

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

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 ton
- Energy: Megawatt-hours, MegaJoules, mmBTU
 - MWH: 1000 Kilowatt-hours, 3600 MJ, 3.4 mmbtu

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***

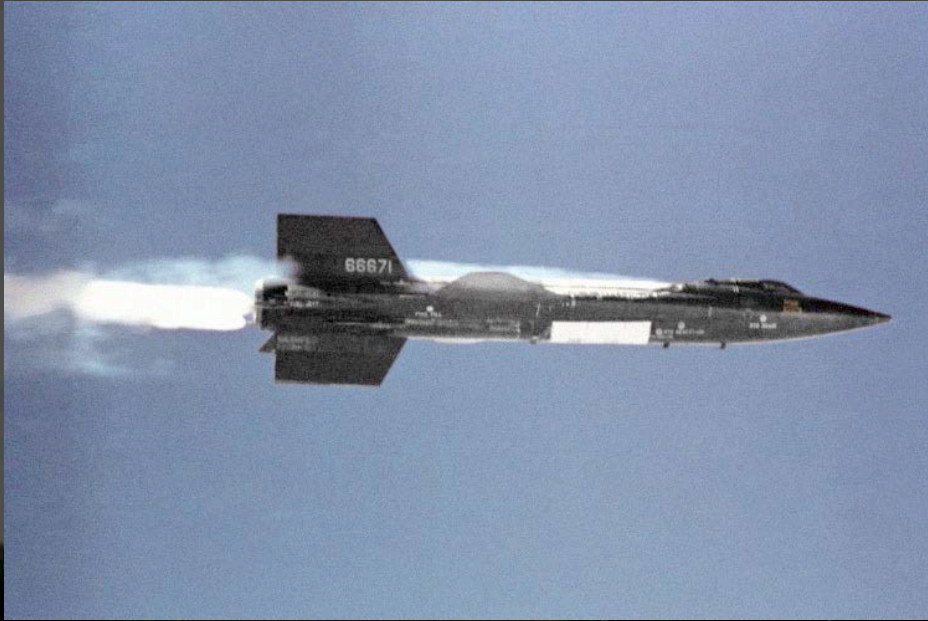
Let's add this up..

- 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

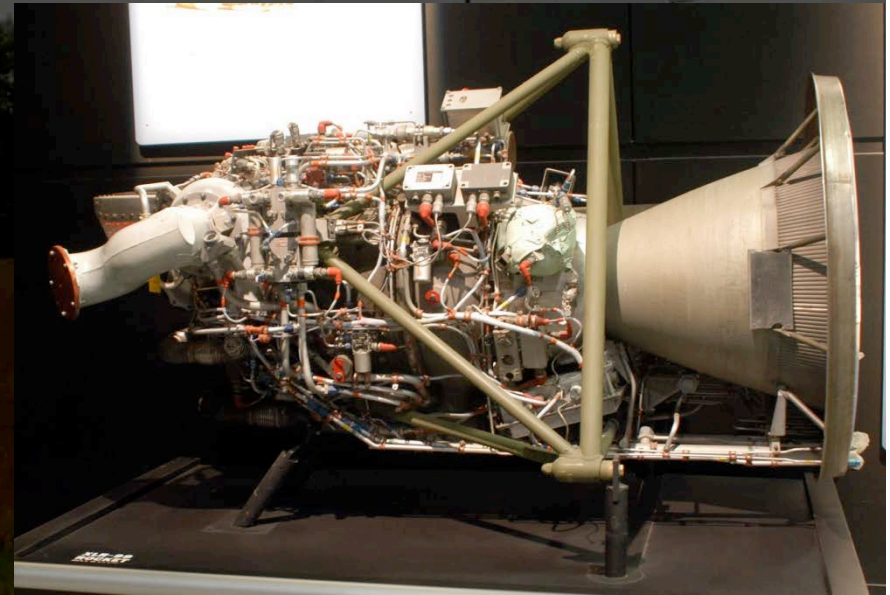
Back to fertilizer: 20GW by 2020

- 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



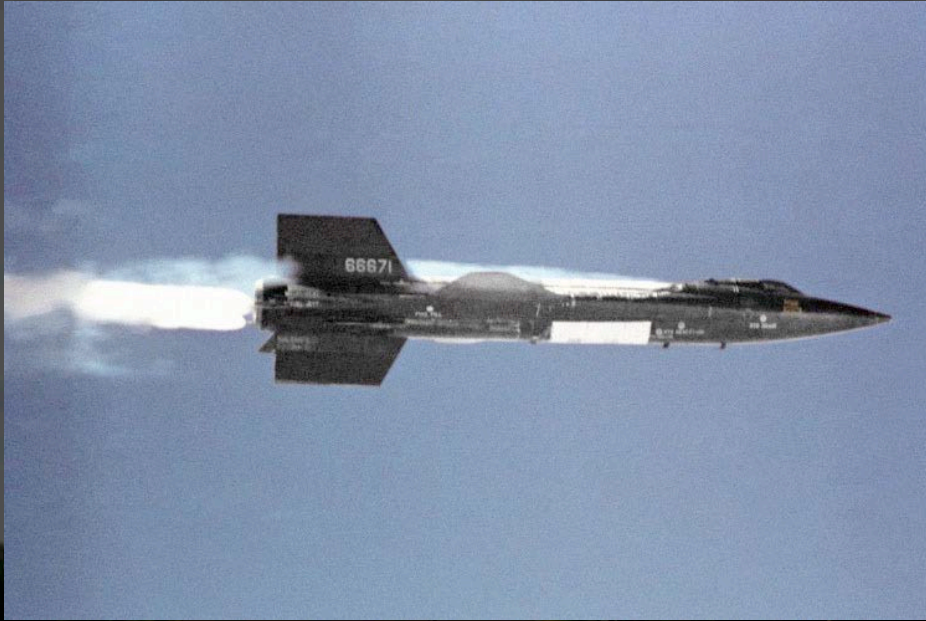
- However, we can supply you with LOX/NH₃ if you must have rocket science



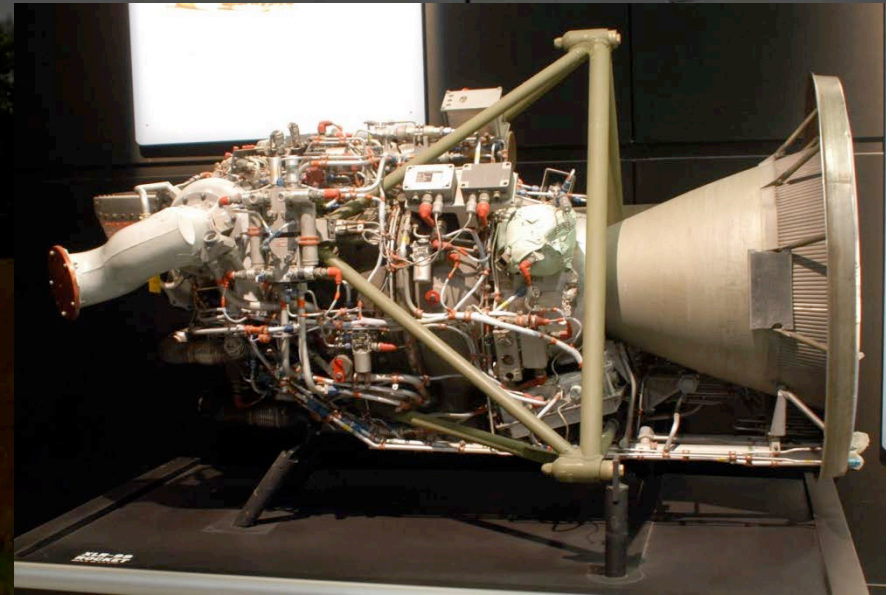
[1] http://en.wikipedia.org/wiki/Reaction_Motors_XLR99

[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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