Biogas as a Source of Renewable Ammonia

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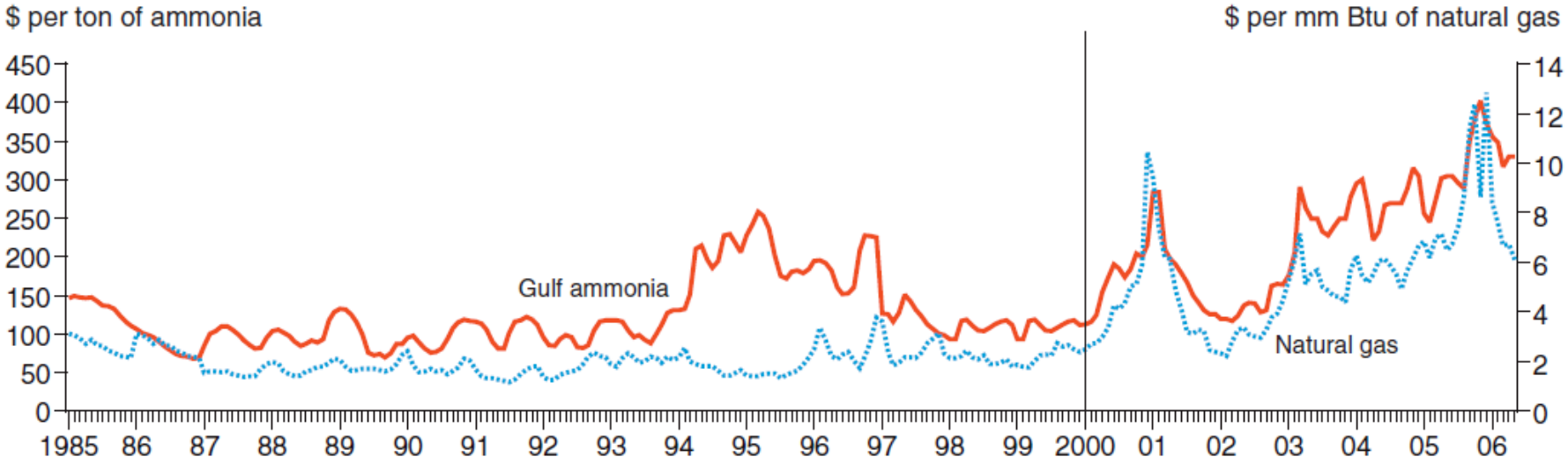
Anhydrous Ammonia

- Essential to corn farming
  - Apply 200 pounds per acre as nitrogen
- Uncontrolled variable cost
  - $252,000 for anhydrous ammonia (AA) at high point in cycle
  - $72,000 for AA at low point in cycle
- Controlled variable cost option
  - Do-it-yourself ammonia plant capable of producing up to 220,000 pounds AA per year
    - ~625 pounds per day

Cyclical Ammonia Costs

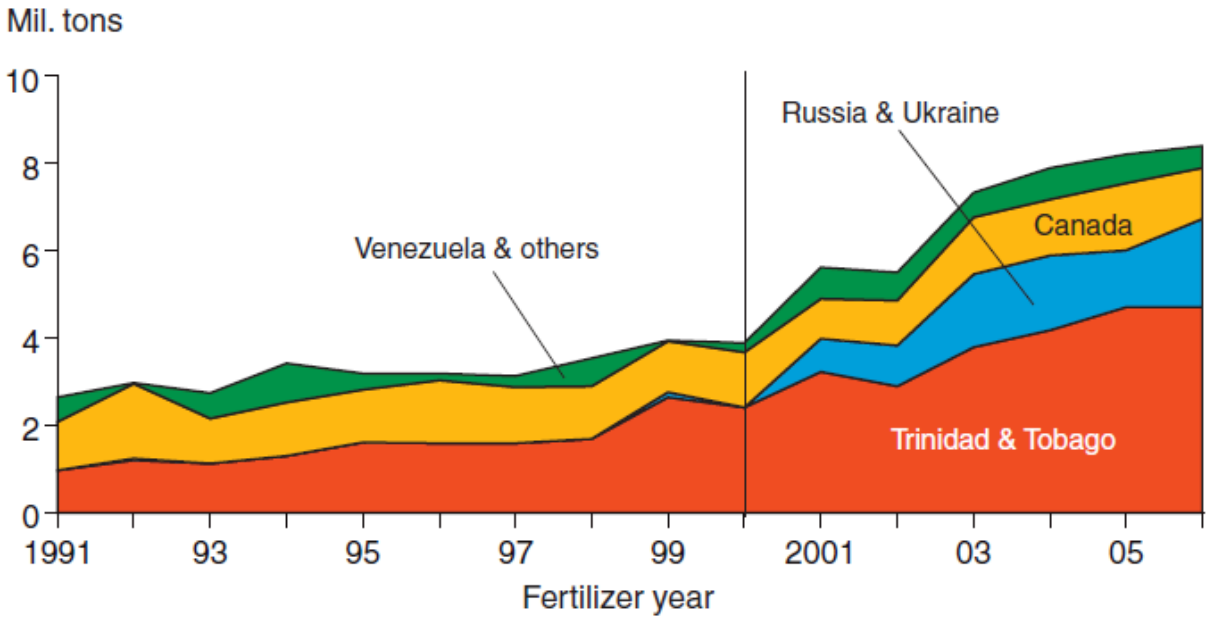
- The cost of ammonia is closely coupled to that of natural gas.
- Above $500 per ton, natural gas cost is >90% the cost of ammonia.



Source: USDA, Economic Research Service using data from TFI (b).

Fertilizer and Food Security

AA Imports to the United States

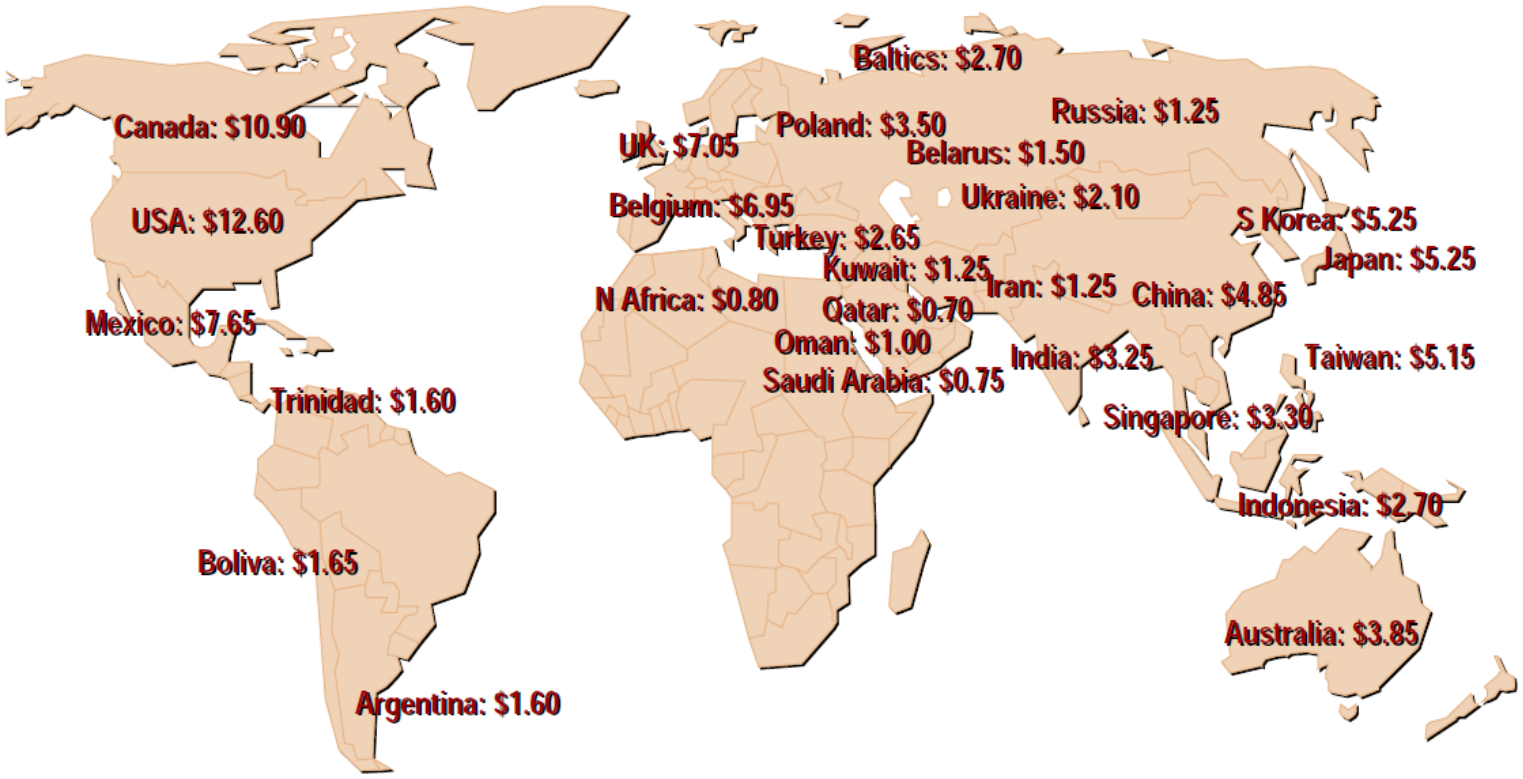


Note: Fertilizer year runs from July of the preceding year to June of the year indicated in the chart.

Source: USDA, Economic Research Service (d).

- U.S. production in 2009: 10.33 million tons
  - Source: U.S. Economic Census

Fertilizer and Food Security



- Regional natural gas costs (2005, US$/MMBtu)
  - Source: American Chemistry Council

Political Background

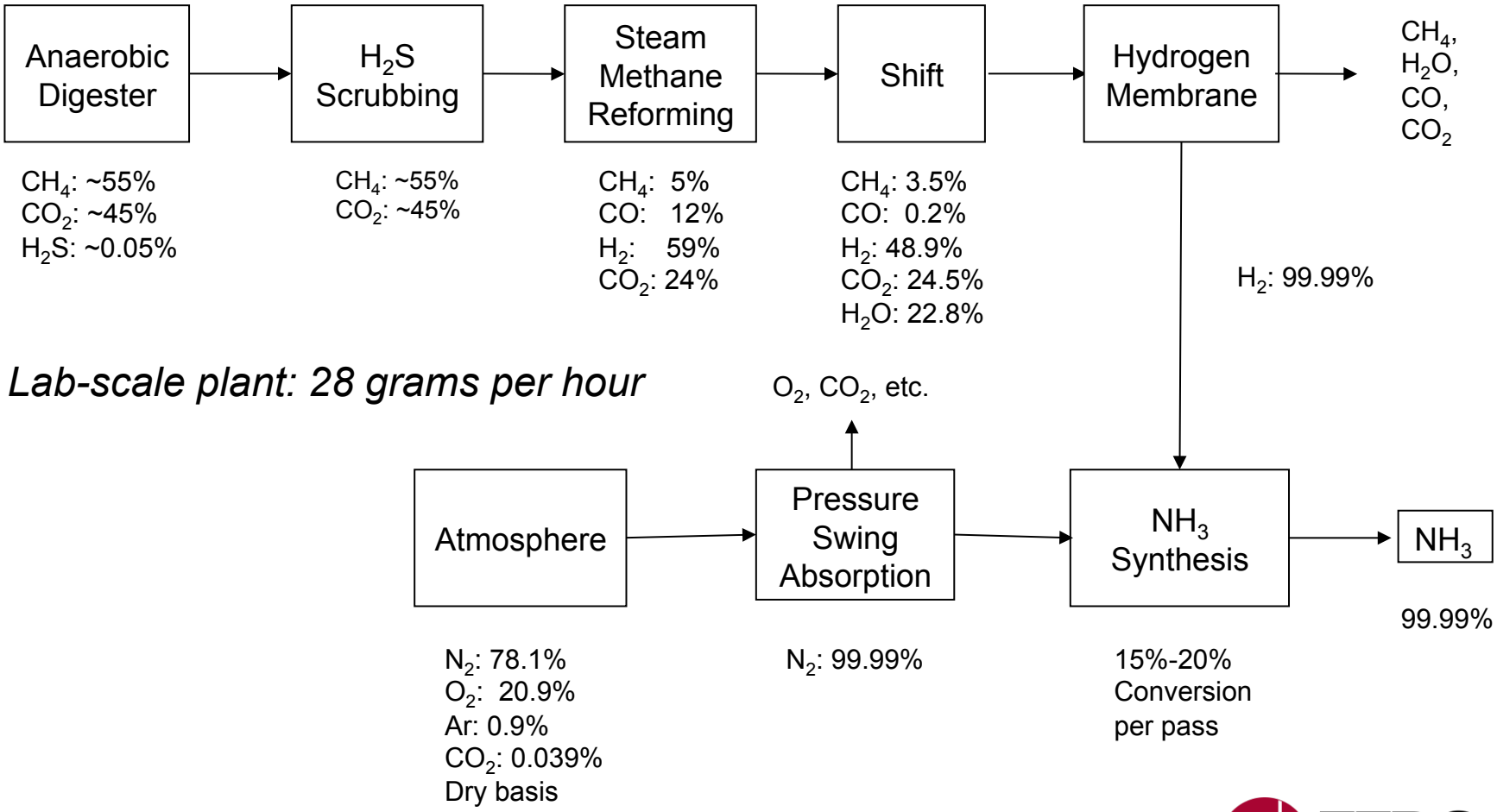
- Industry consolidation
  - CF industries
  - Agrium

- Chemical Facility Anti-Terrorism Act of 2009 (H.R. 2868)
  - Passed House, November 6, 2009.
  - Allows Department of Homeland Security (DHS) to regulate chemical facilities.
  - Mandates use of “inherently safer technology.”
    - Urea in place of ammonia
    - Prohibit transportation of ammonia

Our Project Philosophy

- Break natural gas dependency on ammonia production
- Utilize renewable feedstocks with low or negative costs
- Develop distributed-scale production technology
- Find a fast path forward
- Demonstrate renewable ammonia production
- Engineer renewable ammonia production on a variety of scales:
  - 1000-acre corn/bean/wheat farm
  - 2000-acre corn/bean/wheat farm
    - 26 pph NH_3 production
  - 10,000-acre corn/bean/wheat farm
- Stable cost of production

Block Flow Diagram



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Strategy

- Construct, commission, and operate from back of plant to front of plant
  - Ammonia synthesis loop (ASL) is first unit to be operational.
  - Methane reforming is last unit to be operational.
  - Operate off bottled gas as units are brought up.
    - Simulate feed gas from front-end units via purchase of custom blended gases.
- Achieve operational simplicity

Future Directions

- Assess energy requirements
  - Electrical
  - Fuel
- Hybrid systems
  - Fuel cell options
    - Ammonia synthesis
    - Methane reforming
- Landfill Gas (407 trillion BTU, 2006)
- Catalyst development

Acknowledgment of Partners

JM
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