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# Ammonia as a gas turbine fuel

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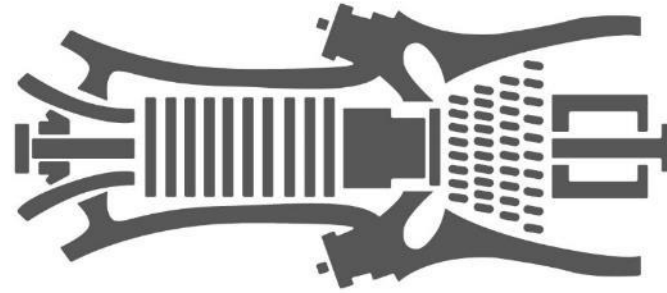
Emergent Technologies Director – Decarbonization

GE Gas Power

# Decarbonizing gas power\* ... a range of options



## Pre-combustion



## Post-combustion

### Use a zero or carbon neutral fuel

- Hydrogen (blue, green, pink)
- Synthetic methane
- Renewable methane
- Biofuels
- Ammonia

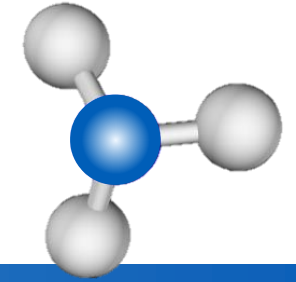
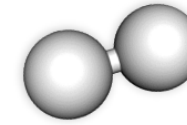
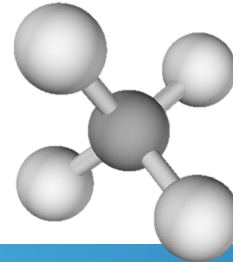
### Remove carbon from the plant exhaust

- Carbon capture (liquid solvents)
- Carbon capture (solid sorbents)
- Oxy-fuel cycles

**Gas turbines offer multiple options to achieve lower or zero carbon emissions**

\* Decarbonization as used herein is intended to mean the reduction of carbon emissions on a kilogram per megawatt hour basis

# A tale of three molecules: **METHANE, HYDROGEN & AMMONIA**



Characteristics		Methane	Hydrogen	Ammonia
Formula		CH <sub>4</sub>	H <sub>2</sub>	NH <sub>3</sub>
Molecular weight	grams/mol	16	2	17
Boiling temperature	°F (°C)	-258.7 (-161.5)	-423.2 (-252.9)	-28 (-33.3)
Lower flammability limit (LFL)	%	4.4	4	15
Flame speed	cm/sec	~30-40	~200-300	~6-7
Adiabatic flame temperature	°F (°C)	~3565 (~1963)	~4000 (~2204)	~3270 (~1799)
Lower Heating value	MJ/Nm <sup>3</sup> (BTU/scf)	35.8 (911.6)	10.8 (274.7)	14.1 (360)

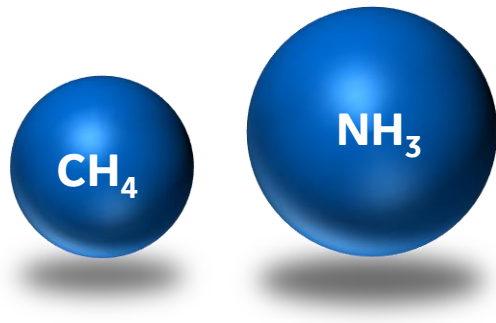
# Use of ammonia as a gas turbine fuel requires system changes



## Fuel System

### Lower heating value

Methane (CH<sub>4</sub>): 912 lb/ft<sup>3</sup>  
Ammonia (NH<sub>3</sub>): 360 lb/ft<sup>3</sup>

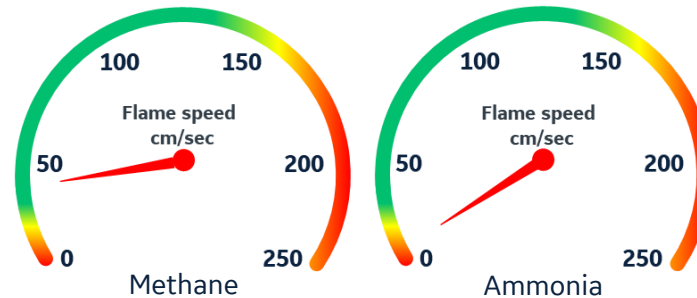


To deliver the same energy content, ammonia requires **2.5X** more volume flow

## Combustion System

### Flame speed (reactivity proxy)

Methane (CH<sub>4</sub>): ~30–40 cm/sec  
Ammonia (NH<sub>3</sub>): ~6–7 cm/sec

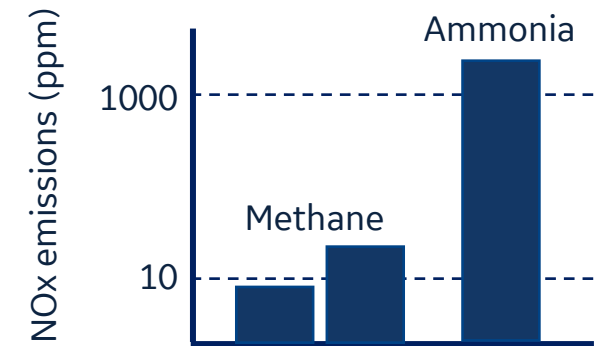


A new combustor may be required to provide same operability

## Emissions Aftertreatment

### Nitrogen content:

Methane (CH<sub>4</sub>): ~0% N<sub>2</sub>  
Ammonia (NH<sub>3</sub>): ~83% N<sub>2</sub>



Without a new combustion system, will need to abate 100x more NOx

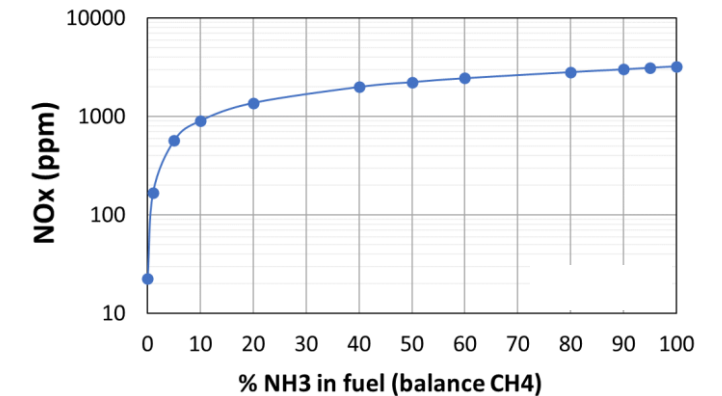
**Operating a gas turbine on blends of ammonia or on 100% ammonia will require changes to key power plant systems**

# Ammonia ... an alternative zero-carbon gas turbine fuel



<b>Emissions</b>	Zero carbon emissions (total carbon footprint of fuel will depend on source of H <sub>2</sub> )	Ammonia is 83% N <sub>2</sub> by mass. Potential for 100x increase in NOx using current lean premixed combustion systems
<b>Operability</b>		

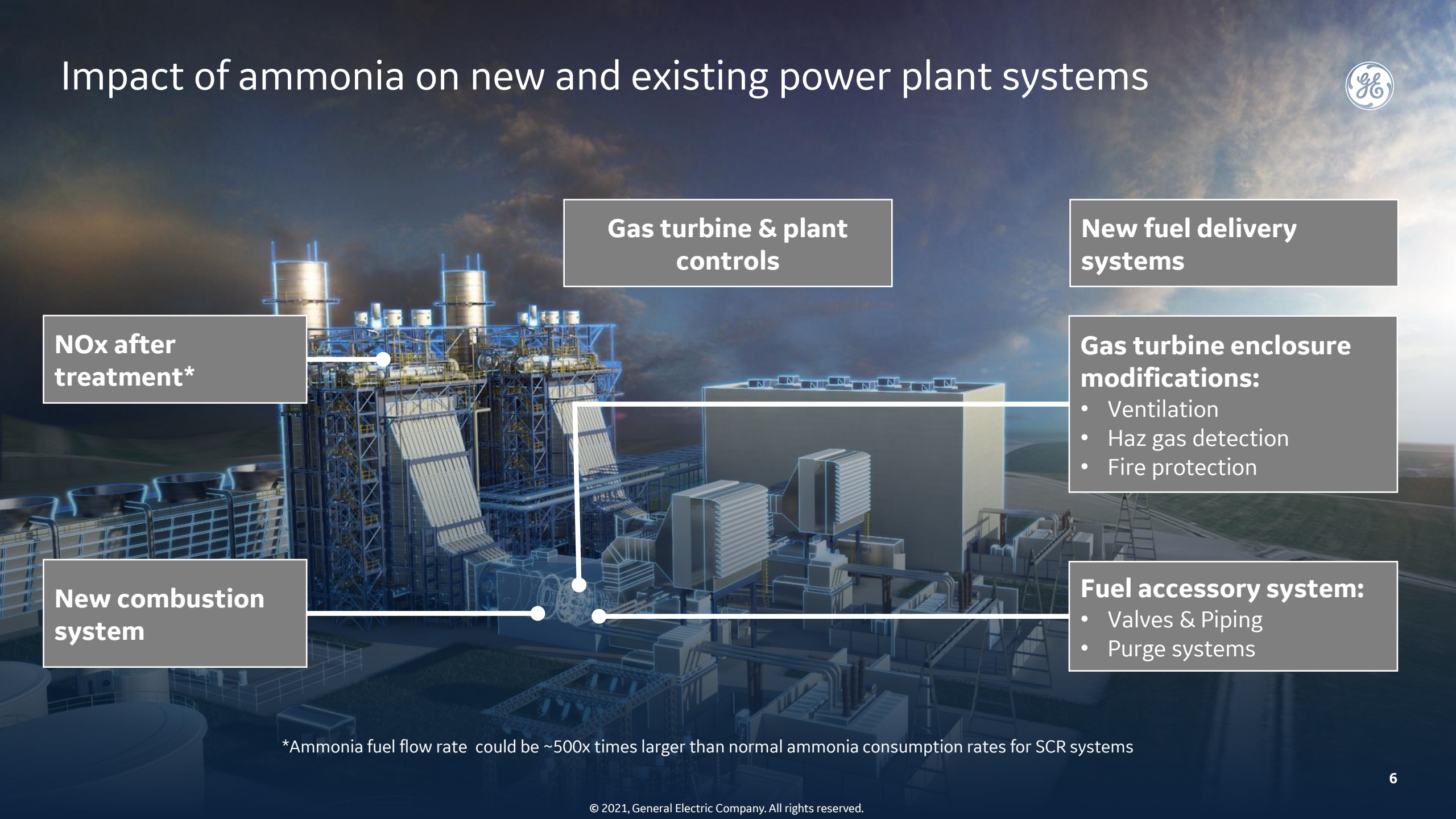
NOx as a function of ammonia blends in **methane**



NOx as a function of ammonia blends in **hydrogen**

**Ammonia's viability as a gas turbine fuel will depend on upgrading power plants, developing a robust supply chain, and getting acceptance of toxicity issue**

# Impact of ammonia on new and existing power plant systems



**Gas turbine & plant controls**

**New fuel delivery systems**

**NOx after treatment\***

**Gas turbine enclosure modifications:**

- Ventilation
- Haz gas detection
- Fire protection

**New combustion system**

**Fuel accessory system:**

- Valves & Piping
- Purge systems

\*Ammonia fuel flow rate could be ~500x times larger than normal ammonia consumption rates for SCR systems



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