

20x2020

How Wind-Powered Ammonia Production can enable 20 Gigawatts of Clean, Renewable wind energy in Iowa by 2020

Ammonia Fuel
Network Conference

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Freedom Fertilizer/SAFE LLC

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Spirit Lake, Manly, & Ames, Iowa

Background: People

- Steve Gruhn, President, Freedom Fertilizer
 - Agriculture, Farmland owner
 - windiest spot in Iowa, Spirit Lake, IA
- Troy Benjegerdes, Chief Technology Officer
 - Manly, Iowa family farm (hauling ammonia in 1992)
 - Iowa State - Solar Car team, 1994-1997, BSEE, 1999
 - Ames Laboratory, Computing research, 2002-'09
 - Freedom Fertilizer CTO, 2009
- Mark Rosenbury
 - Retired COO of Terra Industries
- Craig Arnold, Project Manager
 - CEO Plymouth Energy, Bill & Melinda Gates foundation

Background: Units

- Volume: Liters/Gallons: 3.785L/1g
- Area: Hectares/Acres: 1ha/2.47acres
- Mass: Pounds, tons, short tons, grams, etc
 - Mg: 1e6 grams, 1 metric ton, 2204 lbs, 1.104 short tons
- Energy: Megawatt-hours, MegaJoules, mmBTU
 - MWH: 1000 Kilowatt-hours, 3600 MJ, 3.4 mmbtu

Quantity of various fuels equalling 1 Megawatt-Hour (HHV)					Person-
Fuel	Liters	Gallons	Kilograms	Person-mass	LHV
Diesel Fuel	93	25	79	1.00	1.06
Ethanol	153	40	121	1.53	1.69
Methane (liquid)	158	42	67	0.84	0.93
Ammonia (liquid)	235	62	160	2.03	2.44
Coal	200	53	150	1.90	2.00

Background: Iowa #1 in Corn, #2 in wind

- 60% of the state's 56,272 square miles are row crops (generally corn & soybean rotation)
- 2009 corn crop: 2.5 billion bushels, from 13.7 million acres, or 38% of the state
 - @ 56 lbs/bushel => 637 million Mg (tonne)
 - @ 160 lbs of N per acre => 1.2 million Mg NH₃
 - [500 to 1 ratio] (crop size source: <http://www.nass.usda.gov>)
- 2009 Wind crop: 3,043 MW installed capacity
 - Iowa added 160 MW in second quarter 2009
 - (source: <http://awea.org/reports/>)

Wind



- GE 2.5xl wind turbine
 - Any turbine will do, GE is well known
- 2.5 MW nameplate
- 34% capacity factor
 - Just a guess, but close enough
- 80 units would produce about 595,000 MWH

Hydrogen -- Nitrogen



- NextHydrogen water electrolysis
 - Under development, testing this fall
- 2.5 MW x 26 units
- 9,762 Mg H₂/year
- 77,480 Mg O₂/yr
- 560,000 MWH/year
- Cryogenic Air separation plant
 - Standard production technology
- ~1.0 MW, 1 unit
- 45,000 Mg N₂/yr
- 13,800 Mg O₂/yr
- 8,640 MWH/year

Ammonia



- Ammonia Casale 150 Tons per day Haber-Bosch reactor
- ~2.5 MW
- 21,600 MWH/year
- ***54,000 Mg of zero-carbon, renewable ammonia per year***

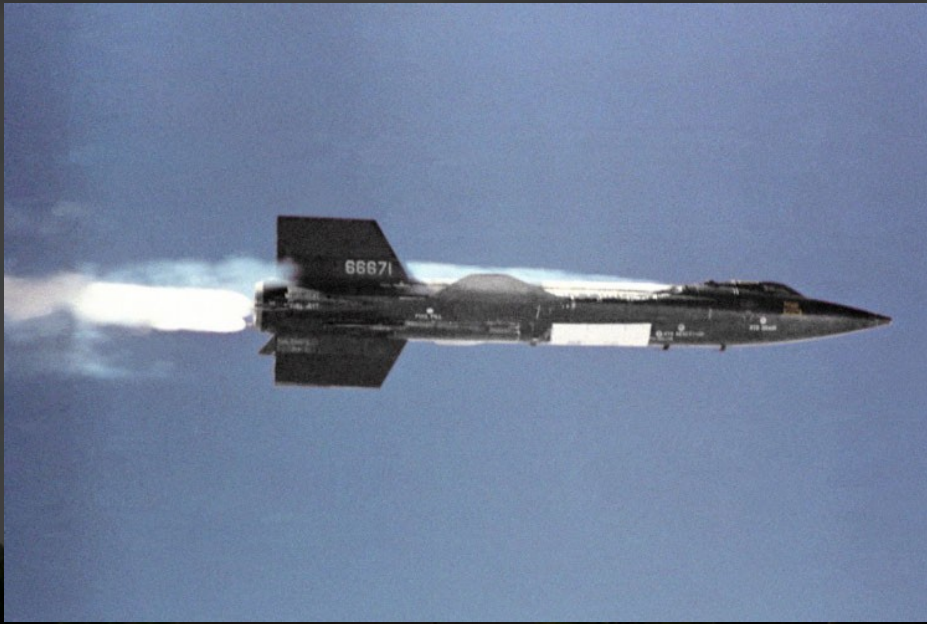
Let's add this up..

- MWH: Turbine generation: 595,000 MWH
- Usage: $560,000 + 8,640 + 21,600 = 590,240$ MWH .. 4,760 MWH left over for the grid
- Optimize some variables, add more electrolysers, add hydrogen storage, include variable-rate Haber-Bosch synthesis..
- 200MW wind farm -> 54,000 Mg (tonnes) NH₃
 - 337,500 MWH (HHV) (57% energy conversion)
 - 40 MPG diesel is 1000 miles per MWH
 - 337 million miles, on 16MPG ammonia engines

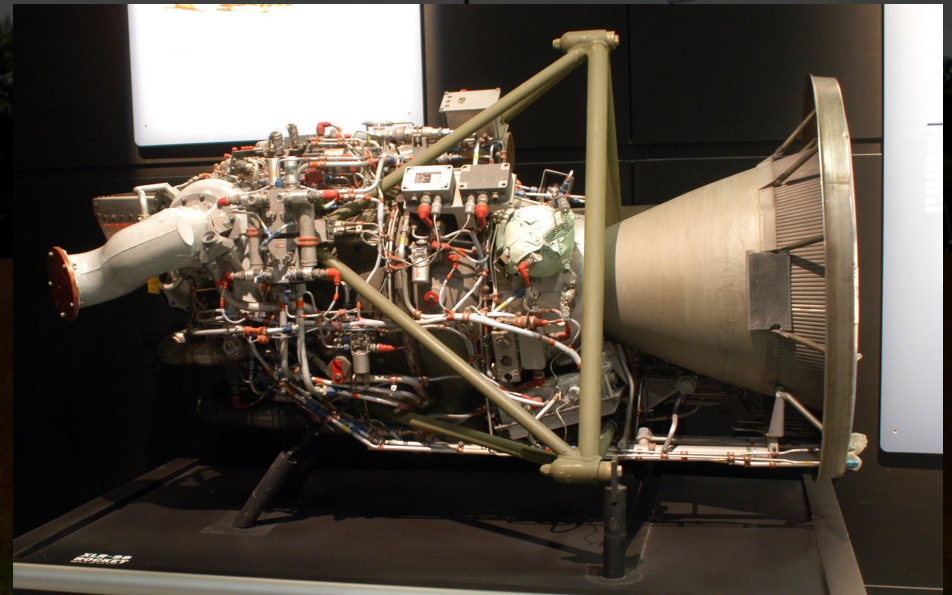
Back to fertilizer: 20GW by 2020

- Iowa: 1.2 million Mg NH₃
- 637 million Mg corn
- 22 Freedom Fertilizer ammonia plants @ 99%
 - Add in an extra 3 for Ammonia fuel
 - 5,000 MW continuous electrical power load.
- Entire state of Iowa is ~11,000MW peak, 5,684 average
 - (<http://www.eia.doe.gov/cneaf/electricity/epa/fig1p1.html>)
- We can meet the base load requirements of Iowa with 20GW of wind, and 15 GW of peak electrolysis capacity, using approx 60 fertilizer plants at 34% capacity factor
- This might cost, worst case: 60 x \$100 million: \$ 6 billion

This is not rocket science



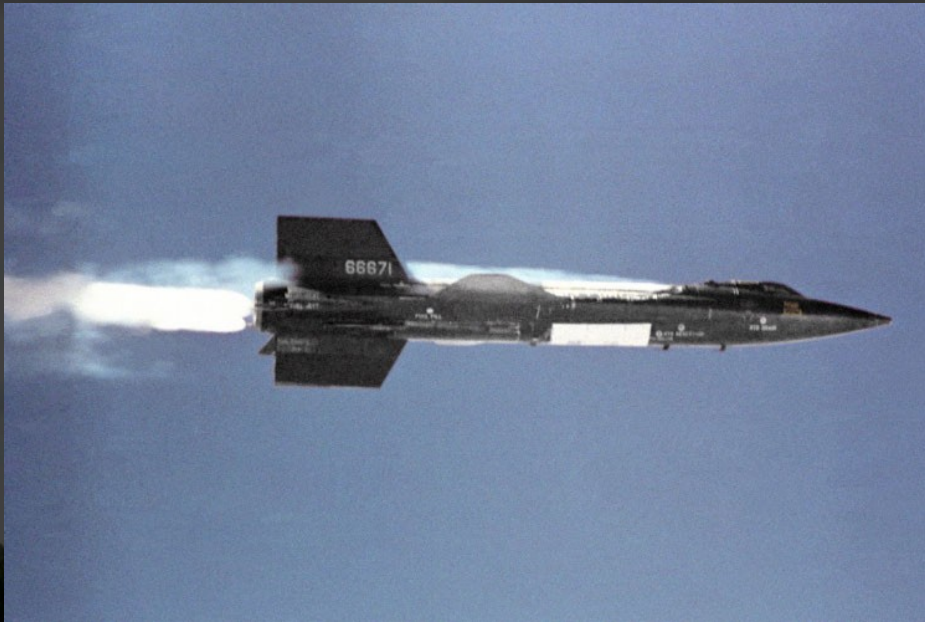
- However, we can supply you with LOX/
NH₃ if you must have
rocket science



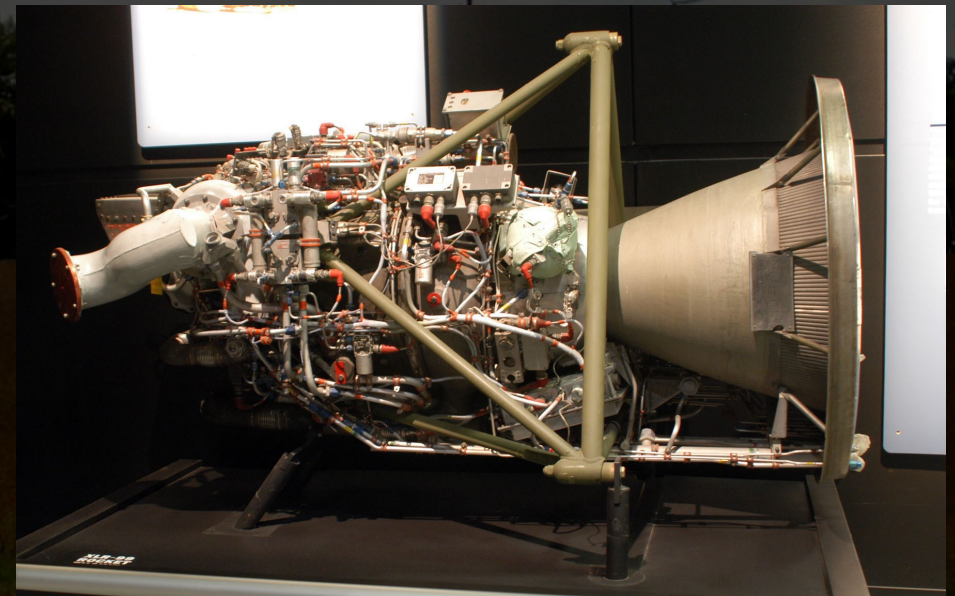
[1] http://en.wikipedia.org/wiki/Reaction_Motors_XLR99

[2] http://en.wikipedia.org/wiki/North_American_X-15

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- Financing the first \$100 million for a wind to ammonia plant is harder

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Questions?

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