

AMMONIA AS AN ENERGY SECTOR FUEL

CLEAN AIR TASK FORCE
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CATF

Our Mission

- Push the change in technologies and policies needed to get to a zero-emissions, high-energy planet at an affordable cost.

Our Goal

- Achieve zero-emissions energy, waste, agricultural, and forest management systems by 2050.

Our Vision

- Meet the world's rising energy demand in a way that is financially, socially and environmentally sustainable.

CATF CAMPAIGNS



Conventional pollution from coal-fired power (1996-present)

CO2 pollution from electric power sector (2000-present)



Carbon capture utilization & storage (2000-present)



High-emitting diesels (2003-2012)



Short-lived climate forcers (especially BC and CH4) (2000-present)



Negative climate impacts of bioenergy (2006-present)



CH4 emissions from O&G sector (2009-present)



Advanced nuclear technologies (2007-present)

Zero-carbon fuels (2013-present)

WE NEED A BIGGER TOOLBOX

- Safeguarding against the worst impacts of climate change requires a deep (perhaps total) reduction in carbon emissions from the mobility, power, and industrial sectors.
- Traditional advocacy goals—more renewables, more efficiency improvements—are insufficient.
- We need to develop and deploy carbon-free fuels that offer the benefits of oil and coal (flexible, stable, energy-dense, plentiful).

ZERO-CARBON FUELS ARE ESSENTIAL

Table 3.3 ▶ World oil demand by sector in the New Policies Scenario

	2000		2015		2040		2015-2040		Ease of substitution
	mb/d	%	mb/d	%	mb/d	%	Change	CAAGR*	
Transport	39.0	51%	51.7	56%	60.5	58%	8.8	0.6%	
Passenger vehicles	18.2	24%	23.9	26%	24.6	24%	0.8	0.1%	Medium
Maritime	3.7	5%	5.0	5%	6.2	6%	1.3	0.9%	Medium
Freight	11.9	16%	16.3	18%	19.7	19%	3.4	0.8%	Low
Aviation	4.6	6%	5.8	6%	9.3	9%	3.5	1.9%	Low
Industry	14.4	19%	17.0	18%	22.7	22%	5.7	1.2%	
Steam and process heat	6.1	8%	5.8	6%	6.5	6%	0.8	0.5%	High
Petrochemical feedstocks	8.1	11%	10.7	12%	15.7	15%	4.9	1.5%	Low
Buildings	7.7	10%	7.6	8%	6.0	6%	-1.6	-1.0%	Medium
Power generation	6.1	8%	5.4	6%	2.9	3%	-2.4	-2.4%	High
Other**	9.4	12%	10.8	12%	11.3	11%	0.5	0.2%	
Total	76.7	100%	92.5	100%	103.5	100%	11.0	0.5%	

* Compound average annual growth rate. ** Includes agriculture, transformation, other non-energy use (mainly bitumen and lubricants).

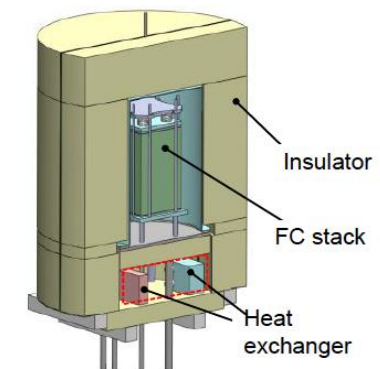
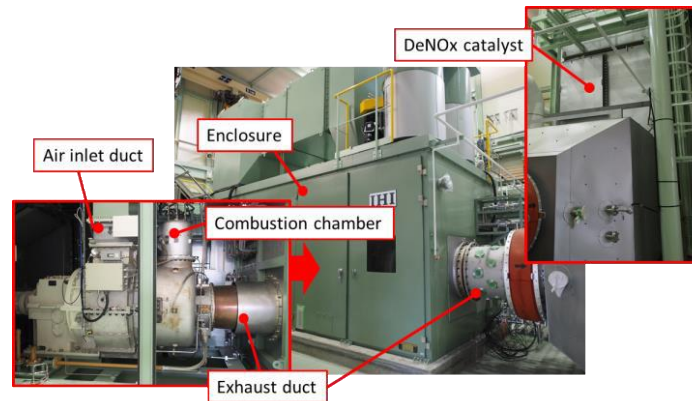
- Electrification is an important tool, but it would solve < half of the global transportation decarb challenge.
- Even if *all* light-duty passenger vehicles are electrified, there will be significant demand for liquid fuel for other vehicles (35.2 mb/d) in 2040 and beyond.
- Fuel also needed for remote/isolated & backup power gen applications.

AMMONIA AS A DIRECT POWER FEEDSTOCK

- Ammonia has to overcome the cost hurdle of being made from natural gas (+CCS) or zero-carbon electricity.
- Likely initial demand for low-carbon ammonia-based power?
 - Off-grid applications
 - Islands and other geographically isolated markets
 - Markets that need to balance their supply of variable renewable energy with a flexible, fast ramping source low/zero-carbon power
 - Existing fossil power stations, including coal-fired boilers, where it makes economic sense to postpone retirement by fuel-switching to a lower-carbon fuel → ammonia's ability to facilitate a gradual decrease in the carbon intensity of coal- or natural gas-derived power could be important.

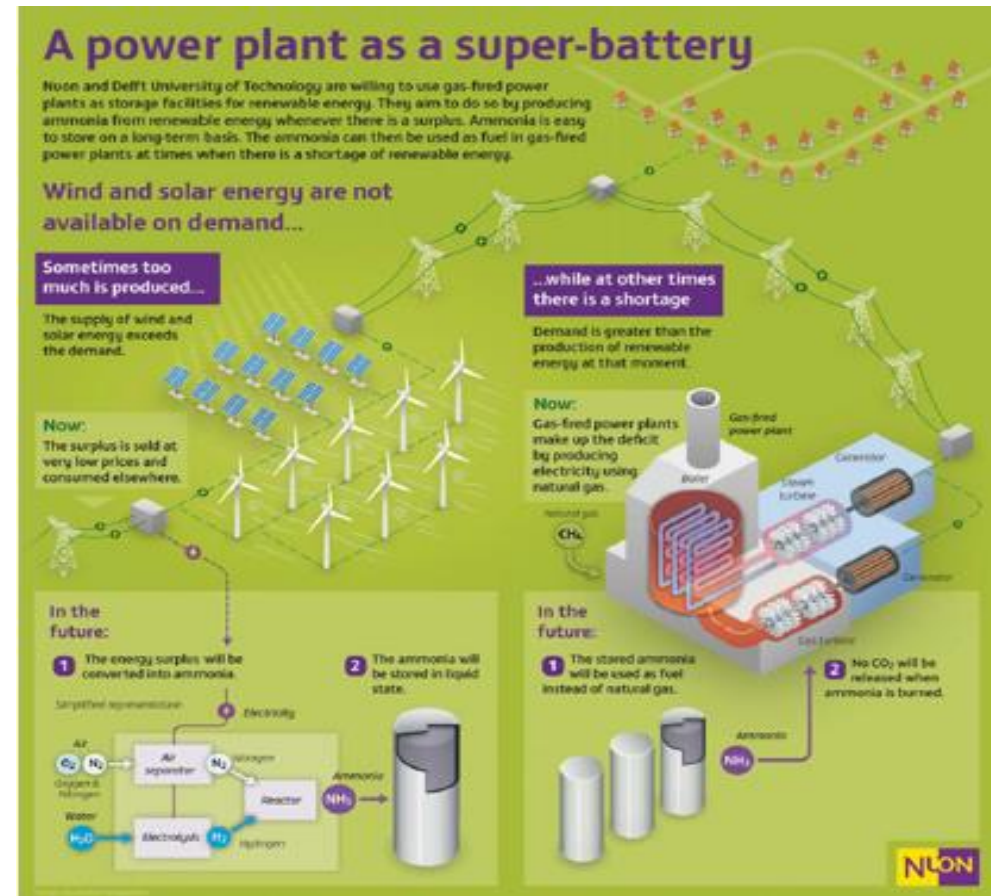
TESTING THE PROPOSITION

- When CATF discusses ammonia's potential as a power sector fuel, we get three questions:
 - FEASIBLE? Does ammonia-based power generation work?
 - AFFORDABLE? Can it compete with other power gen options?
 - SAFE? Can ammonia be produced, handled, and combusted safely (toxic and conventional pollutants)?
- If CATF could design an RD&D agenda to answer those questions ... it would look a lot like IHI's program.



AMMONIA AS AN ENERGY STORAGE MEDIUM

- Can power-to-ammonia-to-power become economically competitive?



Vattenfall/Nuon, *Carbon Neutral Fuels to Enable the Energy Transition* (2017)

POTENTIAL POLICY MEASURES?

- CAA New Source Performance Standards
 - Could ammonia co-firing be used to meet (future) Clean Air Act section 111(d) emission reduction requirements for CO₂ at coal boilers?
- 45Q-type policy
 - Would a tax credit for the production of low/zero-carbon ammonia help accelerate commercialization of ammonia-based power gen technologies?
- California Cap-and-Trade
 - CARB has approved six hydrogen-based fuel pathways for compliance with California's Low Carbon Fuel Standard. Possible precedent for the use of ammonia to comply with CA's Cap-and-Trade program?