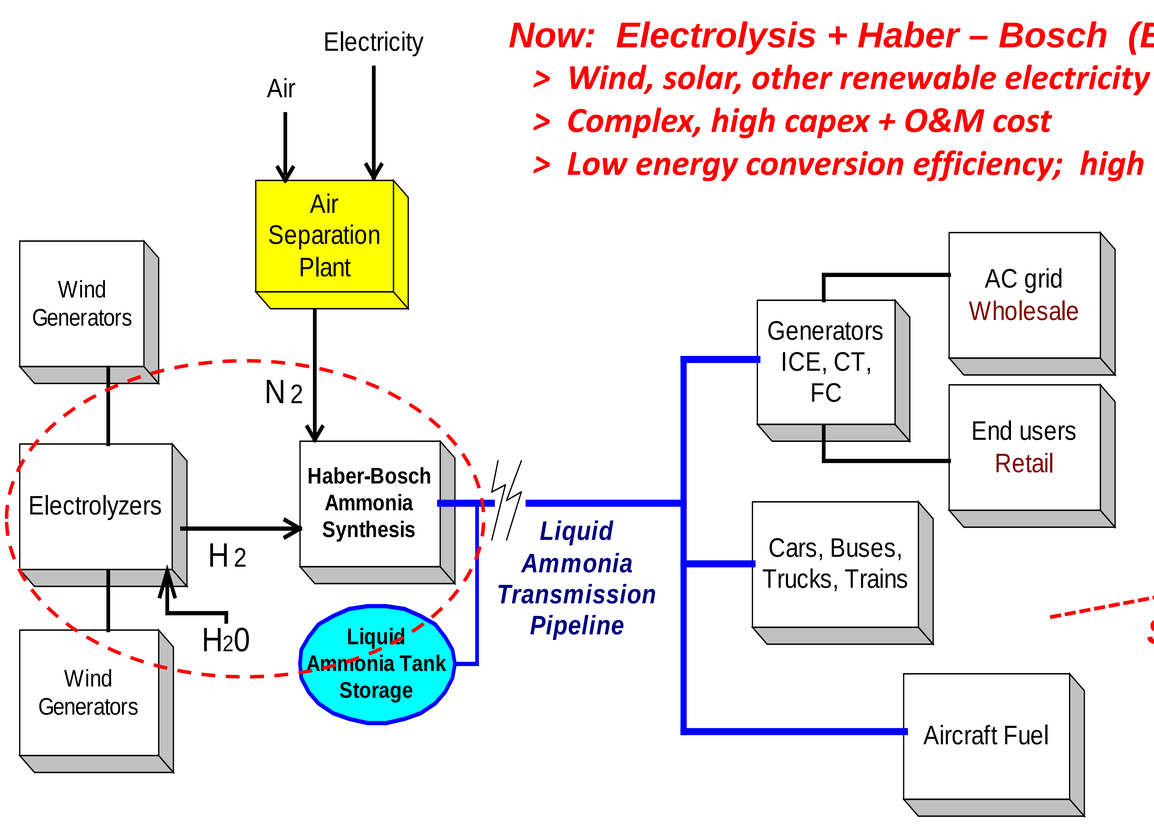
Ammonia Renewable Energy Systems at Continental Scale: Alternative to Electricity for Transmission, Storage, and Integration for Deep Decarbonization of World's Largest Industry

Ammonia's Role As a Low-Cost Energy Carrier and Storage Medium in Integrated, Optimized, Systems for Total Global Energy Supply

Bill Leighty, Director — The Leighty Foundation — Juneau, AK USA
wleighty@earthlink.net — www.leightyfoundation.org/earth.php

- **Shall we try to urgently and deeply decarbonize humanity's total global energy system via "renewable" electricity systems alone, i.e. via "The Grid" ?**
  That's possible, but may be technically and economically suboptimal. Investing in "Smart Grid" and transport electrification via only BEV's may be shortsighted.
- **We should now carefully consider alternatives to the Grid, based on Carbon-free Hydrogen and Ammonia fuels, as complete CO2-emission-free energy systems.**
  - **> All energy, from all sources, for all human purposes**
  - **> Continental scale: transmission at lower cost per GW-km than via Grid**
  - **> R&D and Demonstration projects are required: investment risk**
  - **> Only two Carbon-free fuels: ICE, CT, Fuel Cell operate well on H_2 and NH_3**
  - **> Via underground pipelines: gathering, transmission, and distribution**
  - **> Global trade in "green" NH_3 via commodity tanker ships**
  - **> Low-cost storage: Capex per kWh = $ 0.10 – 0.20 Future batteries $ 100 ?**
  - **> Transport and CHP fuel: Use byproduct heat = high delivery efficiency**



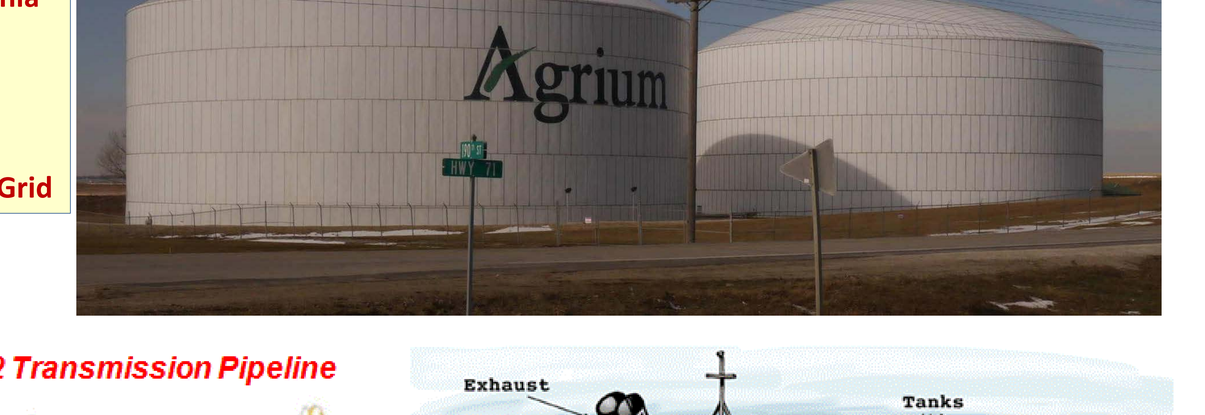
Now: Electrolysis + Haber – Bosch (EHB)

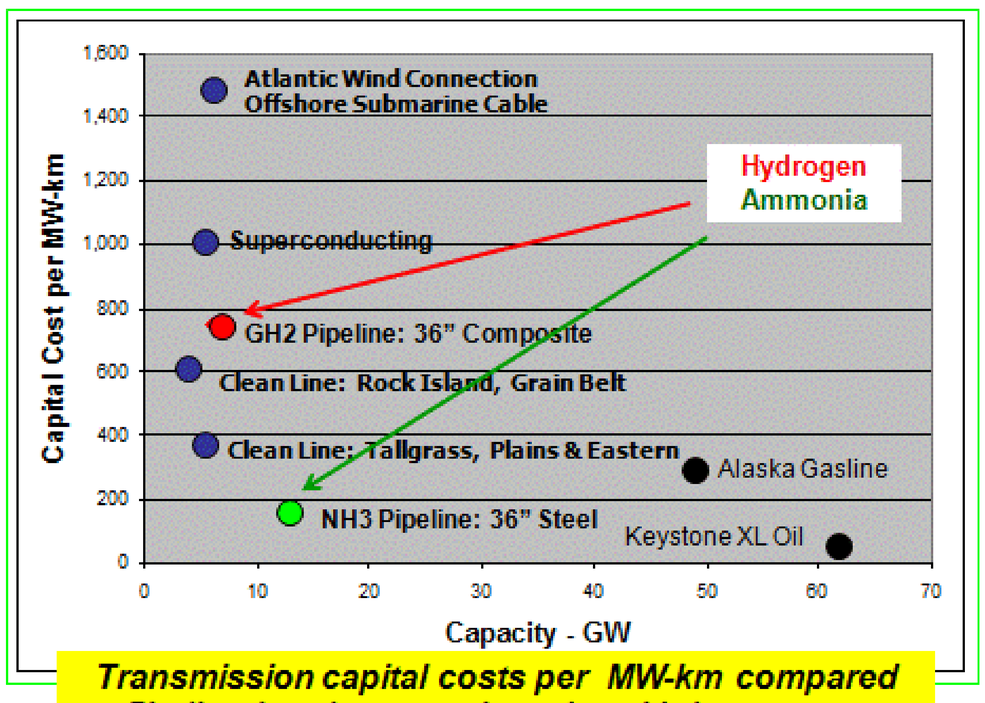
- ***> Wind, solar, other renewable electricity***
- ***> Complex, high capex + O&M cost***
- ***> Low energy conversion efficiency; high T and P***

Simplify

Novel Ammonia Synthesis: ARPA-E "REFUEL" R&D

- ***> Eliminate electrolyzer and Haber-Bosch reactor***
- ***> NH3 synthesis directly from electricity, water, air***
- ***> Lower capex + O&M costs, higher efficiency***
- ***> Four USDOE-funded projects***

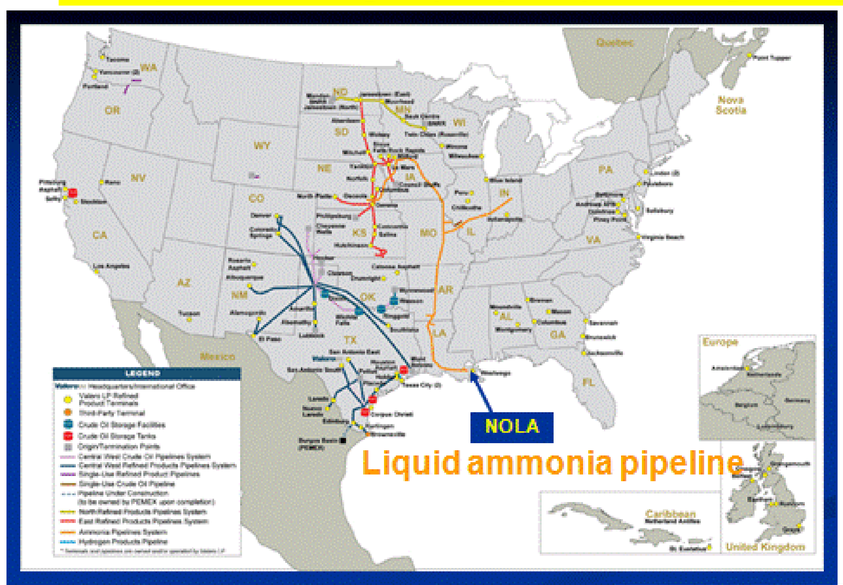


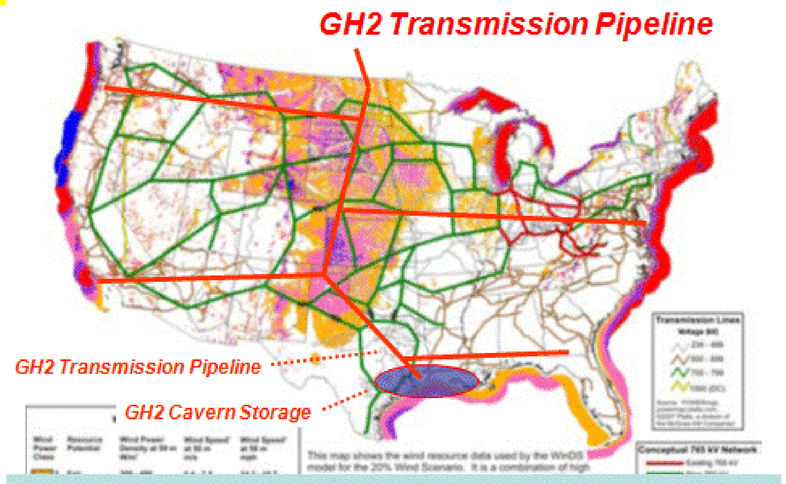


Transmission capital costs per MW-km compared
Pipelines have large capacity and provide large storage

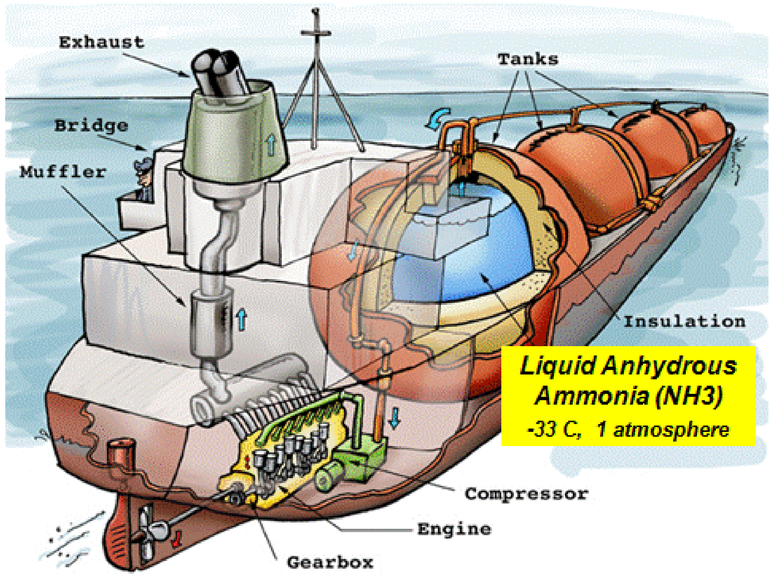
Energy transmission and storage, as Gaseous Hydrogen (GH2) and liquid Anhydrous Ammonia (NH_3), via underground pipelines, costs less than as electricity via the Grid

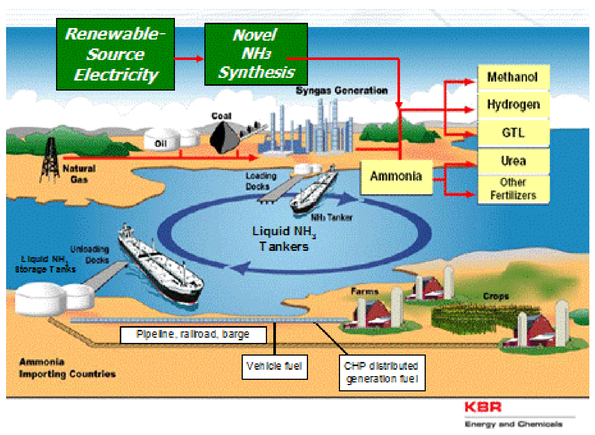
"Atmospheric" Liquid Ammonia Storage Tank (Corn Belt)
-33 C, 1 Atm Each: 30,000 Tons NH_3 = 190,000 MWh
$ 15 M turnkey = $ 80 / MWh = $ 0.08 / kWh capex

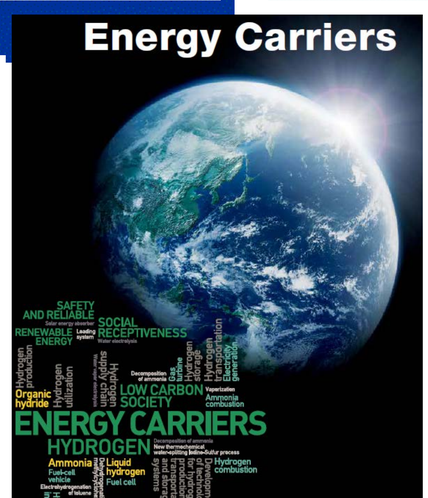




Wind Potential ~ 10,000 GW
12 Great Plains states







3,000 miles of Ammonia pipelines, in-place today, could be expanded to continental scale, to supply all USA energy from CO2-emission-free Great Plains wind and solar, as transportation and combined-heat-and-power (CHP) fuels. A new Gaseous Hydrogen (GH2) pipeline network may be competitive, with low-cost salt cavern energy storage. Tanker loads of "green" liquid Ammonia could be exported from New Orleans and other ports.

Japan wants to import tanker ship loads of Hydrogen-rich liquids made from CO2-emission-free processes, as "Energy Carriers". Their candidates are liquid Hydrogen (LH2; Kawasaki), Anhydrous Ammonia (NH_3; Sumitomo), and organic hydrides (toluene – methylcyclohexane cycle; Chiyoda). NH_3 trade is established. (Japan Science and Technology Agency, Strategic Innovation Promotion Program)