ROLE OF GAS TURBINES IN THE CHANGING ENERGY MARKET

Worldwide Perspective

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Program Manager of Gas Turbine R&D

ETN October Workshop
12 October 2022

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

The Energy Transition

Decarbonization

~10-15 years

Accelerate economy-wide, low-carbon solutions

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

~15-30 years

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

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

Resiliency

~10-15 years

Mitigate climate impacts and cyber/physical risks

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

~15-30 years

Future proof energy system design basis

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

Making Energy More

Clean | **Affordable** | **Reliable**

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Decarbonization Pathways Enabled by Innovation

~10-15 years

~15-30 years

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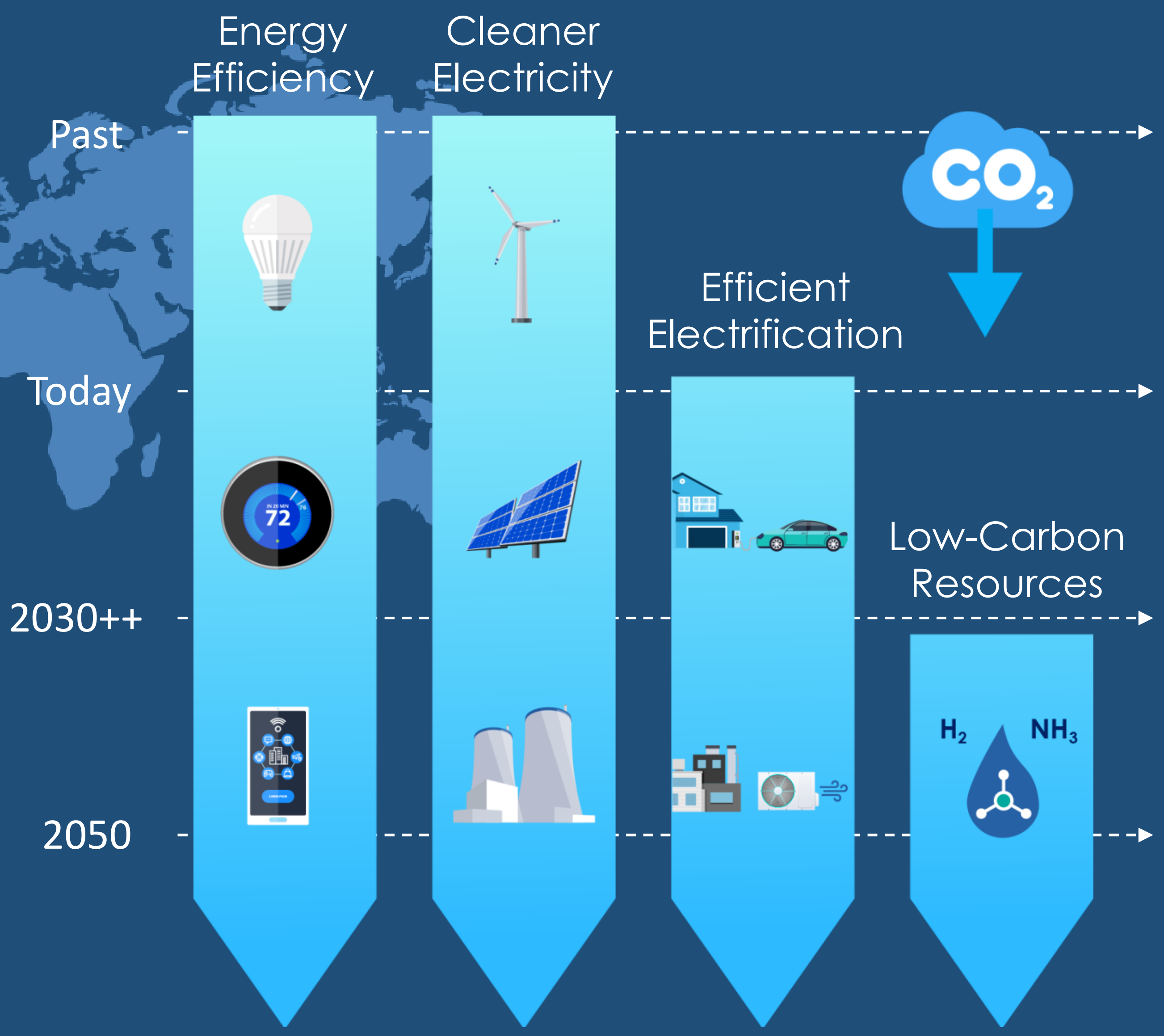
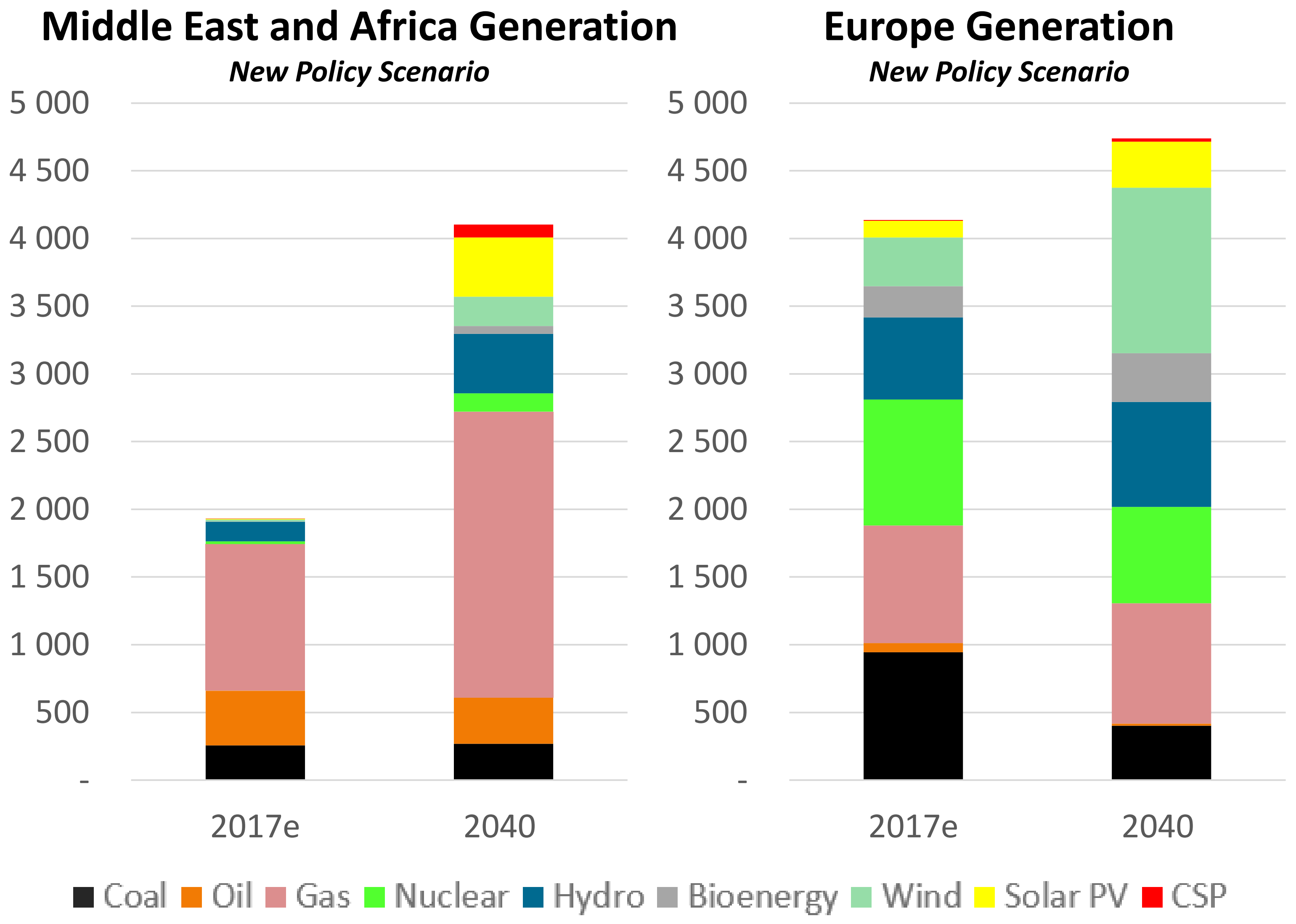


International Generation

Significant Variation
Large Reliance on Gas

- Evolving Generation Forecasts Internationally
  - World Energy Outlook (2018)
- Growing Gas Reliance in Middle East and Africa
- Continued Gas Reliance in Europe



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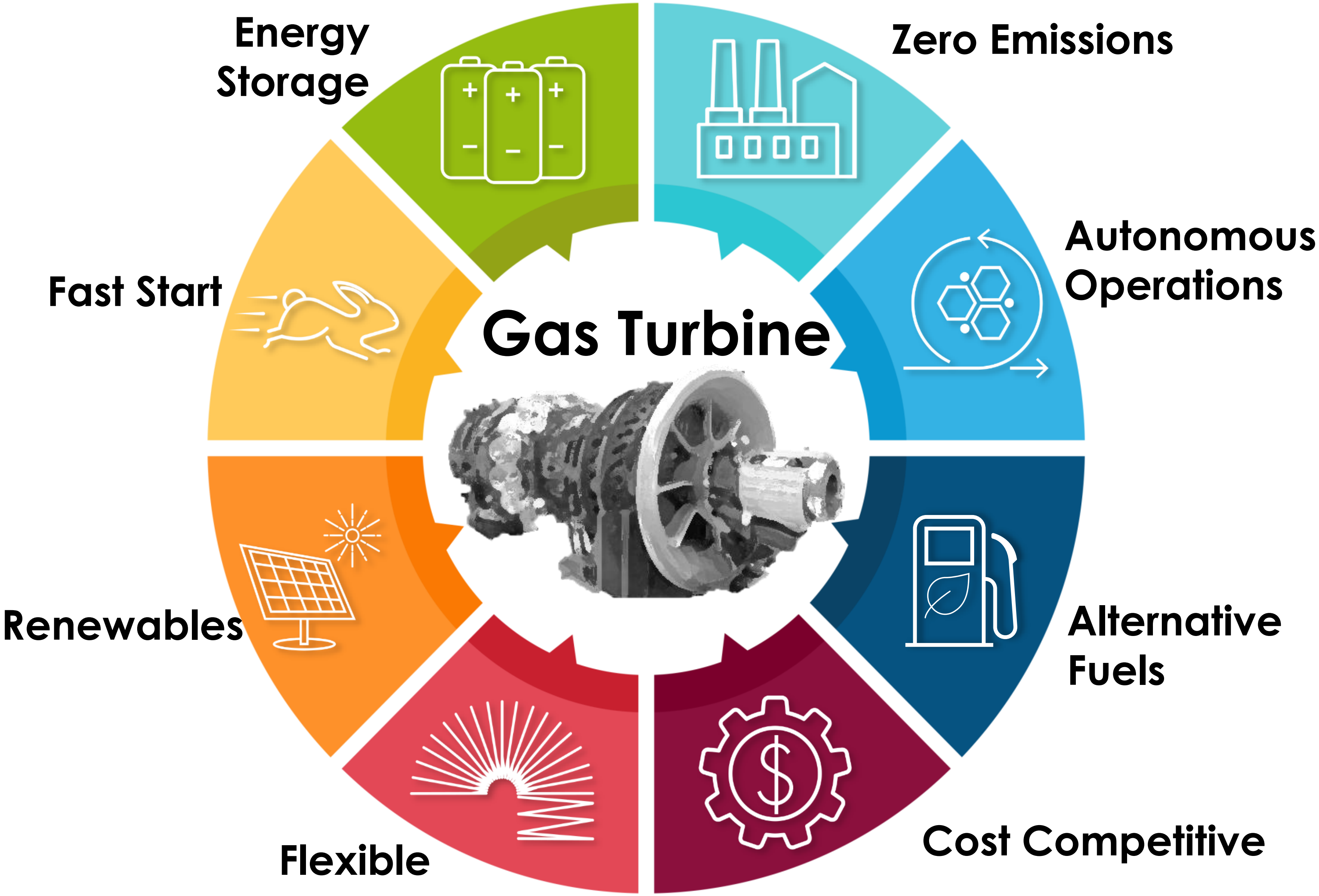
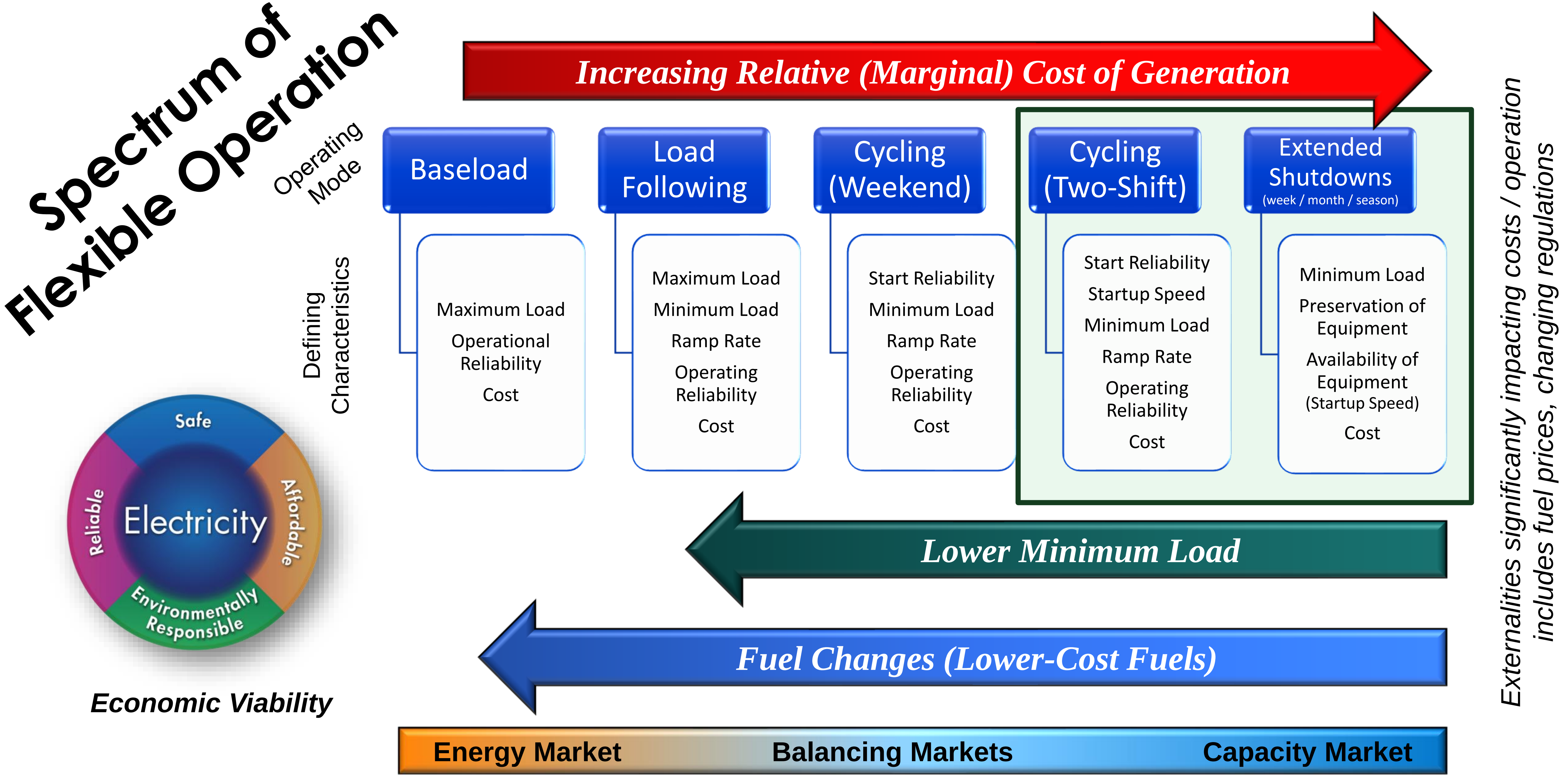
What is the Role for Gas Turbines in the Future?



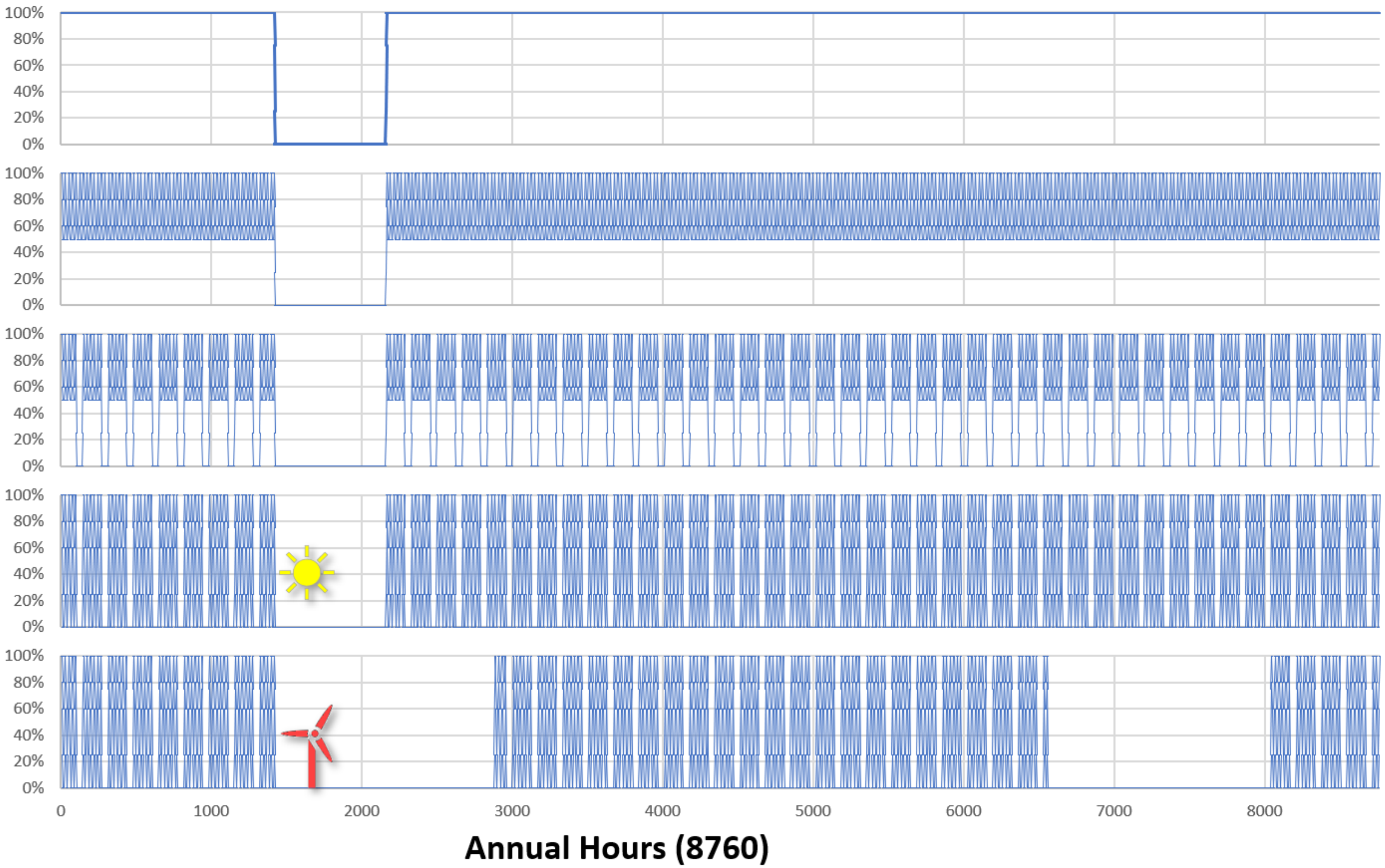
The Flexible Gas Turbine



Retrofits for flexibility are possible but economics can be challenging (especially for ramp rate)

Different Thermal Plant Annual Operation Modes

	Capacity Factor	Service Factor	Starts
Baseload	92%	92%	1
Load Following	66%	92%	1
Weekend Cycling	49%	68%	50
Daily Cycling	35%	43%	250
Extended Shutdown	25%	35%	150



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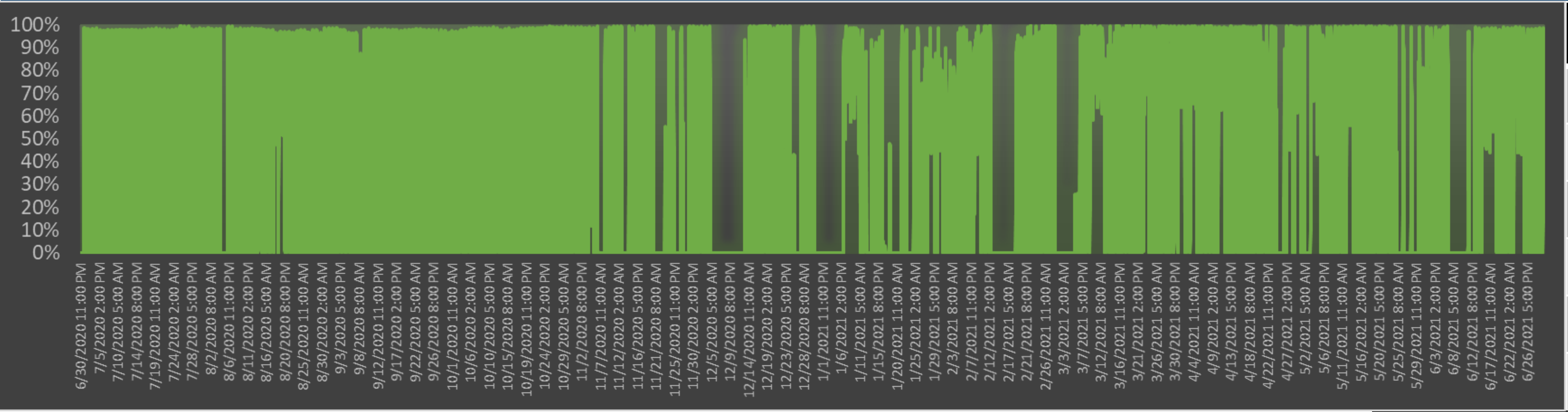
New 600MW CCGT

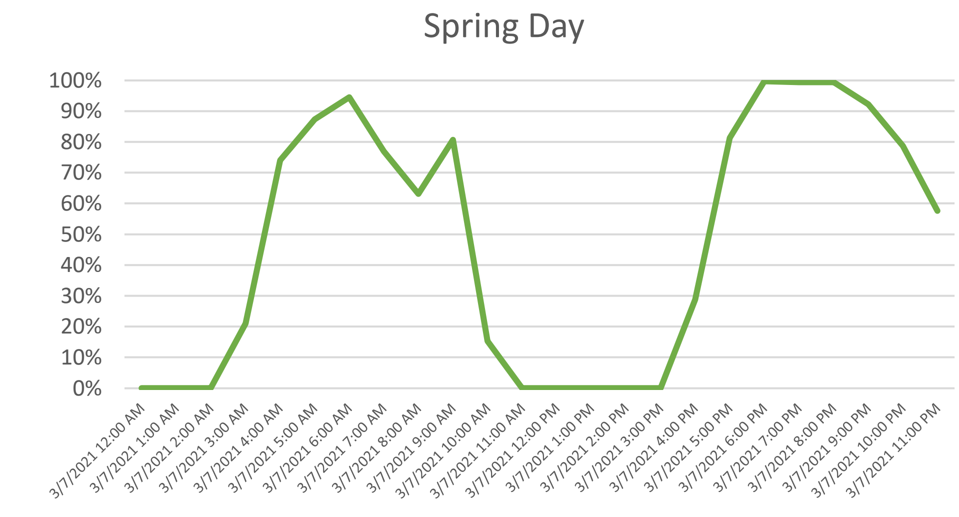
Built on Capacity Contract

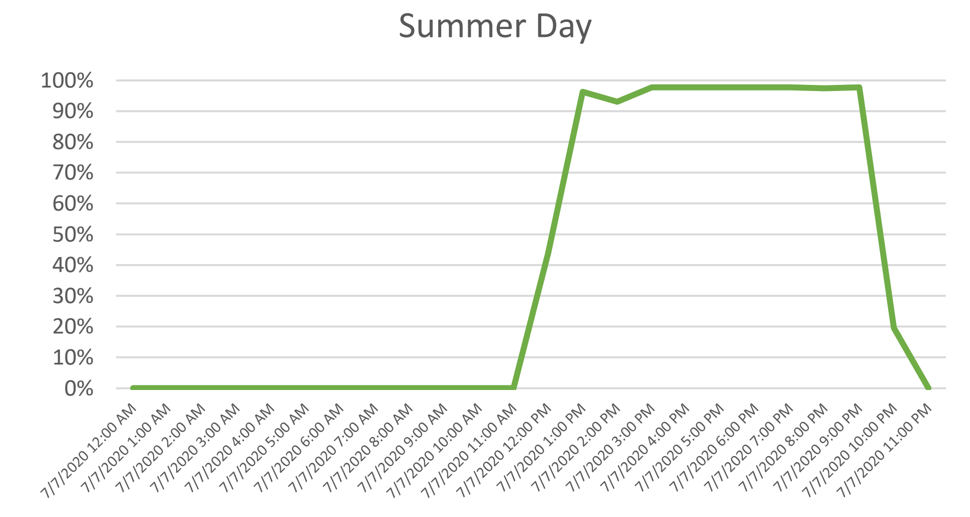
California Operation

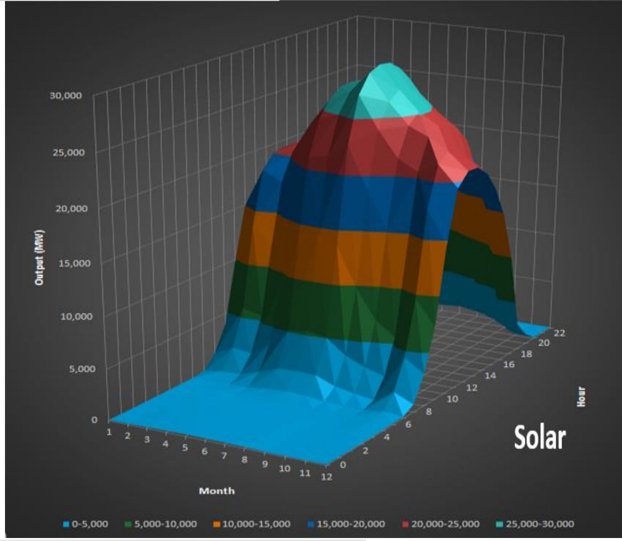
Daily on/off Operation -



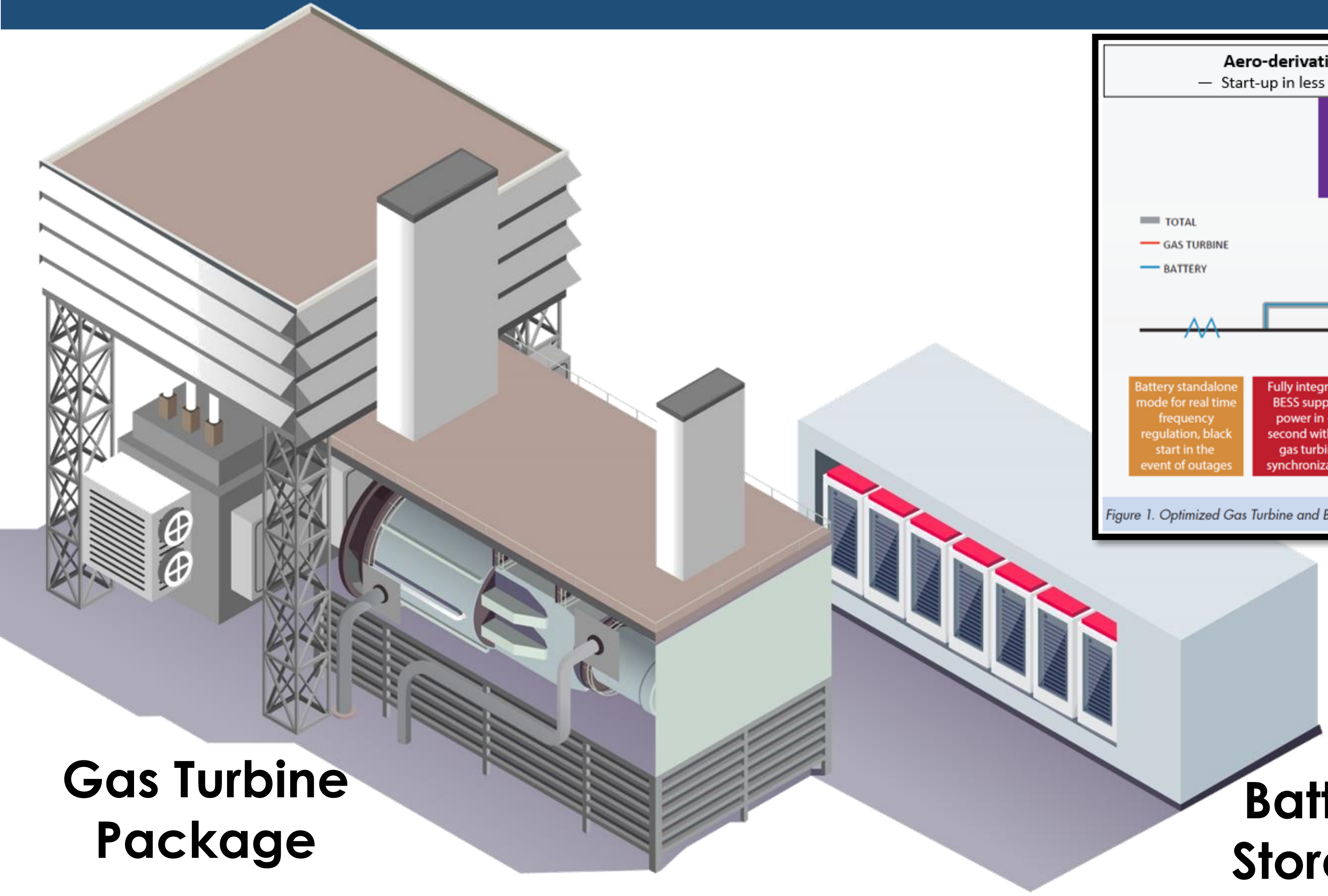
First Year	
Starts	315
>90% Load	2014
>45%<60%	319
>60%<90%	1365
No Load	4320
Cap. Factor	39%







Gas Turbine + Battery + Hybrid System Controller = Hybrid Gas Turbine (Hybrid GT + BESS)



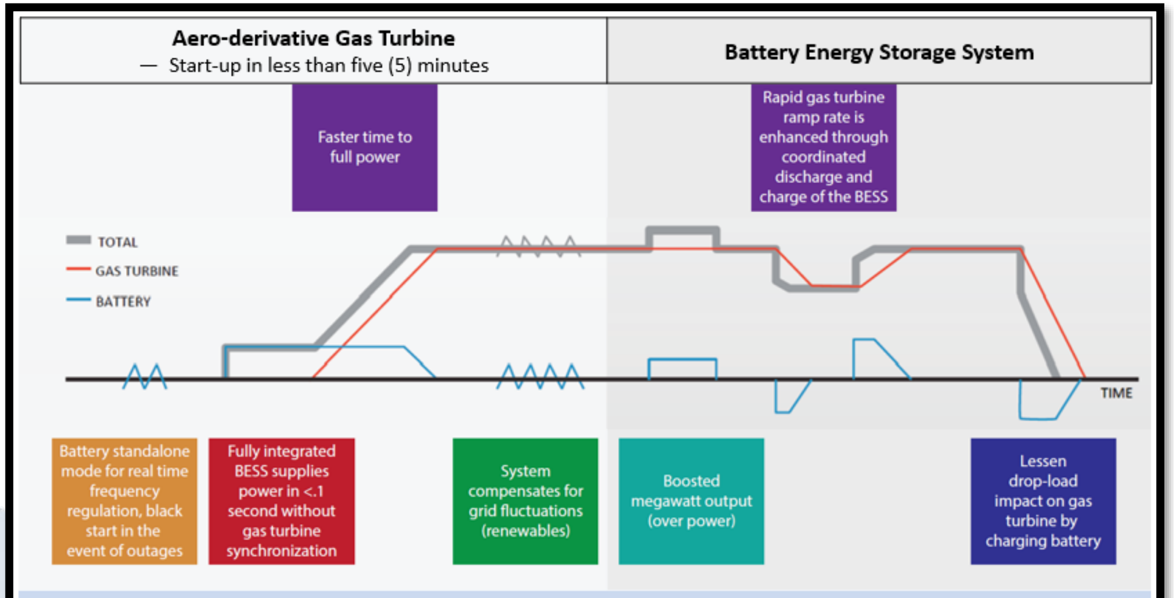


Figure 1. Optimized Gas Turbine and Battery Energy Storage System Operations - Image Copyright 2021, Mitsubishi Power Aero LLC, used with permission

Ultra-Fast Response

Gas Turbine Package

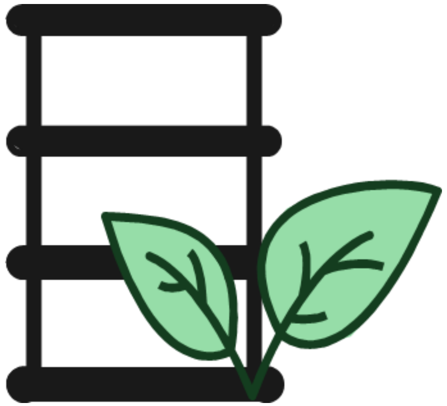
Battery Energy Storage System

The Carbon-Free/Neutral Gas Turbine

CO_2 Mitigation for Natural Gas

Different Interventions
Optimal Solutions?

The Fuel



Low Carbon Fuels

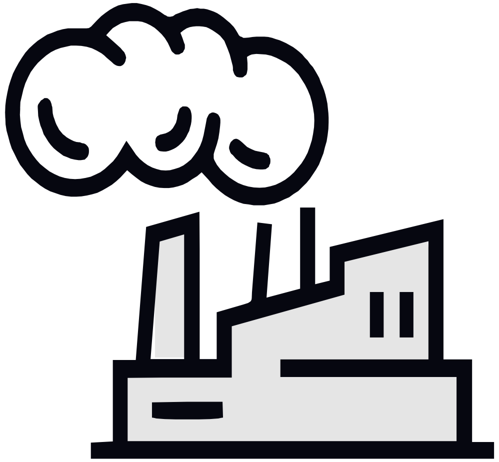
Renewable Natural Gas

Hydrogen

Ammonia

Biofuel/HVO

The Process



CO_2 Capture

Pre-combustion

Post-combustion

Oxy-combustion

The Destination

Carbon Dioxide Removal

Direct Air Capture

Bio-energy with CCS

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Gas Turbine Hydrogen Challenges

Technology	Characteristics
Diffusion Technology	⇨ Full Range H_2 Capabilities ⇨ High NOx
Current DLN Technology	⇨ Limited H_2 Capabilities ⇨ Low NOx
Next Gen DLN Technology	⇨ Full Range H_2 Capabilities ⇨ Low NOx

R&D Needed

Current Development Focus & Need

Hydrogen substitution for natural gas in turbines: Opportunities, issues, and challenges

6.18.2021

By Ben Emerson and Tim Lieuwen, Georgia Institute of Technology

Bobby Noble and Neva Espinoza, Electric Power Research Institute

Click Here for Article

Purpose to identify the **opportunities & challenges** associated with **utilizing hydrogen in energy conversion devices**

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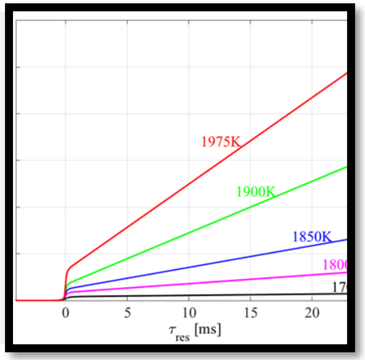
EPRI Supporting Low Carbon Future

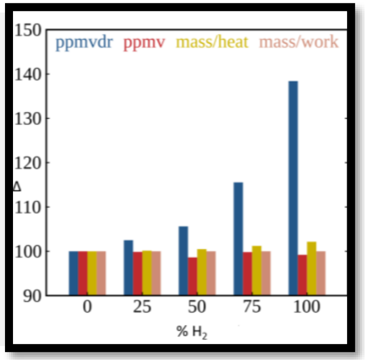
H_2 Combustion Fundamental NOx Production Limit Study

- Current high hydrogen capabilities are for older, diffusion-based GT combustion systems
- Questions to Resolve:
  - How low can we expect NOx for future dry, low-NOx (DLN) H_2 systems?
  - What is the fundamental NOx limit for premixed H_2/Air combustion?



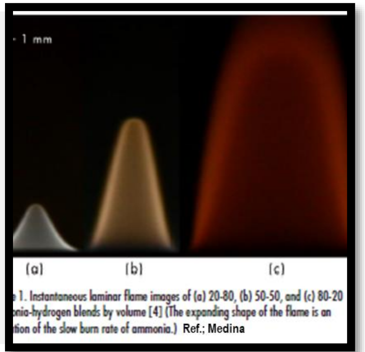
Fuel % H_2 vs. Emissions Correction

- Even with equal mass of NOx, typical corrected values are skewed w/ H_2 in the fuel mixture
  - Scaling by work produced can minimize this effect
  - These effects are a result of replacing CO_2 with H_2O and increasing excess O_2



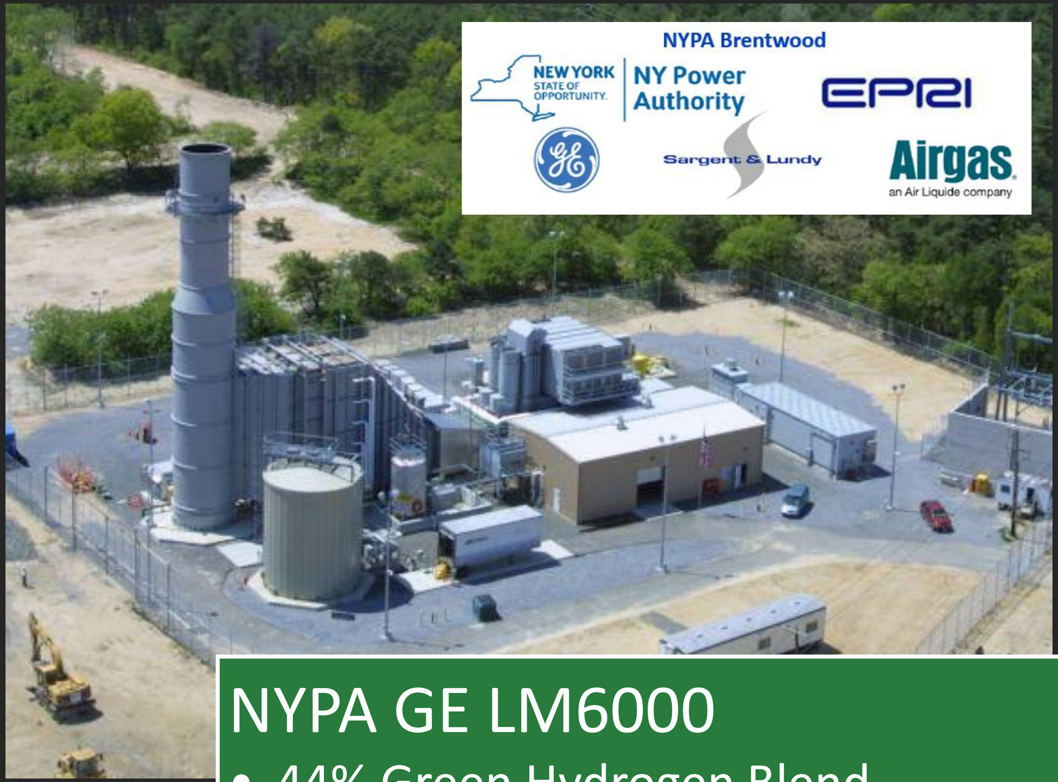
Ammonia Combustion Kinetics Project

- Opportunity for NH3 and/or NH3+H2 blends as a carbon-free fuel for gas turbine power generation
  - Current combustion physics models for NH3 and NH3+H2 blends not anchored to higher pressure data
  - Detailed understanding of the combustion kinetics is necessary to better design for inclusion, specifically for determining possibilities for low NOx technology



EPRI Hydrogen Blending Demonstration Projects

Recent Aeroderivative and Frame Unit Demonstrations



NYPA GE LM6000

- 44% Green Hydrogen Blend
- Standard Combustors/Water Injection
- Maintained NOx & CO reduction

Georgia Power M501G

- 20.9% Hydrogen Blend
- DLN Combustion System
- Maintained NOx
- Increased Turndown Capability

EPRI 50th ANNIVERSARY