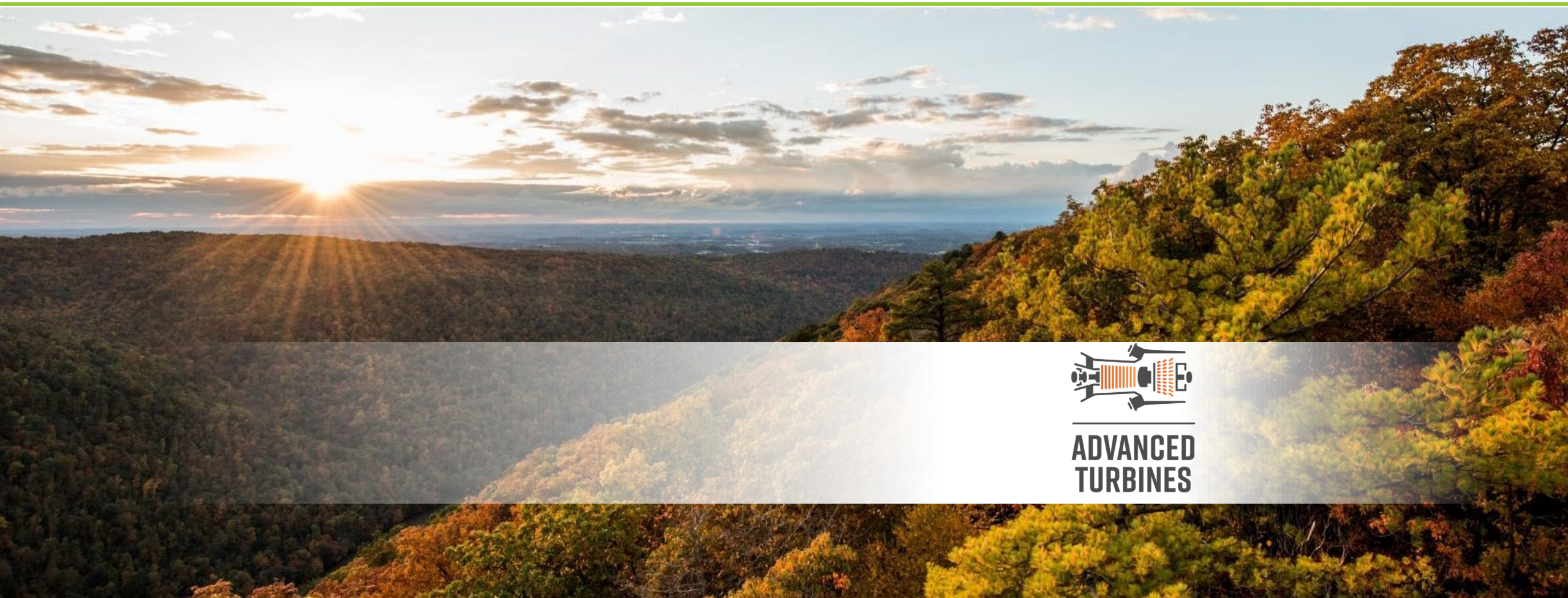
# DOE University Turbine Systems Research Program

## Turbines for Dispatchable Zero-Carbon Power

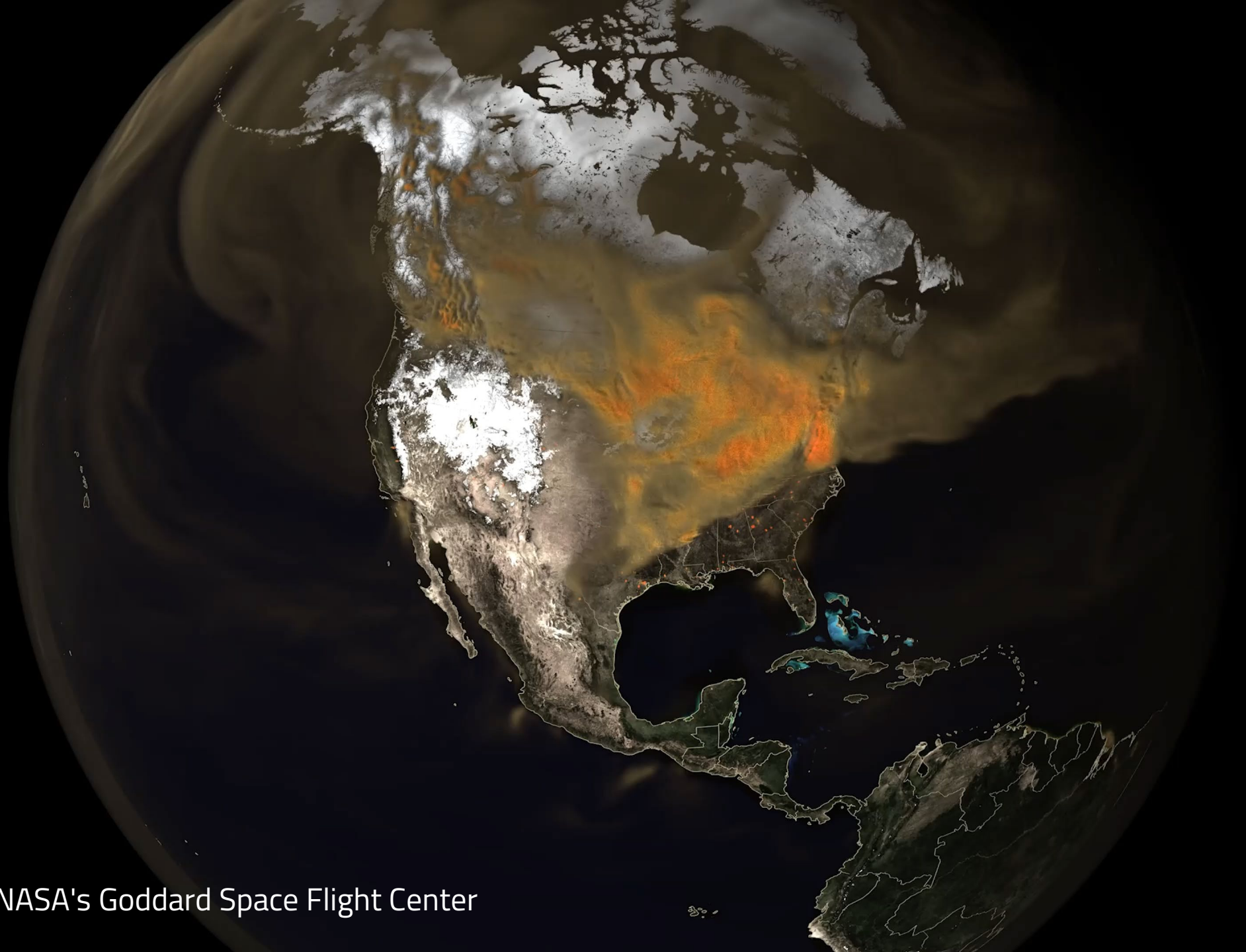
NATIONAL ENERGY TECHNOLOGY LABORATORY

*September 2024*

*John Crane*
*Technology Manager, Advanced Turbines Program*



# Disclaimer

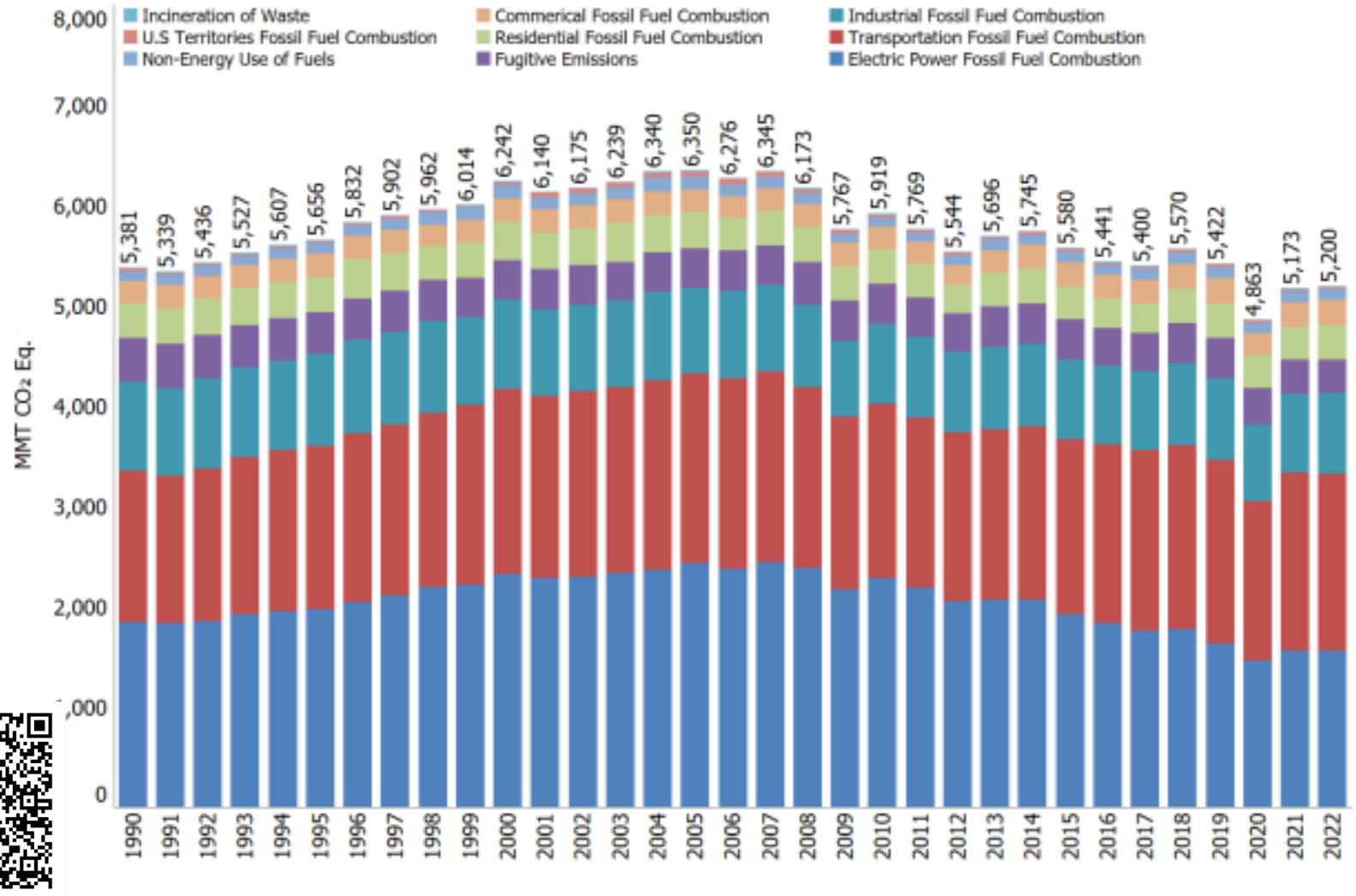


NASA's Goddard Space Flight Center

# GHG Emissions in the U.S. Power Sector

*From U.S. Environmental Protection Agency (2024)*

- From EPA – total GHG emissions in Energy Applications > 5 billion tonnes in 2021
  - 4.86 billion tonnes $CO_2$ from fossil fuel comb.
  - 1.54 billion tonnes $CO_2$ from electricity
- Total emissions have steadily declined since 2007



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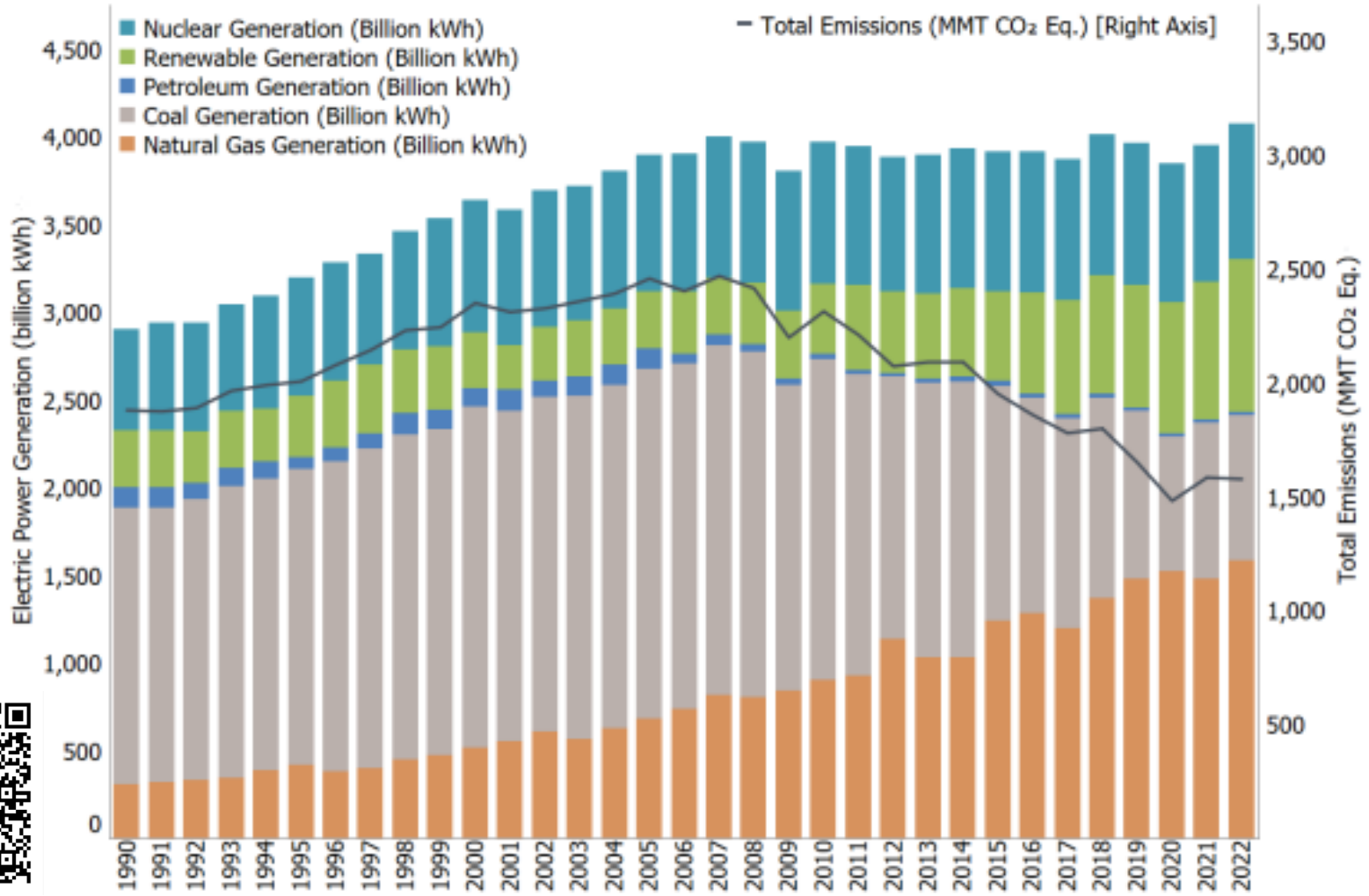
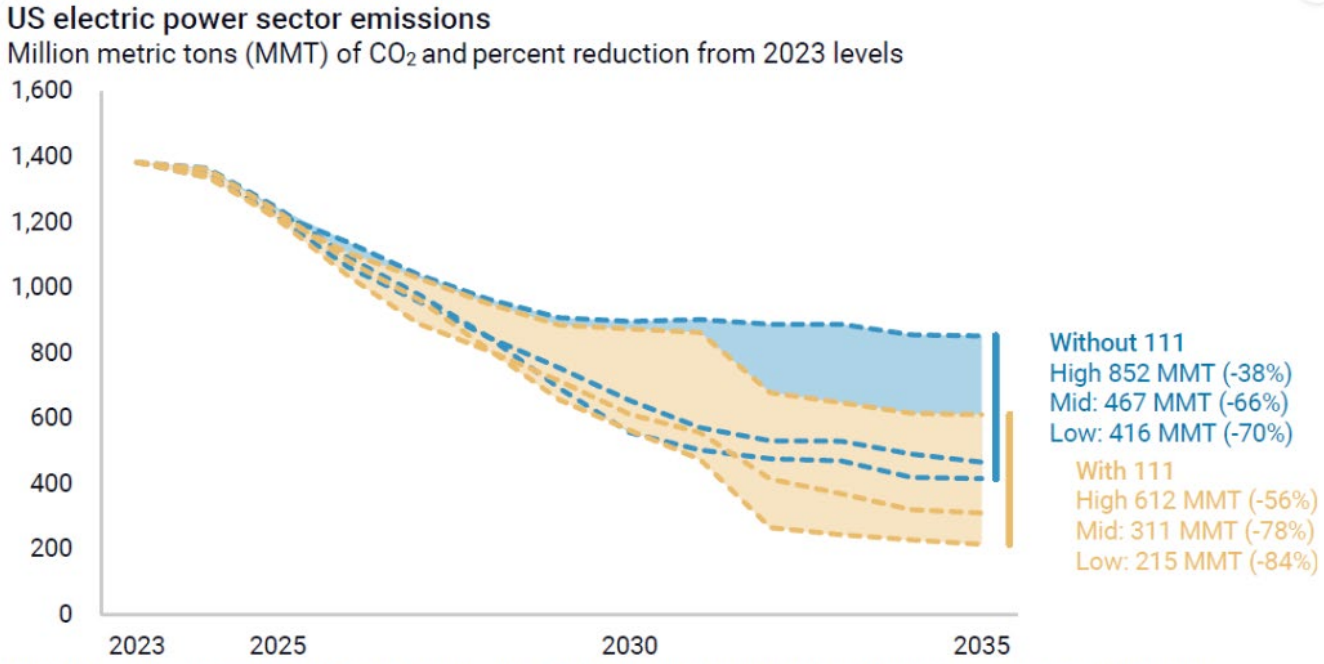


# Electricity Emissions Forecast

*From Rhodium Group Analysis of Proposed EPA 111 Rules*




Source: Rhodium Group. The high, mid, and low ranges reflect uncertainty around fossil fuel prices, economic growth, and clean technology costs.

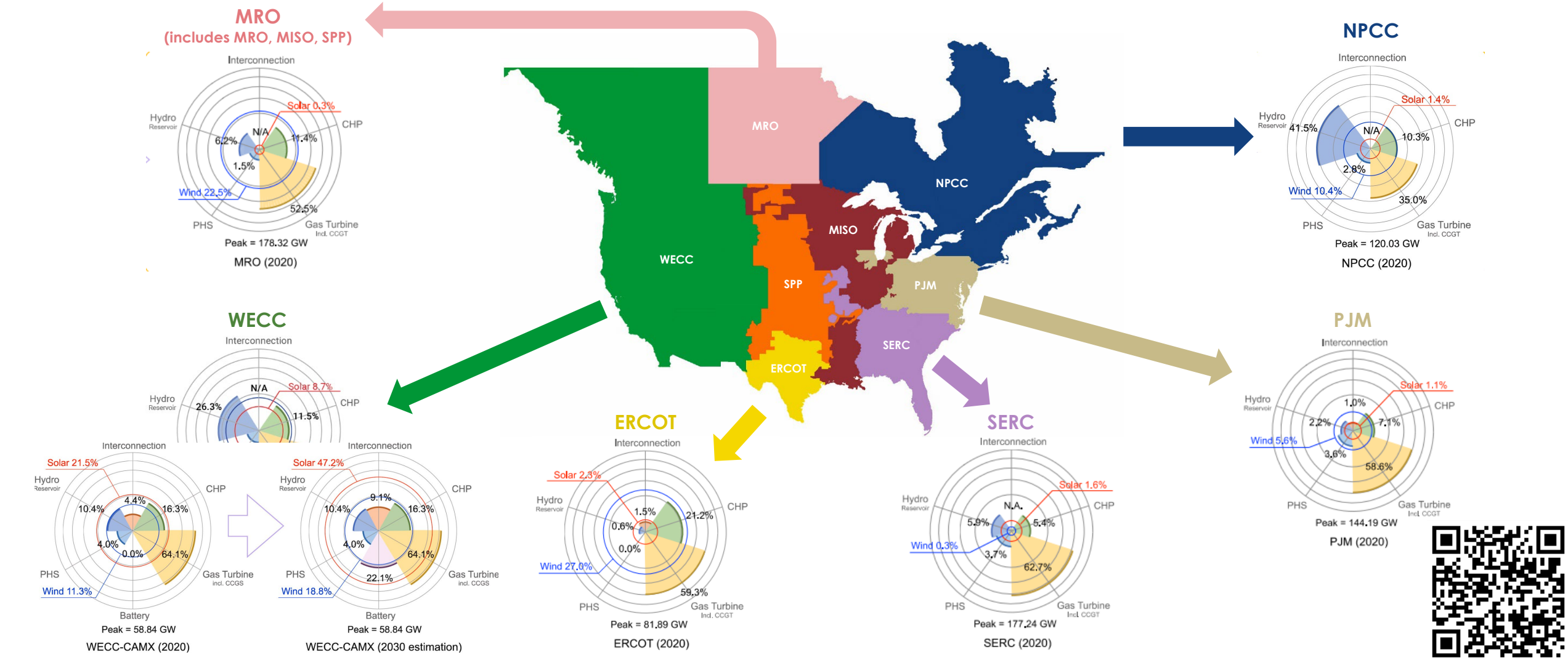
TABLE 1

Fossil generation capacity without and with EPA regulations (in GW)

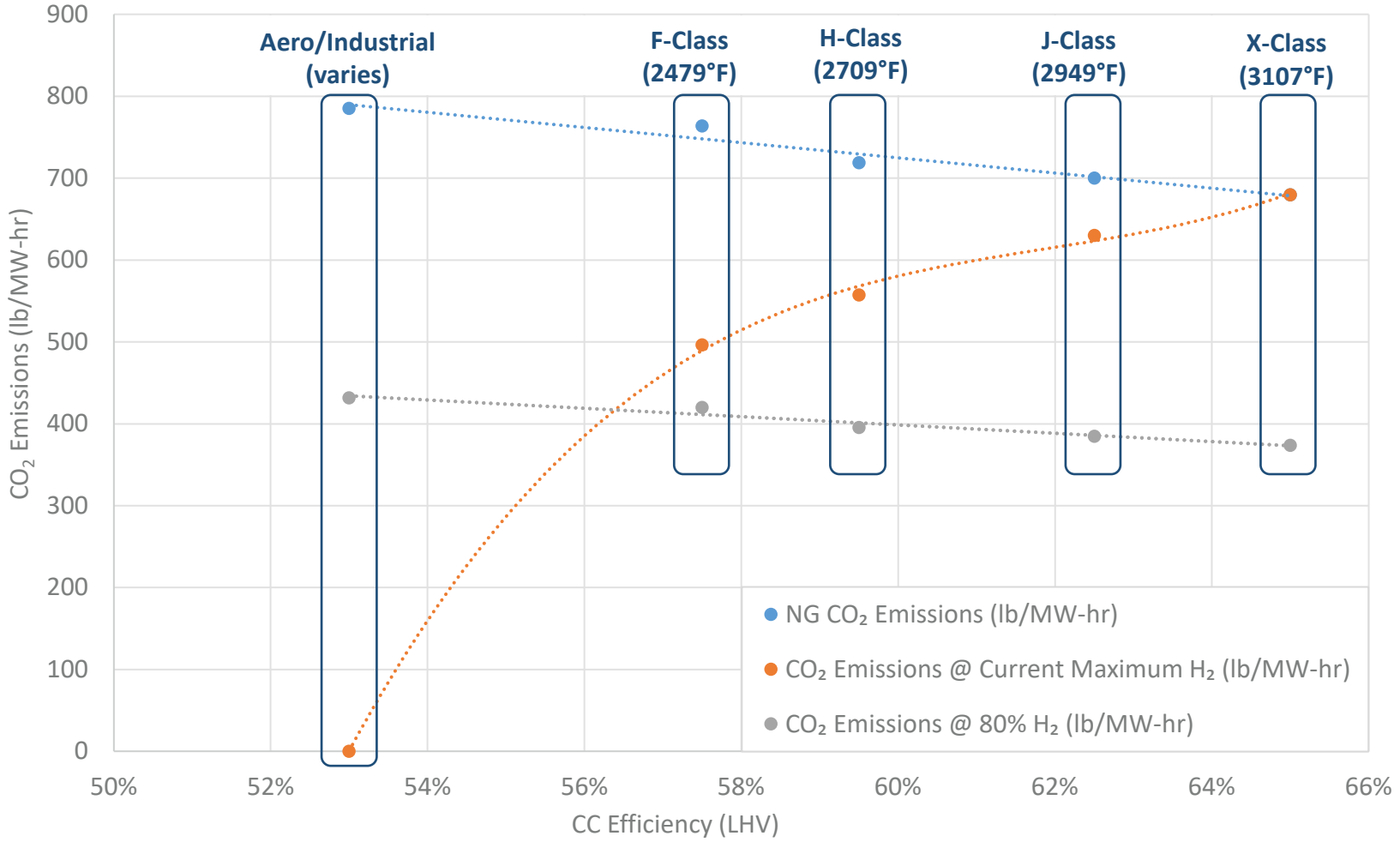
| Plant Type | 2022 | 2035 Without 111 | 2035 With 111 |
|---|---|---|---|
| Coal | 198 | 57-62 | 6-11 |
| Coal with carbon capture | 0 | 4-9 | 7-11 |
| Combined cycle natural gas | 280 | 251-312 | 253-319 |
| Combined cycle gas with carbon capture | 0 | 0-18 | 2-24 |
| Simple cycle natural gas (peakers) | 146 | 216-330 | 210-334 |
| All other fossil | 75 | 54-61 | 71-94 |
| Total | 699 | 524-703 | 545-759 |

# RTO Grid Flexibility for Stability (2020)

https://doi.org/10.1016/j.rser.2022.113116



# Efficiency vs. Decarbonization



# FOA Notice of Intent

DE-FOA-0003409

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY
Albany, OR • Morgantown, WV • Pittsburgh, PA

**Notice of Intent (NOI) No.: DE-FOA-0003413**
**Issue Date: July 25, 2024**

**DISCLAIMER**: This "Notice of Intent to Issue" is for informational purposes only; the Department of Energy is not seeking comments on the information in this notice and applications are not being accepted at this time. Any information contained in this notice is subject to change.

**This is a Notice of Intent to Issue**
**Funding Opportunity Announcement No. DE-FOA-0003409**
**"Pre-Commercial Testing of Low-Carbon Emissions Gas Turbine"**

The Department of Energy (DOE) National Energy Technology Laboratory (NETL) intends to issue Funding Opportunity Announcement (FOA) No. DE-FOA-0003409 on behalf of the Office of Fossil Energy and Carbon Management (FECM) in the 2024 calendar year.

**TECHNICAL OBJECTIVES**

In support of Executive Order 14008 (dated January 27, 2021), "Tackling the Climate Crisis at Home and Abroad," and to further past decades of DOE-supported carbon management research, development and demonstration (RD&D) done in cooperation with industry and academia, DOE-FECM anticipates issuing a FOA. DOE-FECM will seek applications for financial assistance awards supporting research and development (R&D) projects to develop technologies reducing carbon emissions from gas turbines providing baseload and dispatchable power to the US power grid to enable net-zero carbon energy production.

If issued, this FOA will seek to develop technologies to enable the existing gas turbine power infrastructure to achieve net-zero carbon energy through the utilization of carbon-free fuels or through the enhancement of post-combustion carbon capture technology via exhaust gas recirculation.

This notice is issued so that interested parties are aware of the DOE's intention to issue a FOA in the near term. DOE envisions awarding multiple financial assistance awards in the form of cooperative agreements in response to this FOA.

If released, this FOA is anticipated to focus on two areas of interest (AOIs).

**ANTICIPATED AREAS OF INTEREST**

**AOI 1. Hydrogen Combustion Systems for Gas Turbines**

Enabling the utilization of high-purity hydrogen fuel in existing gas turbine power generation infrastructure is a key component for decarbonization of the electric grid. Decarbonization will require further development of gas turbine combustor modules capable of safe, efficient, and low emissions operation while burning hydrogen-based fuels.

This AOI seeks to develop hydrogen fuel capable combustion modules for aeroderivative and industrial (also known as "heavy-duty") gas turbines. The goal of this AOI is to complete rig testing of hydrogen fuel capable combustors to prepare the combustors for subsequent engine integration and field testing in a potential future FOA.

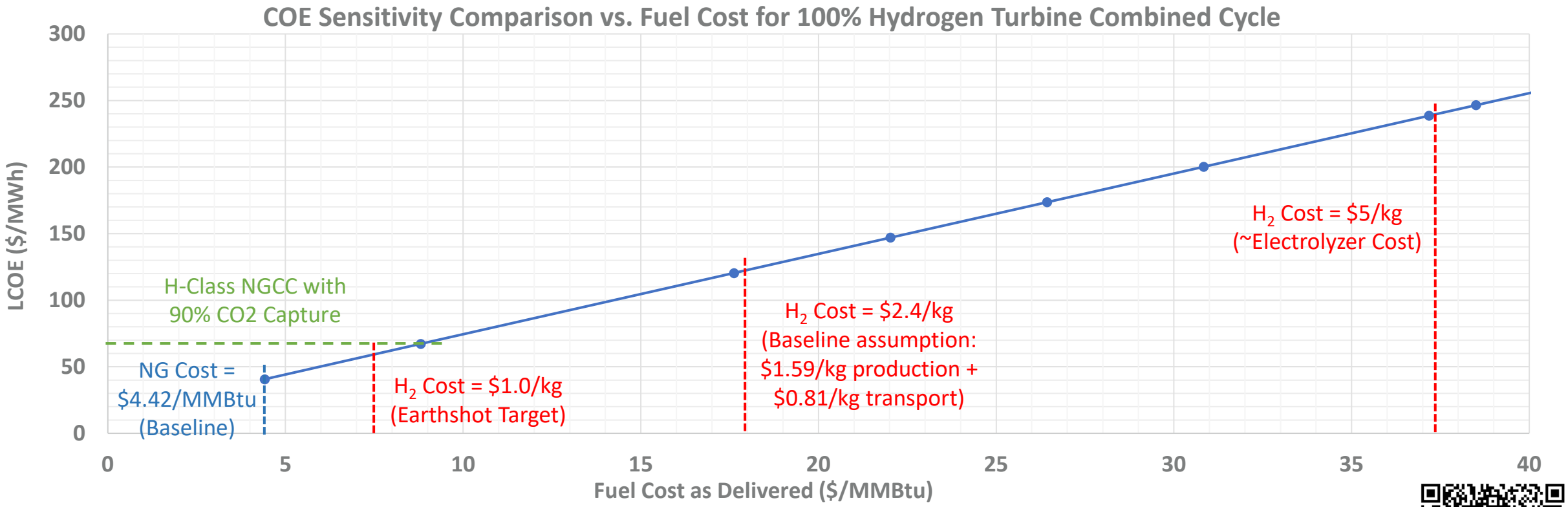
**AOI 2. Exhaust Gas Recirculation Systems for Gas Turbines**

Enabling the recirculation of exhaust gases in existing gas turbine power generation infrastructure will enhance the efficiency of state-of-the-art carbon capture equipment, a key component for decarbonization of the electric grid. This requires further development of gas turbine combustor modules that are capable of safe, efficient, and low emissions operation while burning fuels with greater inert reactants such as carbon dioxide.

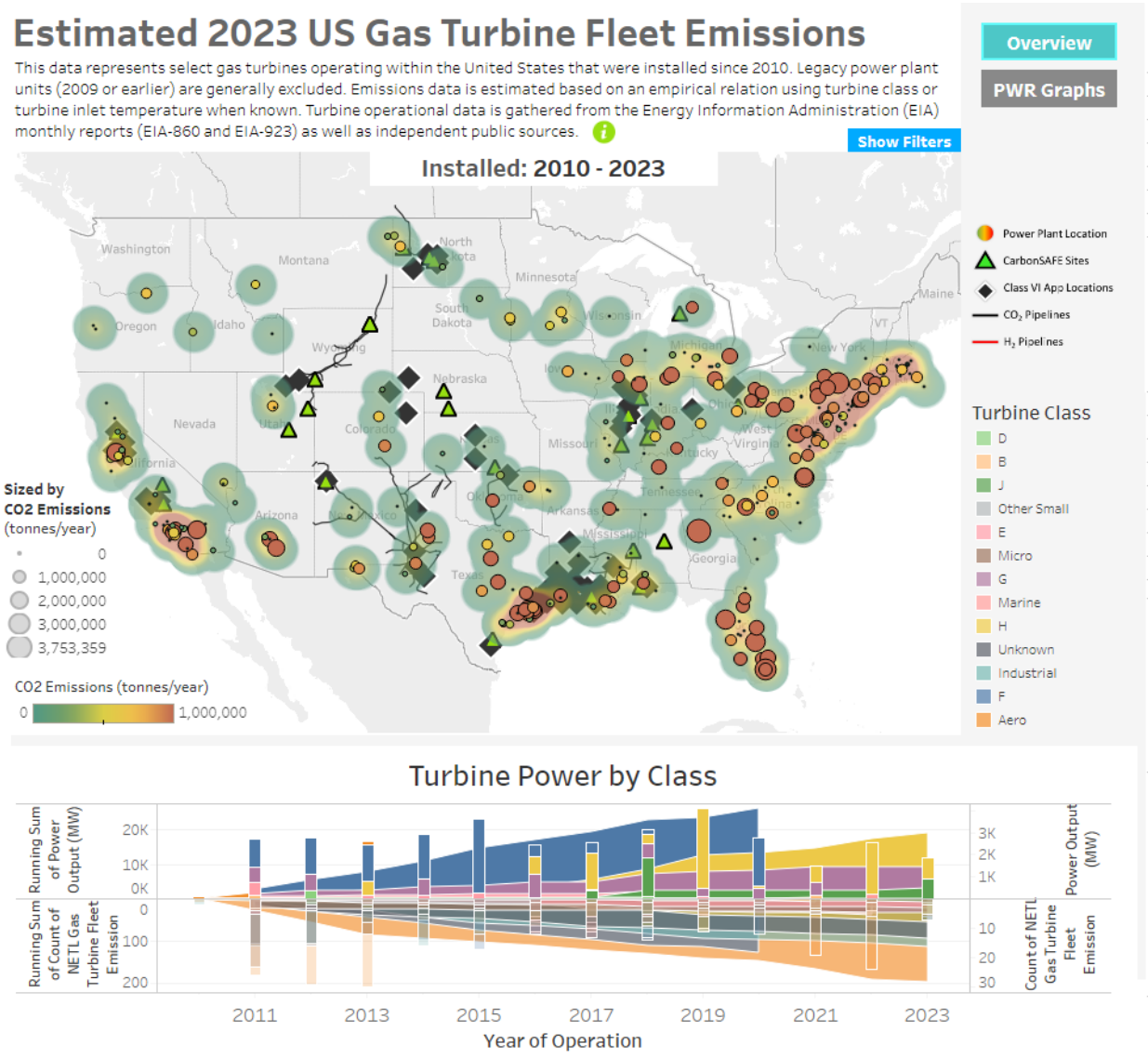
This AOI seeks to develop exhaust gas recirculation modules for aeroderivative and industrial (also known as "heavy-duty") gas turbines to research robust flame stabilization methods to maximize the amount of exhaust gas recirculation (EGR) without impacting combustion stability. The goal of this AOI is to complete rig testing of high-EGR combustors to enable engine integration and field testing in a potential future FOA.

# Cost Analysis for $H_2$ Combined Cycle

Fuel Price Sensitivity

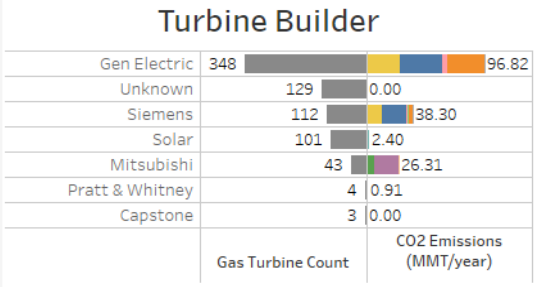


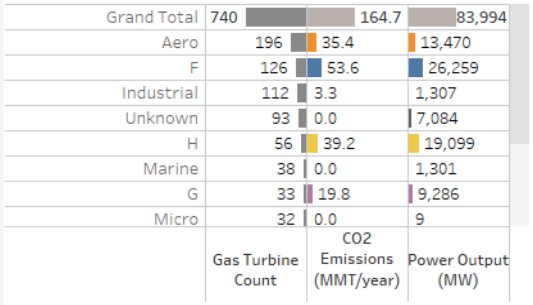
# Interactive Turbines $CO_2$ Emissions Map

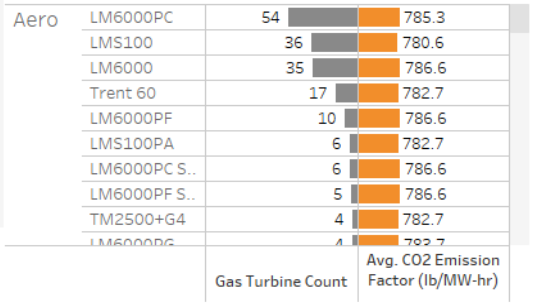









- 84 GW dispatchable turbine power installed since 2010
- Total emissions ~165 MMT in 2023
- Displays proximity to existing infrastructure ($CO_2$ pipelines, $H_2$ pipelines, Class VI sequestration wells)
- Filter by firing class, manufacturer / model, ISO, energy source, sector…

- Recent transition to H-class and Aeroderivative installations (No F-class installations since 2020)
- Majority installed in PJM, Southeast, and MISO

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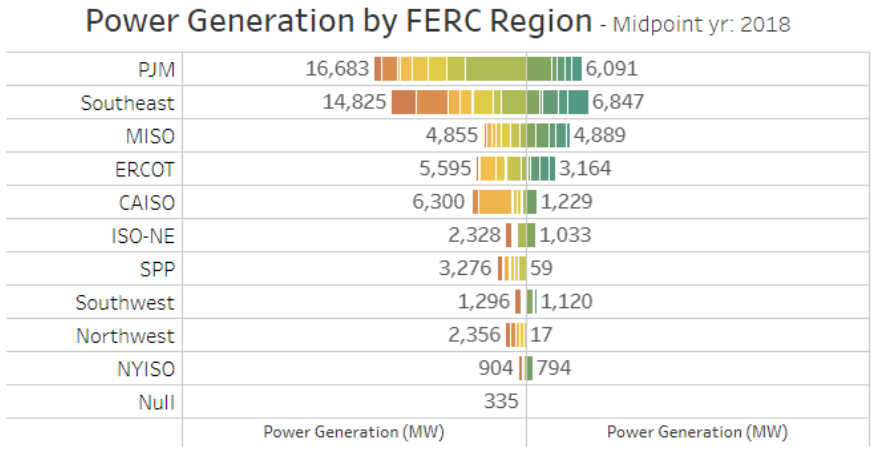


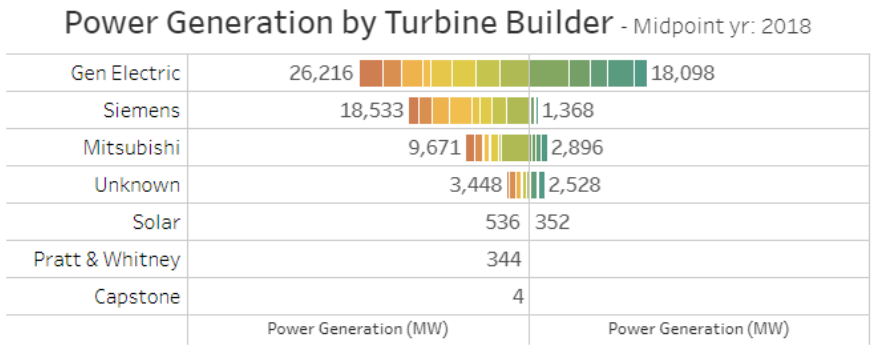


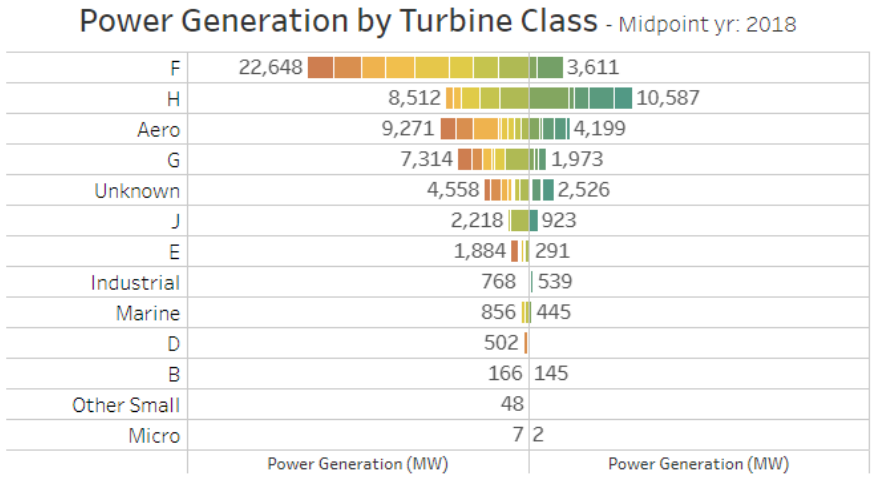


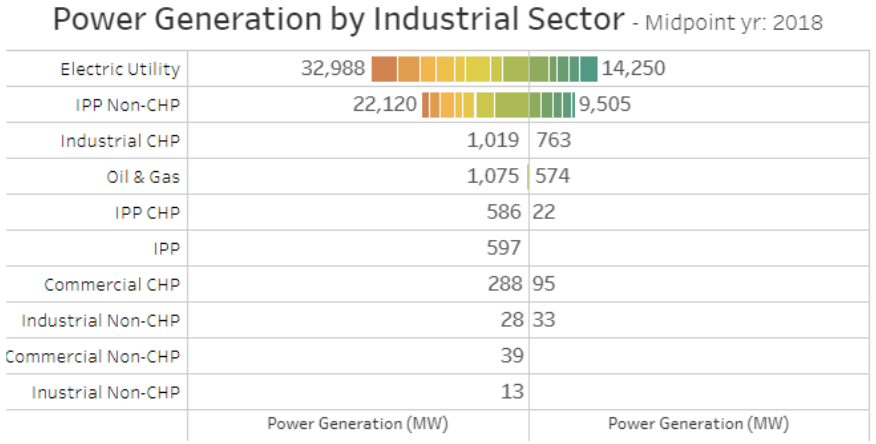


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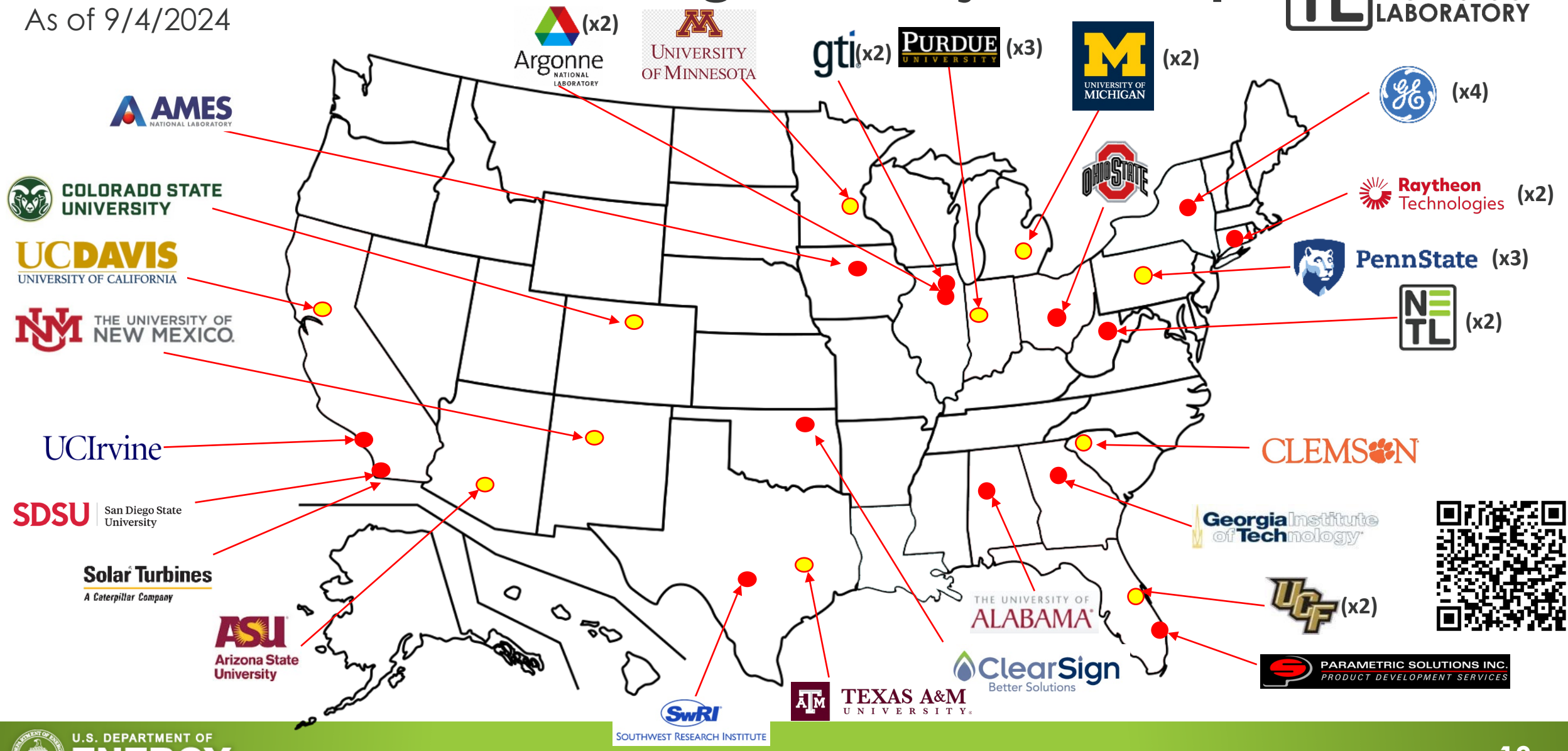
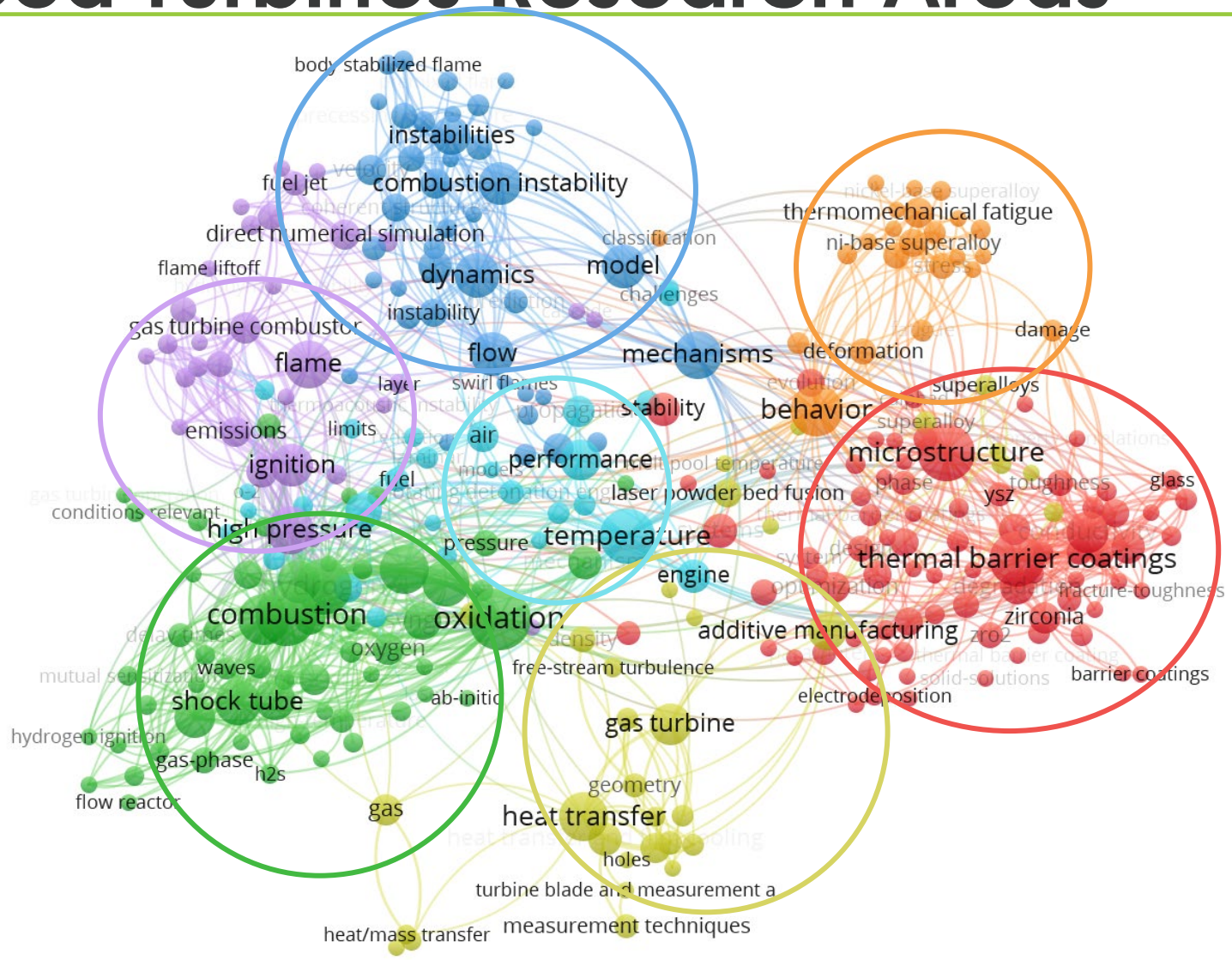
# Advanced Turbines Program Projects Map

As of 9/4/2024



# Advanced Turbines Research Areas

2010-2024




Publication Keywords
Co-occurrence
Color: Research Cluster

Thermal Barrier Coatings

Combustion Instabilities

Advanced Alloys & Lifing

Staged Comb & Emissions

Hydrogen Combustion

Additive Mfg & Heat Trans

Rotating Detonation Engines

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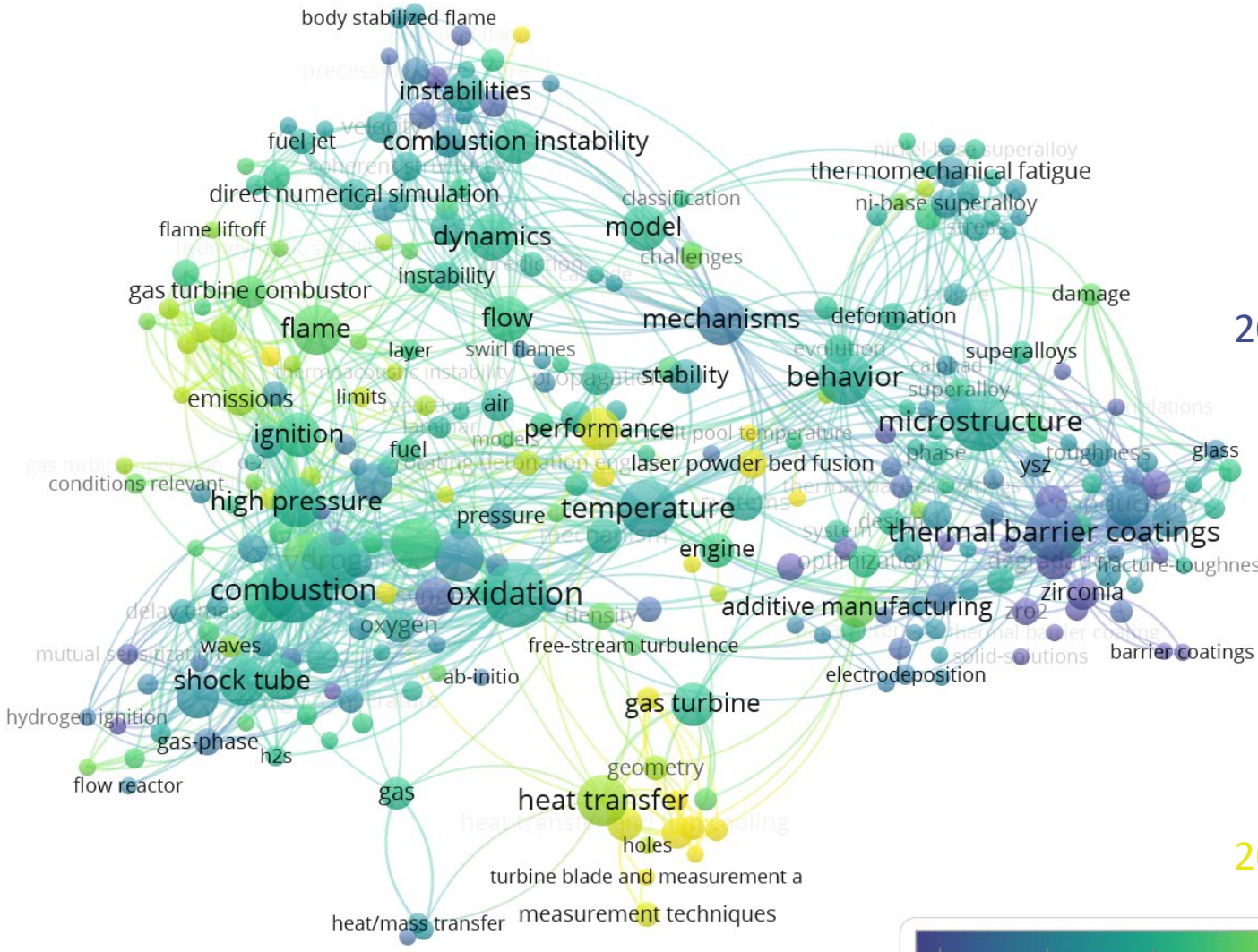
2010-2024




Publication Keywords
Co-occurrence
Color: Average Date

2014 Thermal Barrier Coatings

Combustion Instabilities

Advanced Alloys & Lifing

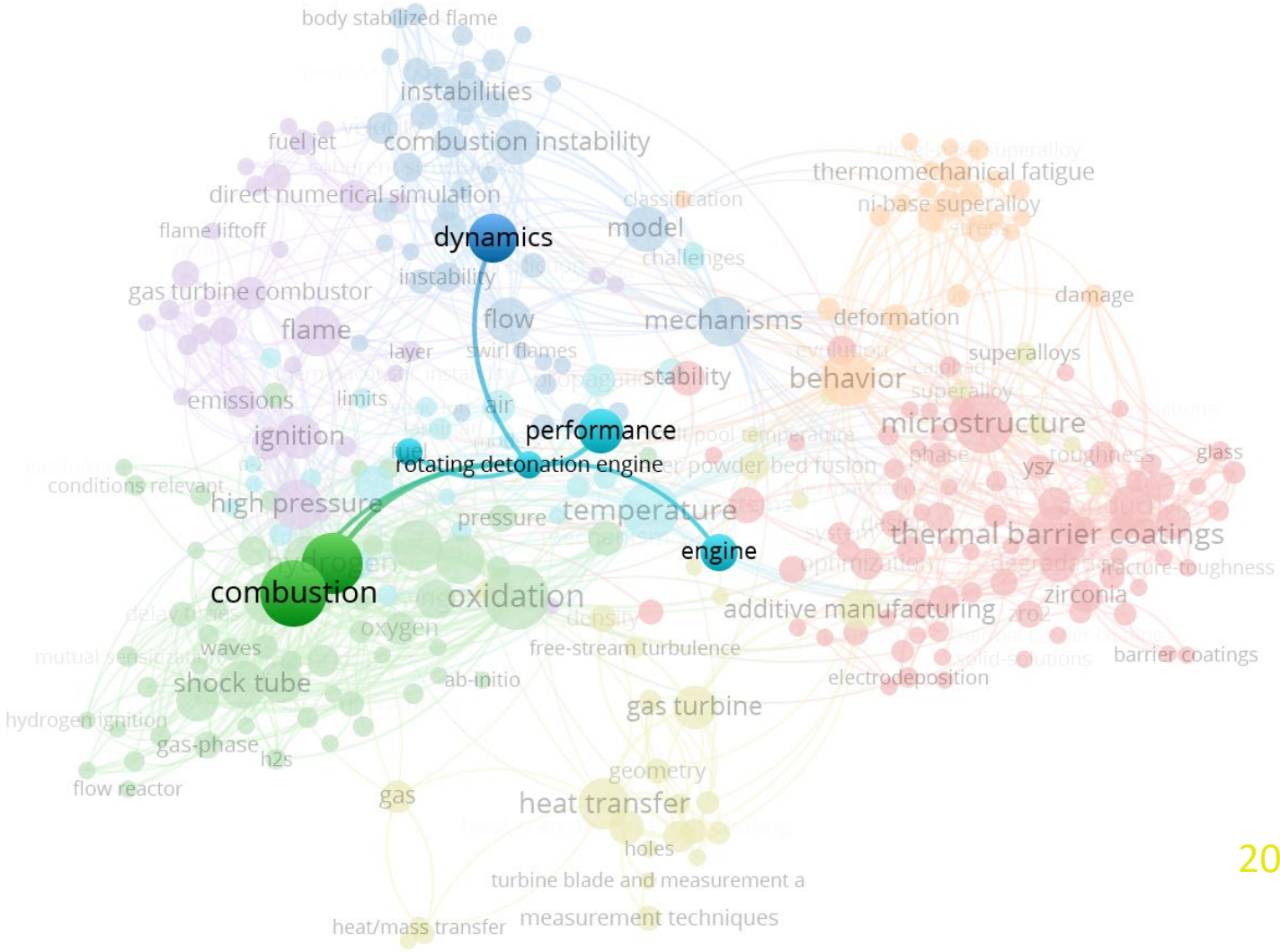
Staged Comb & Emissions

Hydrogen Combustion

Additive Mfg & Heat Trans

2022 Rotating Detonation Engines

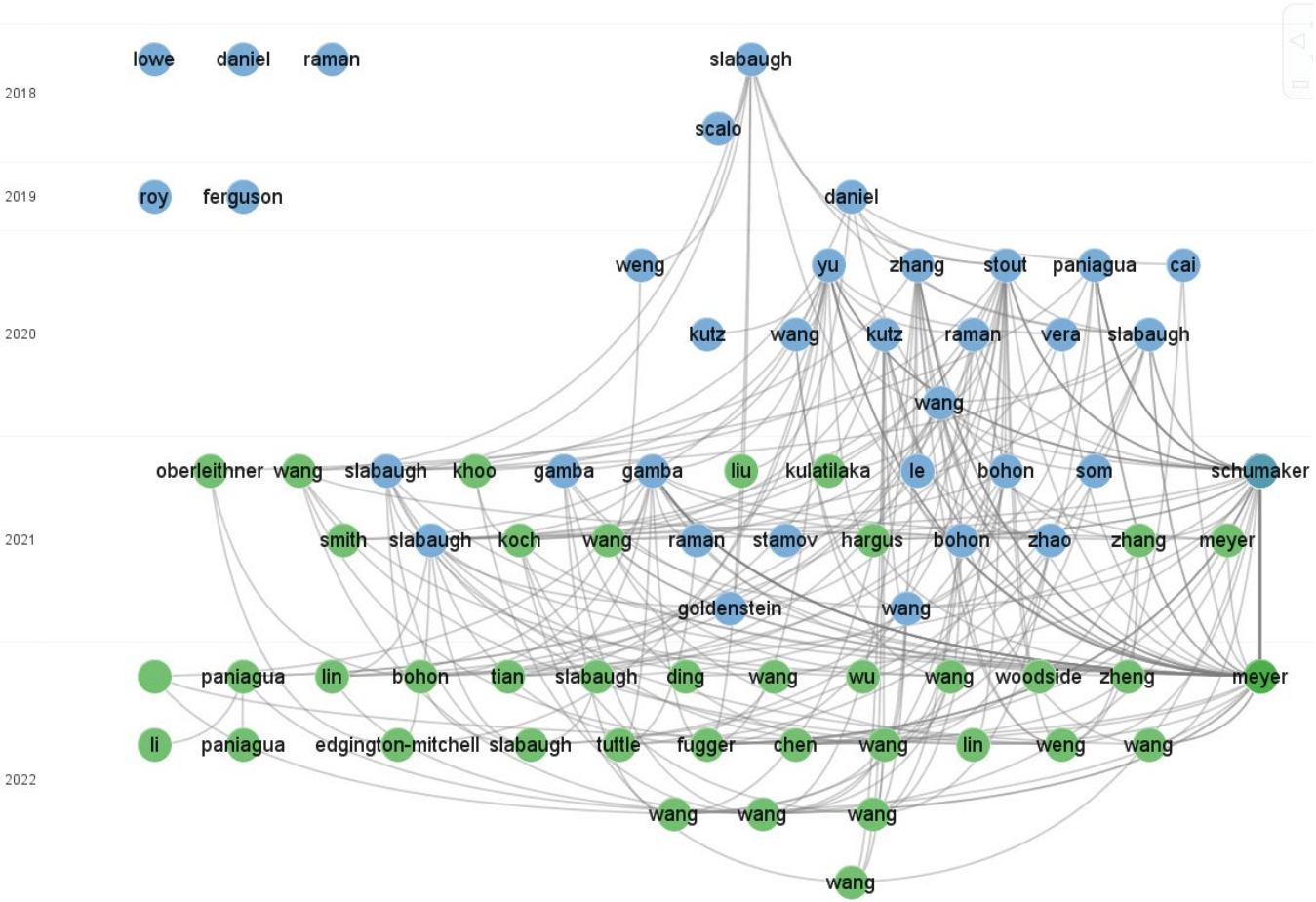
# Rotating Detonation

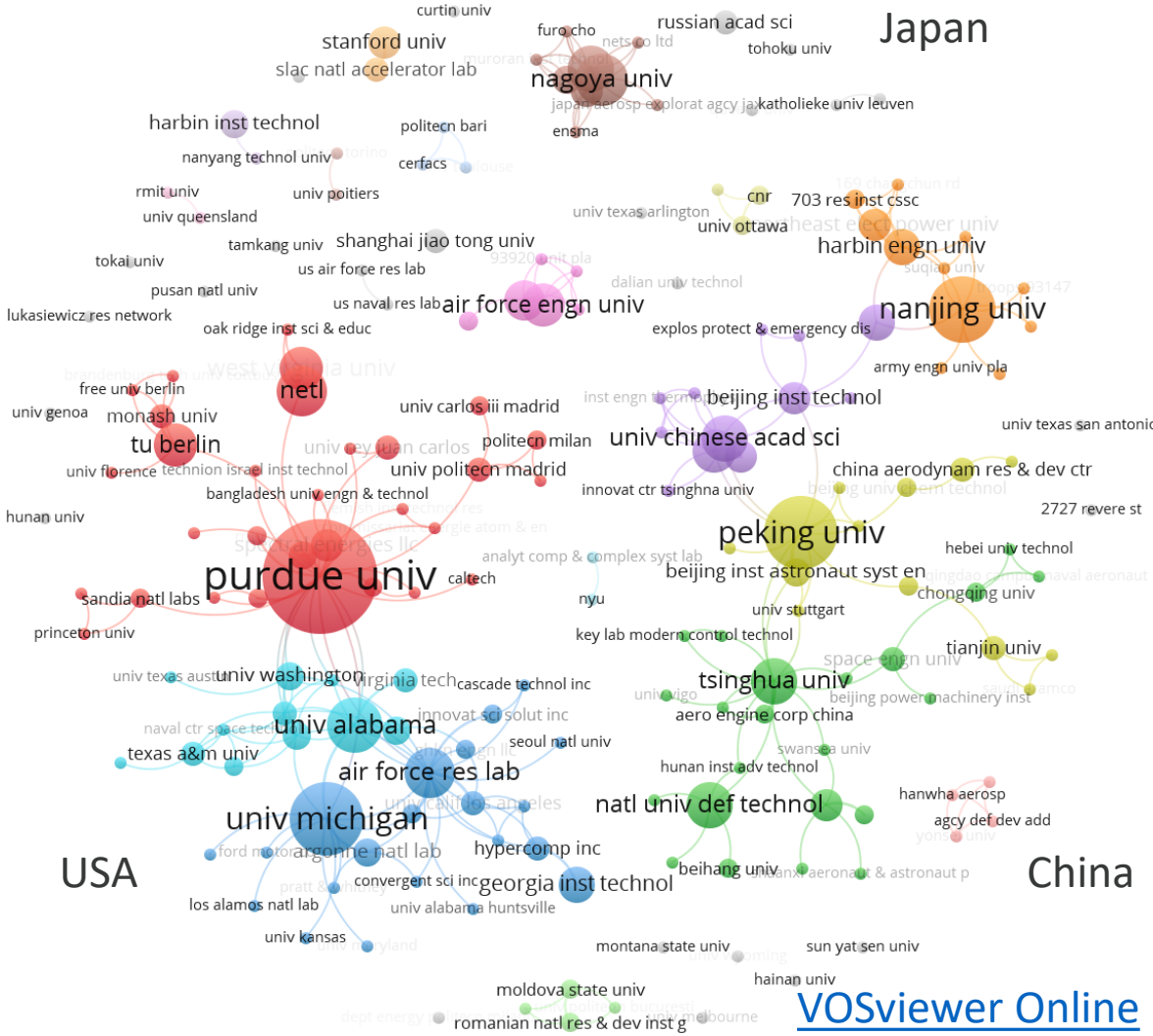



2022 Rotating Detonation Engines

# RDE Citation & Co-authorship

## NETL Publications & Citations




36 Advanced Turbines Publications → 234 Citations

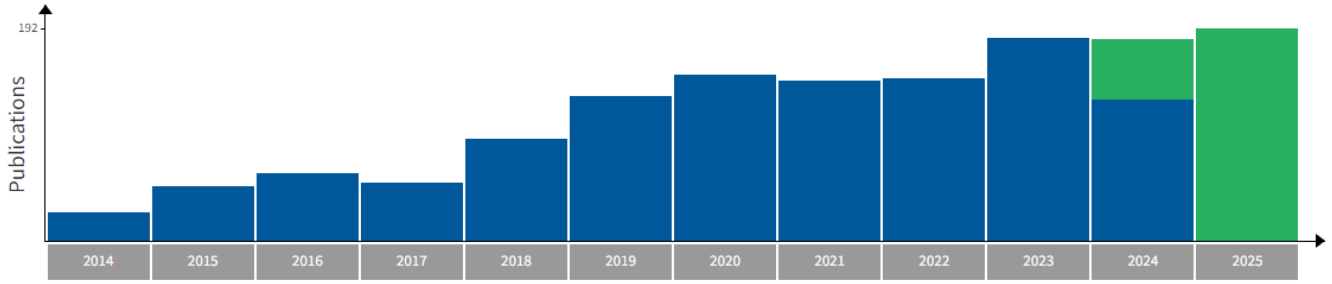
No vertical segmentation → well-connected research areas

[VOSviewer Online]

# RDE Research & Patents

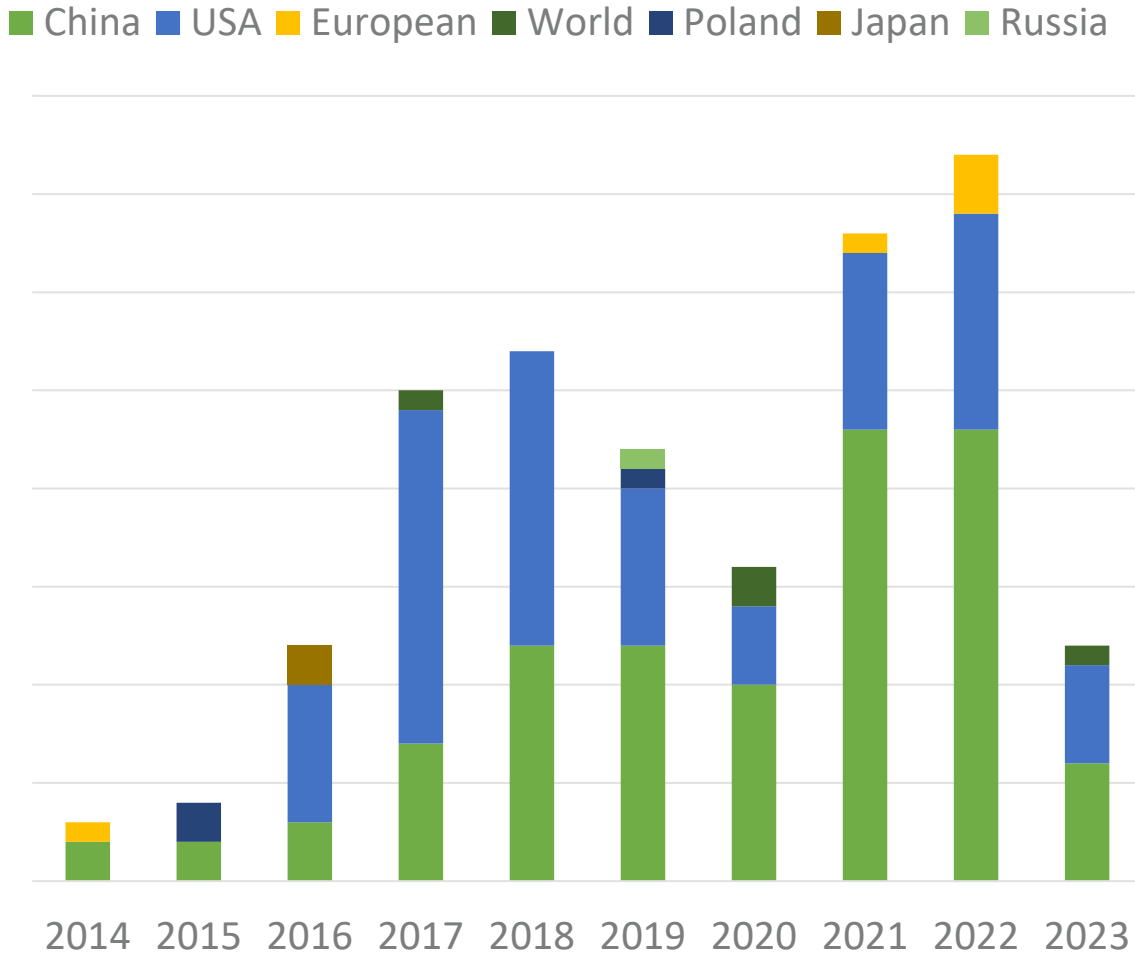
## Mapegy Rotating Detonation Publications

Research | Absolute Counts




Filter | Fields | Integration Date | Search in top 500 results

| | Relevance | Published | Publisher |
|---|---|---|---|
| Effects of different physical properties of anthracite powder fuel on detonation characteristics of a rotating detonation engine | | 2023 | AIP Publishing |
| Development of a Liquid-Propellant Rocket Powered by a Rotating Detonation Engine | | 2023 | American Institute of Aeronautics and Astronautics (AIAA) |
| Thrust Performance of Converging Rotating Detonation Engine Compared with Steady Rocket Engine | | 2023 | American Institute of Aeronautics and Astronautics (AIAA) |
| Study of the characteristics and combustion efficiency of liquid kerosene/oxygen-enriched air rotating detonation wave with different modes | | 2023 | Elsevier BV |
| Investigation of counter-rotating shock wave and wave direction control of hollow rotating detonation engine with Laval nozzle | | 2022 | AIP Publishing |
| Effects of blockage ratio on the propagation characteristics of hydrogen-rich gas rotating detonation | | 2023 | AIP Publishing |



# RDE Research & Patents

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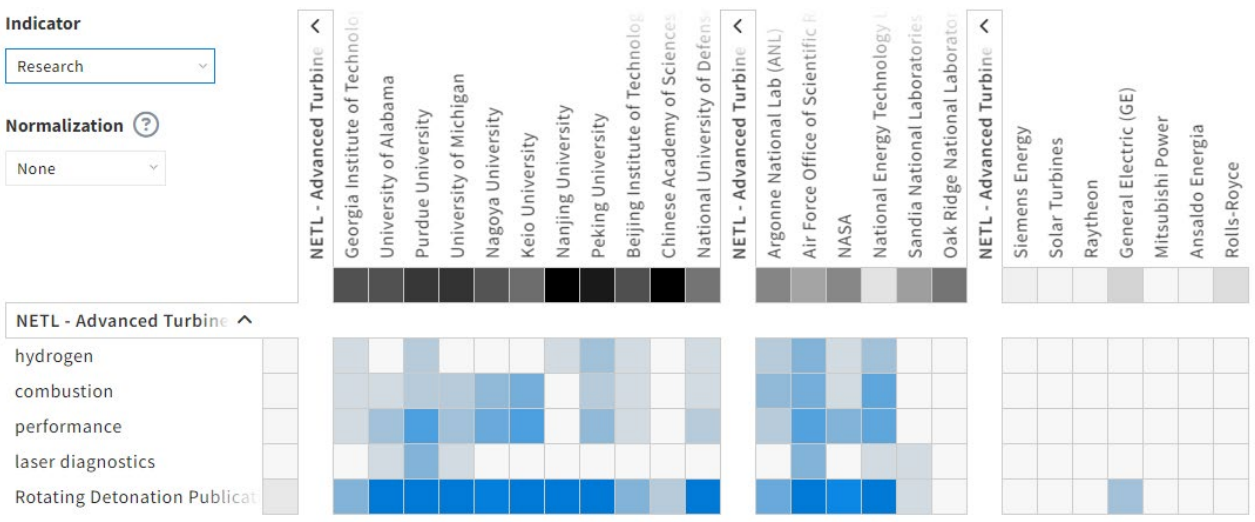


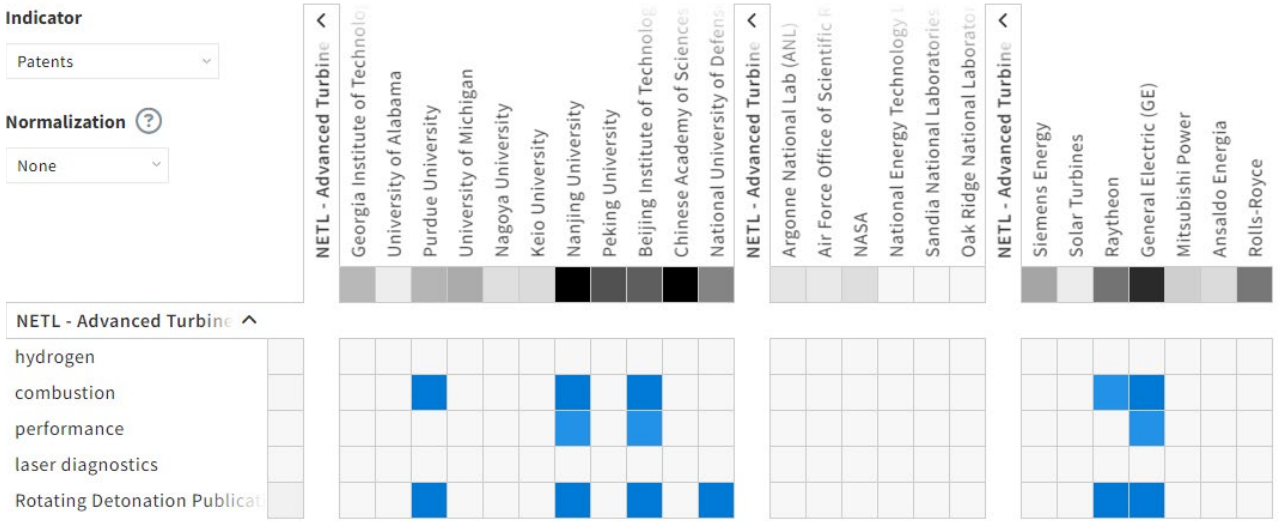

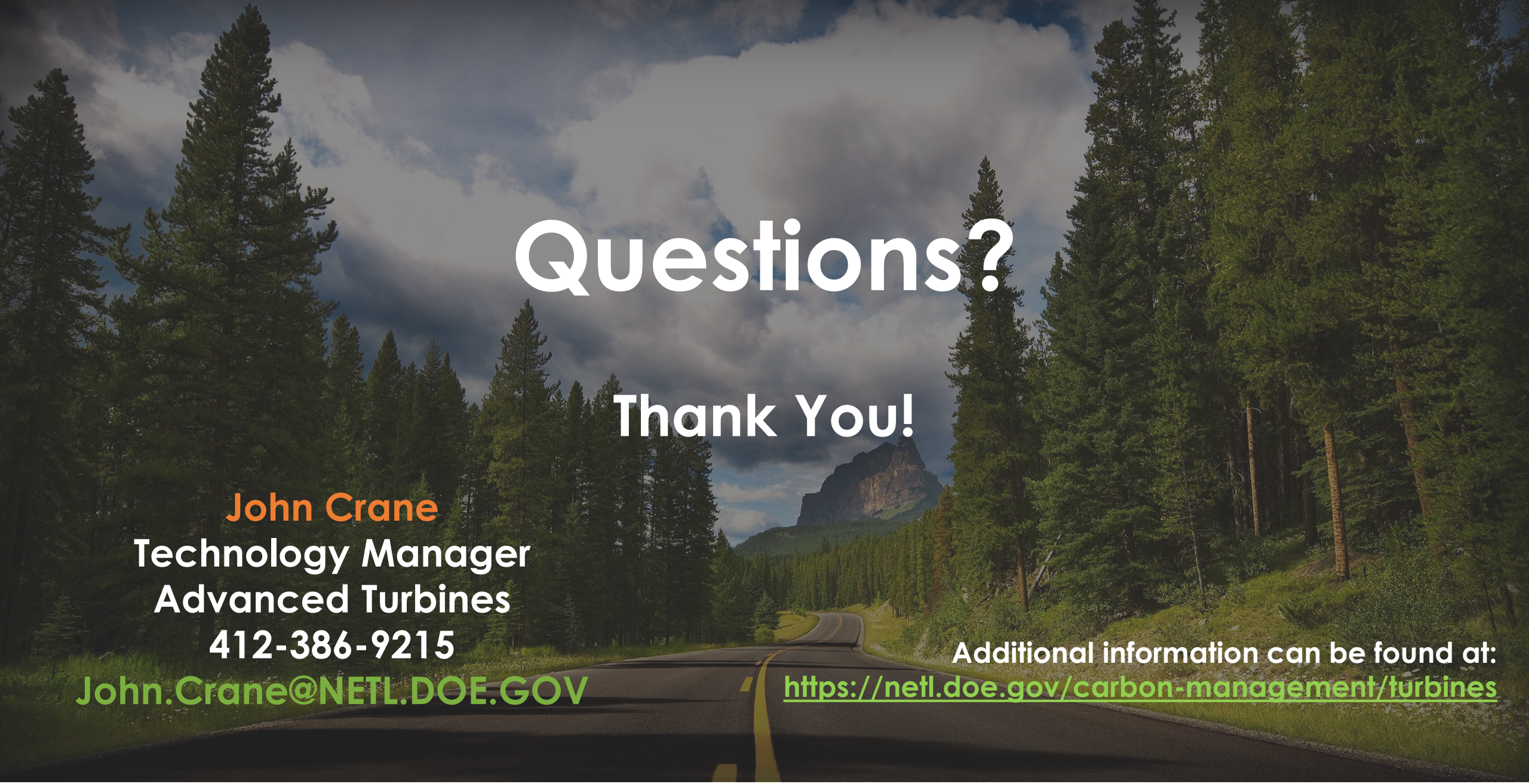


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Additional information can be found at:
https://netl.doe.gov/carbon-management/turbines