ICAC

Critical Control Technologies

ICAC Series on Data Centers and Emissions Control

Considerations for Developers and Equipment Suppliers

Who is ICAC?

Our members are clean technology innovators and provide clean air solutions

For over 60 years, our members have been providing air quality monitoring and control technologies to every industry:

- ✓ Industrial Heat
- ✓ Power Generation
- ✓ Oil and Gas
- ✓ Maritime and Port
- ✓ Cement
- ✓ Ceramics and Glass
- ✓ Metal
- ✓ Manufacturing
- ✓ **Data Centers**

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U.S. Growth in Data Center Development

Unprecedented demand

Cloud computing and AI workloads are fueling a historic data center construction boom across the U.S.

Massive investment ahead

Global data center capital expenditures could surpass **$1.7 trillion by 2030**, with over **40% in the United States** (McKinsey).

Soaring energy demand

The DOE projects U.S. data centers could consume **7–12% of national electricity by 2030**, up from just 4.4% in 2023.

Strategic implications

Data centers are becoming **critical energy infrastructure**, influencing grid planning, emissions policy, and local permitting nationwide.

Opportunity and challenge

The same digital expansion driving innovation also raises urgent questions about sustainability and energy resilience.

Environmental Considerations for Data Centers

Rising regulatory complexity

Developers face an expanding web of federal, state, and local requirements governing emissions, air quality, water use, and energy systems.

Integrated compliance challenge

Successful projects must align air, water, and energy strategies early in design to avoid permitting conflicts and costly redesigns.

Emissions control under pressure

Stricter emission limits demand advanced technologies, clean fuels, and operational constraints that affect cost and reliability.

Uncertain regulatory landscape

Ongoing rule changes and evolving GHG policies create planning and investment risk for new and expanding facilities.

Design-stage decision impact

Site layout, equipment selection, and power strategy all determine long-term environmental footprint and permit viability.

Sustainability as a differentiator

Projects that optimize energy efficiency and minimize emissions can gain community support, regulatory goodwill, and brand advantage.

Takeaways from ICAC's Webinar on Avoiding Air Permitting Pitfalls

- Growth in data center power consumption and **the need to generate power onsite is creating major implications** related to air permitting and emission controls.

- Air quality permitting for data centers is **highly complex and varies** by federal, state, and local jurisdictions.

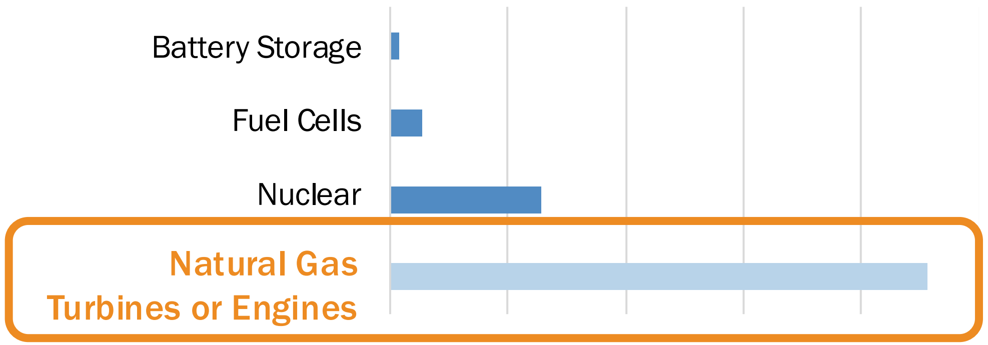
- **Early engagement** with regulators is essential to avoid surprises in the permitting process

- **Air permitting is not the only consideration at data centers.** Attention must be paid to water rights, noise, fuel storage, and public opposition, all of which can further delay projects.

If you missed session 1, you can access it via the ICAC website

How Will Data Centers Be Powered?

Power types planned for on-site use at U.S. data centers



Source: [Cleanview Data Center Tracker]

75% of power equipment planned to be used on site at data centers is **Natural Gas**

Source: [Cleanview "Bypassing the Grid" Report]

30% of data centers are planning to build their own on-site power, combined for a total capacity of **56 GW**

Source: [Cleanview "Bypassing the Grid" Report]

44% of data center operators expect to rely **entirely on on-site power by 2035**

Source: [Bloom Energy "2026 Data Center Power Report"]

Data Center Power Development Timelines

Initial Development

- Quick build
- Power sources online within 6 months or sooner
  - Multiple smaller units which can be permitted quickly
  - Take advantage of the newly created Temporary Combustion Turbine (TCT) subcategory in 40 CFR 60 Subpart KKKKa
    - 2 years from installation, up to 25 ppm NOx (depending on regulatory agency)
    - Applies to the permitted equipment, i.e. swapping for new/replacement turbine does not reset the clock

Longer Term

- Replace or supplement power sources with larger units
  - Reduces footprint
  - More stable operation
  - Less maintenance

Overview of Combustion Emissions and Control Strategies

Primary pollutants

- NOx
- CO
- HC/VOC
- PM
- NH_3 (ammonia slip)
- Greenhouse gases (CO_2, CH_4, N_2O)

Control Options

- **Low NOx Burners**
- **Diesel Particulate Filters**
- **Oxidation Catalysts**
  - CO/VOC reduction
- **Selective Catalytic Reduction (SCR)**
  - NOx Control using ammonia injection
  - Hot SCR for large simple cycle turbines
- **Ammonia Slip Catalyst (ASC)**
- **Carbon Capture**
  - Extracts carbon as CO_2 for reuse or long-term (permanent) storage

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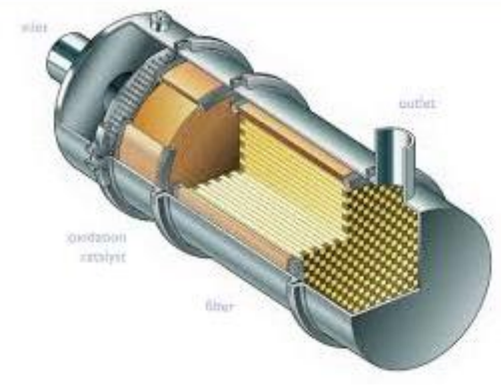
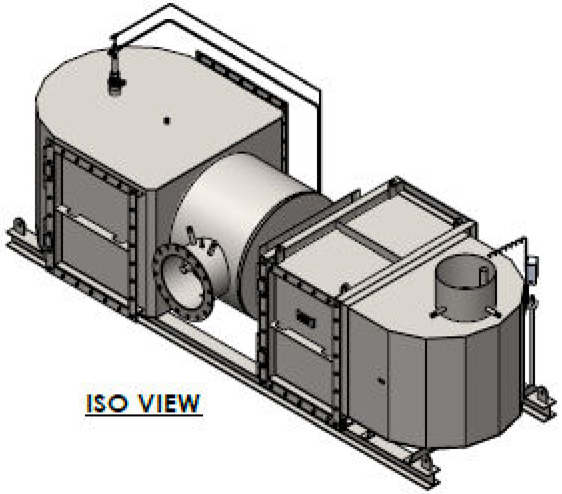
Engine System Solutions

Particulate Filters



Low HP Systems
50 kW – 600kW

Large Engine Systems <10MW



Benefits of Lean-Burn Engines

- Engine selection is based upon the fuel…
  - ✓ *Natural gas or diesel*
- …and whether they are lean or rich burn.
- Most prime **back-up power engines are lean burn**, and that dictates the emission control strategy.

Factor	Lean-Burn
Fuel Efficiency	High
Baseline Emissions	Clean
Aftertreatment	SCR (scalable/ durable)
Load Flexibility	Good
Heat Stress	Lower
Maintenance	Lower
Regulatory Compliance	Easier
Suitability for Data Centers	Excellent
CO Emissions	Very Low
NOx Emissions	Lower

Lean Burn Natural Gas Engines

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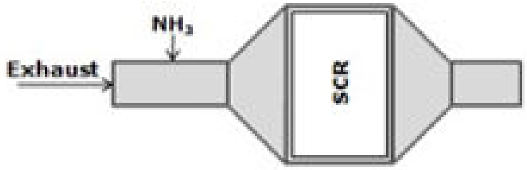
Why Natural Gas vs. Diesel

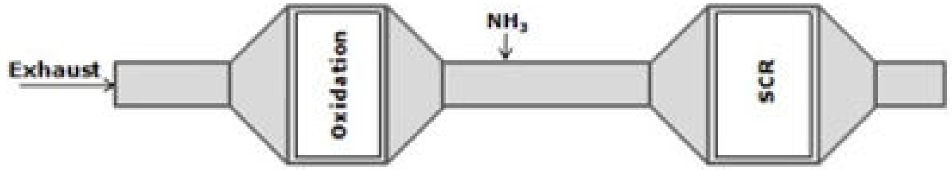
Category	Natural Gas Advantage	Diesel
Fuel supply	Continuous pipeline supply	Must store and refuel
Emissions	Much lower PM, NO_x, SO_2	Higher, requires DPF & SCR
Operating cost	Lower fuel cost, fewer maintenance steps	Higher fuel/storage costs
Noise	Quieter, smoother	Louder
Start-up cleanliness	No smoke or odor	Cold-start PM/odor
Safety/environment	No spills or tanks	Fuel spill and contamination risks
Long-duration run	Excellent	Depends on deliveries

General Emission Control Architecture: Natural Gas

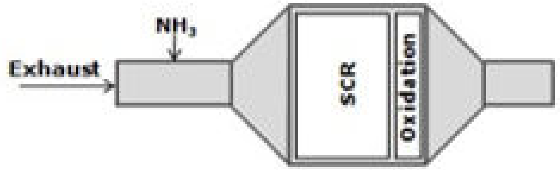
Catalyst systems tailored to performance requirements



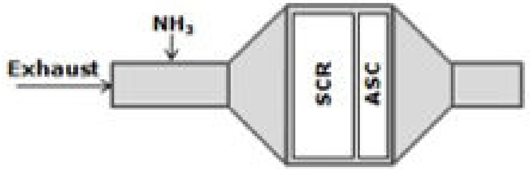
- High NOx reduction over SCR
- No CO reduction



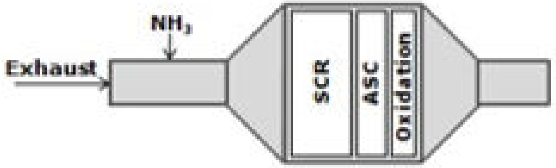
- Oxidation catalyst for CO reduction used upstream of SCR, requires separate housing



- Oxidation catalyst downstream of SCR oxidizes NH_3 slip back to NOx, can also form NO_2
- Requires larger SCR volume



- Compact SCR+ASC for high NOx reduction
- Also achieves CO, HC conversions



- ASC converts NH_3 slip to N_2 allowing compact SCR+ASC+DOC design
- Very high NOx, CO, HC conversions

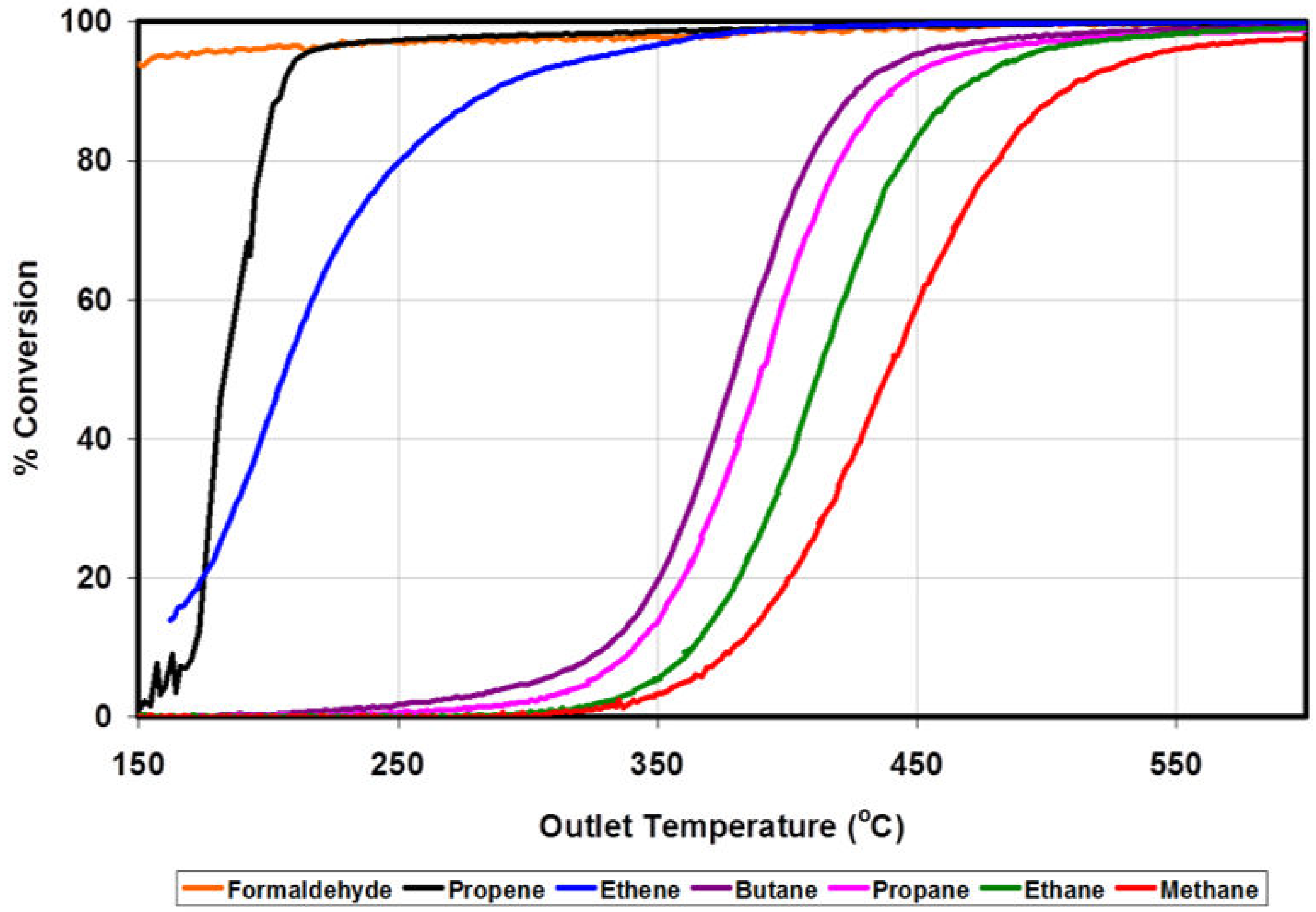
Technology: Oxidation Catalyst for CO/VOC Control

Function:

Oxidizes CO, hydrocarbons

Design criteria:

- Light-off temperature and durability at high exhaust temps
- Sulfur tolerance and catalyst aging
- Converts NO to NO_2 that could impact SCR performance



Technology: Selective Catalytic Reduction for NOx Control

Function:

Converts NOx to N_2 and H_2O using ammonia or urea

Critical Design Parameters:

- Temperature window (typically 250–500 °C; high-efficiency units may exceed 600 °C)
- Catalyst formulation for high-temperature durability (e.g., Cu-zeolite, Fe-zeolite)
- Ammonia injection and distribution control
- NO_2/NOx ratio management from catalyst
- Ammonia slip catalyst (ASC) considerations

SCR Process

NOx is reduced by ammonia across the SCR catalyst according to the following reactions:

$4\,NO + 4\,NH_3 + O_2 \rightarrow 4\,N_2 + 6\,H_2O$

$NO_2 + 4\,NH_3 + O_2 \rightarrow 3\,N_2 + 6\,H_2O$

$NO + NO_2 + 2\,NH_3 \rightarrow 2\,N_2 + 3\,H_2O$

NOx is reduced by urea as follows:

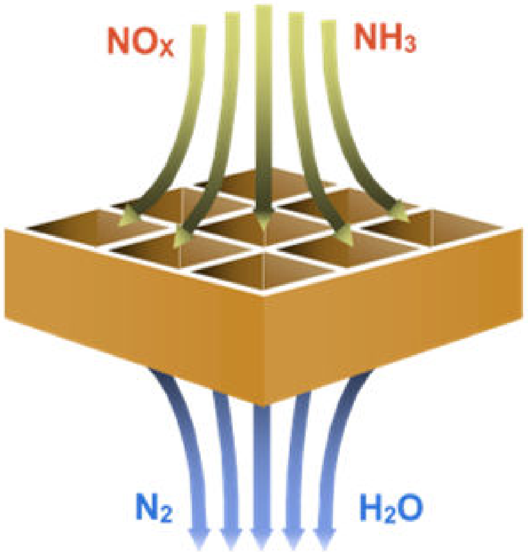
$4\,NO + 2(NH_2)_2CO + O_2 \rightarrow 4\,N_2 + 4\,H_2O + 2\,CO_2$

Undesirable side reactions:

$2\,SO_2 + O_2 \rightarrow 2\,SO_3$

$2\,NH_3 + SO_3 + H_2O \rightarrow (NH_4)_2SO_4$

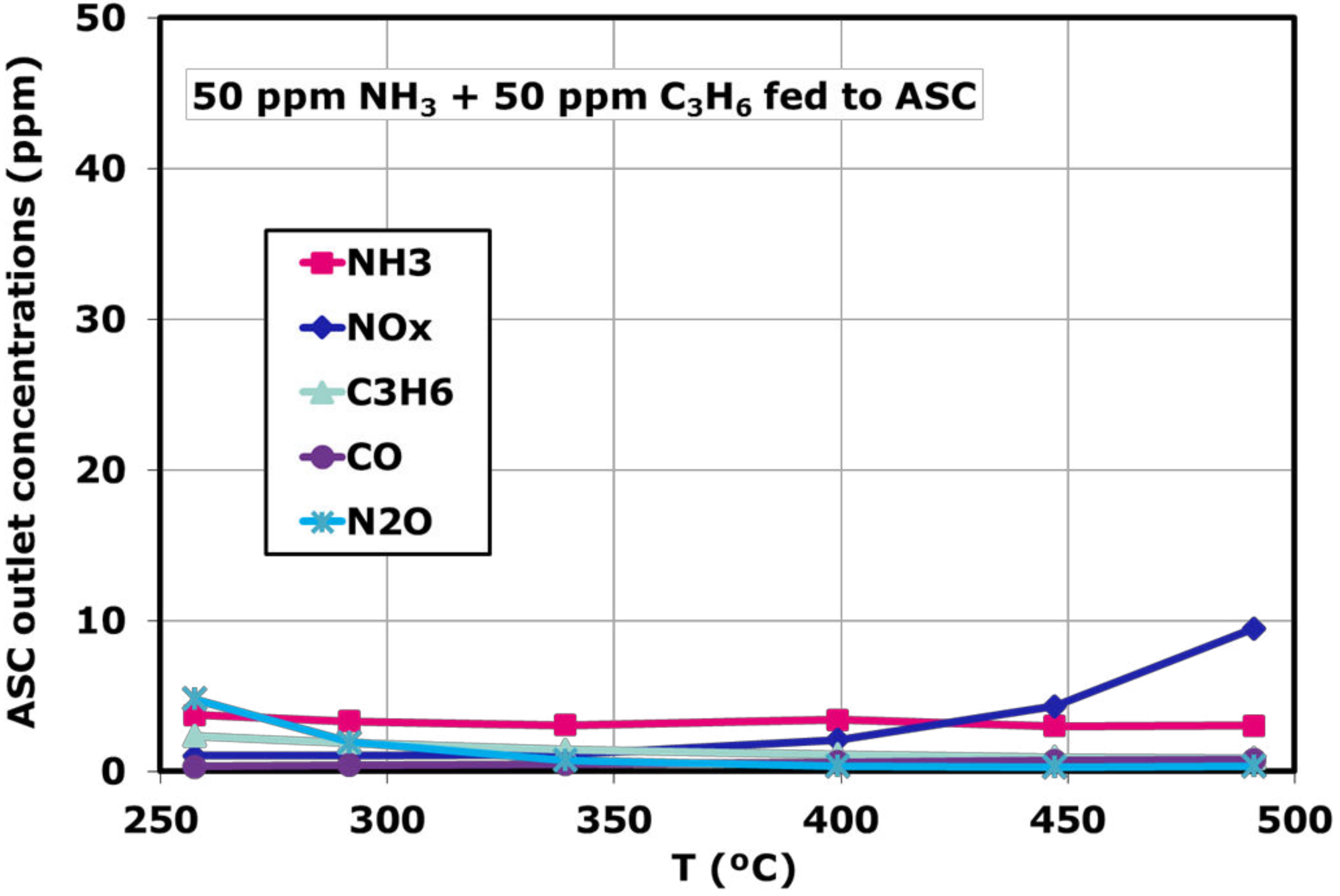
$NH_3 + SO_3 + H_2O \rightarrow NH_4HSO_4$



Technology: Controlling Ammonia Slip with ASC Catalysts

ASC allows continuous operation at ANR > 1

- When NOx is high, sufficient NH_3 for complete conversion
- When NOx is low, ASC converts excess NH_3 to N_2 to meet slip regulations
- Nearly complete conversion of NH_3 slip
- ASC selectively converts NH_3 to N_2, not to NOx
- Formation of N_2O very low
- HC is converted to CO_2, not CO



Natural Gas Application

Application	Power generation
(kW)	1,142
RPM	1,800 rpm
Load	50 - 100%
Operating Hours per Year	8,000 hours
Number of Systems	
Type of Fuel	Natural Gas/BioGas
Maximum Design Exhaust Flow Rate	13,669 lbs./hr. +/- 5%
Exhaust Temperature at Full Load	853 (BG) ºF / 802 (NG) ºF +/- 8%
Max. Design Exhaust Temperature*	957 ºF at 50% load Biogas

Exhaust Component	Catalyst Inlet	Catalyst Outlet (g/hp-hr.) Biogas / Natural Gas	Reduction % Biogas / Natural Gas
NOx (as NO_2)	≤1.1 g/bhp-hr.	≤0.15 / 0.07	**86.4% / 93.6% *****
VOCs (as CH_4)**	≤0.40 g/bhp-hr.	≤0.12 /0.15	**70% / 62.5% *****
CO	**≤2.2 g/bhp-hr.**	**≤0.10**	**95.5%*****

Diesel Engines

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Why Diesel vs. Natural Gas

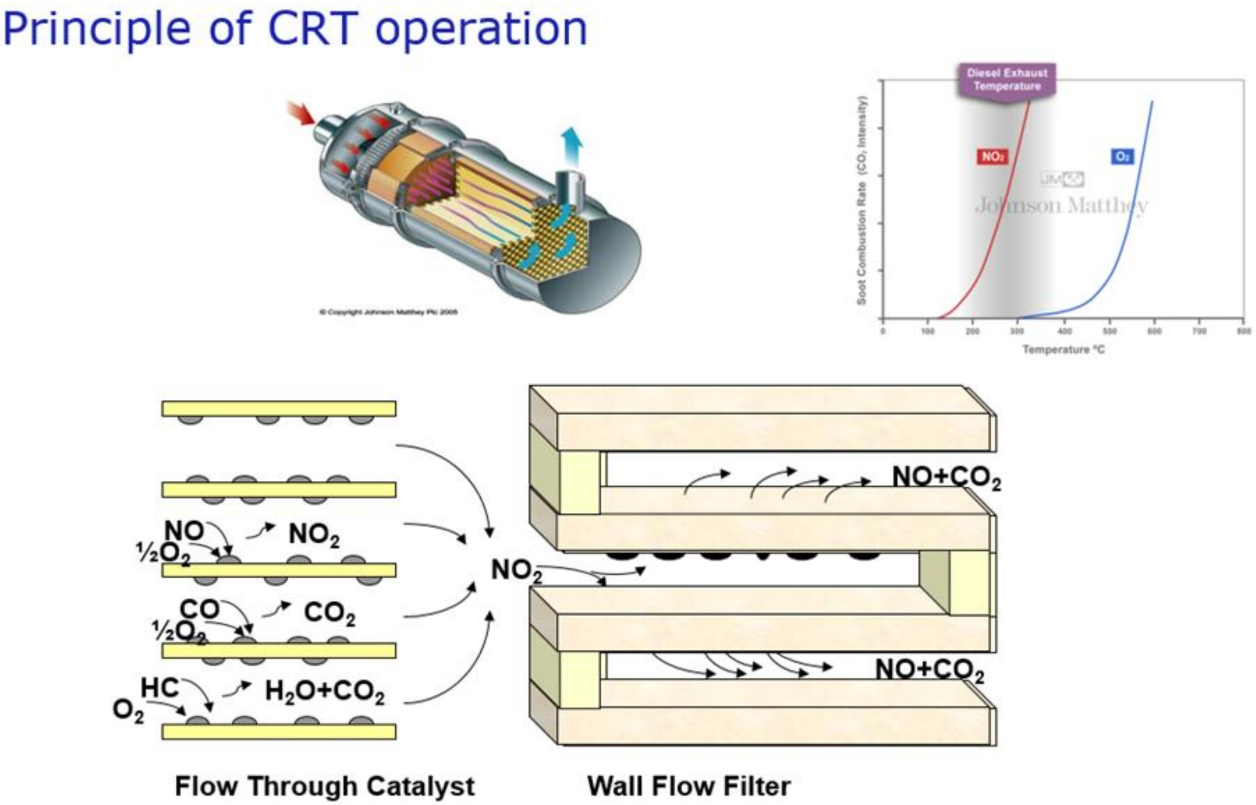
Factor	Diesel Advantage	Natural Gas
Reliability / track record	Excellent	Improving
Load acceptance	Best-in-class	Often slower
Fuel supply certainty	On-site, guaranteed	Dependent on utility
CapEx	Lower	Higher
Permitting	Familiar, easier	Sometimes complex
Operator preference	Strong	Moderate
Emissions	Higher	Much cleaner

Technology: Diesel Particulate Filter for PM Control

Function:
Traps and oxidizes soot/particulates

Key considerations:

- Filter substrate (cordierite, silicon carbide, or advanced ceramics)
- Regeneration method: passive vs. active
- Pressure drop and backpressure management
- Integration with high-temperature operation (material strength, ash loading)



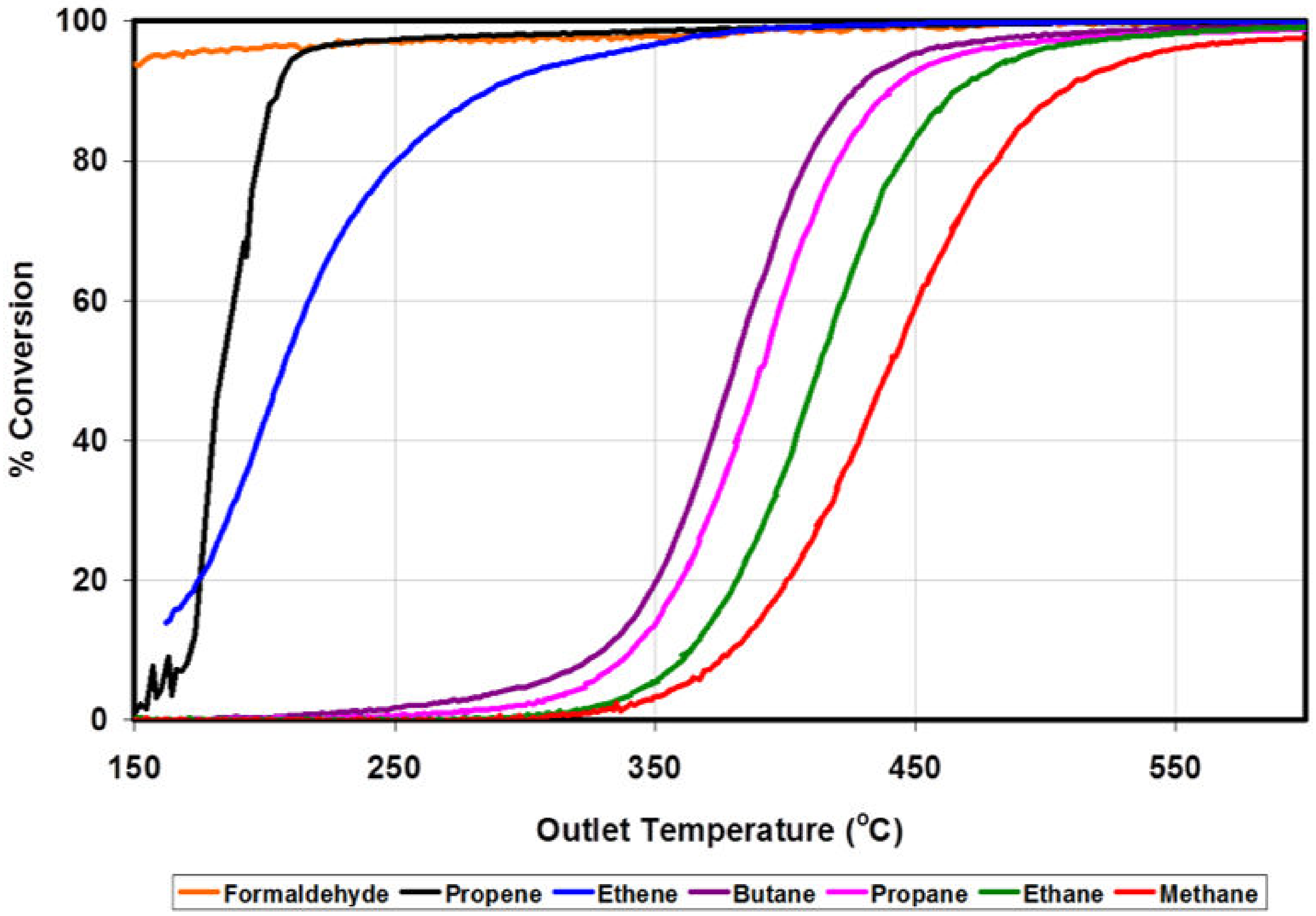
Passive filter regeneration requires >250˚C, and >350˚C is preferred

Technology: Diesel Oxidation Catalyst for CO/VOC Control

Function:
Oxidizes CO, hydrocarbons, and converts NO to NO_2 for DPF regeneration

Design criteria:

- Light-off temperature and durability at high exhaust temps
- Sulfur tolerance and catalyst aging



EPA Tier 4 Limits for Diesel Engines

Tier 4 Limits for Engines >560 kW

- NOx: 0.67 g/kWh
- Particulate Matter (PM): 0.04 g/kWh
- Carbon Monoxide (CO): 3.5 g/kWh
- Non-Methane Hydrocarbons (NMHC): 0.19 g/kWh

- Steady state testing only – transient testing does not apply to engines >560 kW

EPA Tier 4: Certified or Compliant Engine

Aspect	Tier 4 CERTIFIED	Tier 4 COMPLIANT
Definition	Officially tested and approved by EPA	Meets Tier 4 emission limits but not EPA-certified
Verification	EPA issues a **Certificate of Conformity**	Verified by **third-party testing or documentation**
Labeling	Has an **EPA emissions label**	No official EPA label
How Achieved	Built to meet standards at the factory	Often achieved via **retrofits or aftermarket solutions**
Legal Requirement	Mandatory for **non-emergency stationary engines**	Common for **emergency standby or flexible projects**
Cost	Higher (due to certification process and design)	Lower (retrofit or compliance solutions)
Typical Applications	Prime power, continuous duty generators	Standby generators, temporary installations
Operations	If emissions over limit shut down	No such requirement

Diesel Application

Application	Power Generation
Rating	2750kW
Application	Standby Power
Operating Hours per Year	TBD
Fuel	ULSD
Exhaust Gas Flow Rate	21,725 cfm (wet)
Exhaust Gas Temperature	897°F
Maximum Allowable Backpressure	27” W.C.

Exhaust Component	Catalyst Inlet	Catalyst Outlet	Required Reduction
NOx	6.14 g/bhp-hr.	0.5 g/bhp-hr.	91.9%
CO	1.16 g/bhp-hr.	0.23 g/bhp-hr.	80%
HC	0.14 g/bhp-hr.	0.04 g/bhp-hr.	70%
PM	0.09 g/bhp-hr.	0.01 g/bhp-hr.	85%

Gas Turbines

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Data Centers and Gas Turbine Technology

Turbine selection is driven by:

- Build-out timing
  - **Near-term:** mobile or smaller aeroderivative units
  - **Long-term:** permanent, higher-efficiency turbines
- Equipment availability
- Power requirements over time
  - Transition from multiple small units to larger centralized generation
  - Hybrid approaches combining small and large turbines for flexibility

Mobile Aeroderivative Gas Turbine

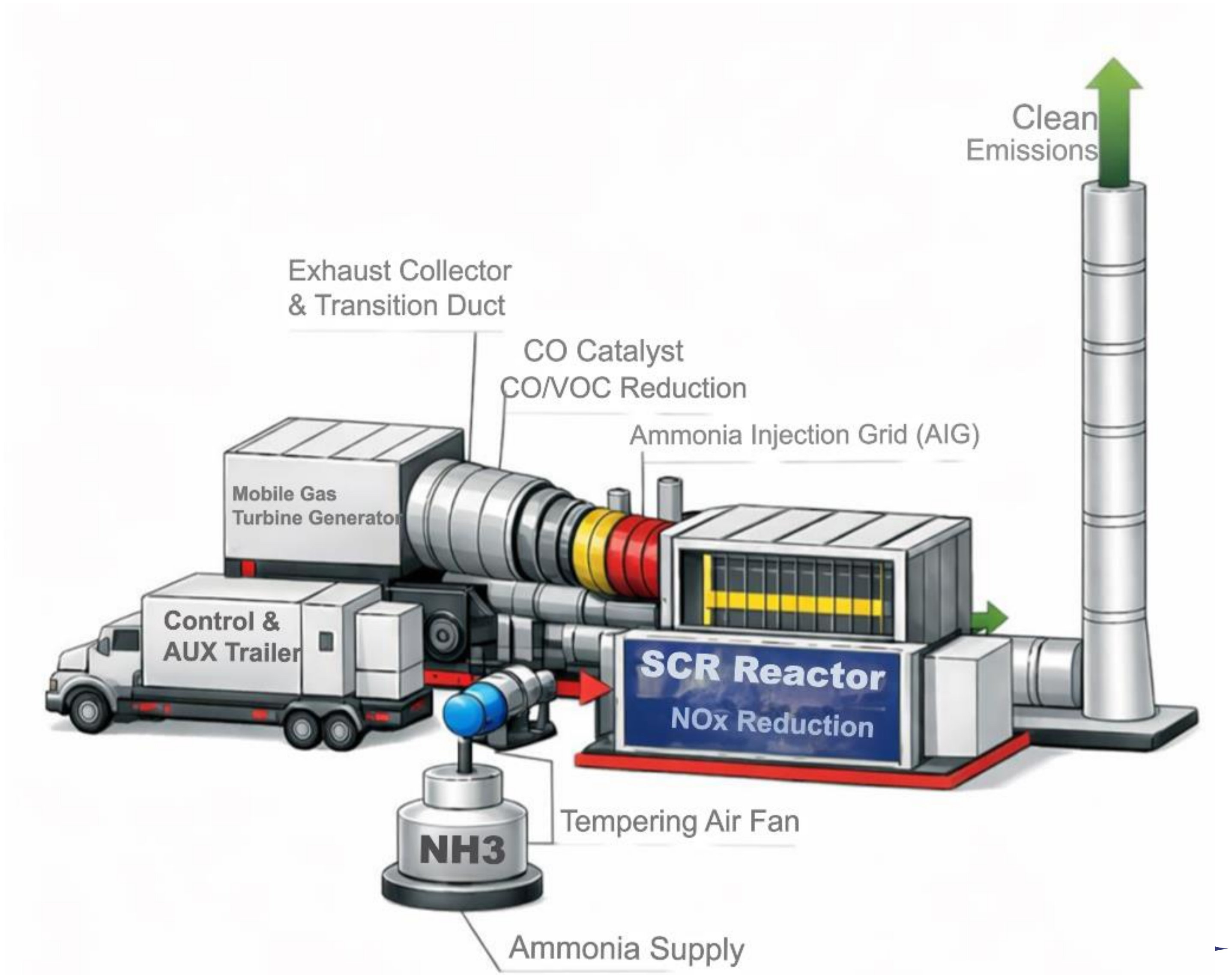
Rapid deployment for near-term or transitional power needs

Compact, modular units suitable for constrained or temporary sites

Niche applications: early-phase data centers, grid support, emergency or bridge power

Add-on emissions controls (SCR, CO catalyst) to reduce NOx, CO, and VOCs

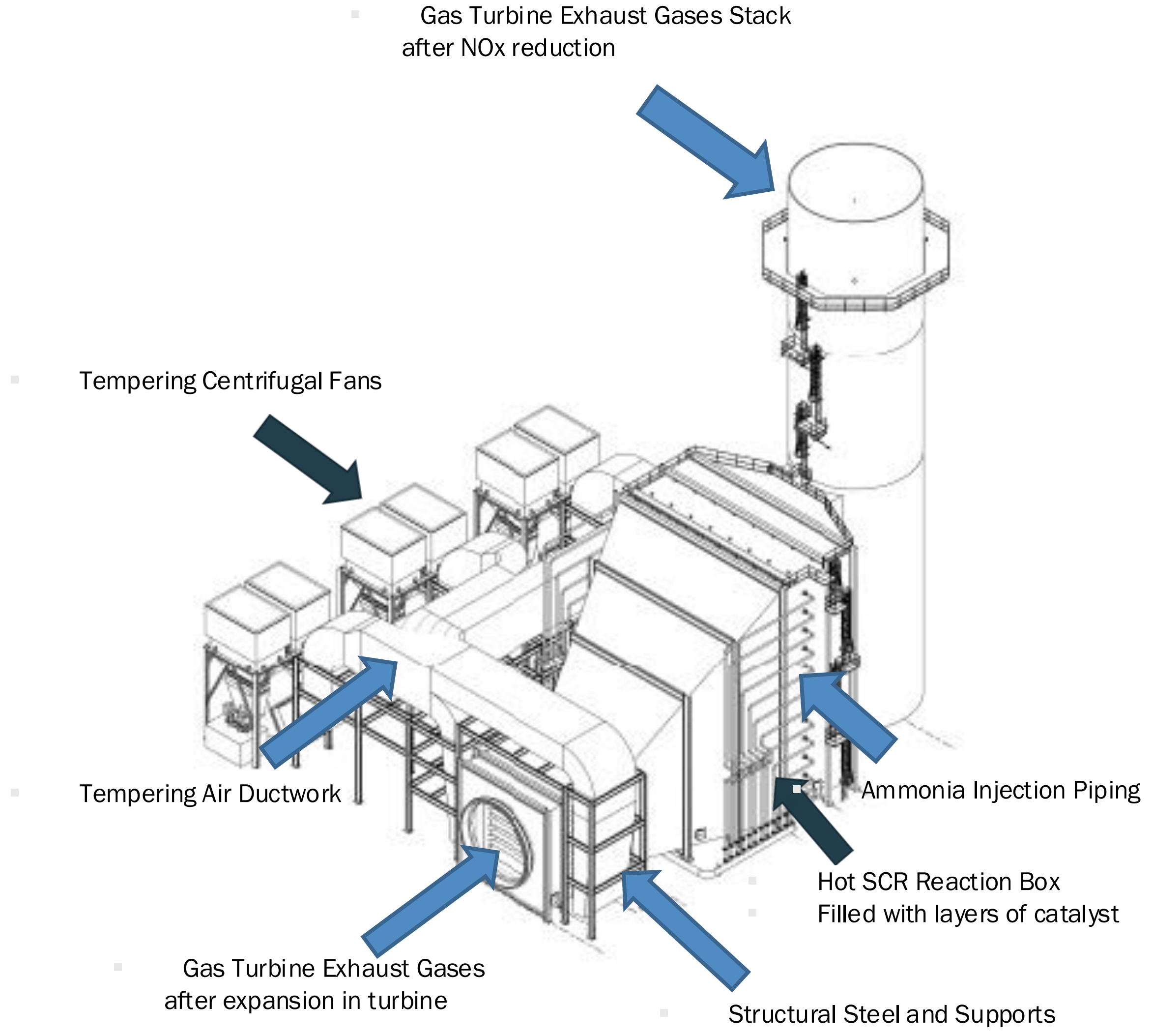
Scalable and relocatable as power needs evolve



Simple Cycle Gas Turbine

Control Configuration

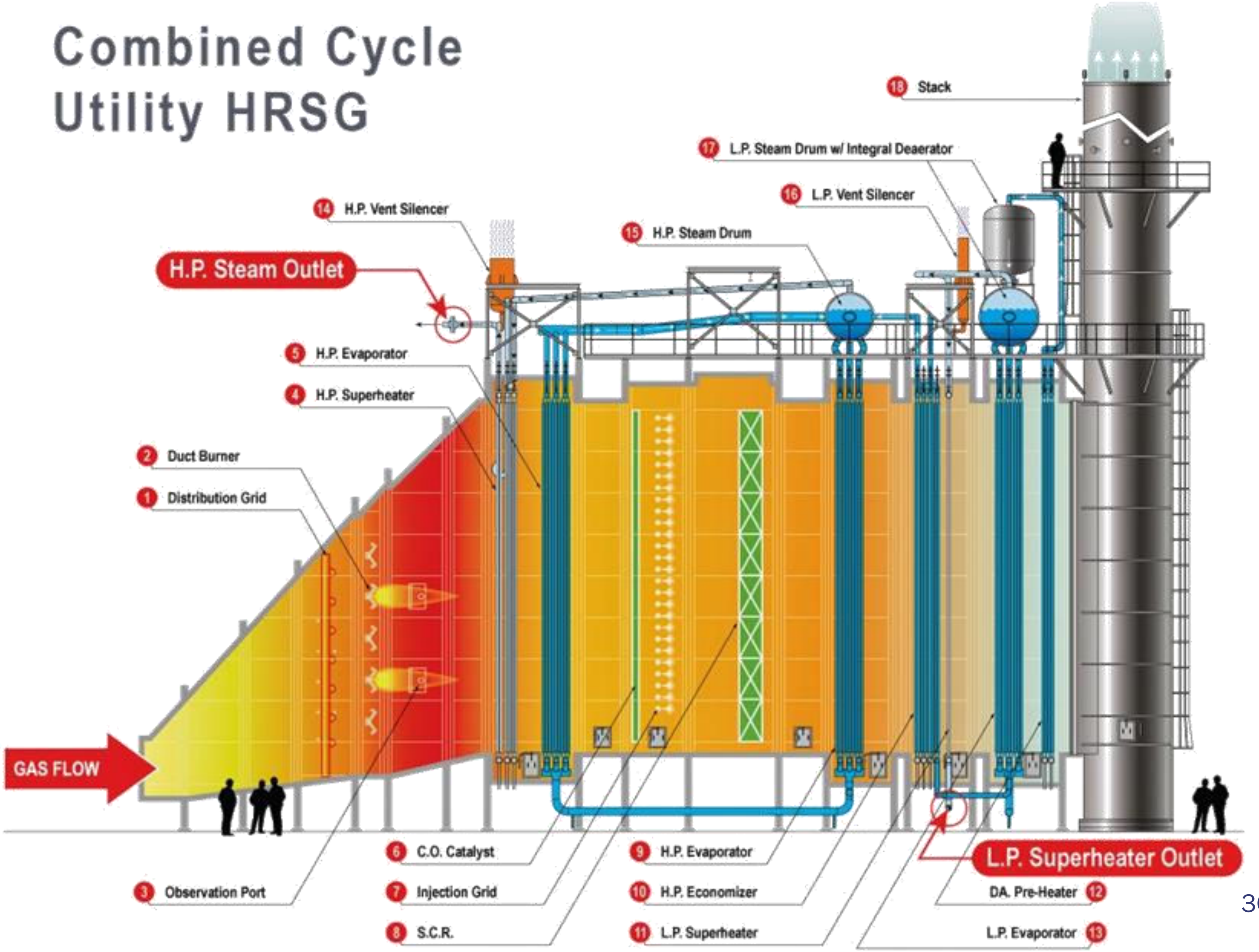
- Combustion gases exit gas turbine directly to the Hot SCR System
- Tempering air (ambient air drawn through centrifugal fans) used for cooling turbine exhaust gas to optimal temperature for SCR
- Gases flow through SCR dual catalyst to reduce NOx and CO/VOC emissions
- Gases flow to stack or to carbon capture system for CO_2 removal



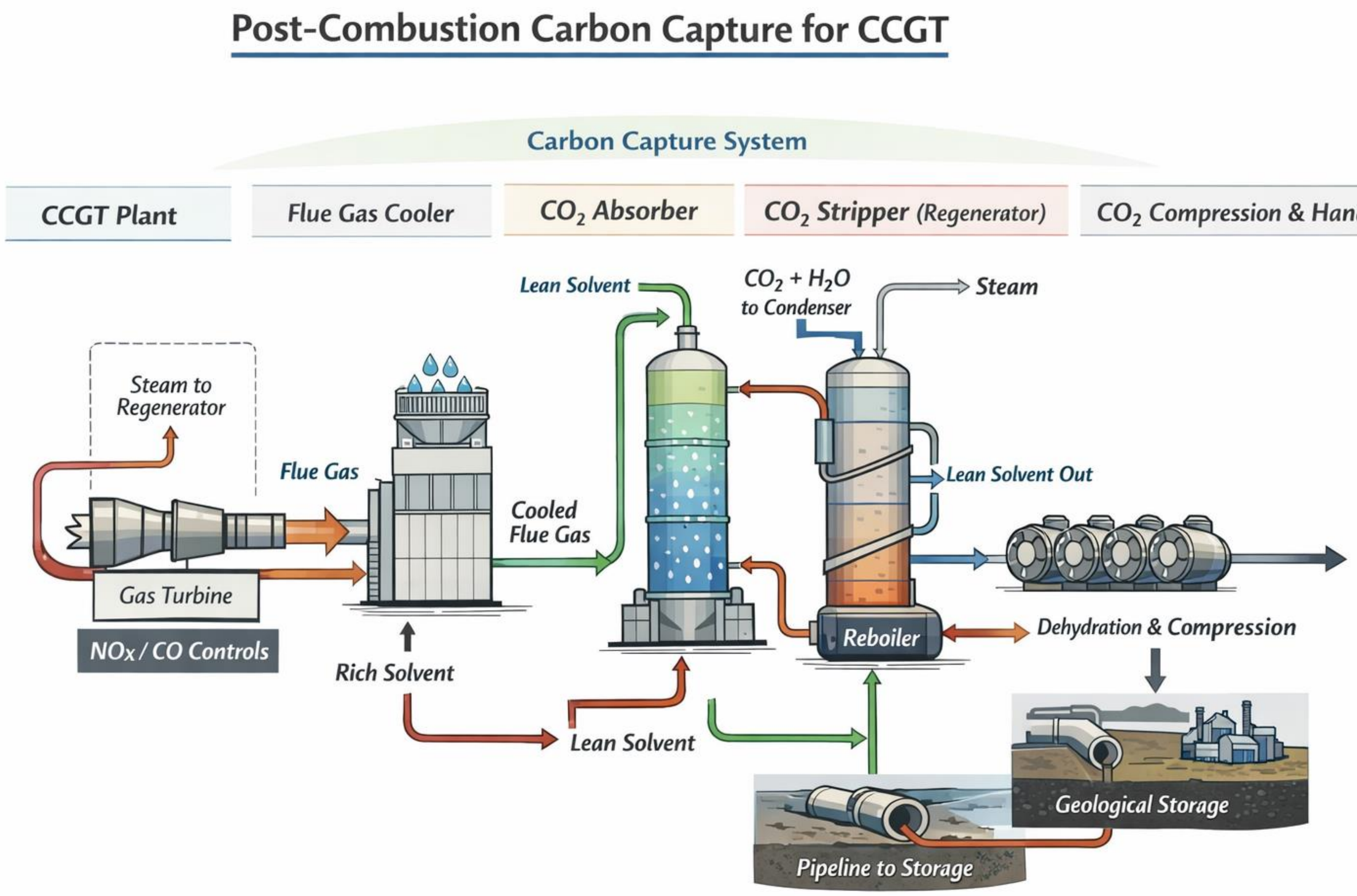
Combined Cycle Gas Turbine

Control Configuration

- Combustion gases exit gas turbine into a heat recovery steam generator (HRSG)
- Supplemental energy can be added with duct burners
- Gases flow through CO catalyst for CO/VOC reduction
- Ammonia injected into air stream after CO catalyst
- Gases flow through SCR to reduce NOx emissions
- Gases flow to stack or to carbon capture system for CO_2 removal



Post Combustion Carbon Capture



Key Takeaways

1. **Clean technologies improve project flexibility operational performance and long-term viability**
2. Data center power solutions and emission controls are well proven and commercially available
3. Emission control is now a design stage requirement---not added afterwards
4. Emission control strategies must be scalable and adaptable as data centers evolve
5. Thermal and operating condition management is central to modern catalyst-based systems
6. SCR and catalyst technologies continue to evolve to meet higher temperature and flexible operation needs
7. Carbon capture can be integrated into turbine-based data center power systems
8. Successful projects require early and ongoing collaboration among developers, OEMs, control technology providers, regulators, and communities

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Q & A

Please submit questions via the 'Q&A' feature on Zoom

The Institute of Clean Air Companies

Market Insight

Engagement with Decision-Makers

Technical Expertise

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Thank you

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Next up will be Sessions 3 (coming March 2026) focusing on Measurement & Monitoring technologies for data center emissions.

Featuring presentations from ICAC members including:

ThermoFisher SCIENTIFIC

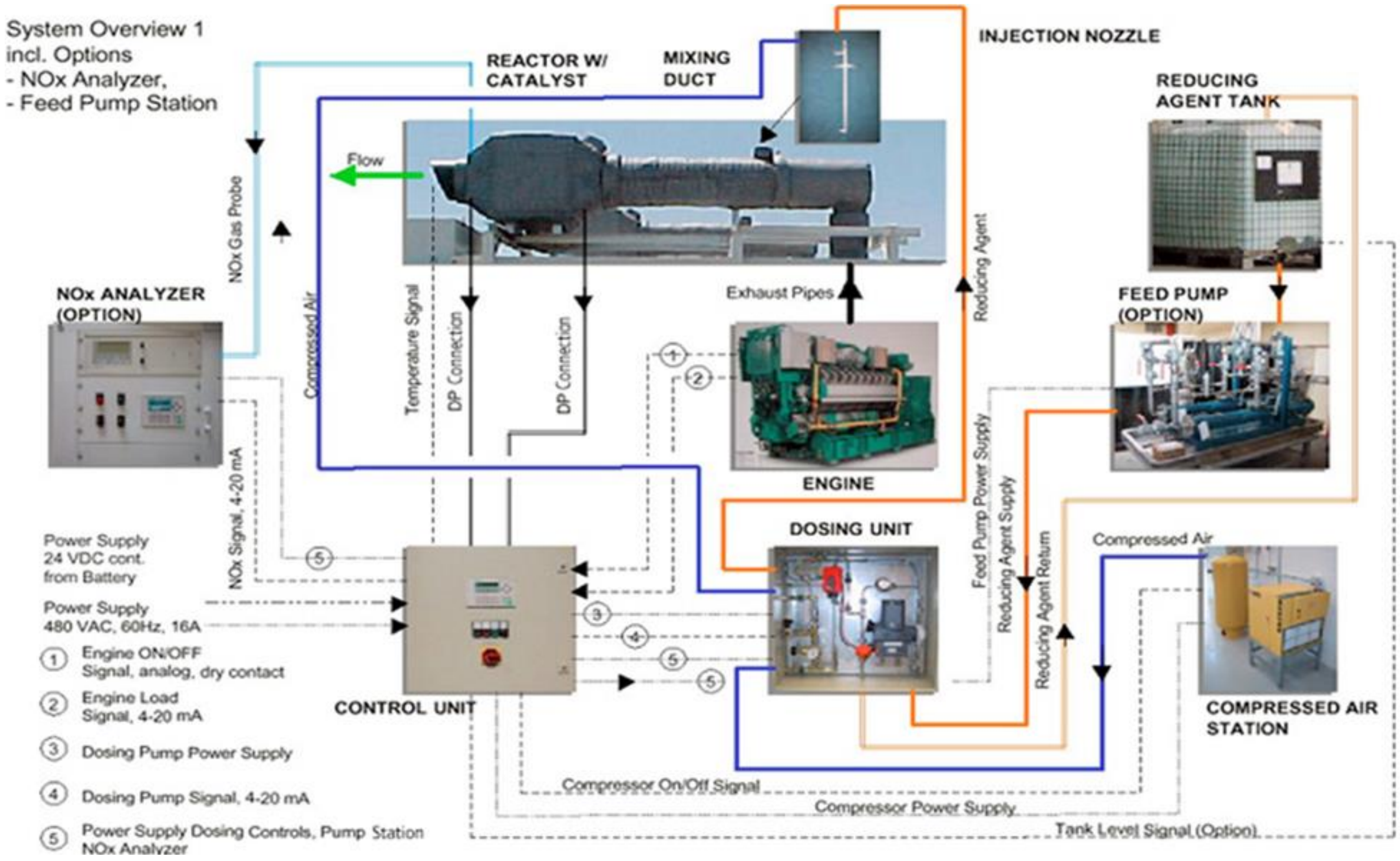
DURAG
DURAG GROUP

Additional Information

Catalyst and filter selection criteria

Component	Key Criteria	Design Challenges
DOC	Light-off, sulfur tolerance	Catalyst aging, high-temp oxidation
DPF	Filtration efficiency, regeneration	Ash loading, thermal stress
SCR	NOx reduction, temperature window	Urea decomposition, durability
ASC	NH3 slip control	Over-oxidation, NH3 storage capacity
TWC (gas engines)	Simultaneous NOx, CO, HC removal	Air/fuel ratio sensitivity

Typical NOx control system



Diesel System Architecture

If EPA Tier 4 regulations DO NOT apply,

it is the same as for a natural gas engine

If EPA Tier 4 regulations DO apply,

then a diesel particulate filter (DPF) is required

- A DPF traps the particulate in the walls of a filter.
- To oxidize the soot, a diesel oxidation catalyst (DOC) is placed upstream of the DPF to convert NO to NO_2.
- The NO_2 is a powerful oxidant and burns the trapped diesel particulate matter.

Current Experience

Natural gas engines

- NOx conversion: 90-95%
- CO conversion: 95%
- Ammonia slip: 10 ppmv

Diesel Engines (>560kW)

Tier 4 (gr/bhp-hr)	Typical Inlet	Tier 4 Outlet
NOx	7 - 9	0.67
CO	8 - 12	3.5
NMHC	1	0.19
Particulate	0.01 - 0.1	0.03

Today's Presenters

Johnson Matthey

Eric Smith
Engine Systems Business Manager, Clean Air Solutions

Stan Mack
Commercial Manager

Johnson Matthey is a global leader in sustainable technologies, leveraging more than 200 years of expertise in advanced metals chemistry to help major energy, chemical, and automotive companies decarbonize and reduce harmful emissions. JM operates across key segments—including Clean Air, PGM Services, Catalyst Technologies, and Hydrogen Technologies—providing emission control catalysts, circular solutions for precious metals, specialty industrial catalysts, and components for fuel cells and electrolysers. Johnson Matthey website

MITSUBISHI POWER

Mark Peak
Principal Environmental Engineer

Mitsubishi Power is a global energy technology company dedicated to developing advanced power generation solutions that support both decarbonization and long-term energy reliability. With a mission to create a future that works for people and the planet, the company delivers a broad portfolio of technologies—including gas turbines, steam power systems, air quality control systems, and services—designed to meet diverse regional energy needs while reducing environmental impact. Mitsubishi website

Today's Presenters

Clare Schulzki
Executive Director

Since before the Clean Air Act was enacted, **ICAC, the Institute of Clean Air Companies**, member companies have represented providers of a diverse array of air pollution control technologies, measuring and monitoring systems, and equipment and services in the U.S. and abroad. ICAC provides a needed voice for the technologies that achieve practical and measurable emissions reductions for stationary sources. ICAC website

Ted Michaels
Partner

For over 20 years, innovative start-ups, Fortune 500 enterprises, and environmental stakeholders have maximized their business goals by leveraging **AJW's** unique coast-to-coast, international, and bipartisan expertise in how markets and governments work. **AJW** works closely with clients to develop sophisticated business strategies and advocate for policies and regulations that support innovators in both domestic and international markets. AJW website