Energy Generation from the Decomposition of Microbially-Generated Nitrous Oxide

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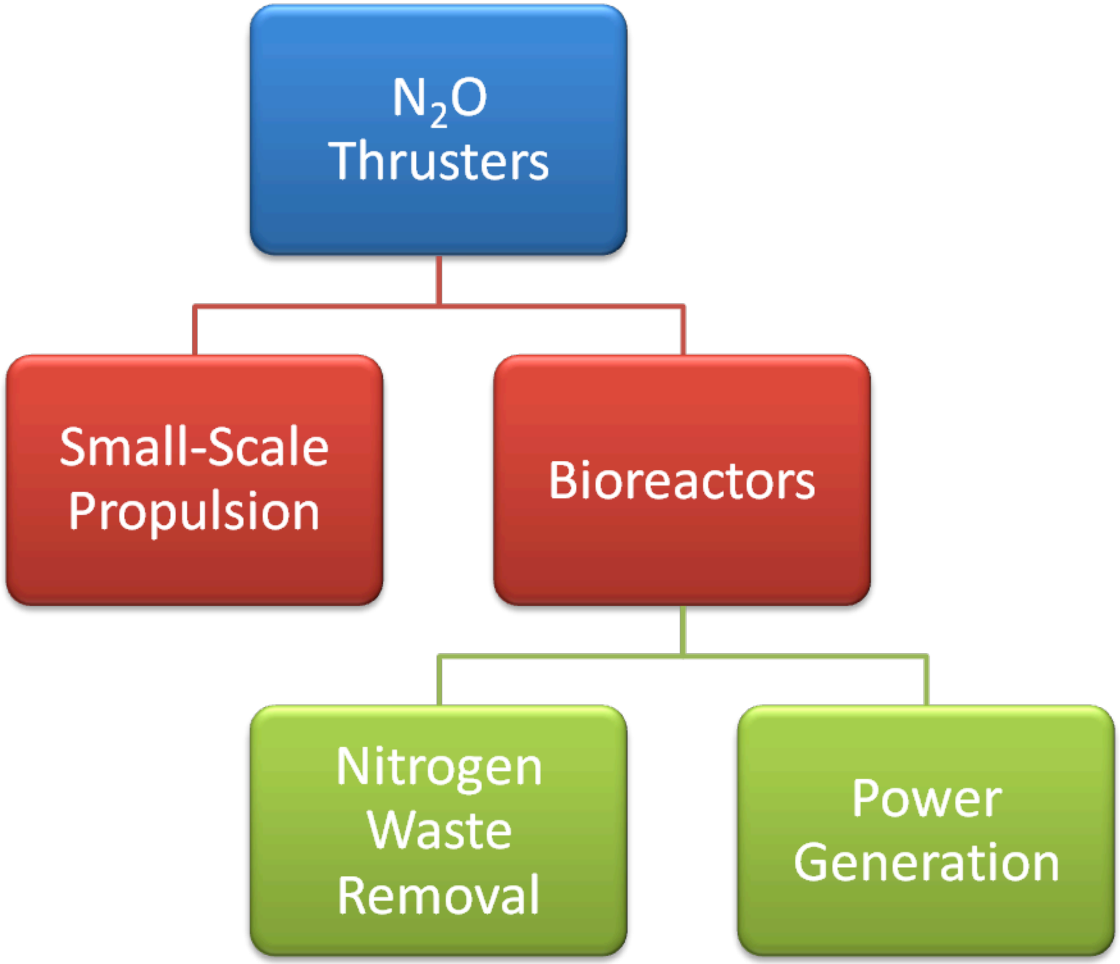
Collaboration with Professor Craig Criddle
Civil and Environmental Engineering

Support: The Woods Institute for the Environment

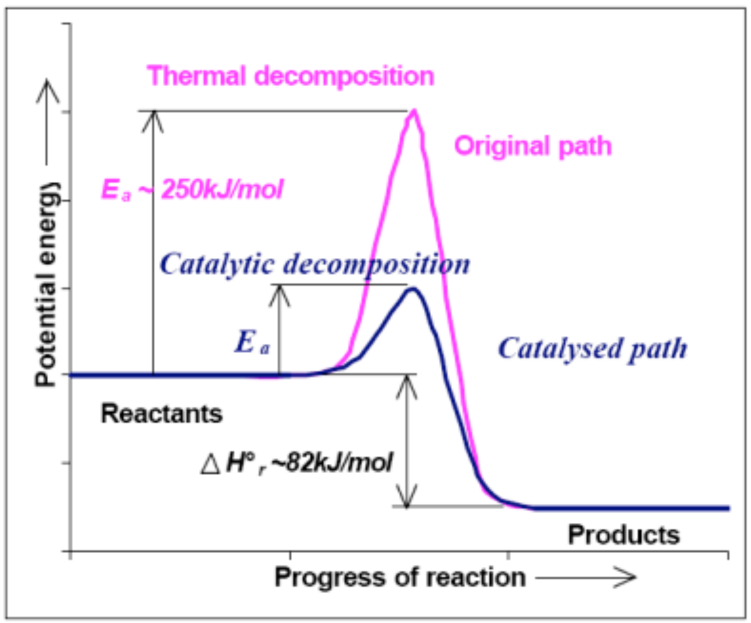
Overview of Research



N_2O Decomposition

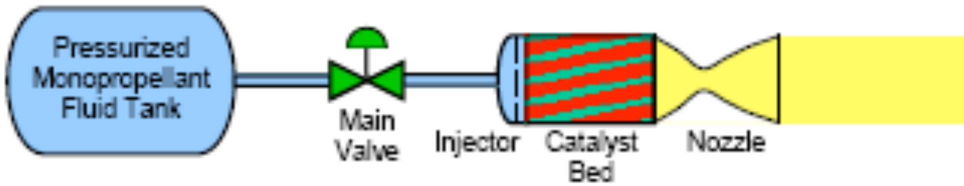
$N_2O \Rightarrow \frac{1}{2}O_2 + N_2 + 82$ kJ/mol

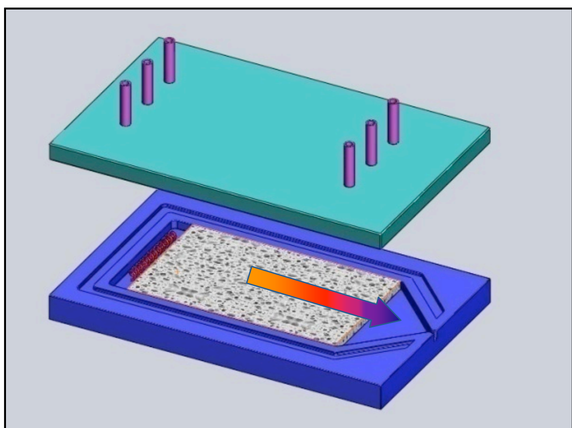
$T_{adiabatic} = 1640^\circ C$

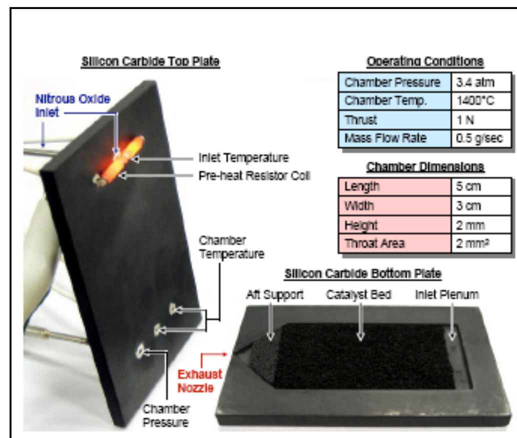


Source: zakirov

MEMS N_2O Thruster



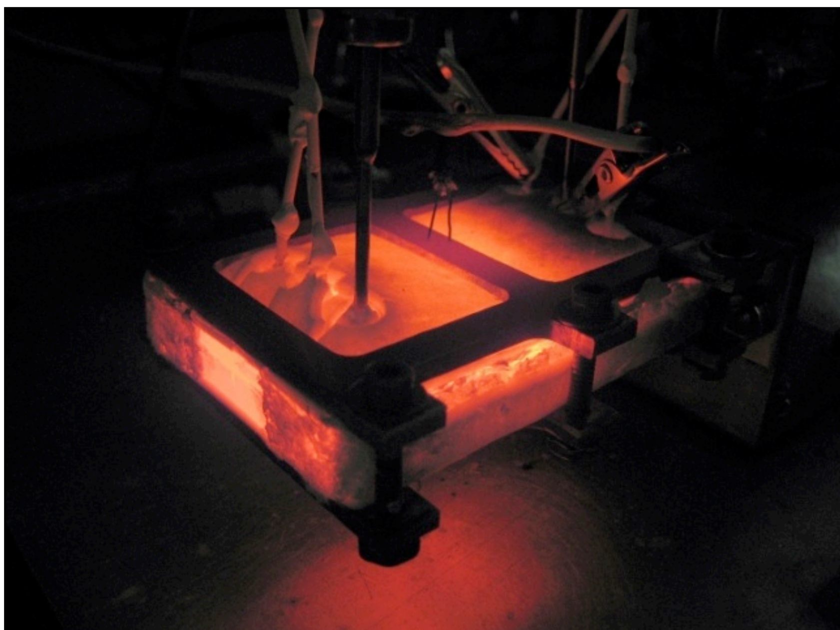


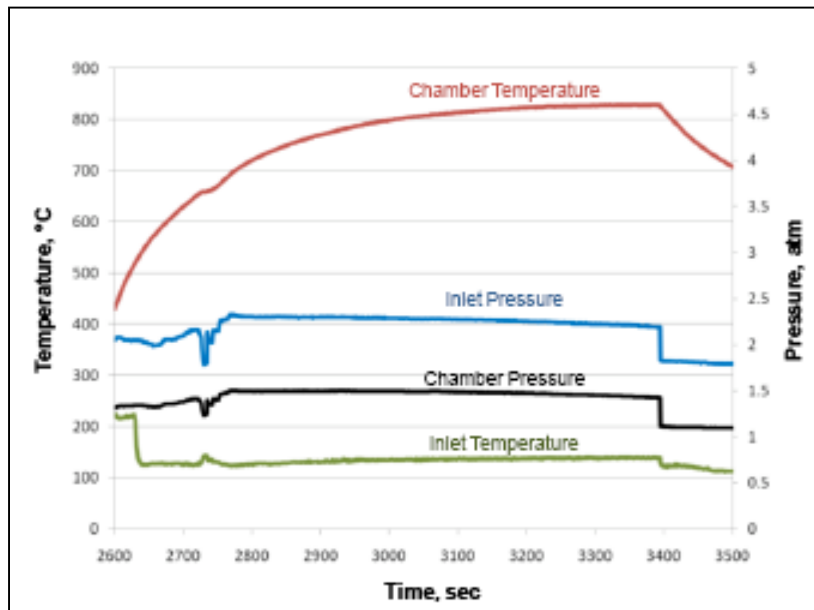


Small-Scale Thruster

- 12 tests conducted
- Rh on alumina catalyst

Performance Parameters	
Bed Loading	5 kg/m²/sec
c*	71%
$T_{preheat}$	400° C (100W Power)
$T_{chamber}$	888° C





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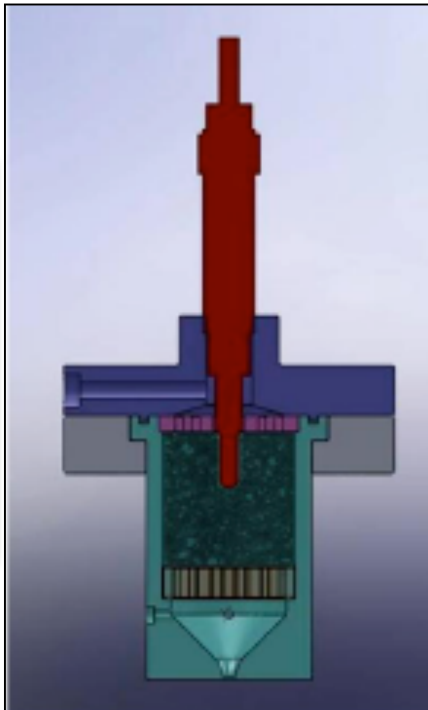
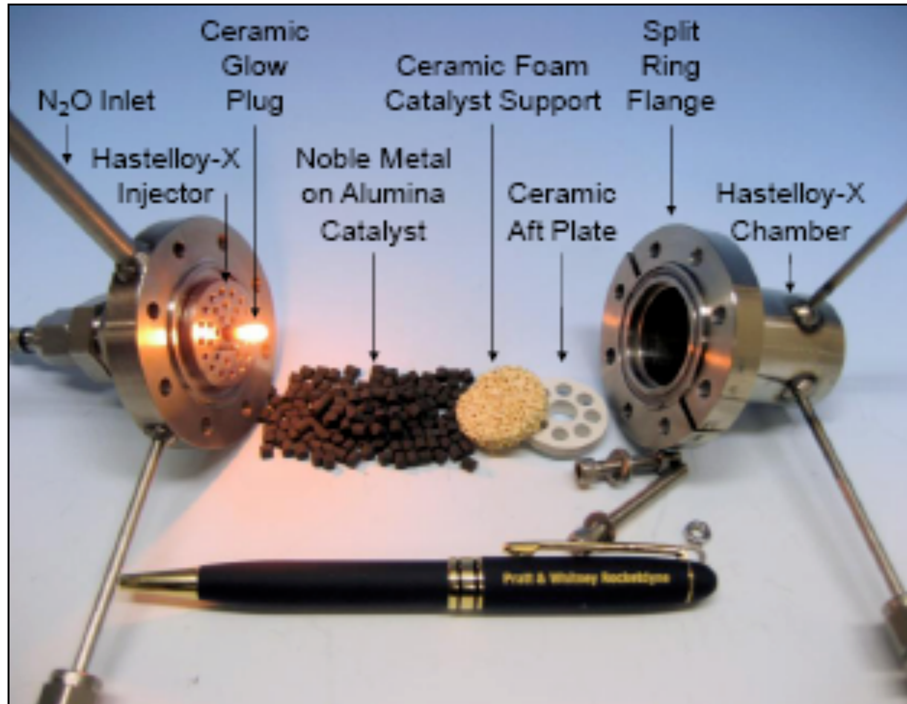
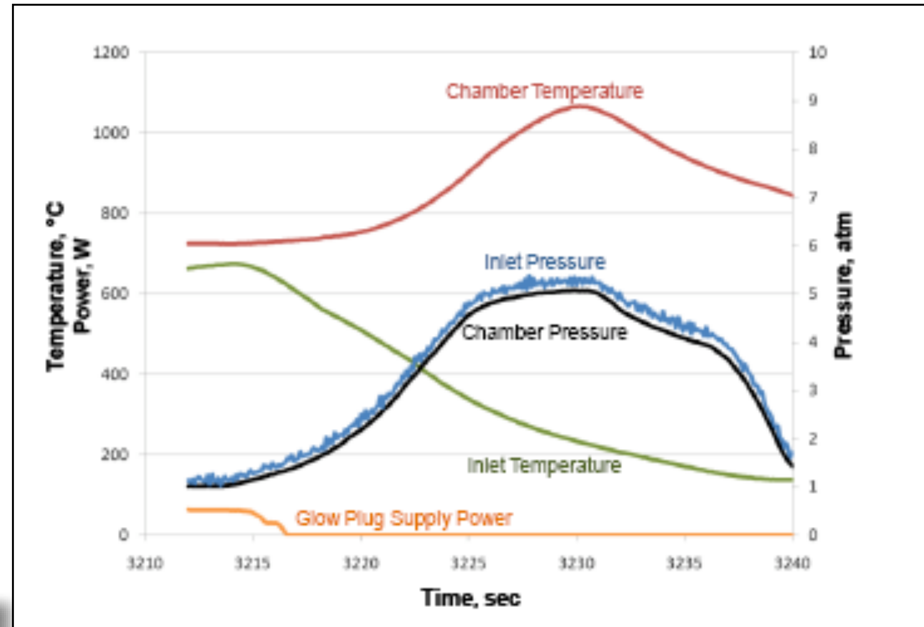
Scaled-Up Device

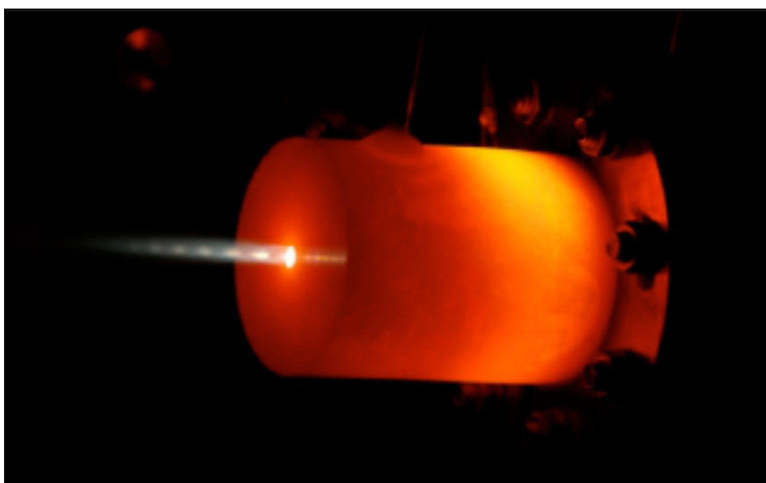




Scaled-Up Device

Performance Parameter
$P_{chamber}$ = 78 psi
Bed Loading = 5 kg/m²/sec
c* = 81%
T_{int} = 300°C
P_{in} = 30W





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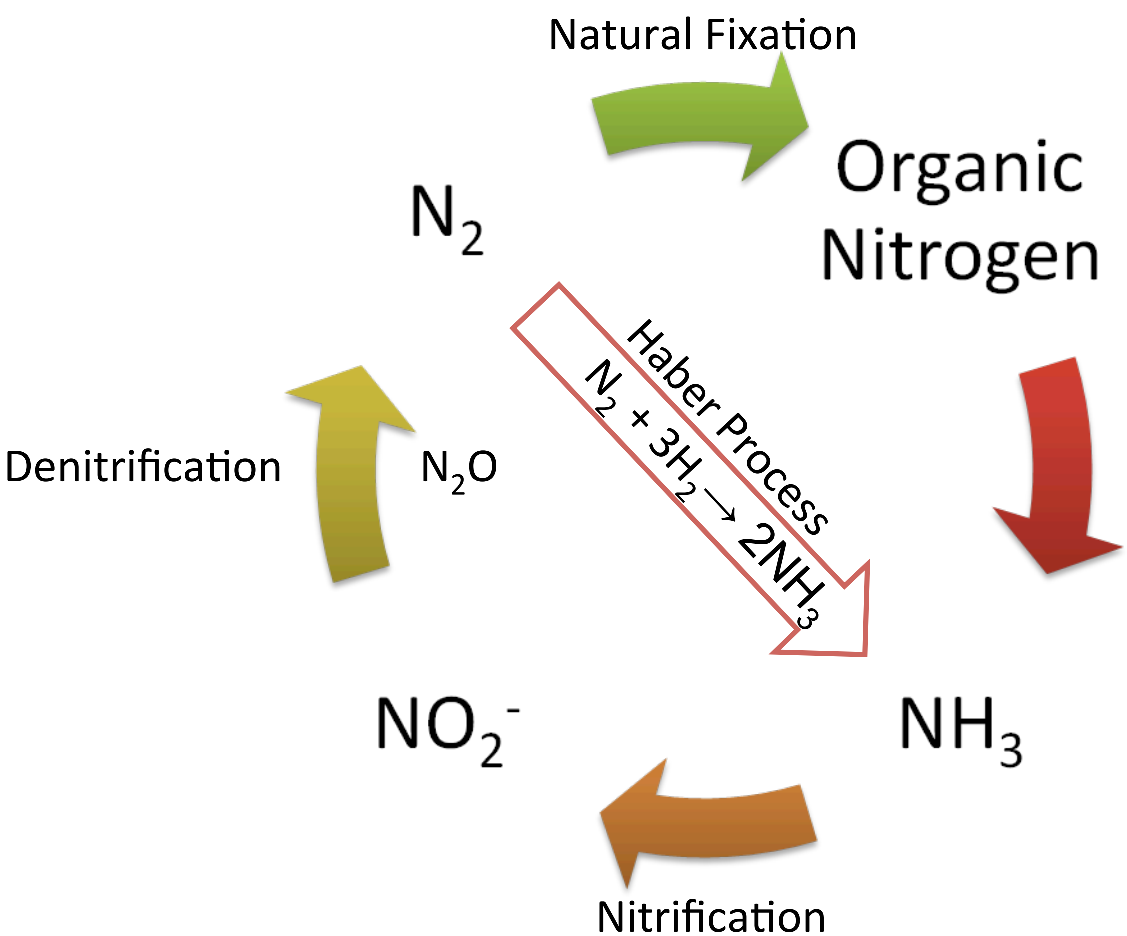
Where can we get N_2O to make ultra-clean energy?

Nitrogen Fixation

Natural Nitrogen cycle spins at 130 Tg N/yr.

Haber Process: 100 Tg N/yr.



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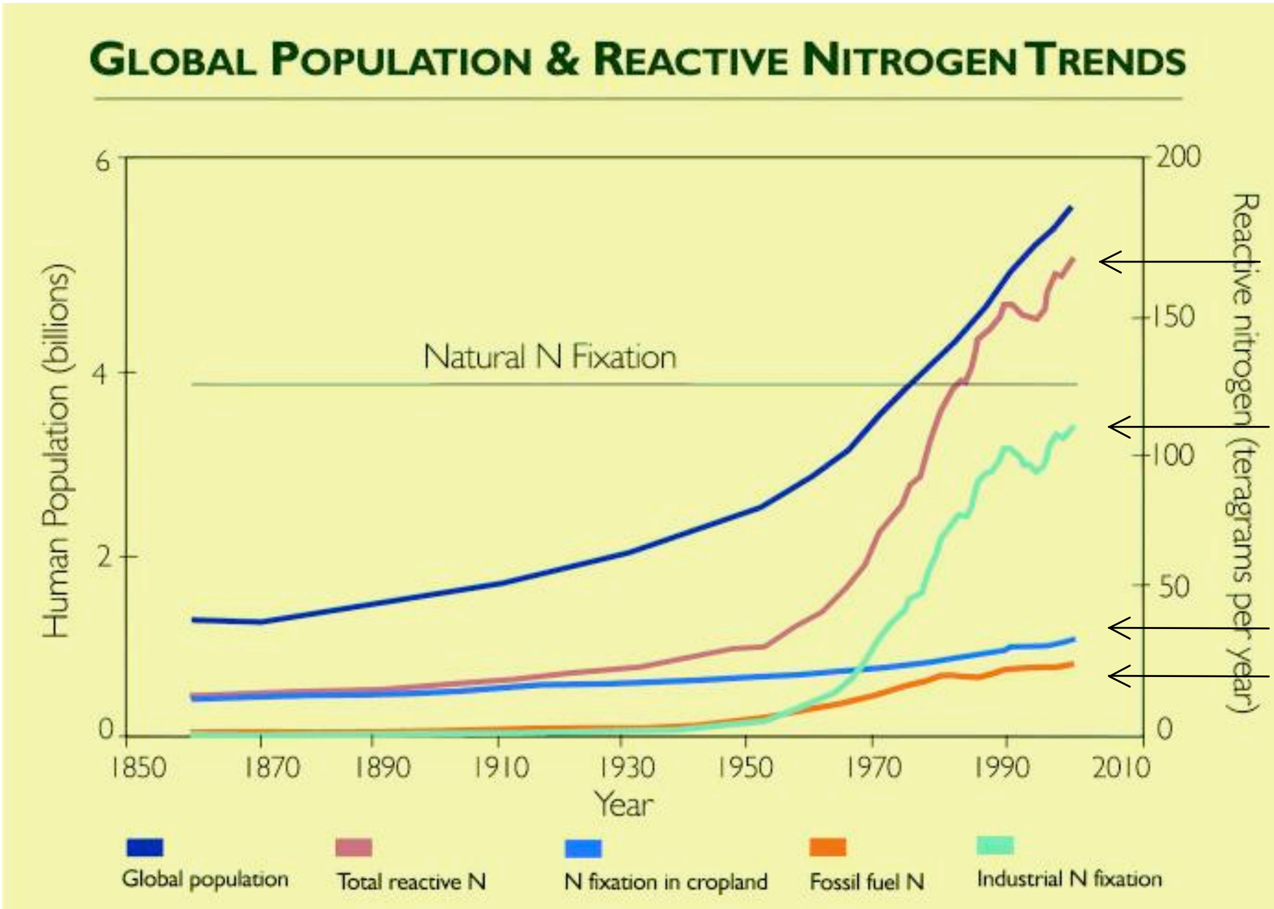
The Problem: Nitrogen Waste



Source: Lambert KF, Driscoll C. 2003. Nitrogen Pollution: From the Sources to the Sea. Hanover, NH: Hubbard Brook Research Foundation; 4.

Total Reactive Nitrogen

Haber Process

Crops

Fossil Fuels

The Problem: Nitrogen Waste

N_2O Green House Gas

- 310 x Global Warming Potential (GWP) of CO_2

N_2O is 5.2% (U.S.) and 8% (world) of GHG emissions

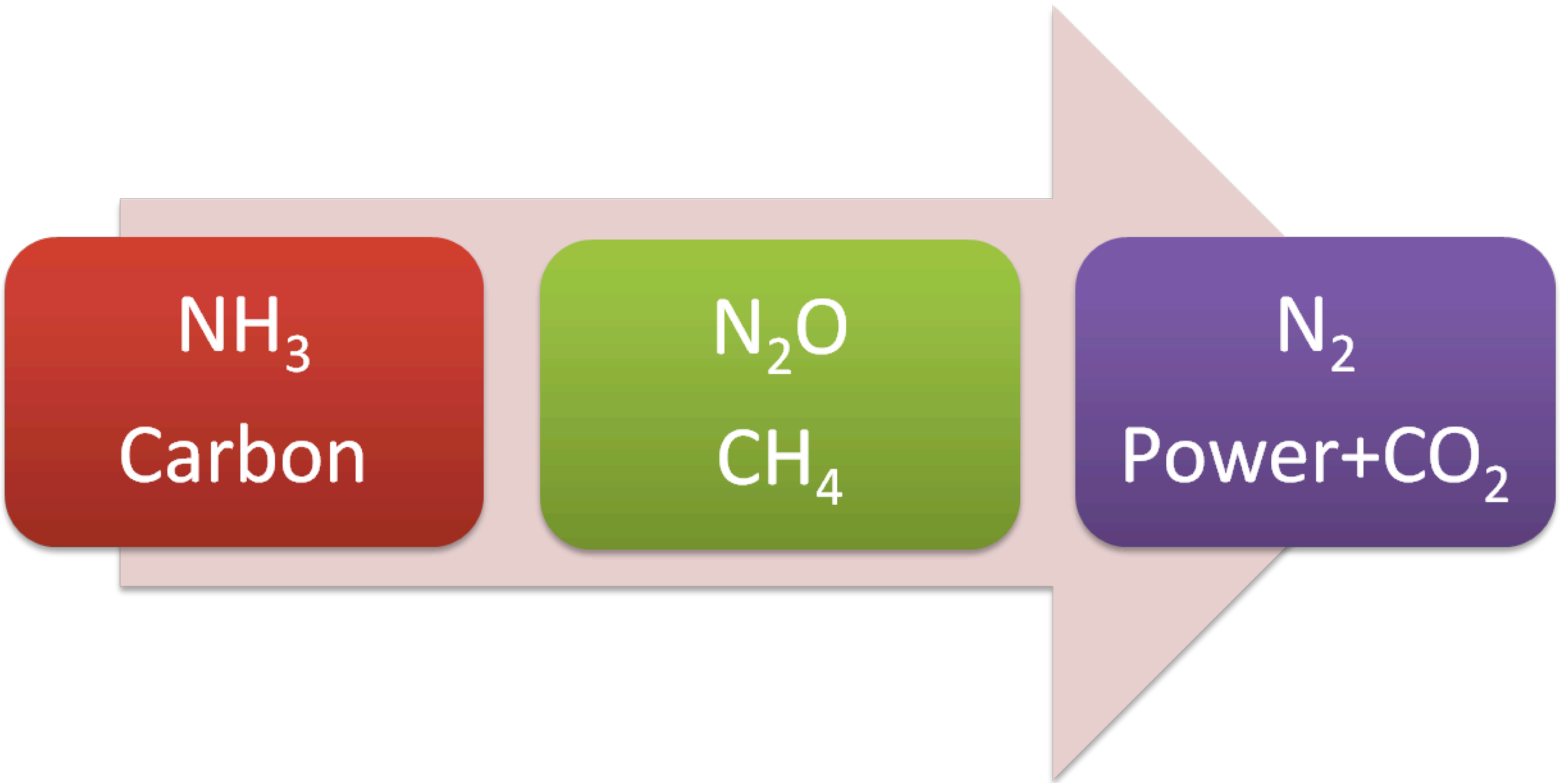
N_2O production is increasing

- IPCC models suggest 415% increase by 2100

Haber-Process produces excess Ammonia

- toxicity to fish, fertilization and eutrophication of natural water bodies, oxygen depletion, and vast dead zones in the ocean margins

Bioreactor Overview



Currently bioreactors **minimize** N_2O and are **inefficient**

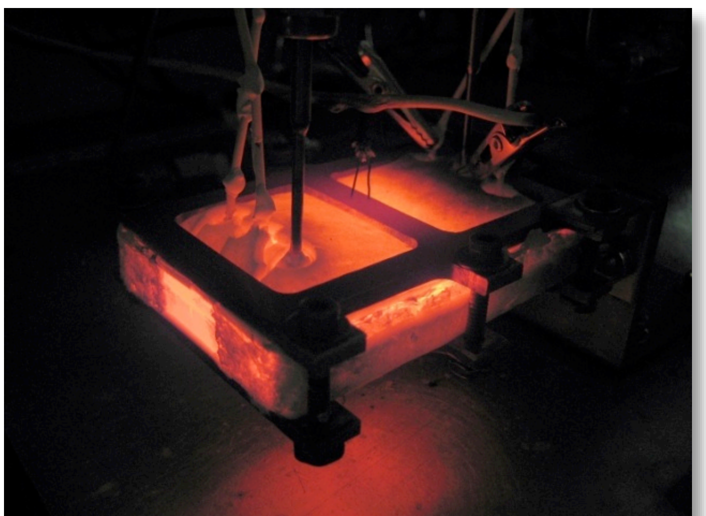
Propose to **maximize** N_2O production, much more **efficient**

This could lead to a ground breaking technology in waste water management!

The Solution

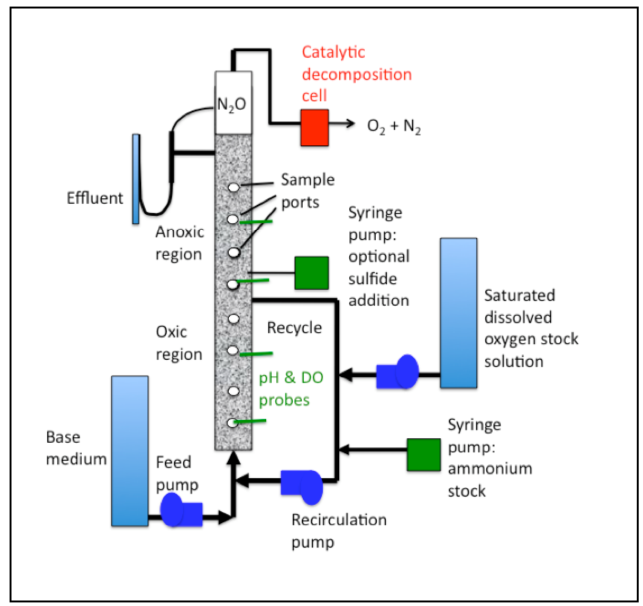
1. Convert reactive Nitrogen waste to N_2O gas
2. Decompose N_2O to enriched air + gen power

Coupled Autotrophic Nitrous Decomposition Operation (CANDO). → Convert Reactive Nitrogen waste to N_2O → Generate significant power ($N_2O + CH_4$) and air → Improve efficiency of bioreactors and reduce their operational cost



N_2O Thruster

+



Bioreactor

Source: Prof. Criddle

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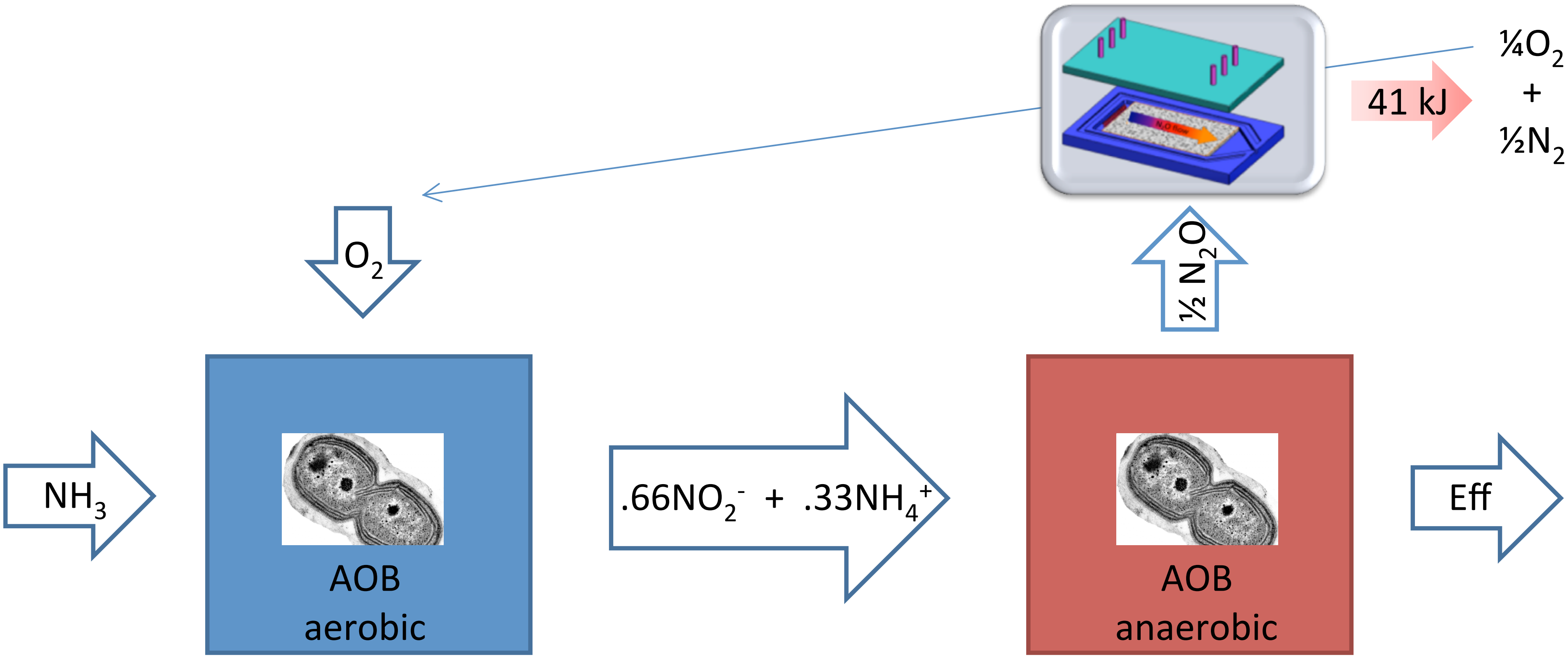
Coupled System: Bioreactor



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Impact on Bioreactor Operation

Methane

- 3-4 times more CH_4 production
- Up to 0.1 L of CH_4 per liter of wastewater treated

Oxygen

- Reduce O_2 requirement by up to 62%
- Aeration is about 50% of the operational costs of a treatment plant

Biomass

- Significantly decrease waste biomass
- Disposal of waste biomass is the second greatest operational expense at treatment plants.

Robustness

- Much faster growing and more robust bacteria than competing process (ANNAMOX)

Local Wastewater Treatment Plants

PALO ALTO	SAN JOSE
20-25 Million Gallons per Day	10 times more!
$N_2O \rightarrow 200$ kW	
Power 190 homes!	
$CH_4 \rightarrow 6.4$ MW	
Power 6600 homes!