SUSTAINABLE PRODUCTION OF AMMONIA

Washkewicz College of Engineering

Ana DiLillo, Brian Chaya, and Jamil Jamal
Advisor: Dr. Marvin Thrash
Department of Chemical and Biomedical Engineering, Cleveland State University, Cleveland, Ohio

AIChE The Global Home of Chemical Engineers

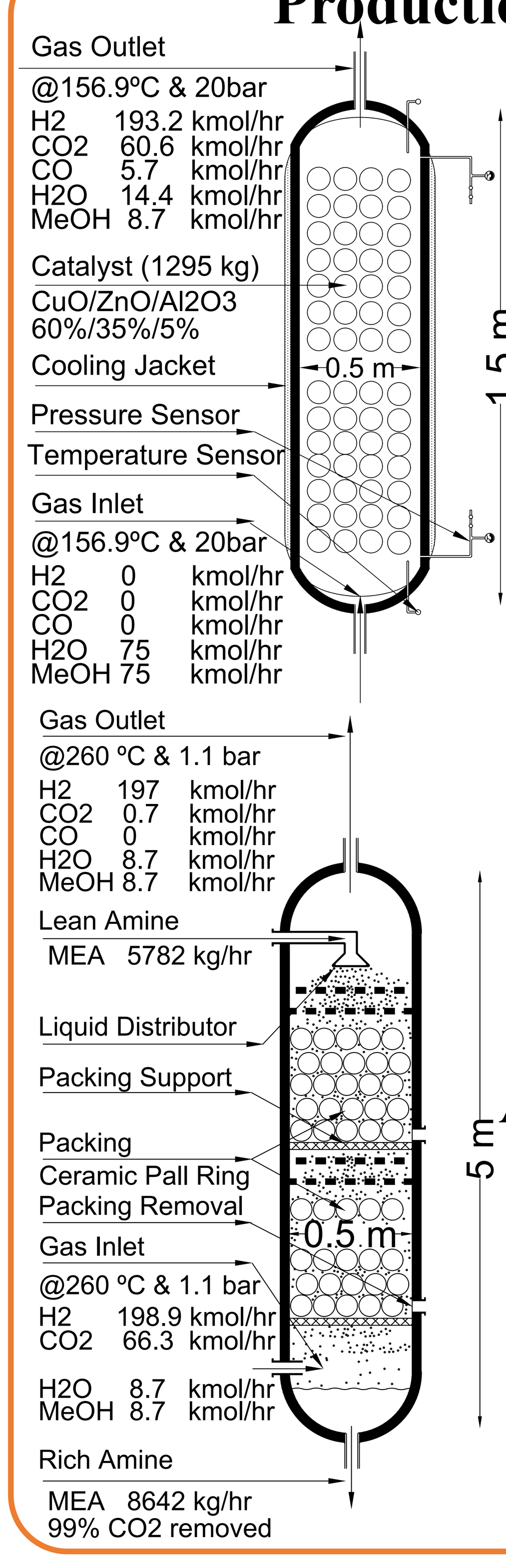
Introduction

Ammonia is used as fertilizer in agriculture when injected into the soil. This has allowed for an immense increase in food production since the development of the Haber-Bosch process in 1910. However, the Haber-Bosh process, still used today, relies on fossil fuels and emits massive amounts of carbon emissions. It has become a major topic of research to develop a sustainable alternative with competitive production rates.

Objective

1. Develop a modular process
2. Reduce pressure demands
3. Eliminate fossil fuels
4. Utilize sustainable wind energy
5. Produce 50 Metric tonnes of ammonia per day with a purity of 99.8%

Production of Hydrogen



Reformers (Produce hydrogen)

1. Steam Methanol Reforming

$$CH_3OH + H_2O \rightleftharpoons 3H_2 + CO_2$$

2. Decomposition of Methanol

$$CH_3OH \rightleftharpoons 2H_2 + CO$$

3. Catalyst Type (Copper-based)

$$CuO/ZnO/Al_2O_3$$

(high selectivity to carbon dioxide)

Water Shift Reactor

(reduce Carbon monoxide)

1. Reaction:

$$CO + H_2O \rightleftharpoons H_2 + CO_2$$

2. Catalyst Type: (Iron-based)

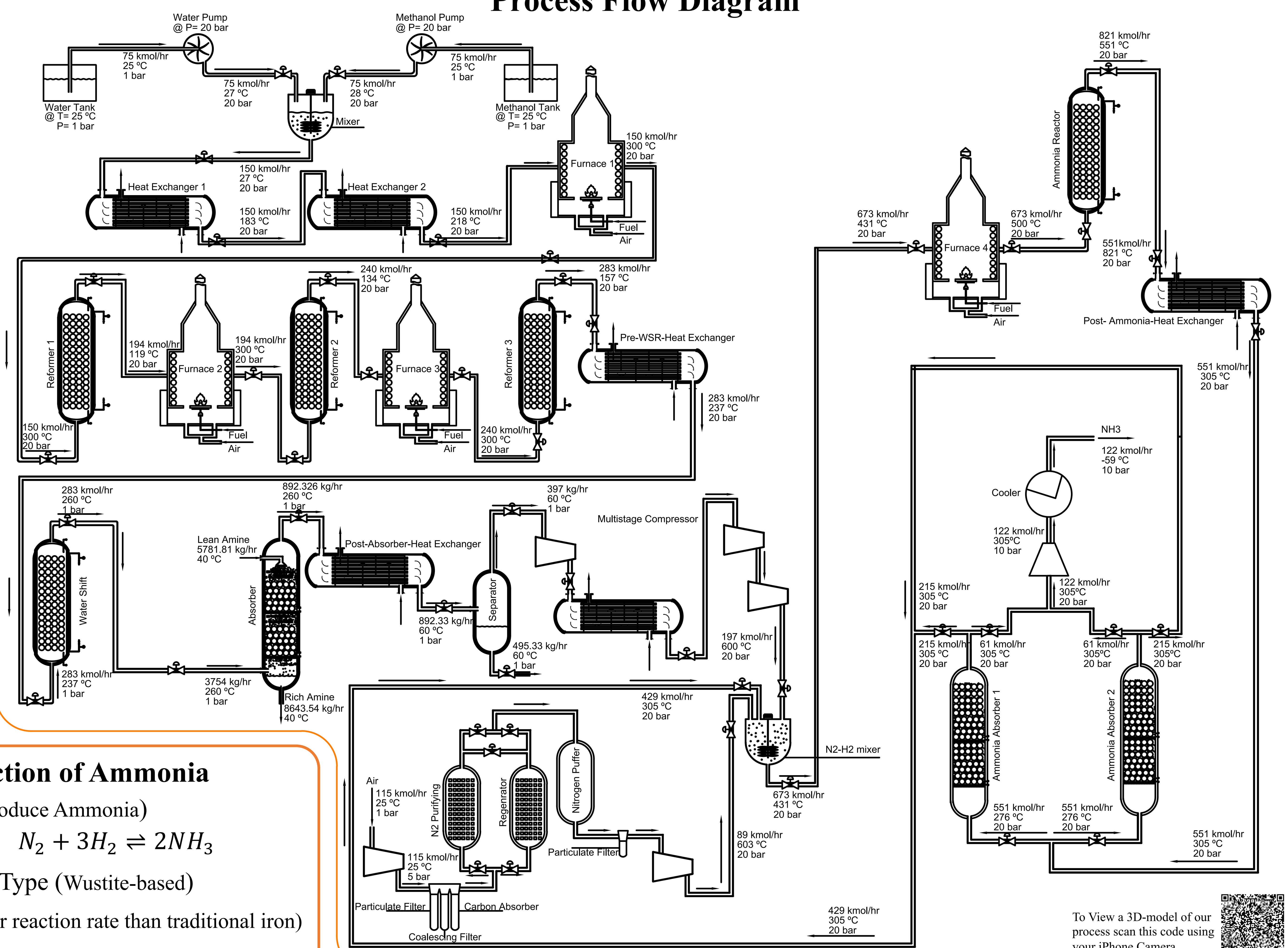
$$Fe_2O_3Cr_2O_3$$

(Increase forward reaction rate)

Absorber (Absorb Carbon dioxide)

1. Lean Amine: (Acid-Gas removal)
   Monoethanolamine
   (high gas absorption and reactivity)
2. Packing Material:
   Ceramic Pall Ring
   (large contact area)

Process Flow Diagram



Production of Nitrogen

- **Compressor** (Compresses air)
- **Pressure swing adsorber** (Separate Nitrogen from air)
  1. Packing Material
     Carbon molecular Sieve
     (High affinity to adsorb oxygen from air)
  2. Description
     - ✓ Two pressure swing adsorption vessels
     - ✓ PSA operates in a cyclic manner
     - ✓ The Second column is regenerating.
     - ✓ One column will be producing high purity nitrogen

Equipment Specifications	
Specification	**Scale up Model**
Purity	99.5%
Diameter (m)	1.4
Height (m)	6
Bed Usage	70%

For more information on this section scan this code using your iPhone Camera

Production of Ammonia

- **Reactor** (Produce Ammonia)
  1. Reaction $N_2 + 3H_2 \rightleftharpoons 2NH_3$
  2. Catalyst Type (Wustite-based)
  (30–90% higher reaction rate than traditional iron)

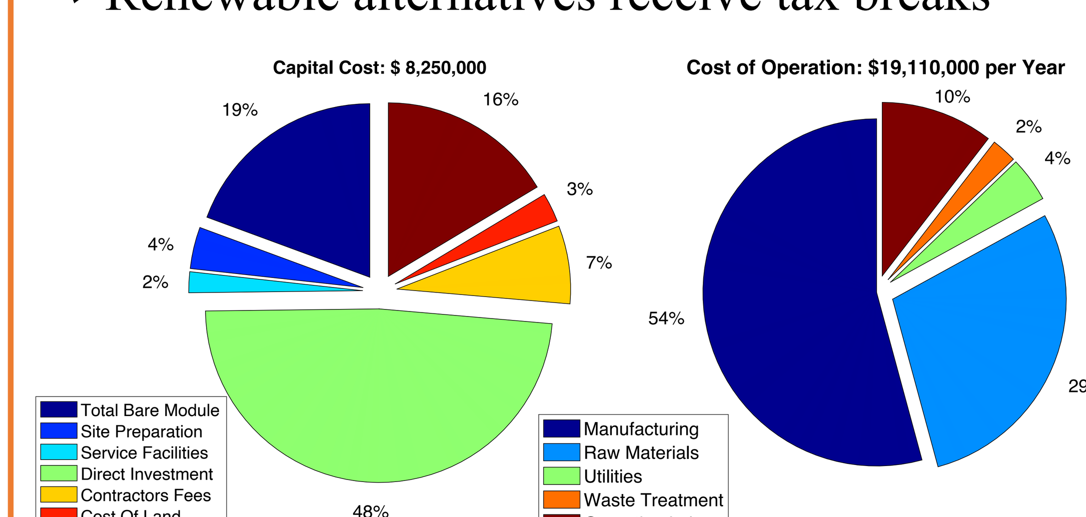
Ammonia Reactor		
Volume	2.6	m^3
Length	3	m
Diameter	1.5	m
Pressure	20	bar
Catalyst Weight	8000	kg
Ammonia Produced	122	kmol/hr

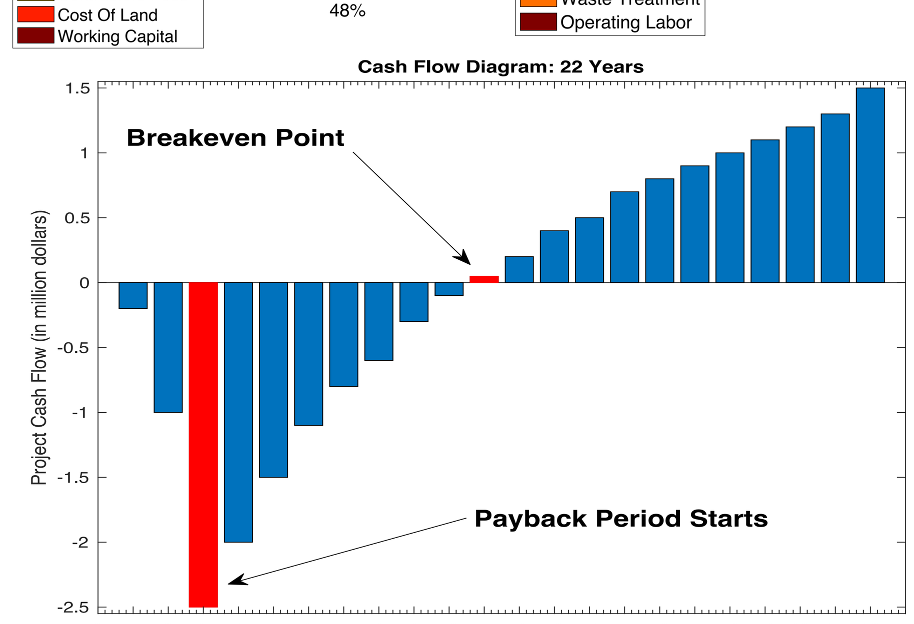
- **Absorption Beds** (Absorbs Ammonia)
  1. Two absorptions beds alternating cycle
     - ✓ Absorbing ammonia on magnesium chloride silica substrate while recycling extra reactants
     - ✓ Regenerating–Vacuum Swing Adsorption
  2. Packing Material:
     Magnesium Chloride
     (High affinity to absorb ammonia)

For more information on this section scan this code using your iPhone Camera

Economic Analysis

- ✓Heat integration allows for utility savings
- ✓Low pressure system utilizes wind energy
- ✓Renewable alternatives receive tax breaks

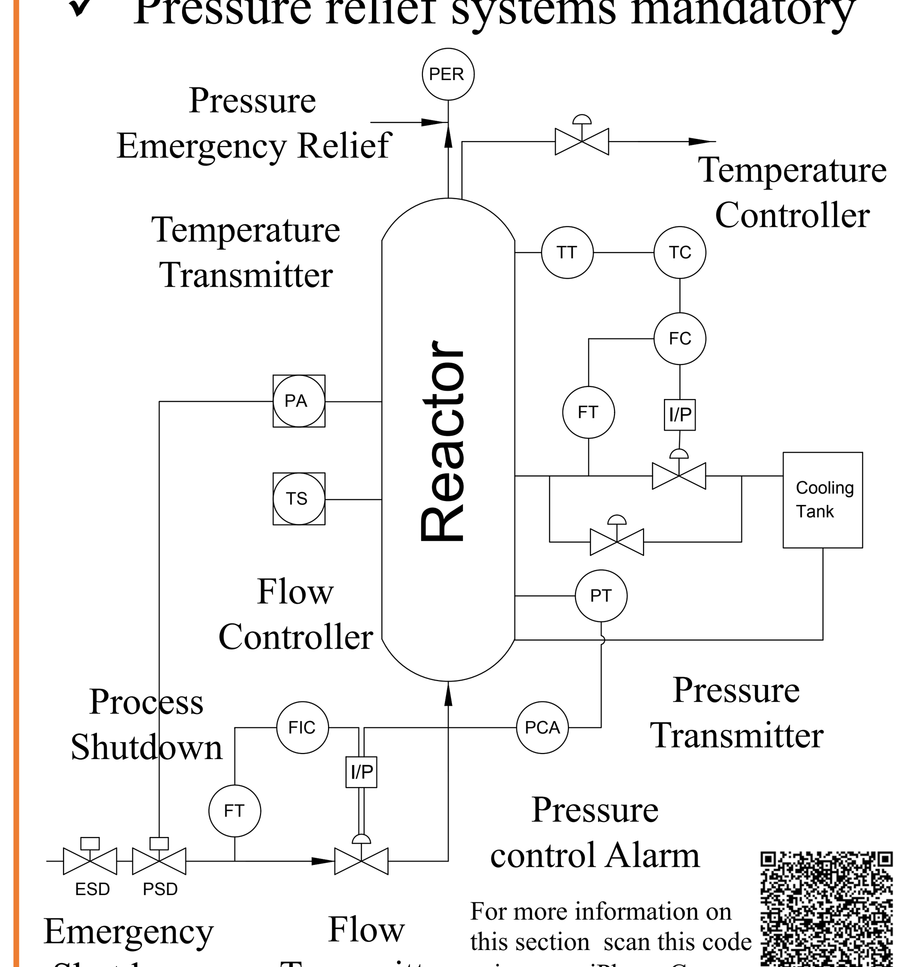




For more information on this section scan this code using your iPhone Camera

Controls & Safety

- ✓ Highly combustible/toxic chemicals
- ✓ High temperature reactors
- ✓ Exothermic reactors must be monitored to eliminate runaway
- ✓ Pressure relief systems mandatory



For more information on this section scan this code using your iPhone Camera

Conclusion & Recommendations

A modular, more sustainable process was developed by dropping pressure demands and utilizing new technology. Carbon emission to ammonia ratio was reduced from the 2.86:1 of the Haber-Bosch process to 0.245:1. 50 Metric tonnes per day of ammonia was produced with 99.8% purity. This plant would be ideal in West Minnesota because the reduced pressure demands allow for the utilization of sustainable wind energy.

Acknowledgments

Appreciation is expressed to the Chemical & Biomedical Engineering Department Faculty and the American Institute of Chemical Engineers

For more information on this section scan this code using your iPhone Camera