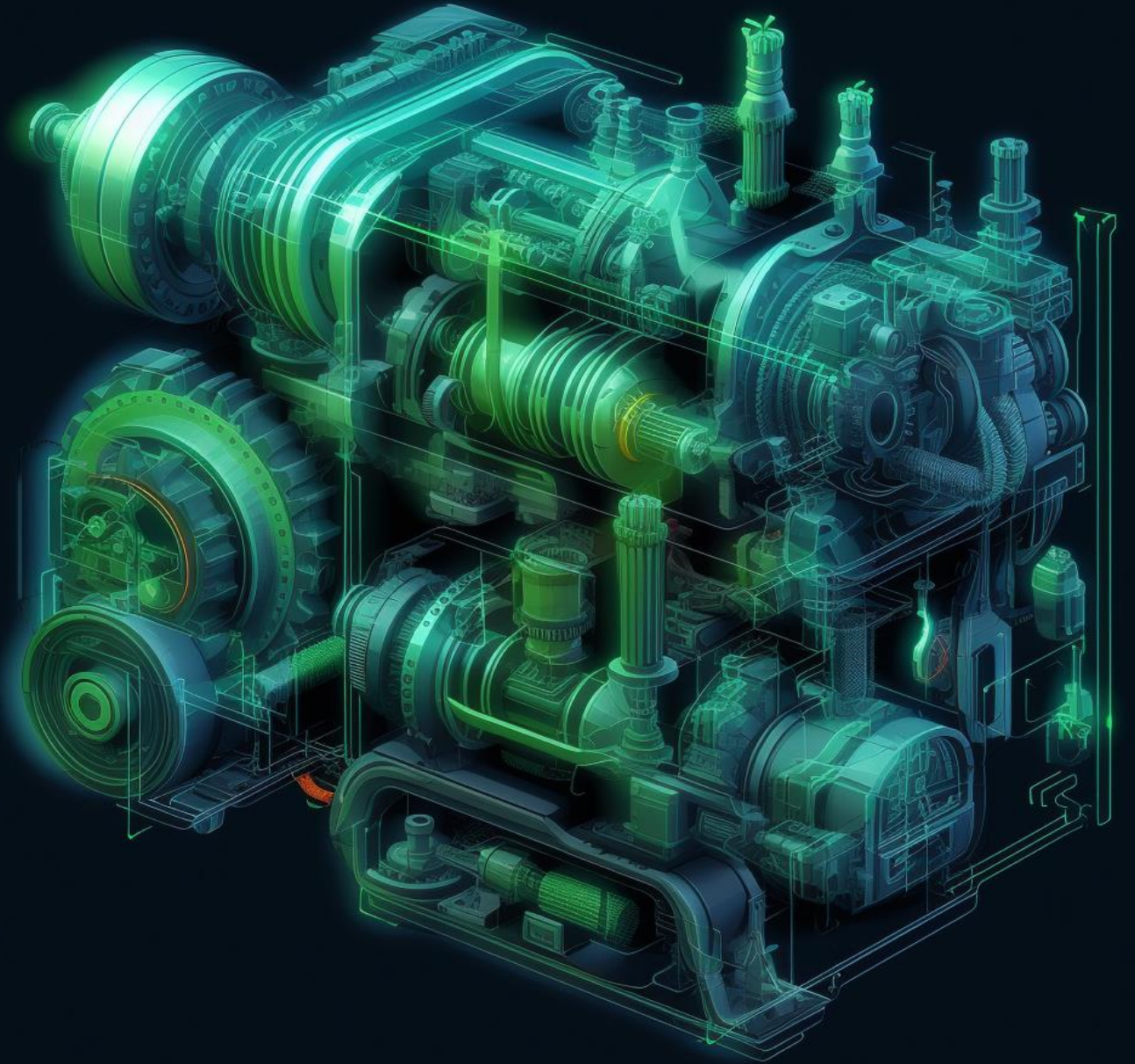




Aza Power




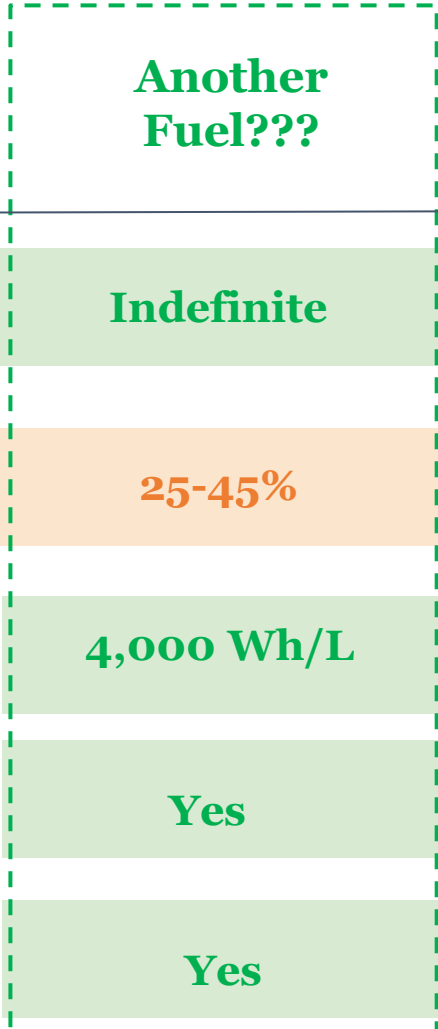
**Carbon-free
ammonia
combustion
technologies**

Ammonia Energy Association
Startup Showcase
November 13, 2024



Challenge: Not Everything can be Electrified



	Renewable Electricity 	Green Hydrogen 	Electro-Fuels 	Another Fuel??? 
Energy Storage	Days	Weeks	Indefinite	Indefinite
Energy conversion loss to electrons	~None	15-30%	<60%	25-45%
Energy Density	250 Wh / kg	1,000 Wh/L	10,000 Wh/L	4,000 Wh/L
Current Infrastructure In Place	Marginal	No	Marginal	Yes
Current Global Production	Marginal	No	No	Yes

Need a solution with high storage density, infrastructure in-place, and current global production



Solution: Ammonia (NH₃) as a Fuel



- ❖ Known and widely used commodity: +180 *million tons* produced annually
- ❖ Global infrastructure already in-place (unlike hydrogen or methanol)
- ❖ Can be low or zero Carbon-Intensity (CI)
- ❖ Energy dense, stores indefinitely, and low cost storage and transport
- ❖ Complimentary to hydrogen: is made from H₂ and cracked back into H₂
- ❖ Leverages +100 year supply chain for internal combustion engines and durability



1. Conversion Technologies

- ❖ Core tech #1: repower engines & backup generators (existing or new)
- ❖ Tech #2: industrial heat components (burners)
- ❖ Utilize known manufacturing capabilities, supply chains, and technician skill sets
- ❖ Use of contract engineering and fabrication network
- ❖ Example success stories: Amogy and ClearFlame

2. OEM Partnerships

- ❖ JVs and partnerships with established OEMs
- ❖ Licensing opportunities
- ❖ Capital light business model
- ❖ Highly scalable opportunity
- ❖ Utilizes 100+ years of industry expertise and global production facilities



Engines, backup generators, and industrial heat equipment can all be converted to 100% ammonia

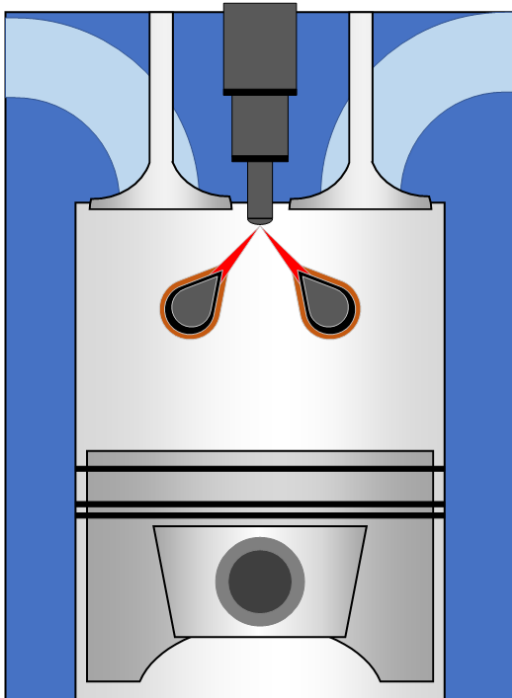
*Note, Aza does not manufacture engines or gensets

NH₃ is *difficult* at smaller scales!



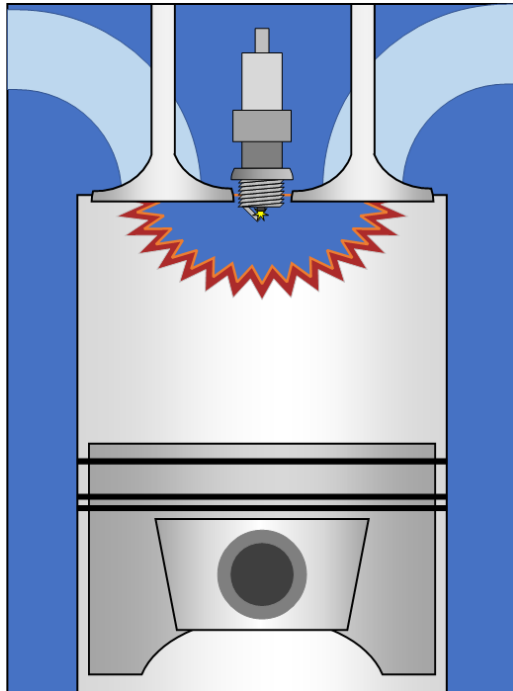
Conventional ICE Ignition

Compression Ignition
(Diesel)



Jet Surface Propagation

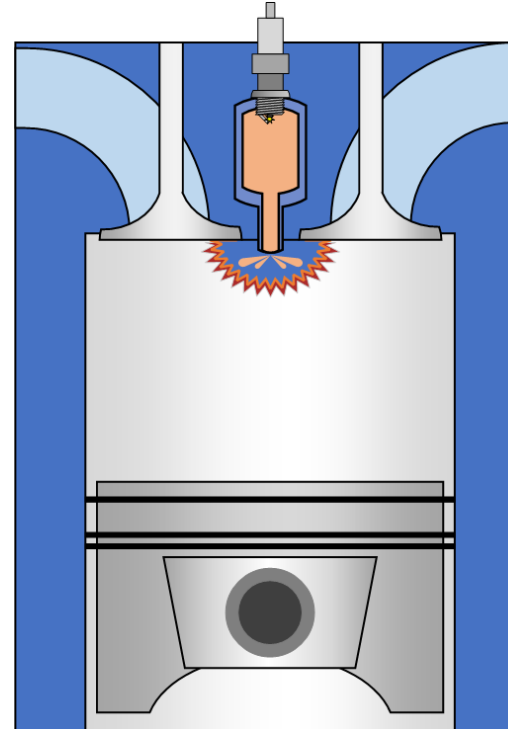
Spark Ignition
(Gasoline)



Radial Propagation

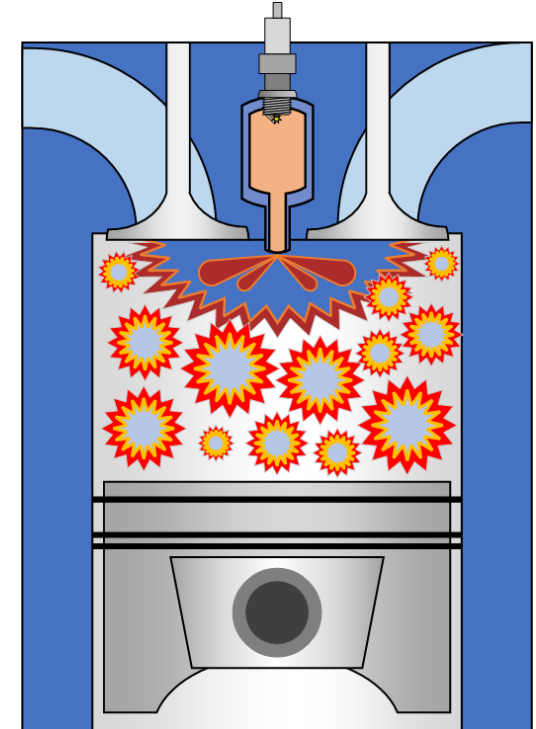
Aza's P/C Turbulent Jet Ignition

Turbulent Jets



Jets + Radial

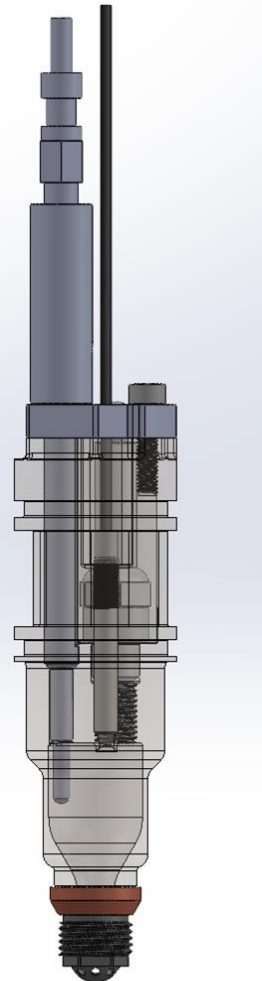
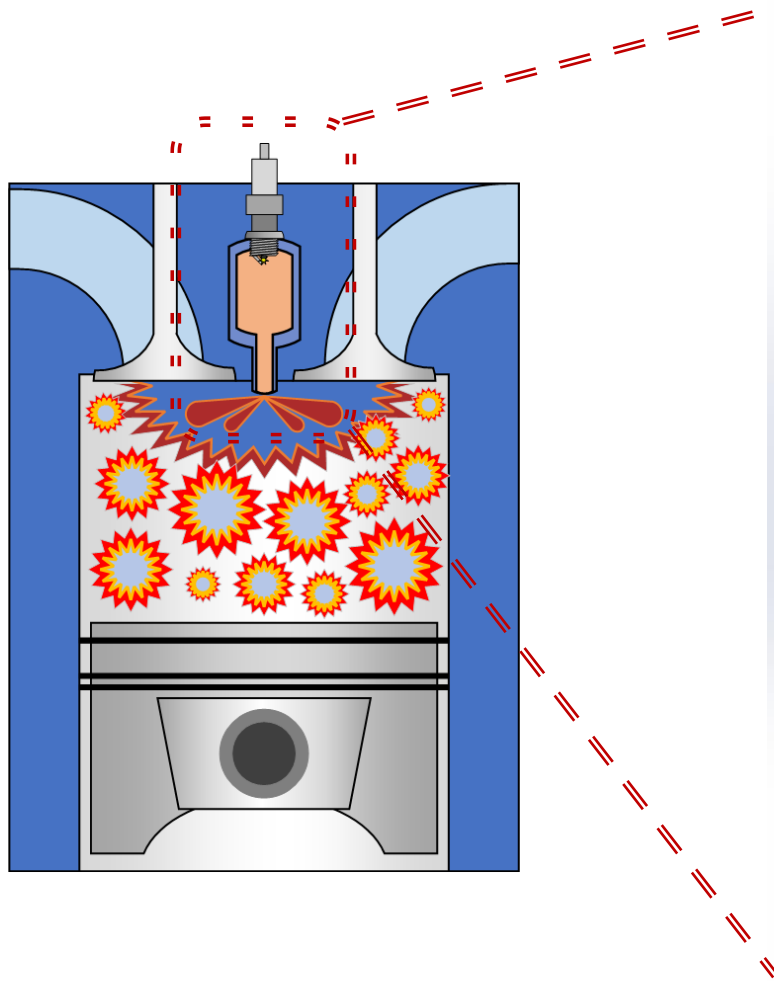
Turbulent Jets



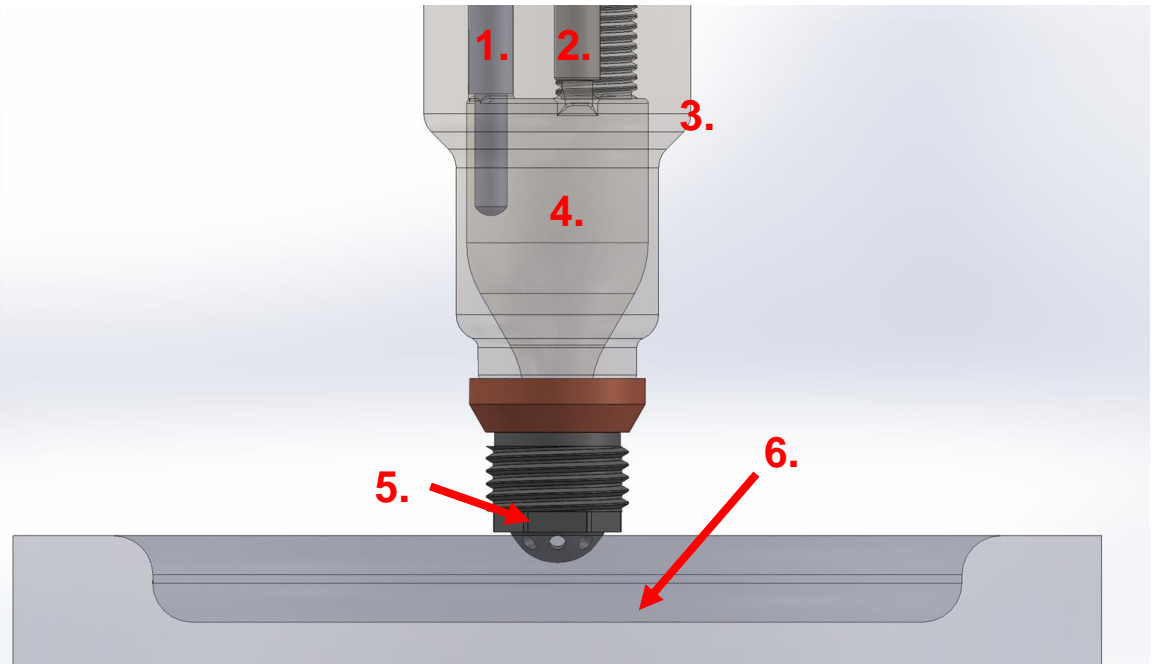
Sonic Propagation

These work, but poorly, with Ammonia

Core Technology: Prechamber Combustion



1. Glow Plug
2. Pressure Meas.
3. Spark Plug
4. P/C
5. Jets/Nozzles
6. Piston



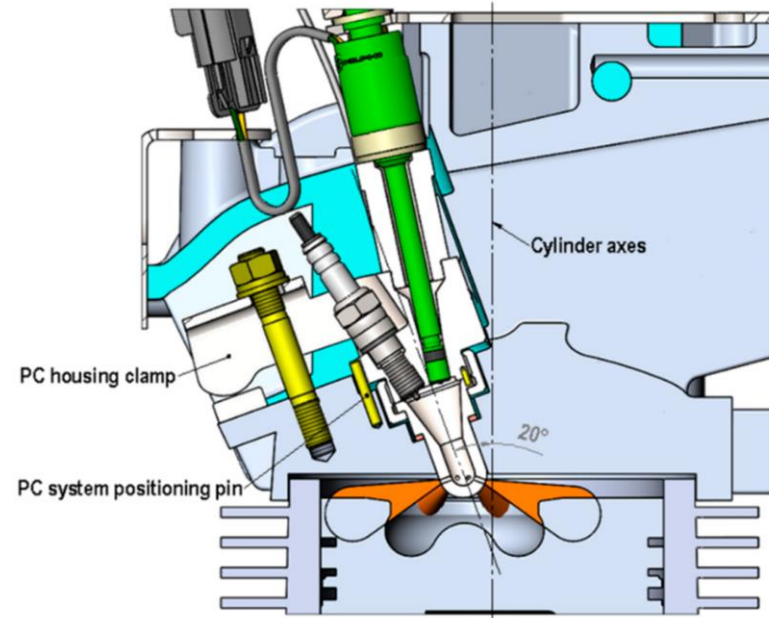
Aza can convert virtually any internal combustion engine or genset to run on 100% ammonia

Ammonia Pre-chamber for Repower

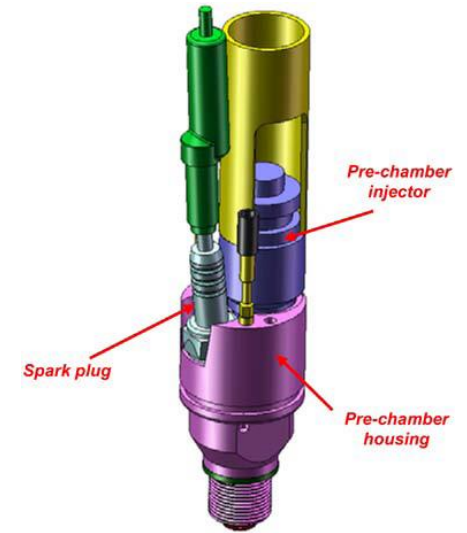


- ❖ Pre-chamber is isolated from main chamber
 - Isolated system can be optimized* for NH₃
- ❖ Generates Turbulence
 - Faster Burn
 - Eliminates NO_x/N₂O
- ❖ Can be retrofit into SI and DI engines
- ❖ Proven technology adapted to novel fuel

*Aza proprietary designs and IP centered on optimizing performance for NH₃ combustion



<https://doi.org/10.3390/en15134758>



Exemplary Mahle Hydrocarbon Pre-chamber

Further Reading on Pre-chambers:

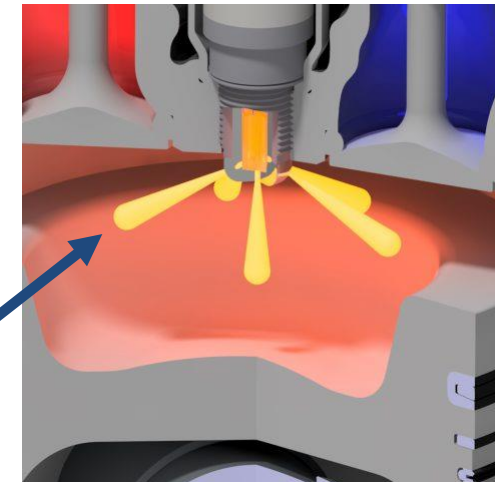
Review of Pre-chamber Technology

<http://dx.doi.org/10.1016/j.applthermaleng.2017.08.118>

Ammonia-fueled Pre-Chamber

<https://doi.org/10.3390/pr10102102>

Turbulent
Flame Jets



Our Repower Process



Aza transforms existing OEM engines to clean burning ammonia powerplants using our repower package of components:

1. Proprietary products
2. Off the shelf products

**Existing OEM
IC Engines**



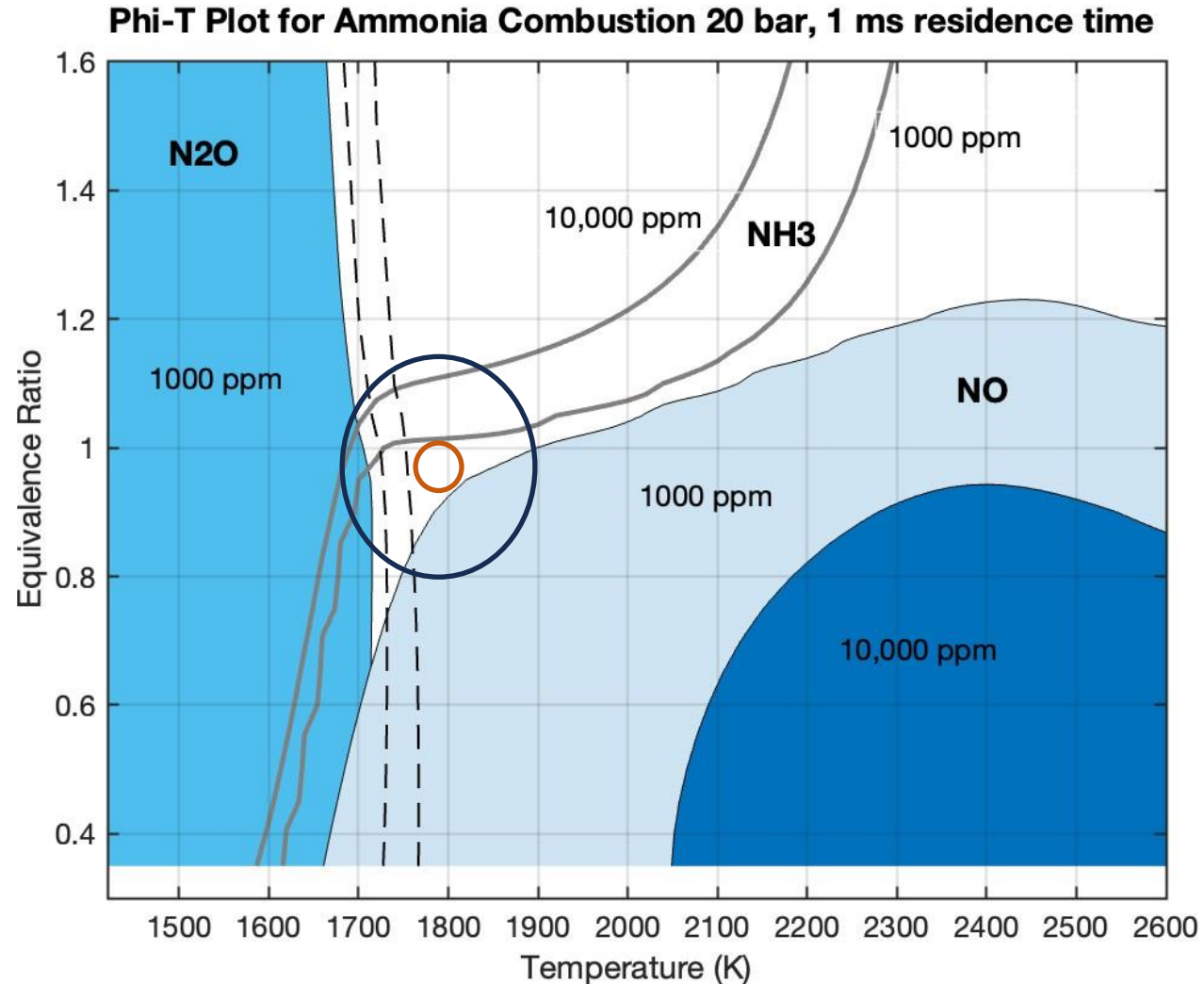
**Pre-chamber
Ignitors**

**Core IP
technology**



Off-the-shelf equipment:
fuel systems, emission
controls, pistons...

Controlling Emissions



❖ Low Emissions “Island”

- Low N₂O (<10ppm)
- Minimal NO / NH₃
- SCR to remove both
- Lean to Stoich Operation

Northrop, William F., Modeling Nitrogen Species from Ammonia Reciprocating Engine Combustion in Temperature-Equivalence Ratio Space. <https://doi.org/10.1016/j.jaecs.2023.100245>



❖ Mobile Electrical Generator

- Zero Carbon Emissions
- Portable
- Powerful (200 kWe!)
- Identical Performance to Diesel

❖ Possible Applications

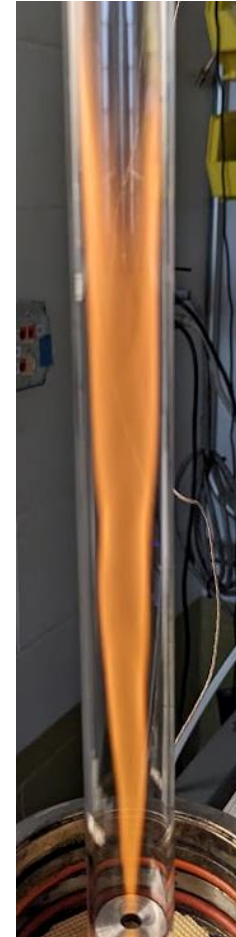
- Construction Sites
- Remote Locations
- Oil Fields
- Mines and Earthworks Projects
- Hospitals and Datacenters



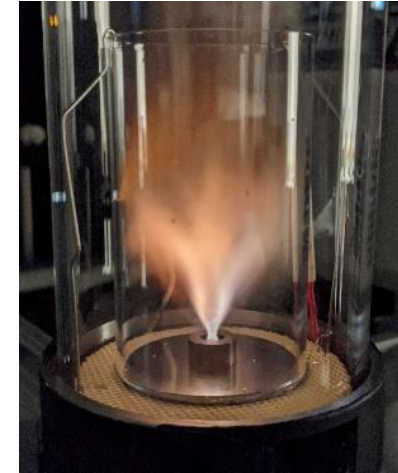
Core Technology: Atmospheric 100% NH₃ Burners



- ❖ 100% Ammonia Fueled
- ❖ Low NO_x/N₂O/NH₃ emissions due to recirculation of these species
 - NO_x ~50 ppm
 - NH₃ ~1-5ppm
 - N₂O ~ 1-5ppm
- ❖ Unique swirl/turbulator geometries yield superior emissions
- ❖ Peak Flame Temp >1,000 °C
- ❖ **Seen this before?**
Highly-improved designs on the way!



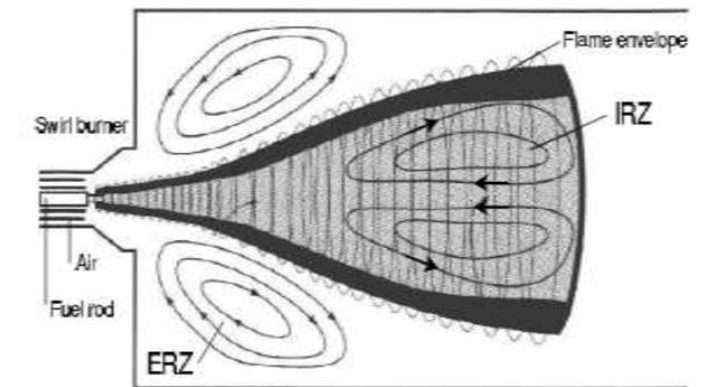
Aza Burner #1



Aza Burner #2



Aza Burner #3



2015, Review of Swirl Generator Used In Gas Turbine Combustor. 2,811-816

Traction and Pilot Projects



1. Runestone Electric Genset project

Conversion of a 200 kWe backup generator for a utility in MN
Customer desires a carbon free solution for peak demand
Status: genset purchased and is being converted



2. University of St. Thomas Microgrid Genset

Conversion of *another* 200 kWe generator for durability testing,
emissions characterization, and lube oil testing



3. UMN Trigeneration Boiler Repower

Conversion of a natural gas boiler burner to run on 100%
anhydrous ammonia. Power output is 6,000 kWth and also runs
a 100kWe steam turbine and an ammonia absorption chiller



4. Kubota RTV-X1100C Fleet Conversion

Conversion of a pair of Kubota X1100C UTVs from Diesel to
Ammonia fuel for demonstration side-by-side with unconverted
units to showcase 1:1 operability on new fuel



Short Term GTM Overview



Backup Power



Grid resiliency / peak demand, remote locations, microgrids, municipal buildings

diesel generators

Utilities, municipalities, island nations

Datacenter Backup Power



Data centers and servers

Diesel generators

Technology companies

Industrial Heat



Boilers
Industrial Dryers
Power generation

Natural gas

Agriculture, steel, glass, aluminum...
Utilities

Specific markets

Incumbent solution

Customer profile

Long Term Market Overview



Maritime (Short Haul)

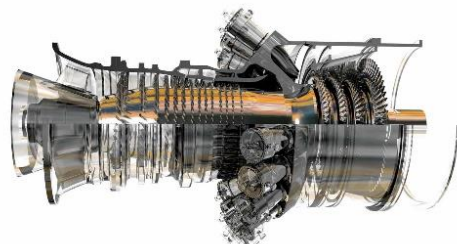


Offshore supply vessels
Tugboats
ferries

Diesel engine and
diesel generator

Offshore energy
companies (US, Norway,
Singapore, Aberdeen
UK)

Industrial Heat



Boilers
Industrial Dryers
Power generation

Natural gas combustion

Utilities
Heavy industries (steel,
glass, aluminum...)

Locomotive



Class 1,2,3
locomotives

Diesel engines

Large public companies,
municipalities, transit
agencies

Tractors



Tractors (agriculture)

Diesel engines

Farms, co-ops, and
equipment OEMs

Mining



Mining
and construction

Diesel engines

Mining companies and
equipment OEMs

Specific
markets

Incumbent
solution

Customer
profile

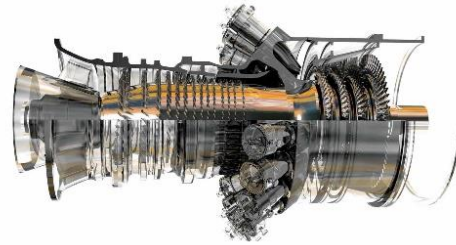
Large Markets with Gigaton Carbon Emissions



**Maritime
(Short Haul)**



Industrial Heat



Locomotive



Tractors



Mining



Annual CO₂
Emissions
(mm tons)

50 - 75

500 -
750

60 - 150

~5 - 10

~500

TAM
(\$mm)

~\$820

~\$1,500

~\$6,000

~\$1,500

~\$1250



“Meeting your energy needs, without the carbon”

Seamus Kane, Ph.D
skane@azapowersys.com

Tim Krebs, CFA
tkrebs@azapowersys.com

Will Northrop, Ph.D
wnorthrop@azapowersys.com

