

Ken-ichi Aika, Tokyo Institute of Technology

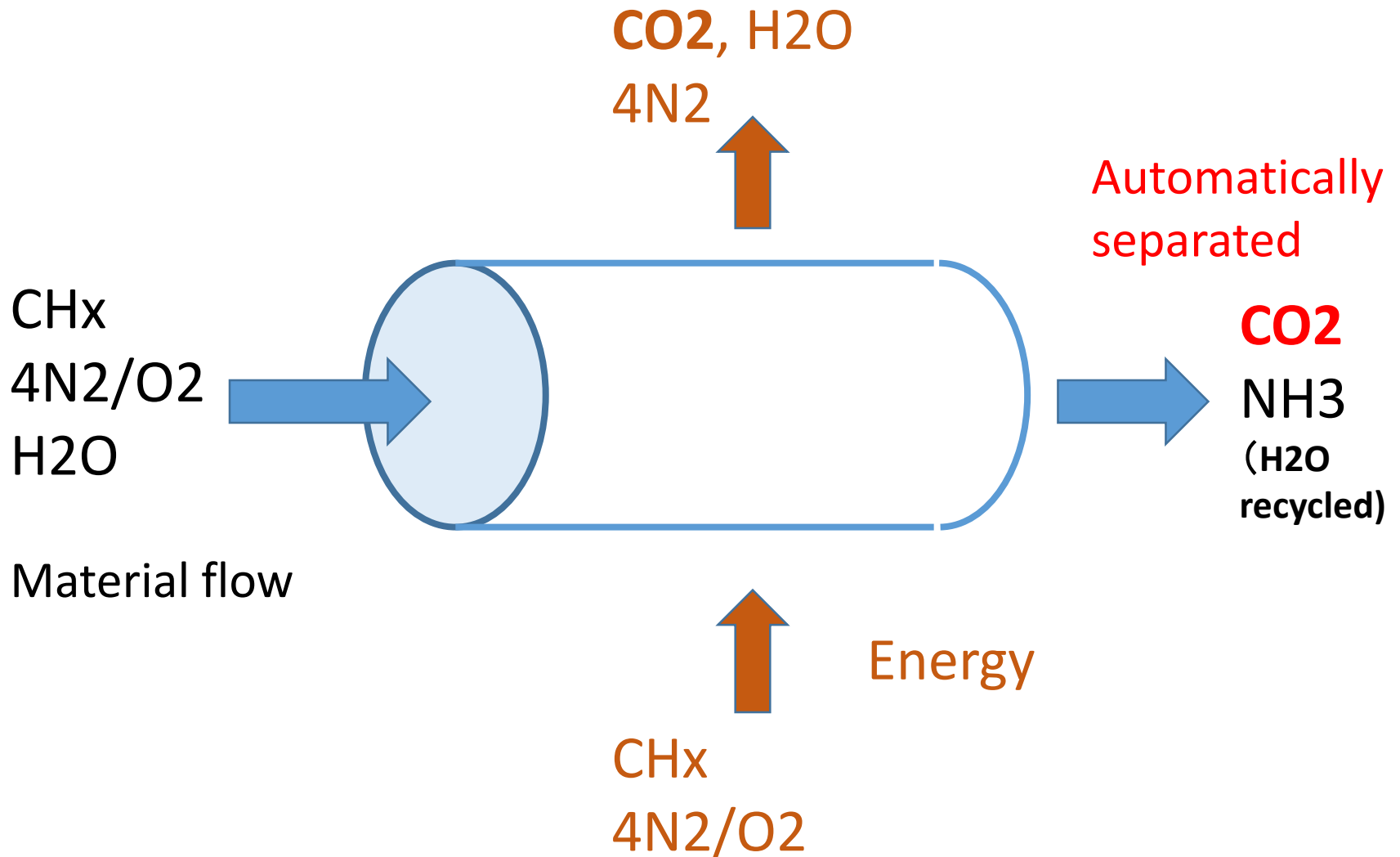
Japan needs inexpensive CO₂ free NH₃ from abroad

1. Present NH₃ production (but with EOR or CCS)
2. NH₃ partly mixed with renewable energy source

H. Anderson, Norsk Hydro, World Hydrogen Energy Conference, Montreal, 2002

- **Central** H₂ and **NH₃ production** seem to be the most efficient way to produce **CO₂-free energy carriers**.
- **NH₃ infrastructure development is easier** because truck transport is possible, supply and demand will be in balance through time.
- **On-site** natural gas reforming and methanol steam reforming have **highest CO₂ emissions**.

Process CO₂ and Dispersed CO₂ in NH₃ process



Andrew McFarlan, Canmet ENERGY, 9th Annual NH3 Fuel Conference, San Antonio, TX, 121001

- NH3 production from NG or coal produces pure CO2 byproduct which lowers cost of large scale CCS, and can be used for enhanced recovery of oil or coal-bed methane.
- **NH3 from coal with CCS practiced commercially in Beulah N. Dakota since 2000.**

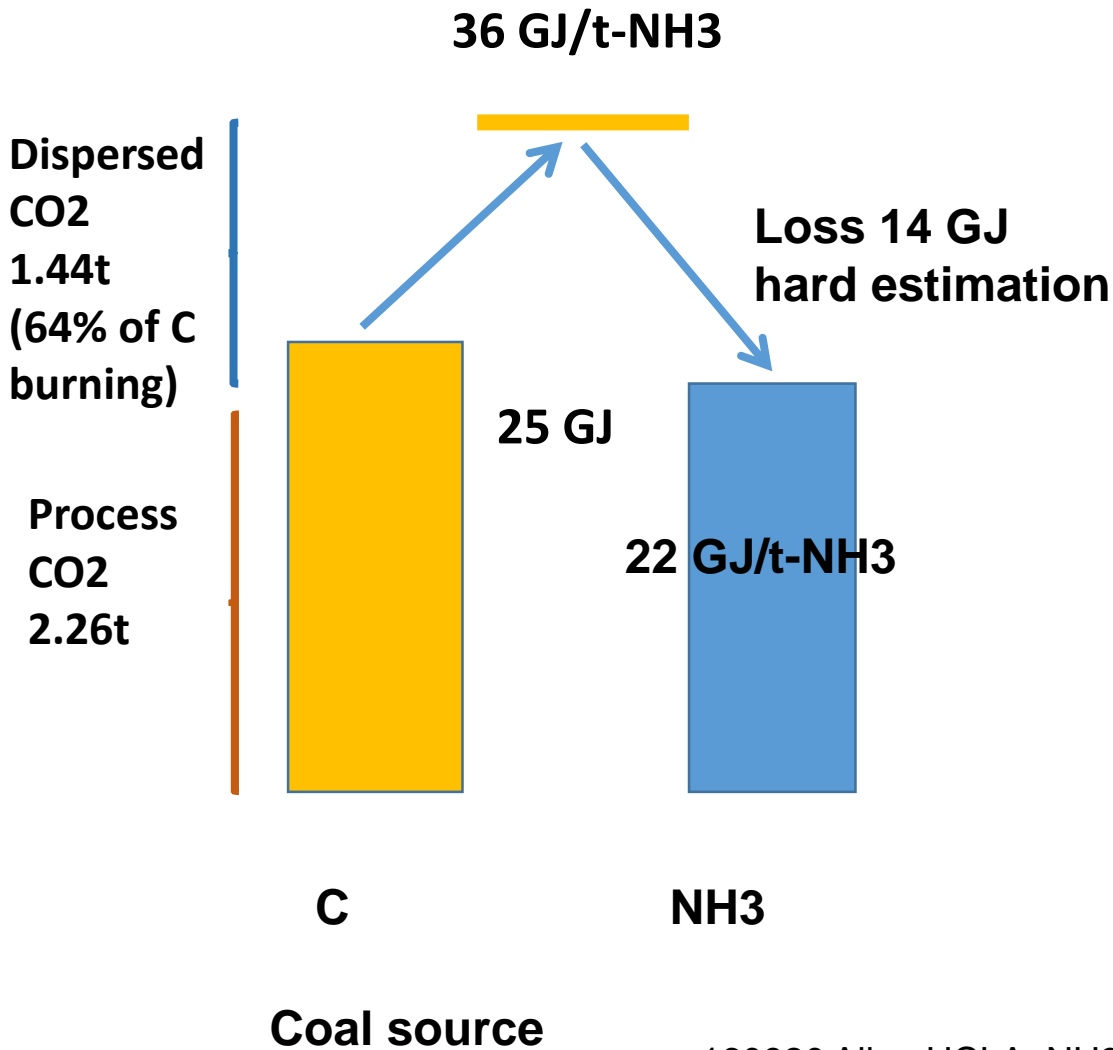
1,150 stpd ammonia; **process CO2 emissions: 2604 stpd (2.26t-CO2 per t-NH3)**

- The plant also captures about 8,000 mtpd CO2, which it pipes 205 miles to Saskatchewan for EOR in the Weyburn and Midale oil fields, the “largest CCS project in the world.” <https://ammoniaindustry.com/beulah-nd-dakota-gas/>

NH₃ synthesis from coal (Air as 4N₂+O₂)

- $C + 2H_2O(l) \rightarrow CO_2 + 2H_2$ $\Delta H = 178.1 \text{ kJ}$ (endothermic)
 - $C + O_2 + 4N_2 \rightarrow CO_2 + 4N_2$ $\Delta H = -393.5 \text{ kJ}$ (exothermic)
 - $N_2 + 3H_2 \rightarrow 2NH_3$ $\Delta H = -92.2 \text{ kJ}$ (exothermic)
 - **3 eqs. are added**
 - **$\frac{7}{8} C + \frac{3}{2} H_2O + \frac{1}{8} O_2 + \frac{1}{2} N_2 \rightarrow \frac{7}{8} CO_2 + NH_3$**
 - **$\Delta H = 38.3 \text{ kJ}$ (endothermic)**
- $\frac{7}{8} CO_2$; process CO_2 ; 2.26t-CO₂ per t-NH₃**
- **38.3kJ (endothermic)**; 10.0% of NH₃ combustion heat (**382.6 kJ**); if compensated with coal combustion; **theoretical energy** of NH₃ synthesis from coal; **24.76 GJ/tonNH₃**

NH₃ from coal; Energy diagram



No NH3 can be complete CO2 free;
LCA is important

Future NH3 is (I hope) labelled when
shipped, even if mixed.

Labelled carbon foot print and cost are
the sales point.



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