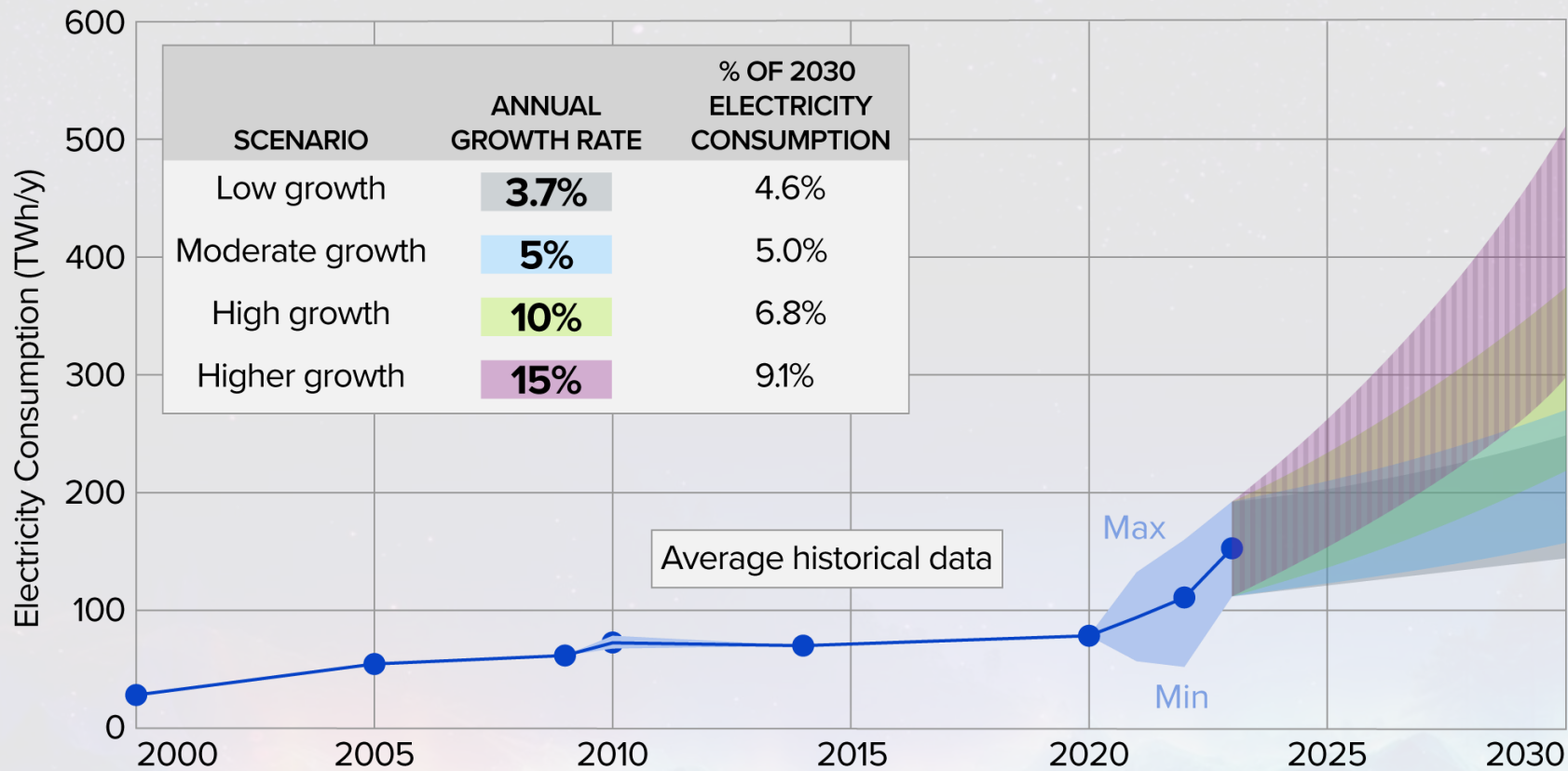
Output on Peak Hour vs Installed (GW)



Peak Daily Energy vs Installed (GWh)



U.S. Data Center Power Demands are Growing



Revisions Coming Soon:

- Load doubled from 2017-2023, reaching 176TWh (LBNL, Dec 2024)
- 3.7% and 5% growth scenarios unrealistic given investment levels
- Likely will add a 20% annual growth scenario
- Growth rate will moderate as installed base grows
- Will add crypto load

Source: EPRI, *Powering Intelligence*, May 2024

TECH · ENTERGY

Entergy's stock is surging after a \$10 billion Meta deal — the CEO says mega AI data centers are changing the utility business



BY SHARON GOLDMAN
AI REPORTER

February 20, 2025 at 5:35 PM EST



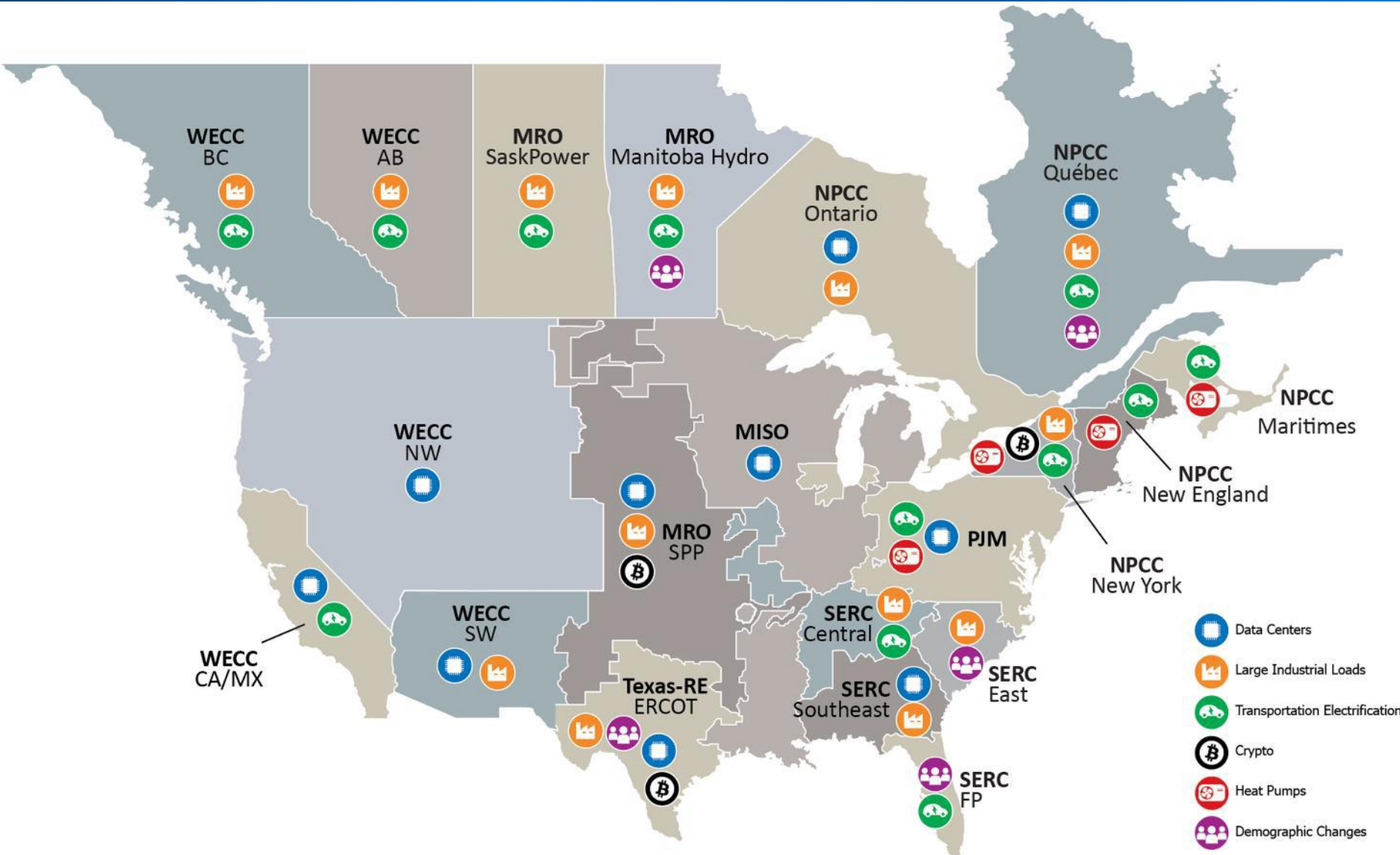
Drew Marsh, chairman and chief executive officer of Entergy Photographer: Jordan Vonderhaar/Bloomberg via Getty Images

NERC Assessments

From Long Term Reliability Risk 2024

North America

Regional Reliability Concerns



Data Centers
Driving Load
Growth in the
United States

NERC Long-Term
Reliability Assessment

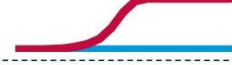
EPRI

<https://dcflex.epri.com/>

Summary of OBBBA (2025)

Energy Tax Credits

US Energy Supply Changing Policy

Technology	IRA Incentives (2022-2025) vs OBBBA Policy Changes (2025 onward)		Industry Outlook ² in the U.S. with OBBBA	
Solar & Wind		48E and 45Y credits available until 2033 - Phased out after 2027¹; sourcing rules tightened (FEOC)		- Continued growth trend through 2030, significant slow-down by 2035³ - Overall higher electricity end-user prices
Green Hydrogen		45V credit available until 2033 - Phased out by 2028		Deployment undermined by weak demand, loss of incentives, and sourcing restrictions
Electric Vehicles		30D, 25E, and 45W credits for EVs; 30C for charging infrastructure - Phased out by 2026 (30D/25E/45W by Oct 2025, 30C by Jul 2026)		Consumer adoption hit by loss of credits and policy uncertainty
Manufacturing		45X and 28C credits support clean tech supply chain 45X phased out after 2027 (wind) and 2028 (solar/storage); 48C compromised by sourcing rules		- Clean energy manufacturing hit by loss of credits and supply chain constraints - Subsidy loss threatens existing investments
Carbon Capture		45Q credit available until 2033 - Preserved; EOR provisions enhanced		Growth in oil and gas CCS, challenged by foreign entity restrictions
Energy Storage		48E credit available until 2033 - Preserved in full		Preserved credits support growth, challenged by foreign entity restrictions
Biofuels		45Z credit available until 2027 - Extended to 2029; feedstock sourcing rules tightened; capped SAF		Slow adoption, challenged by foreign entity restrictions
Geothermal		48E and 45Y credits available until 2033 - Preserved in full		- Moderate growth from low baseline - R&D support for superhot geothermal
Nuclear		- ITC/PTC for new, 45U for existing plants available until 2033 - Preserved in full; fuel sourcing rules apply after 2028		- Challenges remain for large ~1GW reactors - More optimistic outlook for SMRs, XMRs
Oil, Gas		- No support - Gains tax breaks, public land access, and regulatory rollbacks		Stable or rising share, as renewables face disadvantage

Source: Columbia Business School ([link](#))

(1) Construction by 4 July 2026 = 4 years to completion, after = in service before 2028. (2) EV, Carbon Capture, Energy Storage, Biofuels, Hydrogen and Oil, Gas & Coal's Outlook use EIA's reference case and alternative transportation case. (3) Outlook expectations for solar and wind based on EIA's 2025 AEO, using "Reference" Case and "High Zero-Carbon Technology Cost" Case. Sources: Congress, [One Big Beautiful Bill Act](#) (2025); DOE, [Inflation Reduction Act](#) (2022); Norton Rose Fulbright, [Effects of "One Big Beautiful Bill" On Projects](#) (2025); CKI Analysis (2025). Credit: Mariana Castaño, Ariela Farchi, Nicolas Herrera Isaza, Isabel Hoyos, Hyae Ryung Kim, and [Gernot Wagner](#). Share with attribution: Castaño *et al*, "Climate Impact of One Big Beautiful Bill Act" (15 July 2025).

2024 Finalized EPA Regulations



GHG Rule (111 b/d)

Existing Coal & New Gas

- Existing Coal
- Operate beyond 2038 – CCS
 - Operate thru 2038 – 40% NG Co-firing
 - Control by Jan 1, 2032 (CCS) or Jan 1, 2030 (Co-firing)
- New/Major Gas
- Defined as Commencing construction after May 2023
 - >40% Cap Factor - CCS
 - 20%<CF≤40% - High Efficiency Req

Repeal proposed



Effluent Guidelines (ELG)

Existing Coal

- Control no later than Dec 2029
- Retire by 2028 – nothing additional
- Zero Liquid Discharge (ZLD)
- WGD Wastewater
 - All ash transport water
- Landfill leachate
- Operate to 2034 – Hg & As limits
 - Operate beyond 2034 – ZLD

Extension proposed



Legacy CCR Impoundments

No Operating Unit Impacts

- Inclusion of previously excluded inactive ash impoundments & landfills
- Meet 2015 Rule Requirements
- Inspections
 - Groundwater Monitoring & Corrective Actions
 - Closure & Post Closure Care
 - Others

Options & Extension proposed



MATS Risk & Technology Review

Existing Coal & Oil Fired

- Lower filterable particulate matter (PM) standard
- Lower Hg standard for lignite units
- PM Continuous Emissions Monitoring (CEMS) required for compliance

Repeal of Portions proposed

Anticipated Actions

Accelerated Coal Retirements

40% CF Caps for New gas

Significant Post-retirement Water Treatment

Additional Impoundment Closures / Remediation

Additional Continuous Emissions Monitoring

Isolated Unit-specific Controls Improvements

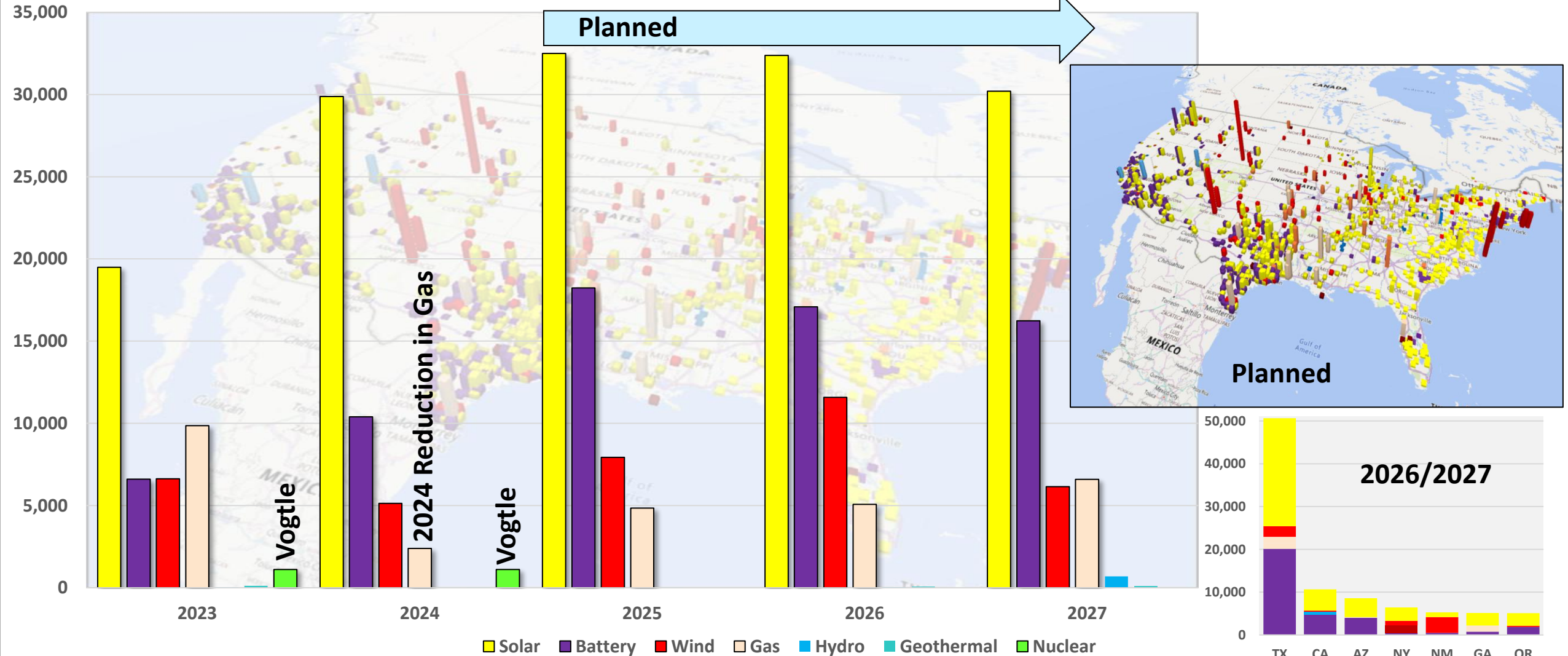
US Additions

EIA 860 Data Generation

Planned and Actuals

Solar and Batteries still dominate in Planned

EIA 860 Planned Additions (MW)

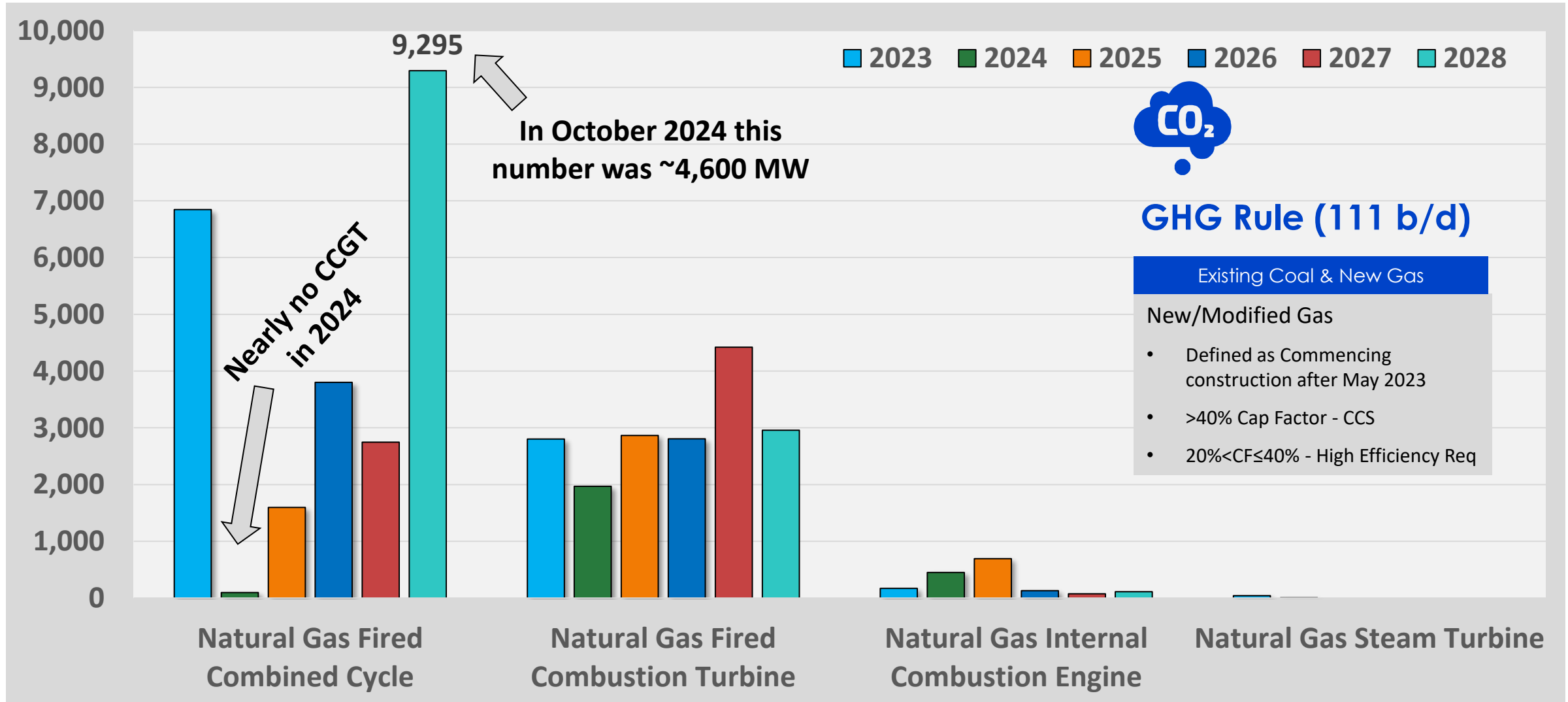


Changing Gas Generation

July 2025 Data

Impacts of Rules

And Demand Growth

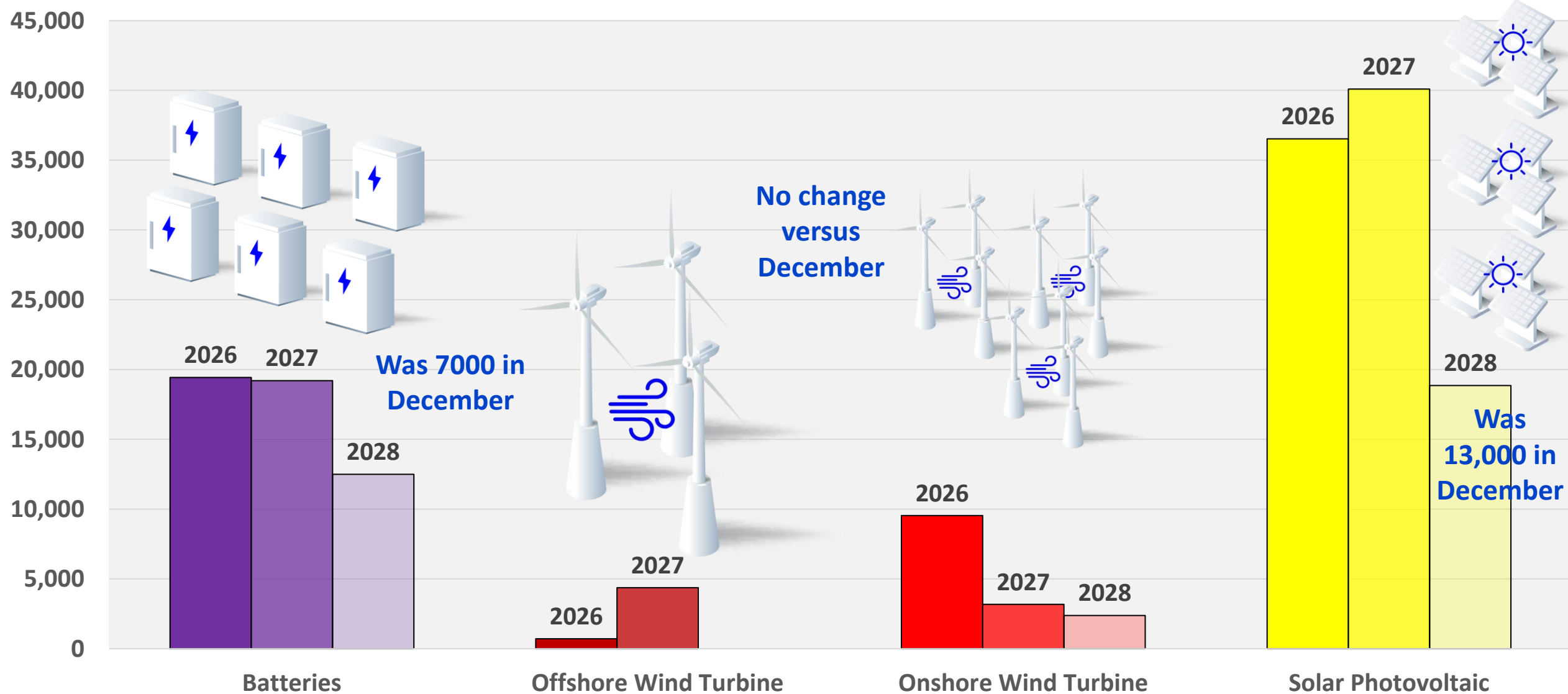


Changing Renewable + Storage

United States (plans as of July 2025)

Impacts of Rules

2028 Reductions? ...

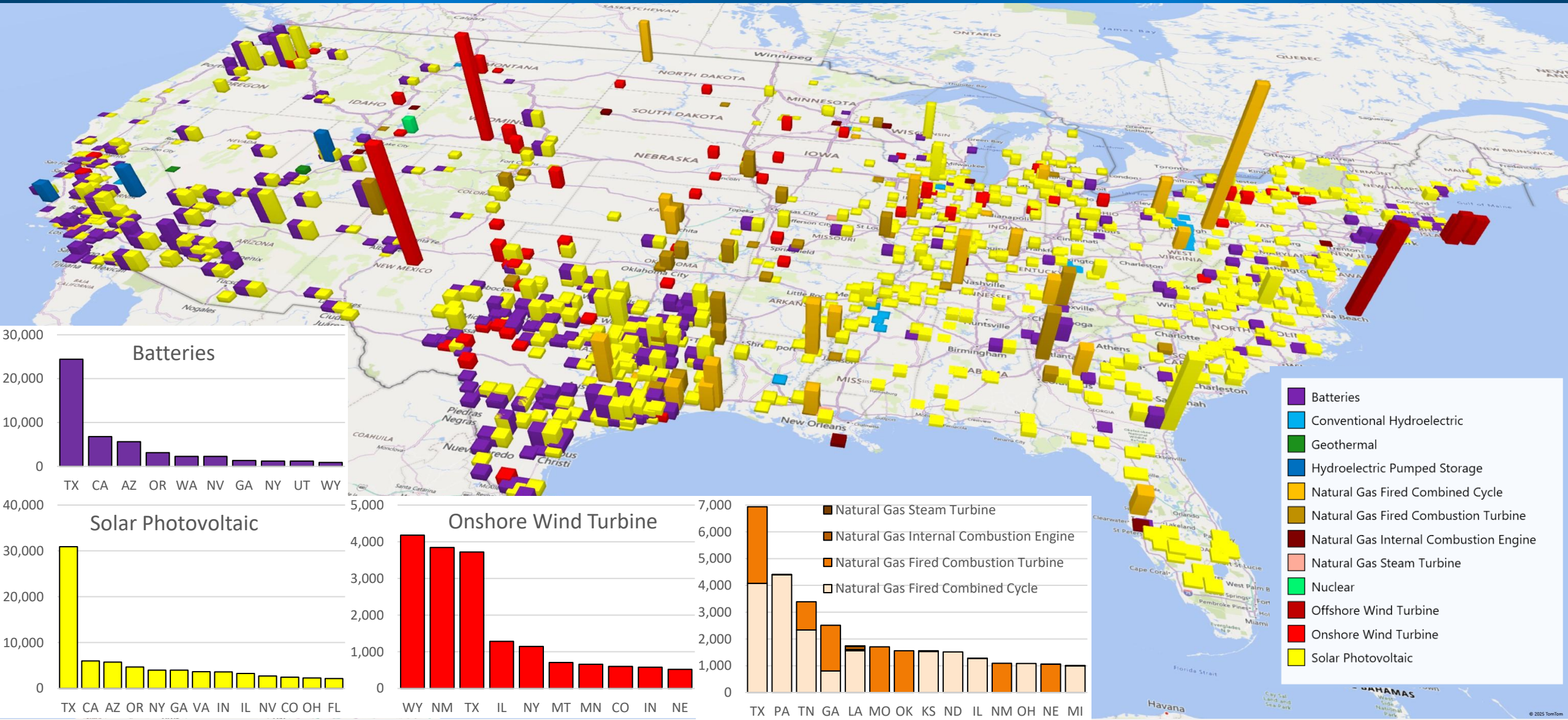


US Additions

EIA 860 Data Generation

Planned 2026-2031

State by State



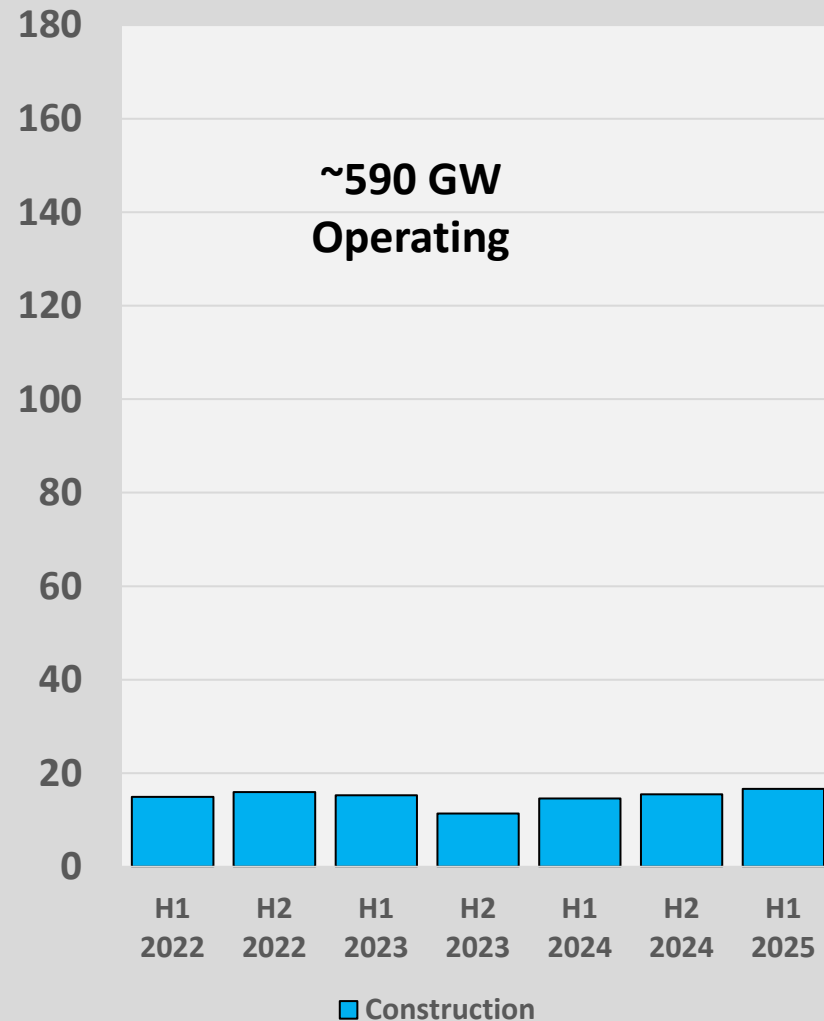
Gas and Oil Generation

Predominantly Gas

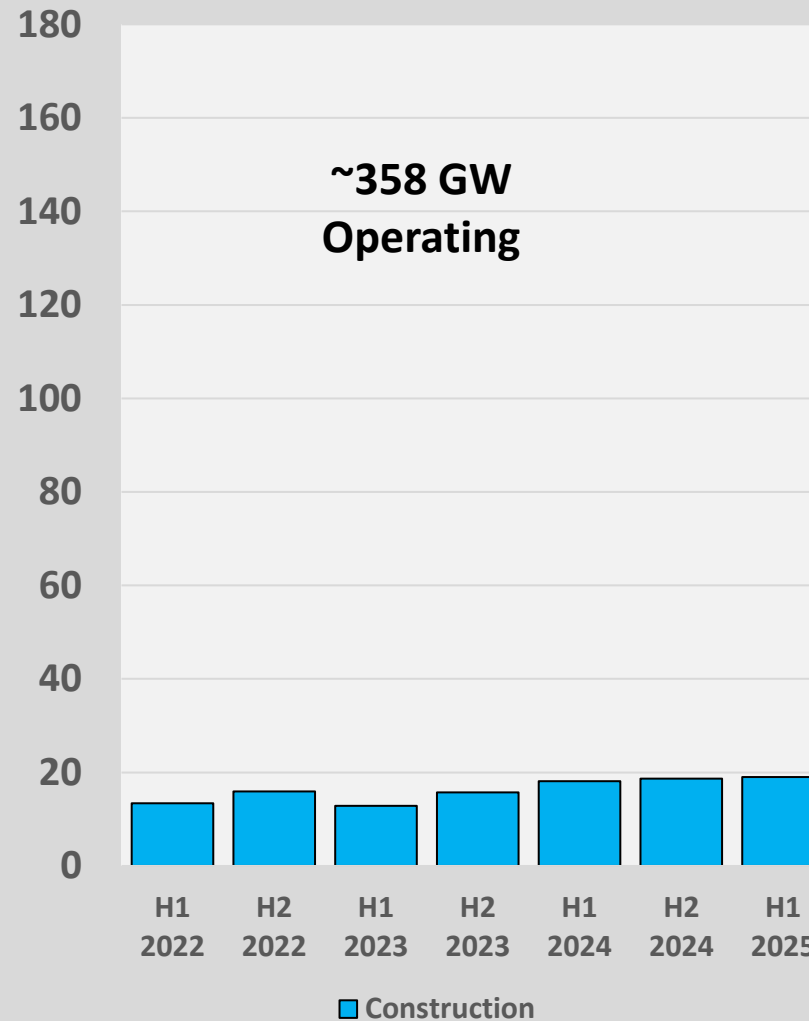
Significant Regional Growth

North America Plans, Western Asia Construction

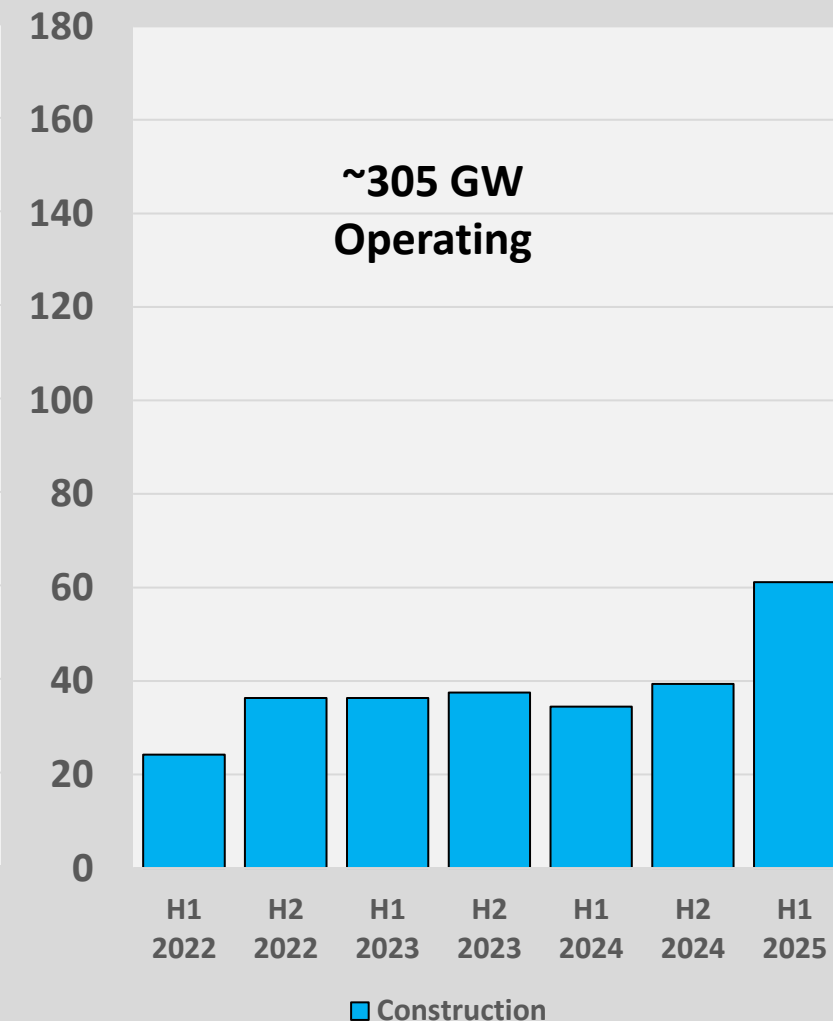
North America



Europe



Western Asia



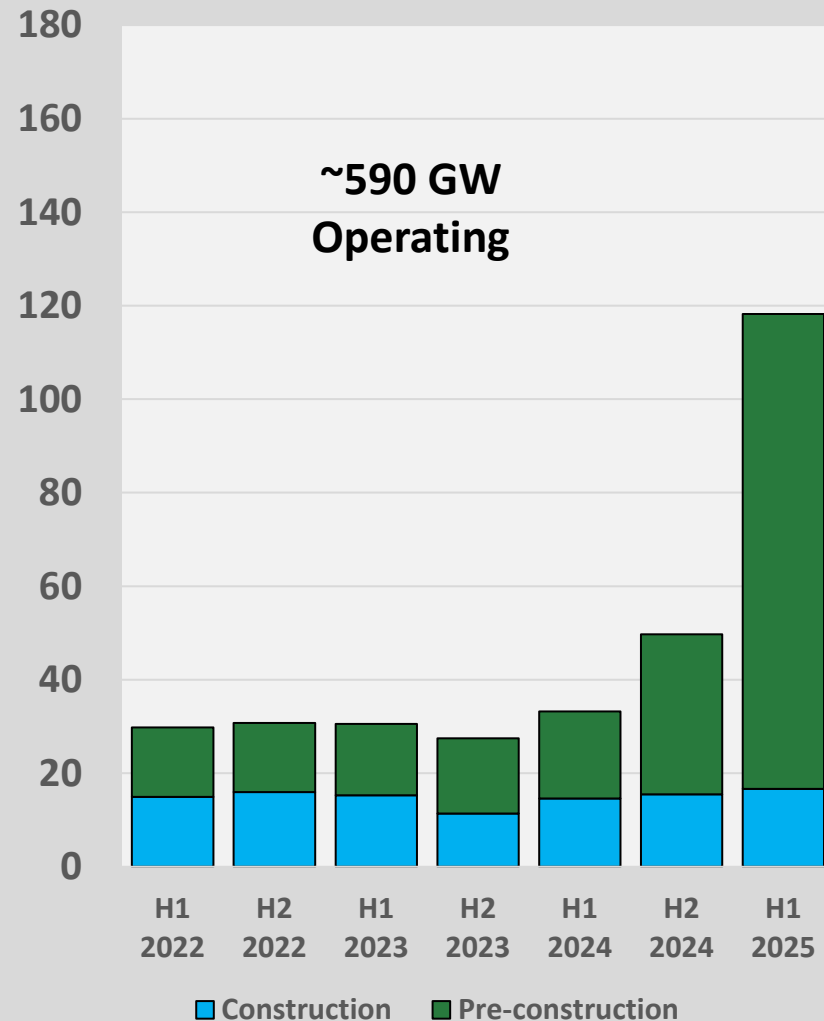
Gas and Oil Generation

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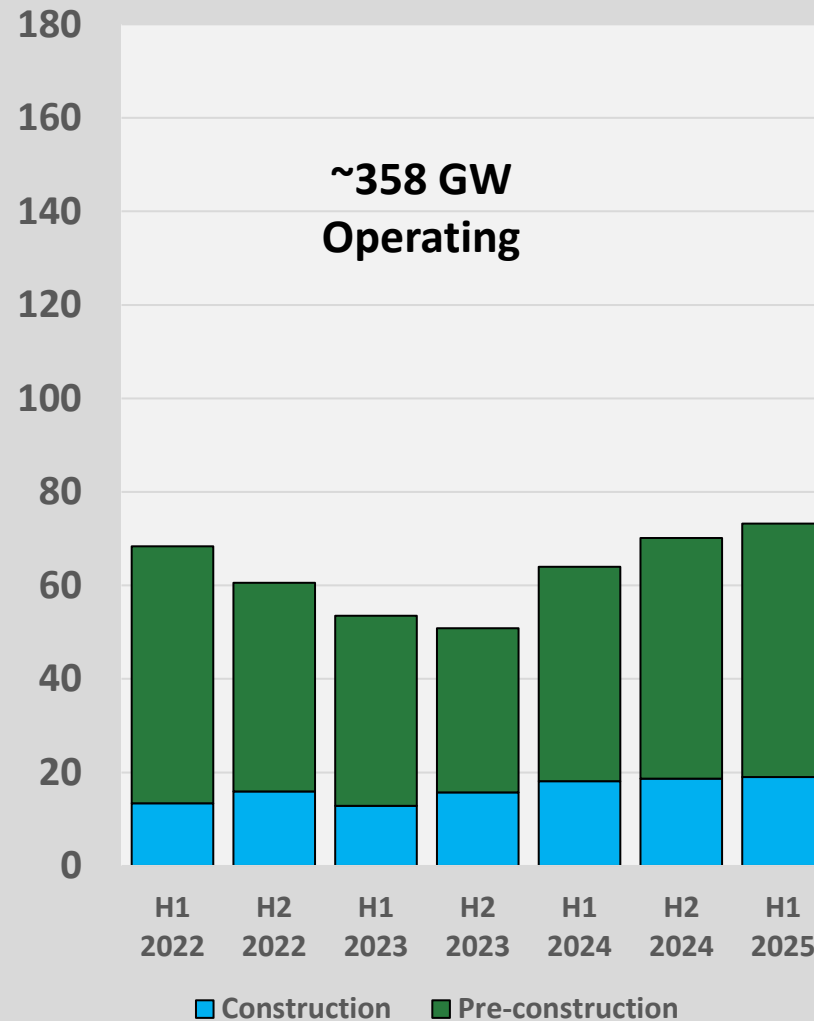
Significant Regional Growth

North America Plans, Western Asia Construction

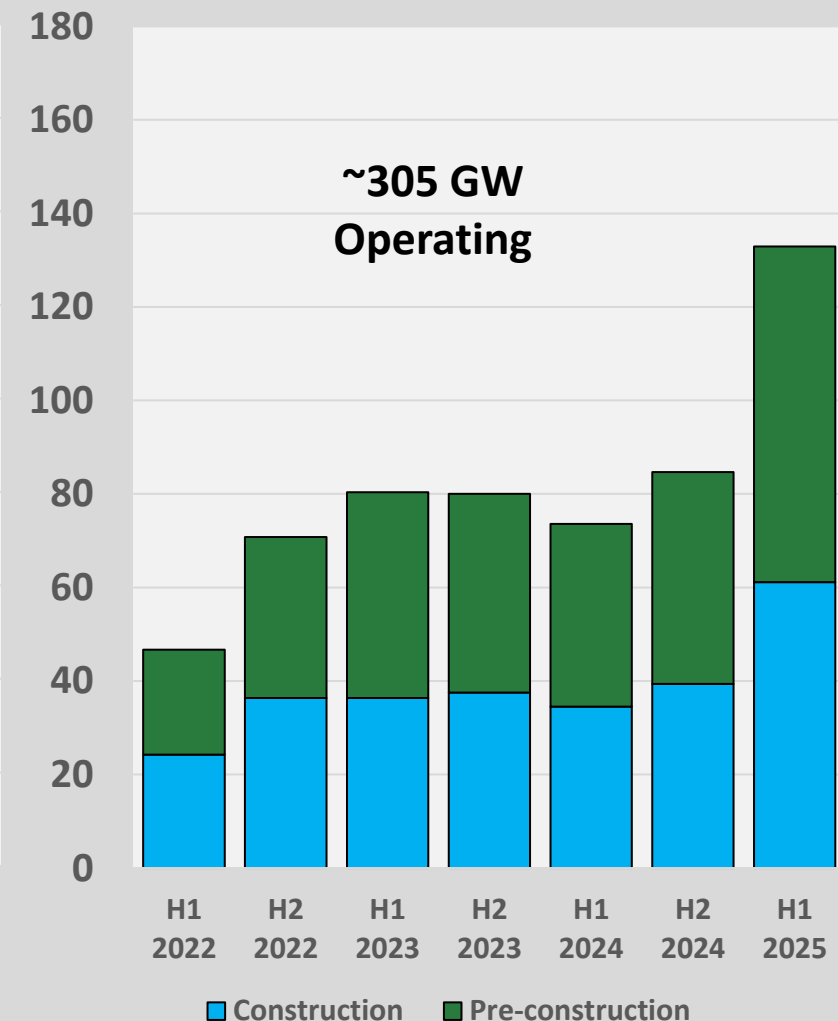
North America



Europe



Western Asia



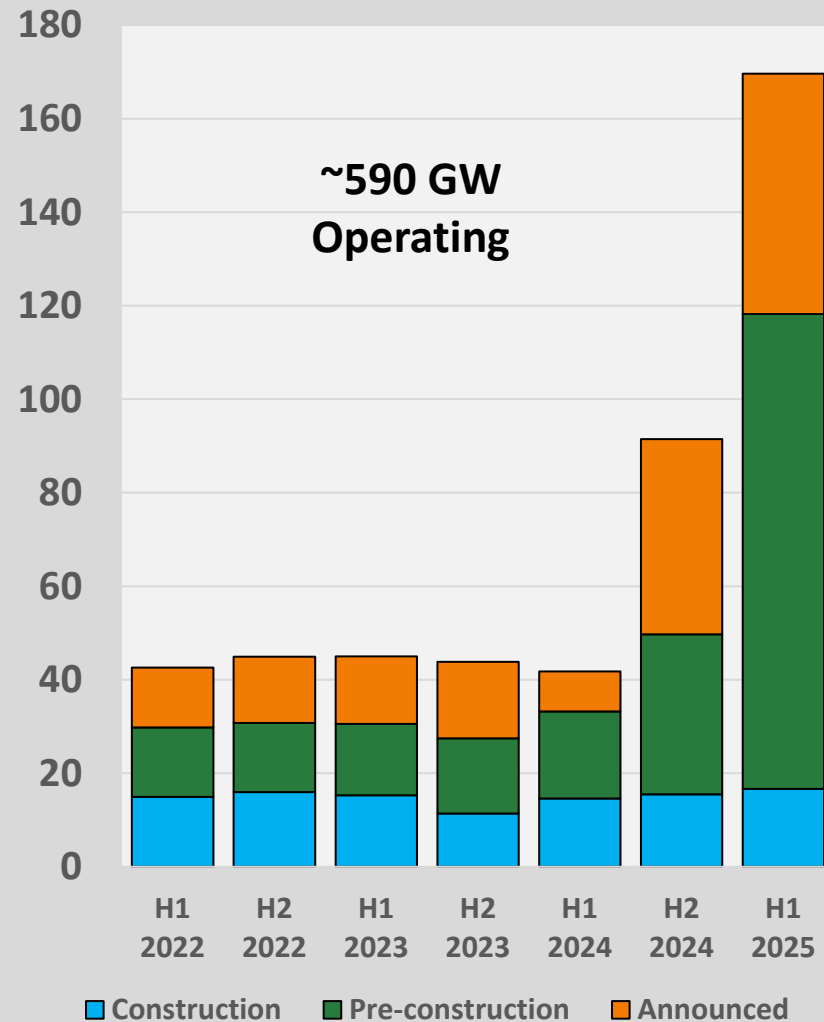
Gas and Oil Generation

Predominantly Gas

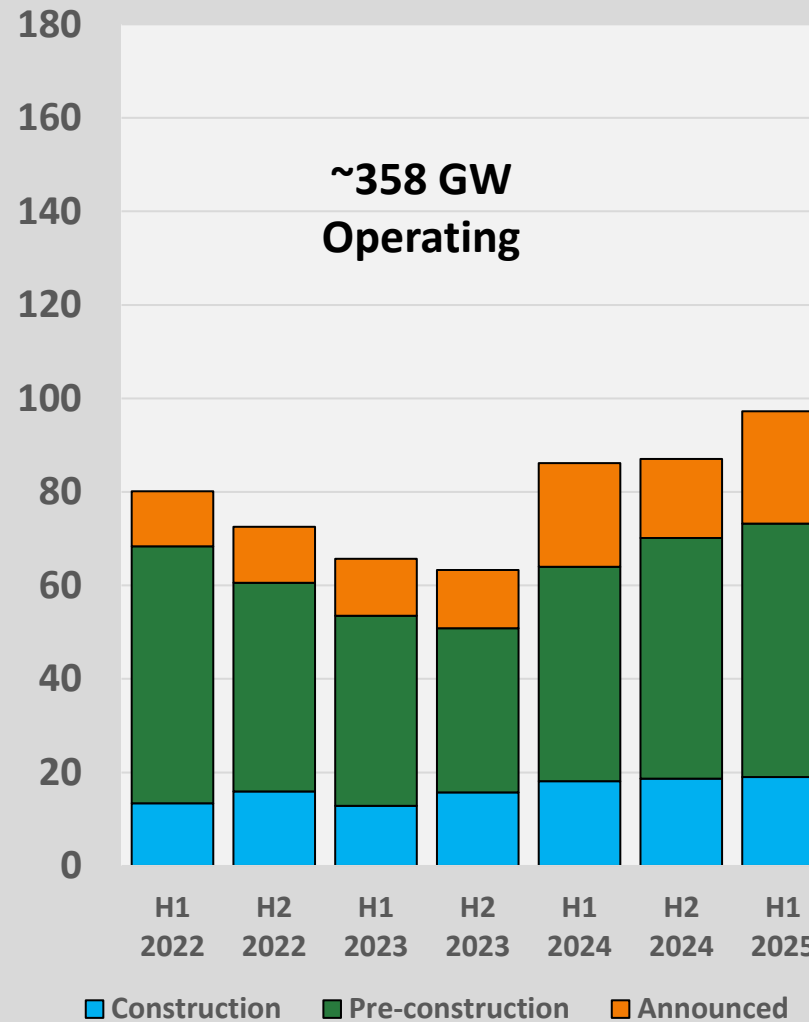
Significant Regional Growth

North America Plans, Western Asia Construction

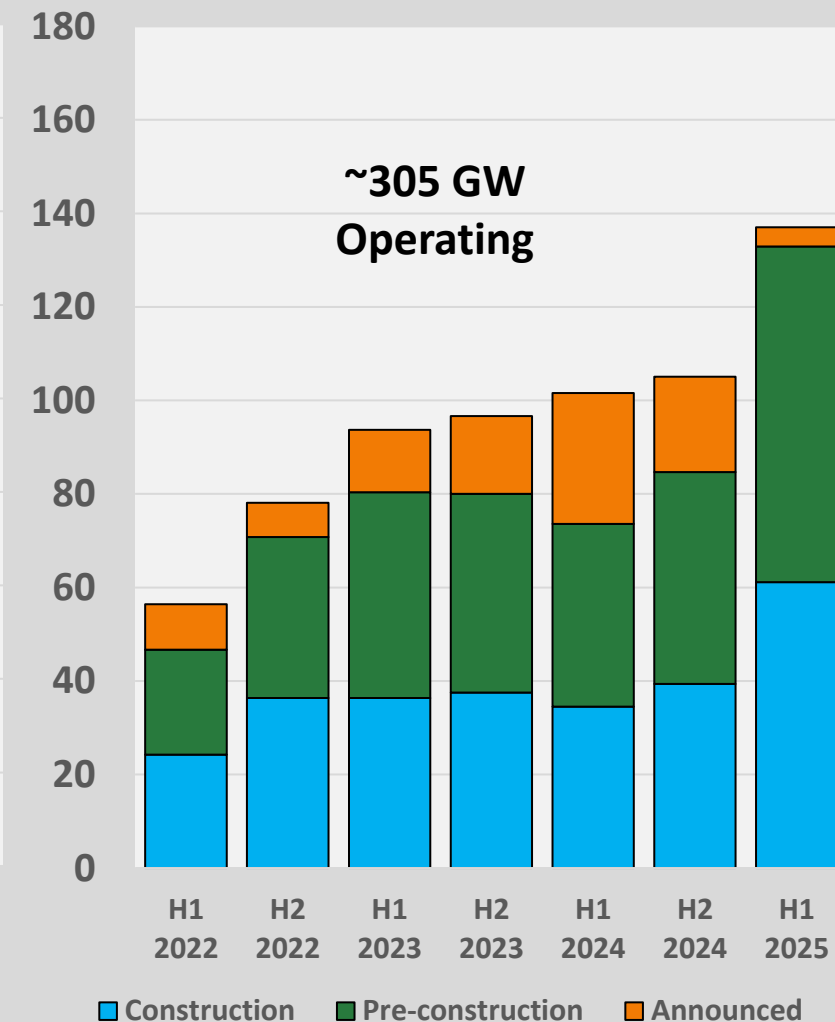
North America



Europe



Western Asia



Supply Chain



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#4 Aging Gas Turbine Fleets: Time for Tough Choices

05/04/2025

NGI NATURAL
GAS
INTELLIGENCE

Natural Gas Data

News & In

Daily Gas Price Index

Earnings

Power Generation

‘Higher-for-Longer’ Natural Gas Power, With Equipment Sold Out Through 2027, Says GE Vernova CEO

Thu, Aug 28 2025

Gas
outlook

ANALYSIS

US & Canada

Financing

Costs to build gas plants triple, says CEO of NextEra Energy

Grist

Follow

Georgia was about to retire coal plants. Then came the data centers.



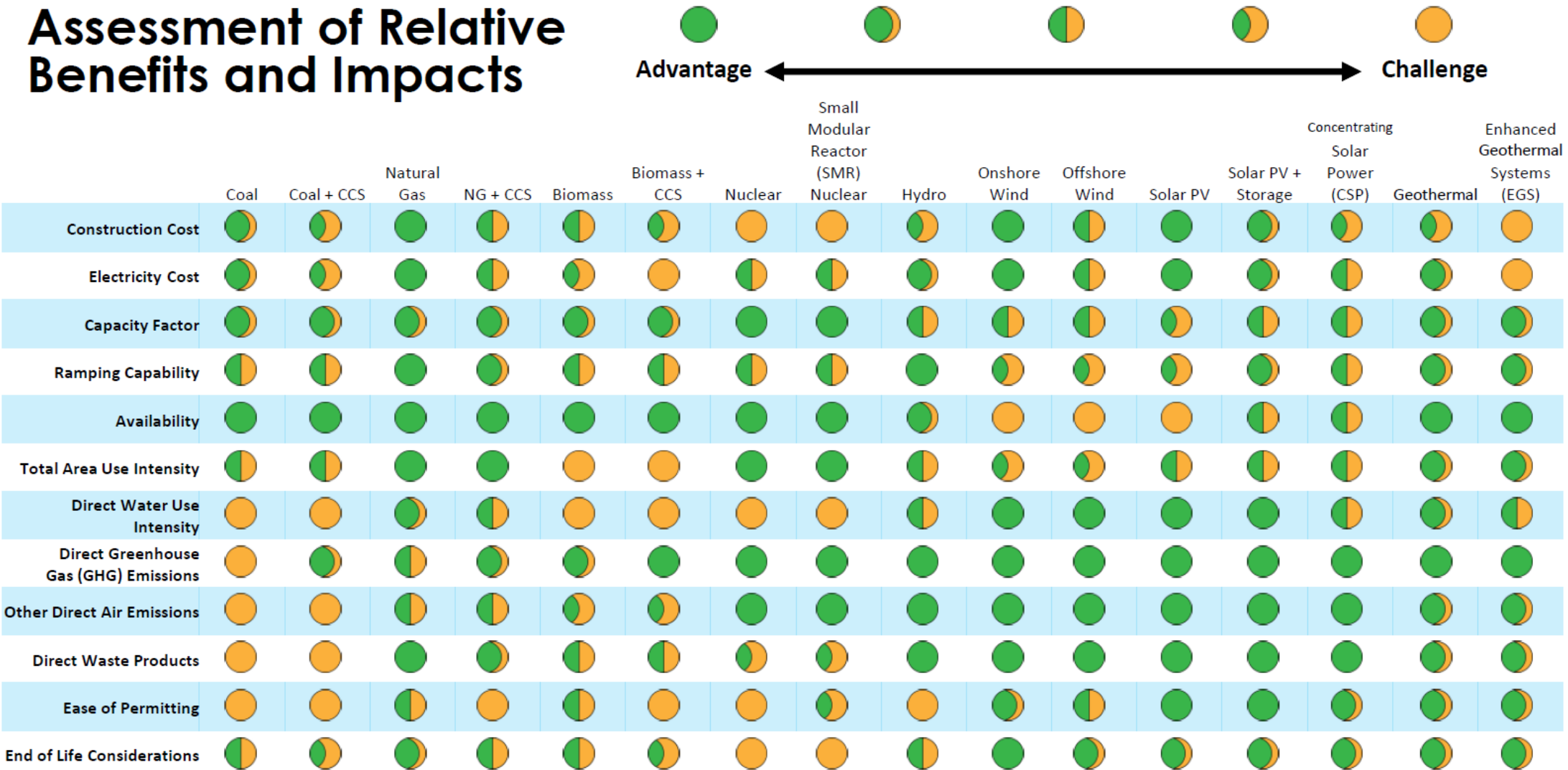
Supply chain impacts current fleet & new builds

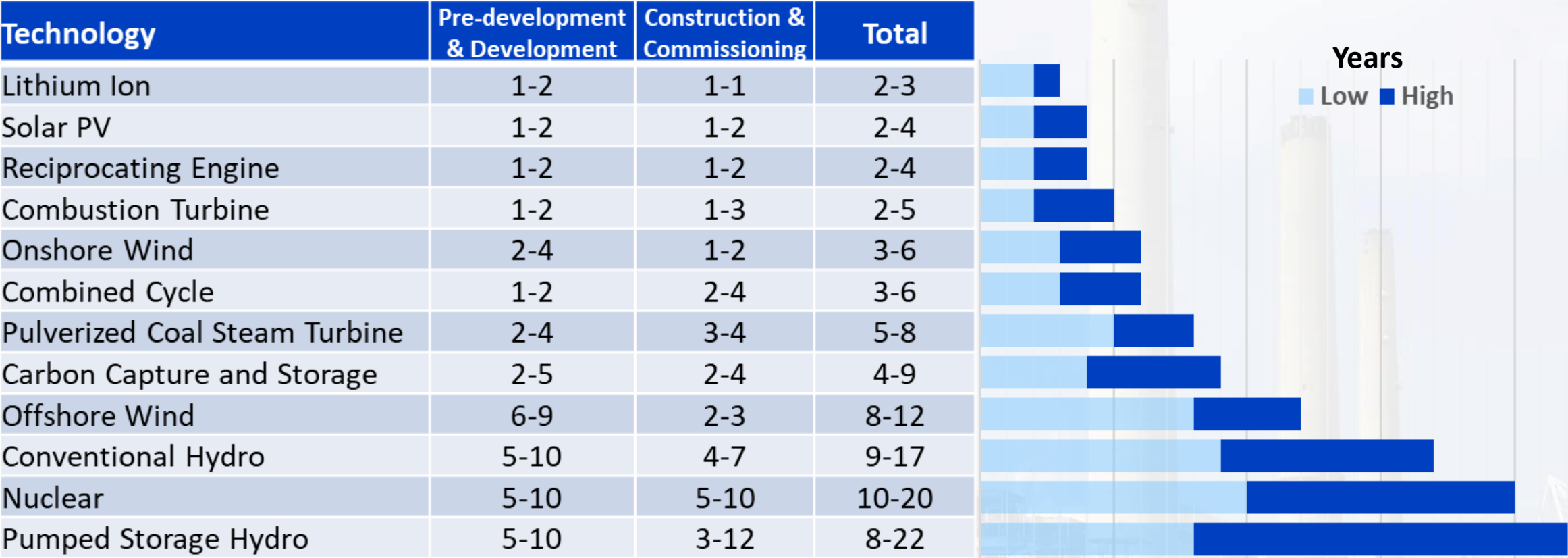
Relative Advantages

Generation Sources

Varying Advantages and Challenges

Assessment of Relative Benefits and Impacts





2025 United States Energy & Employment Report

CONSTRUCTION

50%

Insufficient Qualifications
(Certifications or Education)

40%

Lack of Experience, Training, or
Technical Skills

20%

Other

WHOLESALE TRADE

37%

Competition / Small Applicant Pool

33%

Insufficient Non-Technical Skills
(Work Ethic, Dependability)

33%

Lack of Experience, Training,
or Technical Skills

PROFESSIONAL & BUSINESS SERVICES

42%

Lack of Experience, Training,
or Technical Skills

32%

Competition / Small Applicant Pool

26%

Finding Industry-Specific
Knowledge, Skills, & Interest

OTHER SERVICES

50%

Insufficient Qualifications
(Certifications or Education)

31%

Insufficient Non-Technical Skills
(Work Ethic, Dependability)

31%

Competition / Small Applicant Pool

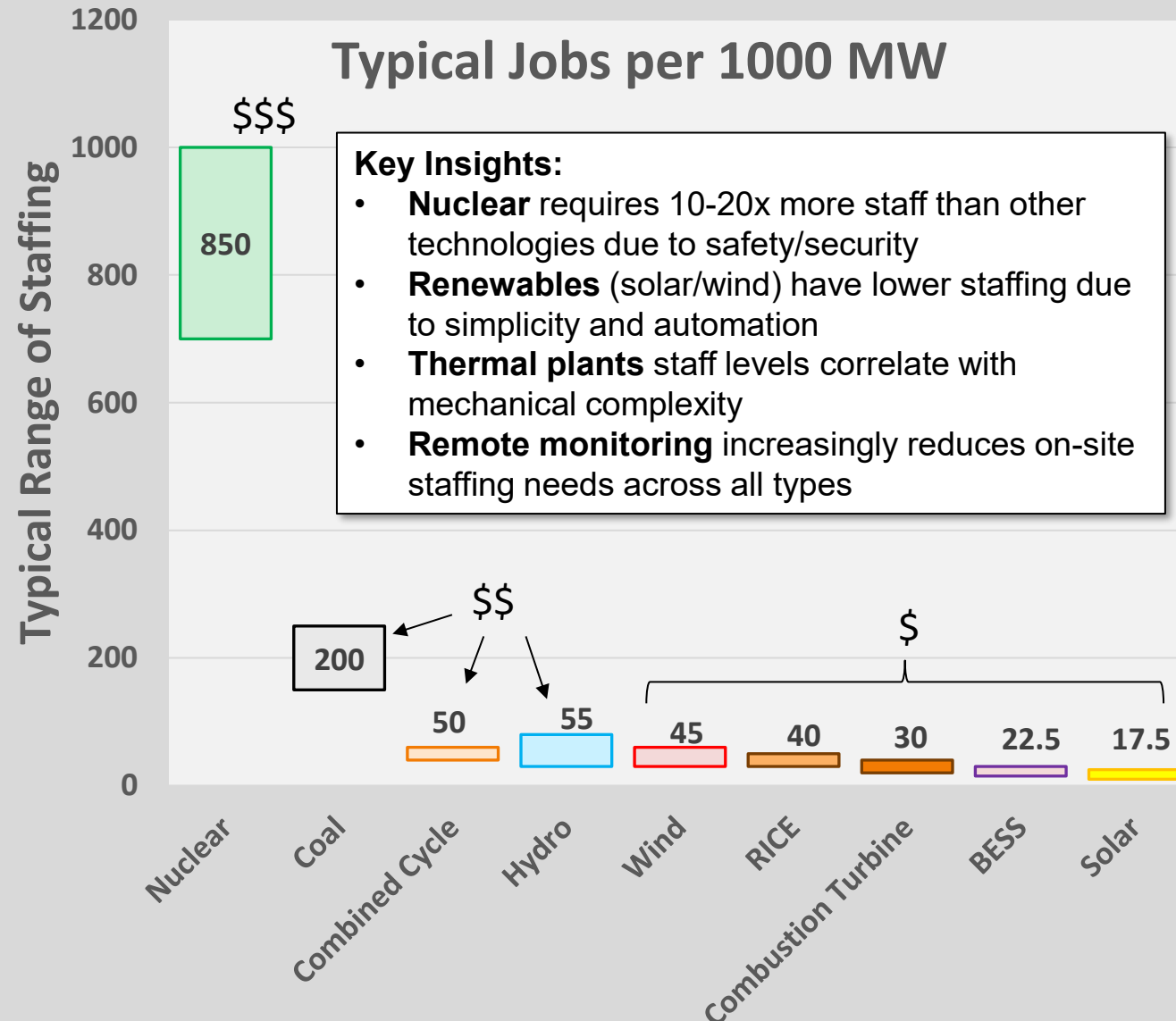
NOTE: Multiple responses permitted;
totals may not add up to 100%.

Operating Staffing Estimates

Not Definitive – Indicative Numbers

1000 MW facilities

Vary based on technology, automation level, regulatory requirements, and operational philosophy



Nuclear Power

Operations: 200-300 (licensed operators, shift supervision)
Maintenance: 250-400 (extensive preventive maintenance)
Engineering: 100-150
Security: 100-150 (NRC requirements)
Radiation Protection: 30-50
Management/Support: 50-100
Nuclear plants require by far the largest staff due to safety requirements, security, and regulatory compliance.

Coal Power Plant

Operations: 60-80 (boiler, turbine, coal handling, emissions control)
Maintenance: 60-100 (more equipment complexity)
Engineering/Environmental: 20-30
Management/Support: 10-40

Gas, Hydro, Solar, Wind, BESS

Operations: (multi-skilled)
Maintenance: (can be mechanical, electrical, I&C technicians)
Management/Support/Engineering

Varies by technology but typically 80-90% Operations and Maintenance, 10-20% Management/Support/Engineering

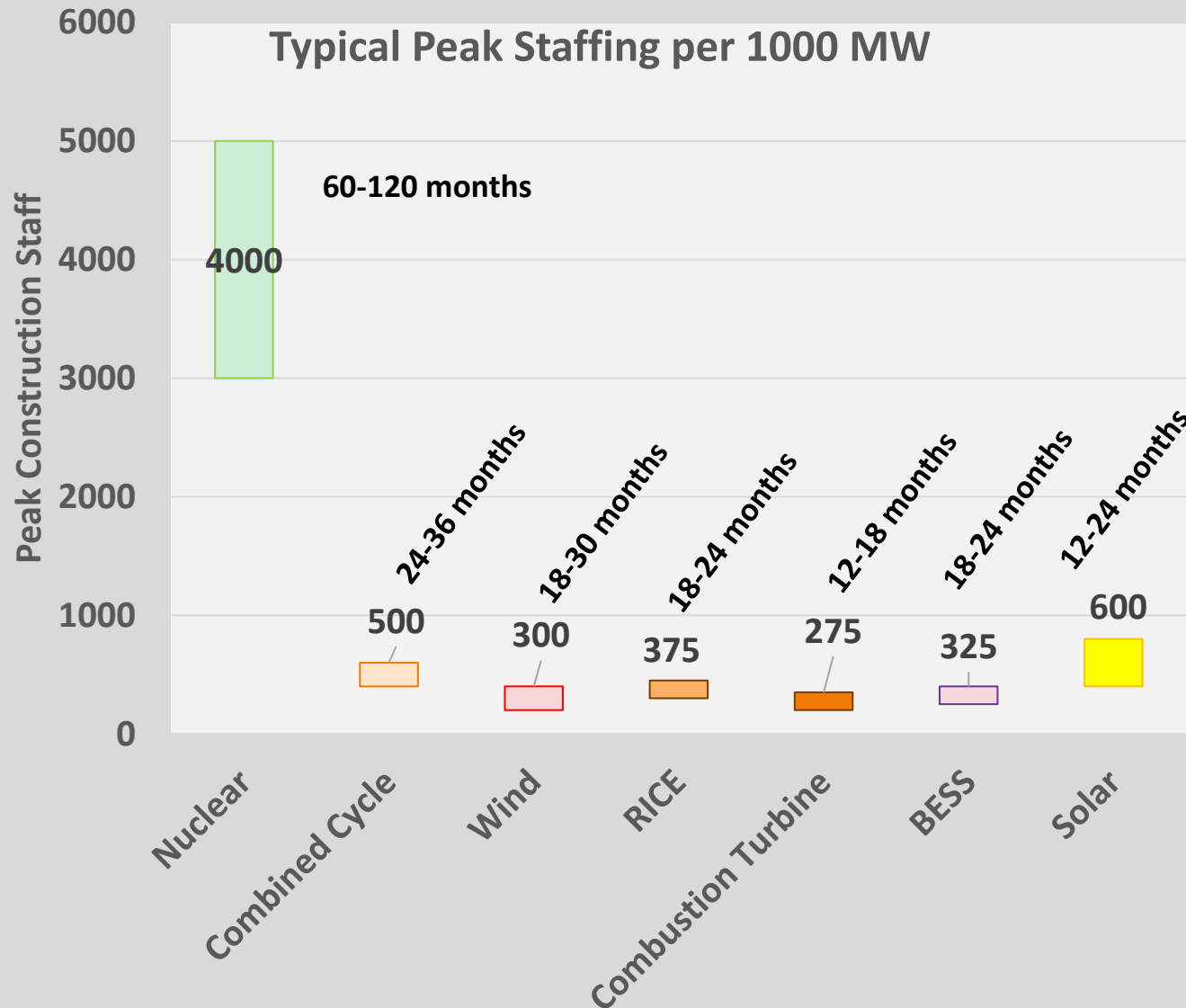
Indicative Numbers Only
Actuals may vary widely

Construction Estimates

Not Definitive – Indicative Numbers

1000 MW facilities

Vary based on technology, automation level, regulatory requirements, and operational philosophy



Combined Cycle Gas Turbine (CCGT) - 1000 MW

- **Engineering/Management:** 40-60
 - Project managers, construction engineers, QA/QC, schedulers
- **Mechanical trades:** 120-180
 - Pipefitters, welders, millwrights, HVAC technicians
- **Electrical/I&C:** 80-120
 - Electricians, instrument technicians, controls specialists
- **Civil trades:** 100-150
 - Concrete workers, ironworkers, heavy equipment operators, carpenters
- **Specialized contractors:** 40-60
 - Turbine/generator installation, commissioning specialists
- **Support:** 20-30
 - Safety, warehousing, logistics

Solar Field (PV) - 1000 MW

- **Engineering/Management:** 40-60
 - Project managers, electrical engineers, civil engineers
 - **Electrical trades:** 150-300
 - Electricians, wire pullers, termination specialists
 - **Civil/Installation:** 150-300
 - Equipment operators (grading), pile drivers, racking installers
 - **Solar installers:** 50-120
 - Panel installation crews (often semi-skilled labor)
 - **Specialized contractors:** 10-20
 - Inverter installation, SCADA systems
- Large solar projects are labor-intensive but with shorter skill requirements; workforce can scale up quickly.

Indicative Numbers Only
Actuals may vary widely

Workforce & the Generation Transition

1. **Demand for labor is increasing** faster than new capacity or capability can be created
2. The workforce supporting the existing fleet is **already constrained**
3. **The current workforce is reducing**, making successful recruitment, training, and retention essential
4. Transitioning the workforce to other roles is **valuable but challenging**
5. Many organizations have mitigation and retention strategies, but **cross-industry collaboration** can provide **significant value**



An Industry-wide effort is needed.

Powering the Future: A Modern Workforce Strategy

Cultivating a Skilled, Agile, and Optimized Utility Workforce



Workforce Training

Educate and develop staff.

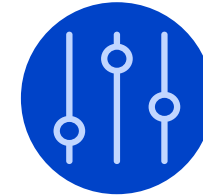
- ✓ Educate staff on new technologies and applications. Address knowledge gaps on existing technologies and job functions.
- ✓ Deliver training in an effective manner by leveraging emerging technologies and delivery mechanisms.
- ✓ Leverage training resources to build resilient expertise.



Build the Pipeline

Proactively cultivate a deep and diverse talent pool through strategic partnerships.

- ✓ Partner with schools and colleges for internships & apprenticeships.
- ✓ Recruit from non-traditional sources like veterans and career changers.
- ✓ Address the why and the impact to attract talent.



Optimize Labor

Use data and technology to schedule projects with maximum efficiency and foresight.

- ✓ Collaborative approach for smart major project scheduling.
- ✓ Use data-driven analytics for strategic, proactive outage planning.
- ✓ Capture institutional knowledge through structured mentorship.

Ongoing EPRI Research

Moving Forward: Modernized Workforce Development

- Modernization of Training:** Active Learners are Lifelong Learners
 - SAT Based and Purposeful
 - Active Learner Centric
 - Appropriate Use of Technology
- Pipelines to Braided Rivers:** Individualized Career Progression
 - Non-Linear Career Pathways
 - Diverse Backgrounds
 - Sustainable and Adaptive
- One Workforce Perspective:** Same Tasks Across Technologies
 - Leverage Technology Synergies
 - Unified and Versatile Workforce
 - Task Oriented Competencies and Qualifications
- Regional and Community Focused:** Regional Economic Needs
 - Build Regional Workforce Collaborations
 - Purposeful K-12 Focus
 - Individual Ties to Community
- Enable Sustainable Models:** Resilient and Modern Approaches
 - Shared Training and WFD Resources
 - Scalable: Up and Down
 - Continual Technology Advancements

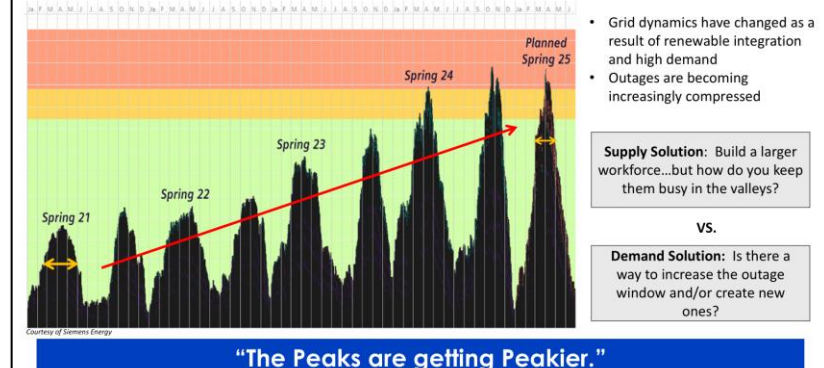


Delivered Impact: What you can Expect from the Program

Workforce and Stakeholder Engagement For Emerging Fuels And Technologies

Collaborative opportunities	3+ Regional in-person events per year	20+ Virtual opportunities per year	100+ Stakeholder groups engaged	Addressing workforce needs	20+ Regional workforce needs spotlighted	3+ Regional training facilities showcased	20+ New workforce and labor connections
Educational and training activities	20+ Universities conducting student projects	5+ Courses or expert speaking sessions	2000+ Learners	New deployed resources and tools	50+ Stakeholder Surveys	3+ Impact assessments	25+ Metrics tracked and reported
Workforce and stakeholder mapping	10+ Stakeholder mappings	Training infrastructure mapping	Informing on gaps in training and education	Real-world projects and practical initiatives	20+ Reports on key actions from events/surveys	10+ Tech briefs on social feasibility studies	2+ In-depth implementation on projects

Demand Side: Current Outage Constraints



Increase integration of training resources.

Leverage common trainings across fossil and nuclear.

Building the pipeline is critical to success.

Partner with universities, community colleges, unions, etc. to ensure needed skills are being integrated into programs.

Collaborative optimization of labor deployment to support workforce development and increase efficiency

Generation Workforce Affinity Group

- **Industry wide.** Members, Labor Unions, OEM's, EPC's & Others
- Coordinate, facilitate, expedite workforce solutions
- **Free to Join.**

KICKOFF WEBCAST – SEPT 30th



A Big Tent, Industry-wide approach.



Generation Workforce Affinity Group



Generation Workforce Affinity Group

TOGETHER...SHAPING THE FUTURE OF ENERGY®

Siting and permitting, the
future of generation,
workforce development,
reliability, supply chain