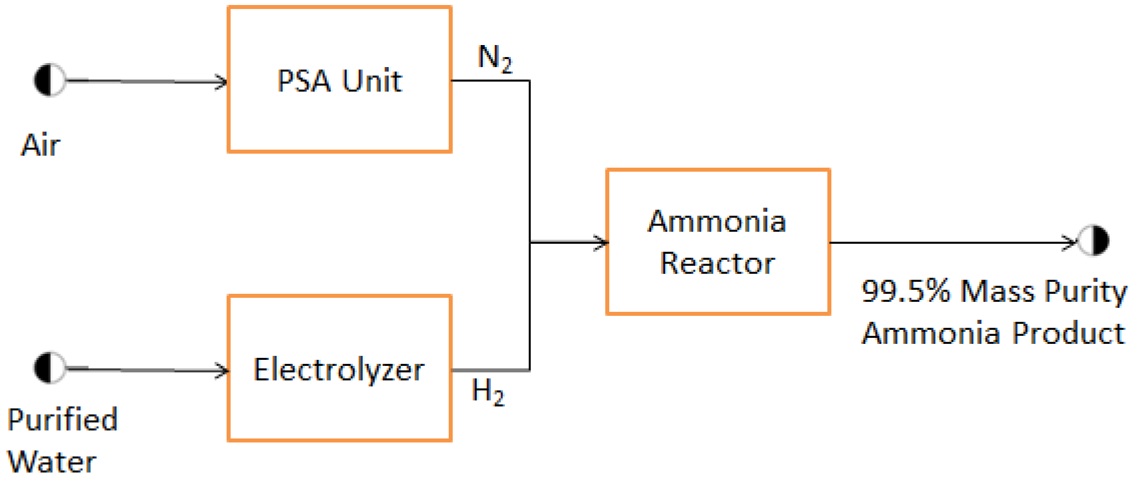
AIChE Design Presentation

Zech Walker

The Process

- Sustainable production of anhydrous ammonia
  - On-site production of N_2 and H_2 with renewable energy sources
    - N_2 produced via pressure swing adsorption
    - H_2 produced through electrolysis
  - Haber-Bosch synthesis of ammonia



The Design

- 50 metric tons per day of commercial-grade, 99.5% mass purity, anhydrous ammonia
  - Small relative plant size
    - Loss of scale
    - Modular Numbering-up approach

- A greener approach in electrolysis
  - Methane reformation typical
  - Contract local wind energy providers

Discussion of Major Equipment

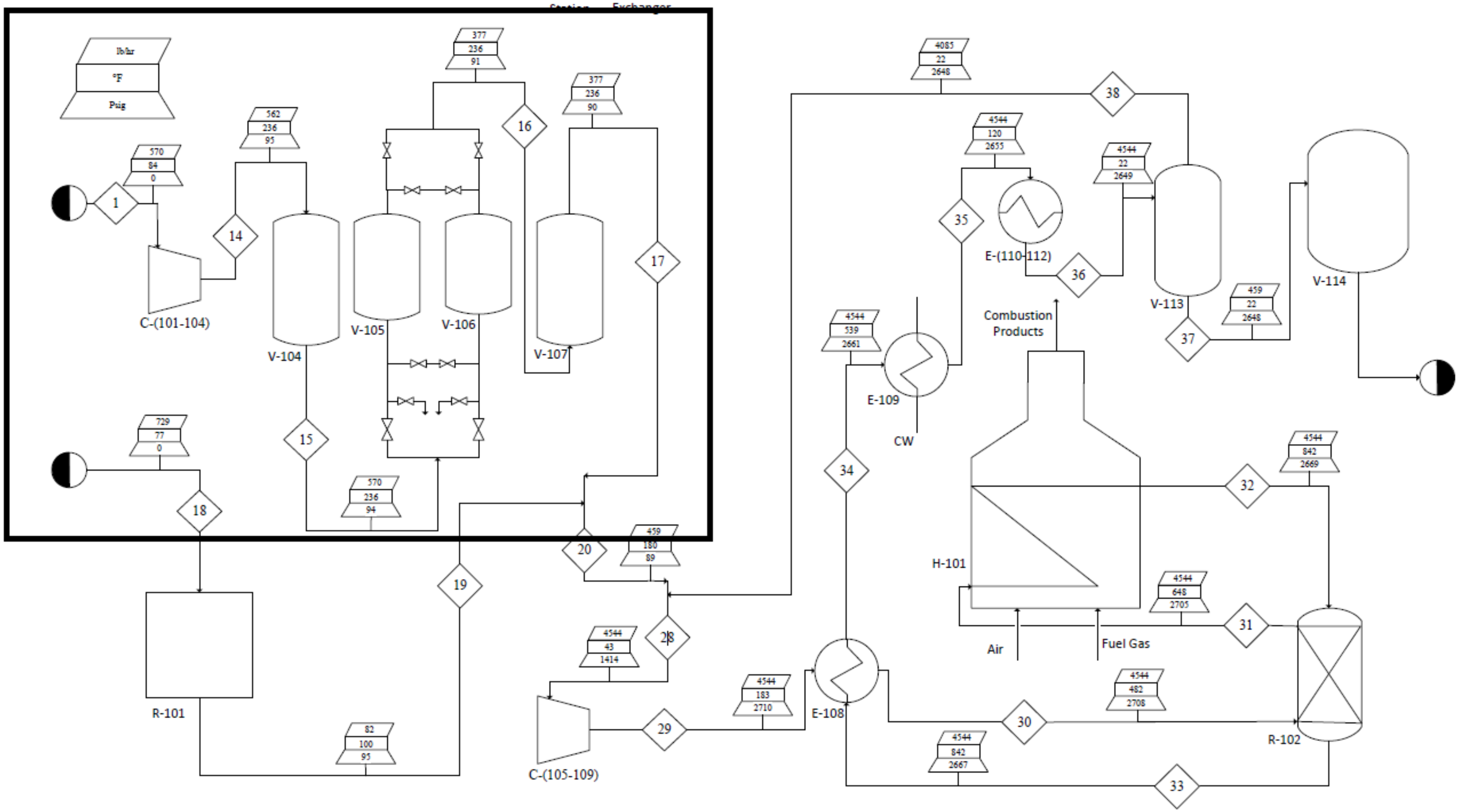
Per Module:

- PSA Equipment
  - Four (4) stage reciprocating compressors
  - Three (3) interstage cooling water heaters
  - Three (3) cooling water centrifugal pumps
  - Three (3) knockout drums
  - **Four (4) pressure vessels**

- Electrolysis Equipment
  - One (1) water purification system
  - **One (1) electrolyzer**

PSA Unit

C-(101-104) PSA Compressor Station | V-104 Air Buffer Vessel | V-105 Oxygen Adsorption Vessel | V-106 Oxygen Adsorption Vessel | V-107 Nitrogen Buffer Vessel | R-101 Electrolyser | C-(105-109) Haber Bosch Compressor Station | E-108 Reactor Effluent Heat Exchanger | H-101 Furnace | R-102 Ammonia PBR | E-109 Reactor Effluent Cooling prior to Chiller | E-(110-112) Condenser/Chiller | V-113 Vertical Separator/ Demister | V-114 Ammonia Storage Vessel



PSA Unit

Pressure Vessel Design: V-104, V-105, V-106, V-107

Pressure Vessels	**V-104**	**V-105**	**V-106**	**V-107**
Orientation	Vertical			
Design Pressure (barg)	11.	11.	11.	11.
Volume (m3)	11.5	7.7	7.7	11.5
Diameter (m)	1.25	1.	1.	1.25
Length (m)	9.	10.	10.	9.
Process Temperature (°C)	113.	113.	113.	113.
Material of Construction	Carbon Steel			

Discussion of Major Equipment

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- PSA Equipment
  - Four (4) stage reciprocating compressors
  - Three (3) interstage cooling water heaters
  - Three (3) cooling water centrifugal pumps
  - Three (3) knockout drums
  - **Four (4) pressure vessels**

- Electrolysis Equipment
  - One (1) water purification system
  - **One (1) electrolyzer**

Electrolyzer Parameters

Electrolyzer Operating Parameters

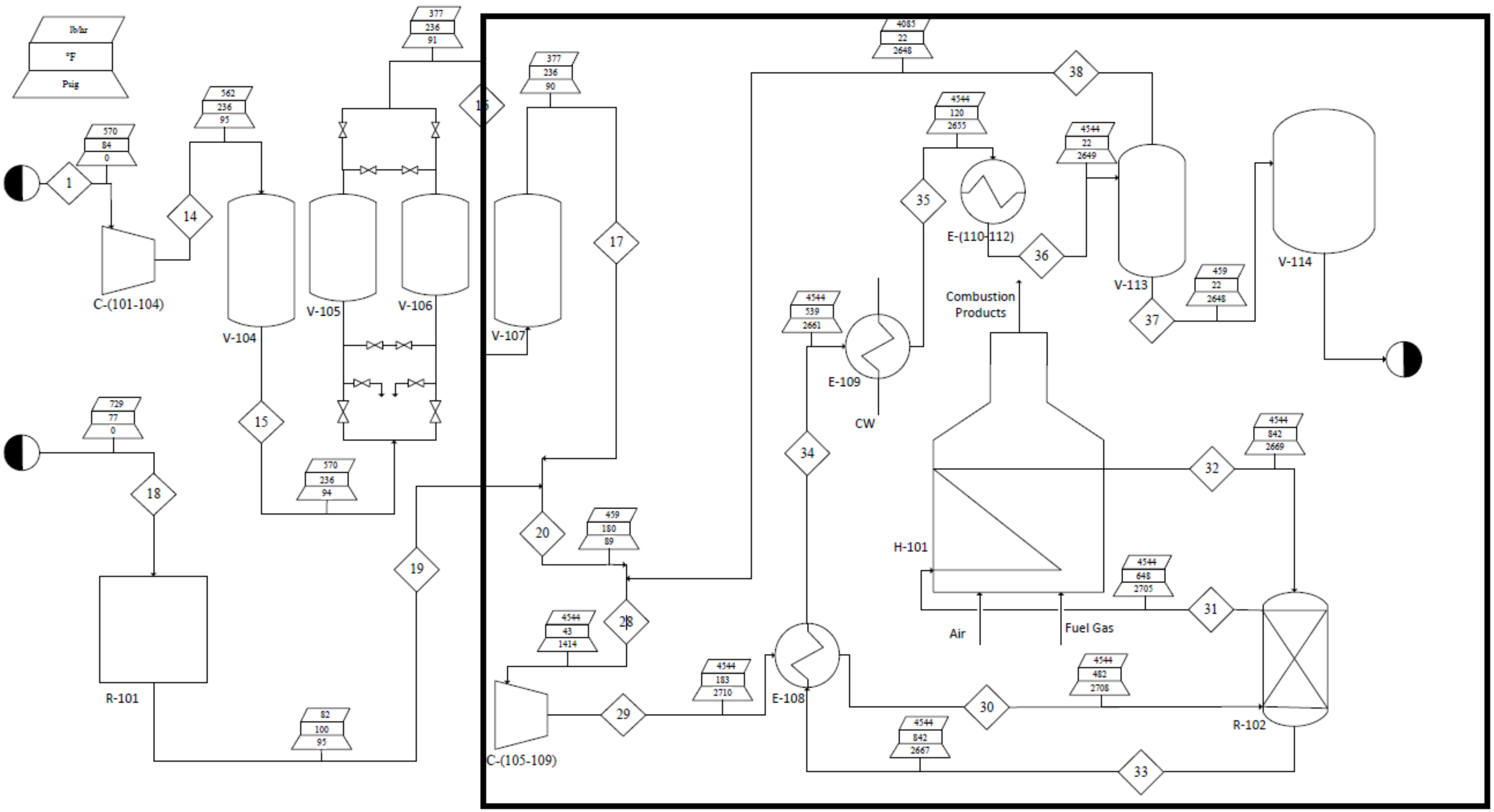
Specifications	Range	Single Module Values
Net Production Rate	300 - 485 Nm^3/h	412 Nm^3/h
Power Consumption	3.8 - 4.4 kWh/Nm^3	4.1 kWh/Nm^3
Hydrogen Purity	99.99%	99.99 %
Oxygen Content in Hydrogen	< 2ppm	<2 ppm
H2O Content in Hydrogen	< 2ppm	<2 ppm
Delivery Pressure	1-200 barg	7.6 barg
Ambient Temperature	5-35 °C	35 °C max
Electrolyte	25% KOH	25% KOH
Feed Water Consumption	-	129 gph

Discussion of Major Equipment

- Ammonia Reactor Equipment
  - Five (5) stage reciprocating compressors
  - Four (4) knockout drums
  - Three (3) interstage cooling water heat exchangers
  - Four (4) cooling water centrifugal pumps
  - One (1) reactant / reactor effluent heat exchanger
  - One (1) reactor effluent / cooling water heat exchanger
  - **One (1) reactant heating furnace**
  - **One (1) fluidized bed reactor**
  - **One (1) cooling tower**
  - One (1) liquid ammonia separator
  - One (1) ammonia storage tank
- **Ammonia Refrigeration Unit**
  - One (1) R717 evaporator
  - One (1) R717 chiller
  - One (1) interstage cooling water heat exchanger
  - Three (3) stage reciprocating compressors
  - Two (2) cooling water centrifugal pumps
  - One (1) knockout drum

Ammonia Reactor Loop

C-(101-104) PSA Compressor Station
V-104 Air Buffer Vessel
V-105 Oxygen Adsorption Vessel
V-106 Oxygen Adsorption Vessel
V-107 Nitrogen Buffer Vessel
R-101 Electrolyser
C-(105-109) Haber Bosch Compressor Station
E-108 Reactor Effluent Heat Exchanger
H-101 Furnace
R-102 Ammonia PBR
E-109 Reactor Effluent Cooling prior to Chiller
E-(110-112) Condenser/Chiller
V-113 Vertical Separator/ Demister
V-114 Ammonia Storage Vessel



Fired Heater

Furnace Design: H-101

Specification	**Single Module**
Required Heat Load (MJ/h)	970.
Design Heat Load (MJ/h)	1075.
Efficiency	.8
Inlet Temp. °C	342.
Outlet Temp. °C	450.
Design Pres. (Barg)	205.
Process Fluid Piping	Alloyed Steel
Fuel Gas	Natural Gas

Fluidized Bed Reactor

Reactor Design: R-102

Design Factors	**R-102**
Reactor Volume (m^3)	1.53
Diameter (m)	1.8
L/D Ratio	0.334
Design Pres. (barg)	205.
Reaction Heat (kJ/h)	655000.
Catalyst Charge (kg)	11600.
Void Fraction	0.5
Materials of Construction	Stainless Steel

E-108 Annual Cost Savings

Designation	**Single Module**	**Whole Design (Ten Modules)**
Duty (MJ/hr)	1150	11500
Flow Rate Natural Gas (ft3/hr)	1440	14400
Annual Cost Savings	**$53,000**	**$530,000**

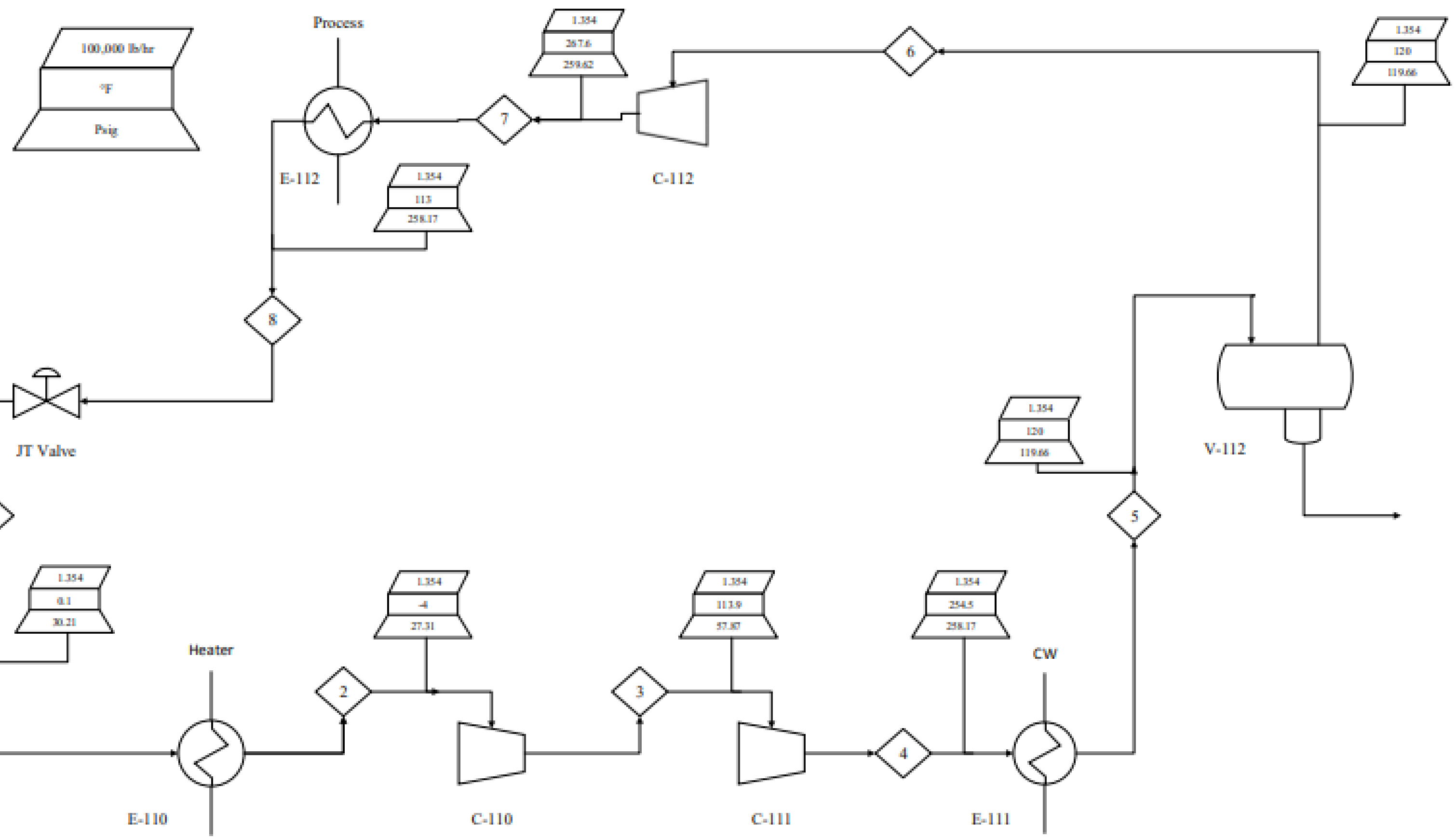
Cooling Tower

Cooling Tower Design: T-101

Cooling Tower	**T-101**
CW Supply Temp (°C)	48.89
CW Return Temp (°C)	29.44
Duty Removed from CW System (kJ/hr)	$10x10^6$
Water Cooling Capacity (gpm)	442.52
Power Supplied for Fan (kW)	11.12
Power Supplied for Pumps (kW)	12.15
% Water Loss to Evaporation (%)	0.033

Refrigeration Unit

E-110	C-110	C-111	E-111	V-112	C-112	E-112	JT Valve
Chiller Refrigerant Evap Heater	Chiller Stage One Compressor	Chiller Stage Two Compressor	Chiller Inter-stage Heat Exchanger	Chiller Compressor Knock-out Drum	Chiller Stage Three Compressor	Chiller Process Cooler Heat Exchanger	Joule-Thompson Expansion Valve



Refrigeration Unit HEX

Heat Exchanger Design: E-110, E-111, E-112

Heat Exchangers	**E-110**	**E-111**	**E-112**
Type	Refrigerant R717 Evaporator	Floating Head Interstage Cooler	Refrigerant R717 Cooler
Area (m2)	21	12	86
Duty (kJ/h)	637,500	104,900	817,200
Shell			
Temp. (°C)	-20	124	131
Design Pres. (barg)	6	12	22
Phase	Vapor + Liquid	Vapor	Vapor + Liquid
Materials of Construction	Carbon Steel	Carbon Steel	Carbon Steel
Tube			
Temp. (°C)	40.7	40.7	40.7
Design Pres. (barg)	4.9	4.9	4.9
Phase	Liquid	Liquid	Liquid
Materials of Construction	Stainless Steel	Stainless Steel	Stainless Steel

Health, Safety, and the Environment

- Production trains as an inherently safer design
  - o Reduced complexity with identical designs
  - o Less process fluid in any one section of the plant
  - o Potential for storage in smaller tanks, reducing the chance for disaster should one module fail

- Minimization of the carbon footprint
  - o Fired heater as the primary source of carbon emissions

- Improved safety in the absence of methane reformation and sulfur recovery
  - o Elimination of poisonous gas exposure, such as with H_2S

Potential Consequence Summary

No.	Hazard	Equipment Damage	Environmental Compliance	Loss of Life	Disruption of Other Business Units	Legal/PR	Community Impact
1	*Rupture of High Pressure Process Piping (No Ammonia Released)*	Medium	Non-Toxic Release (N/A)	Medium	Low	Low	Low
2	*Rupture of High Pressure Process Piping (Ammonia Released)*	Medium	Toxic Release, Severe Environmental Action Needed	High	Medium	High	High
3	*Loss of Containment from Ammonia Storage*	Low	Toxic Release, Moderate Environmental Action Needed	Low	Low	Medium	Low
4	*Fire in Processing Unit (No Ammonia Released)*	Medim	Non-Toxic Release (N/A)	Low	Medium	Low	Low
5	*Fire in Processing Unit (Ammonia Released)*	Medium	Toxic Release, Moderate Environmental Action Needed	Medium	Medium	Medium	Low
6	*Overpressure / Explosion of Ammonia Storage Unit*	High	Toxic Release, Severe Environmental Action Needed	High	High	High	High
7	*Overpressure / Explosion of Ammonia Process Unit*	High	Toxic Release, Moderate Environmental Action Needed	Medium	High	Medium	Medium
8	*Loss of Containment of R-717 from Chiller Circuit*	Low	Toxic Release, Moderate Environmental Action Needed	Medium	Medium	Medium	Low

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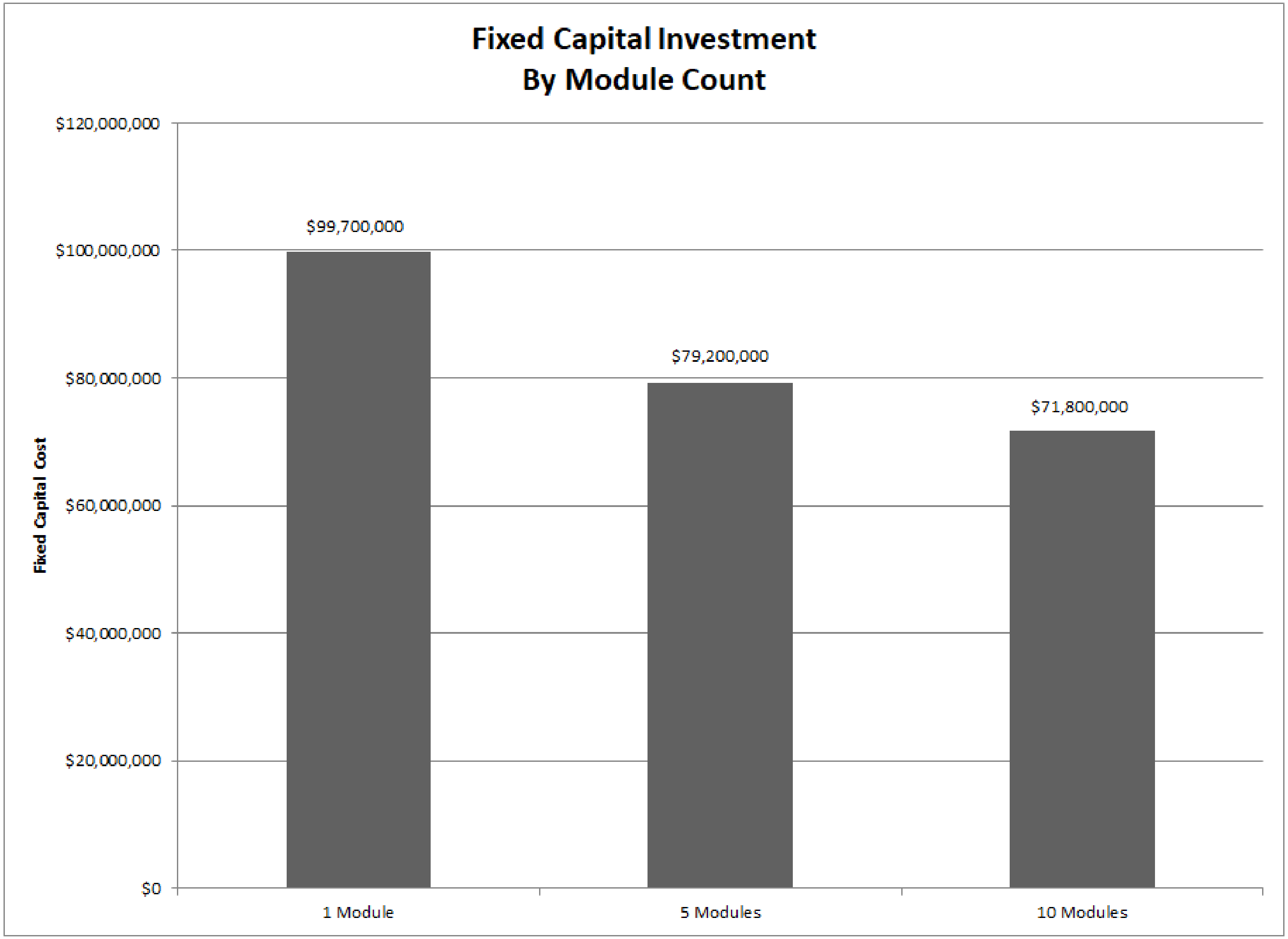
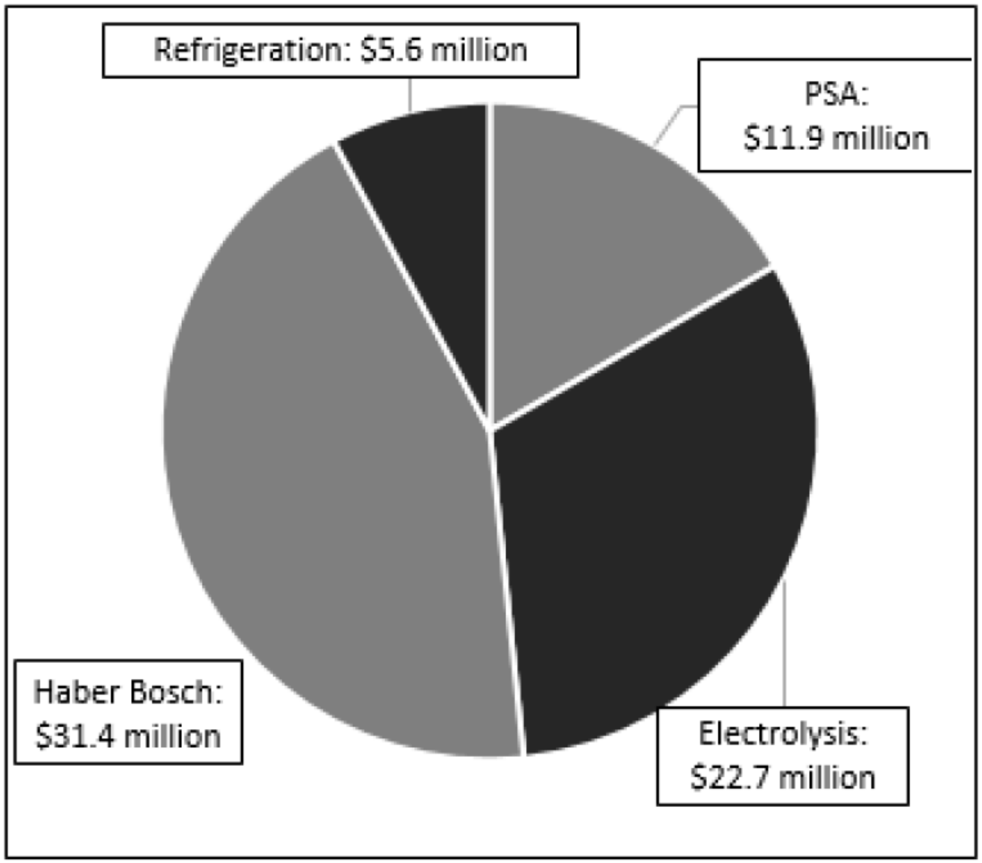
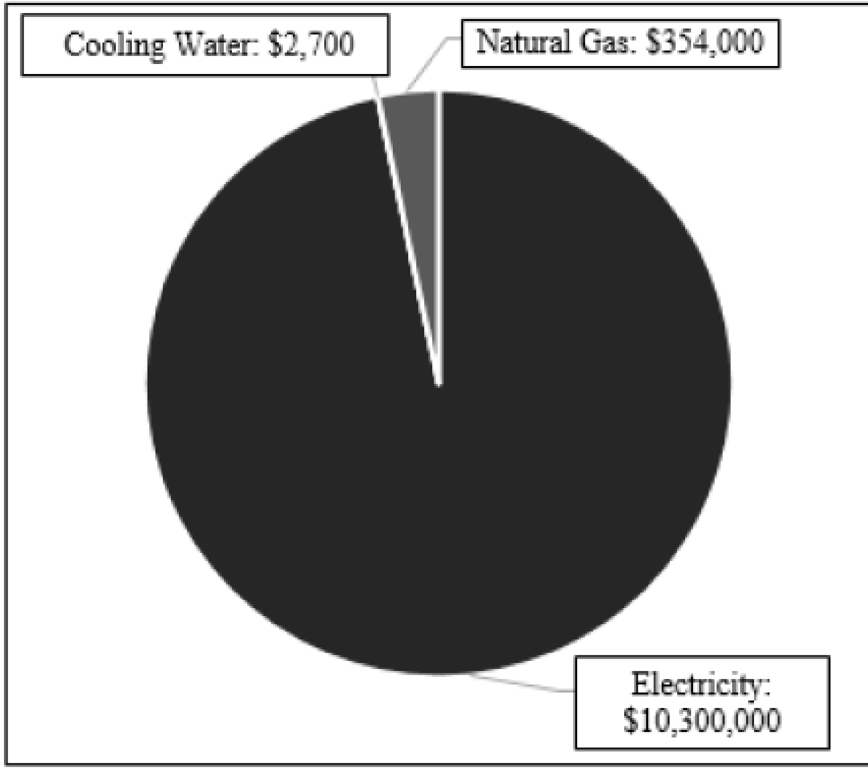
Fixed Capital Investment Costs



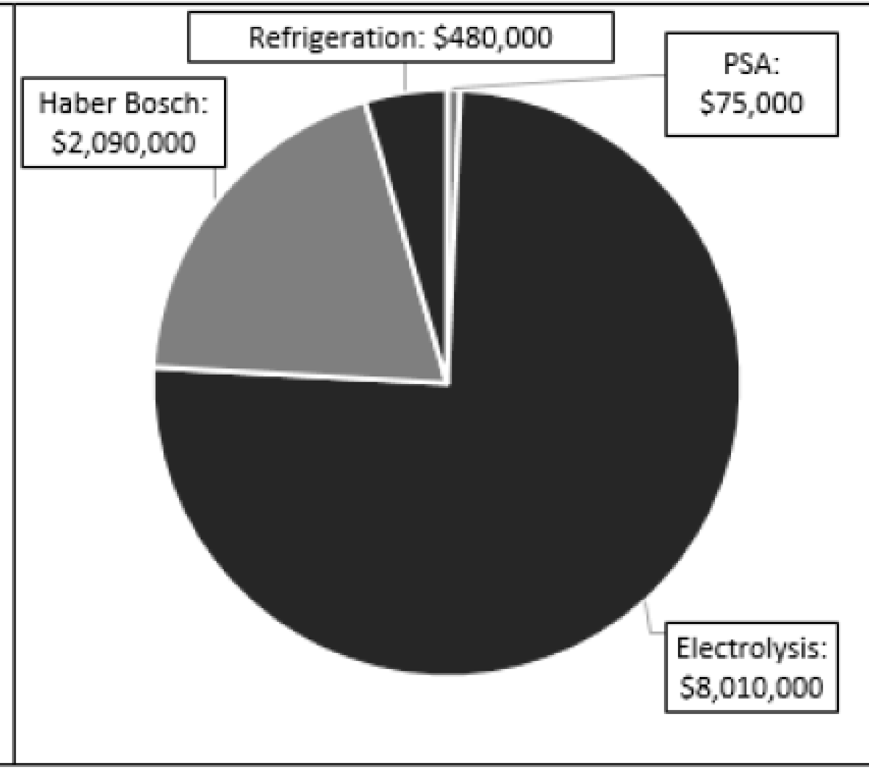
Fixed Capital Breakdown



Utility Costs

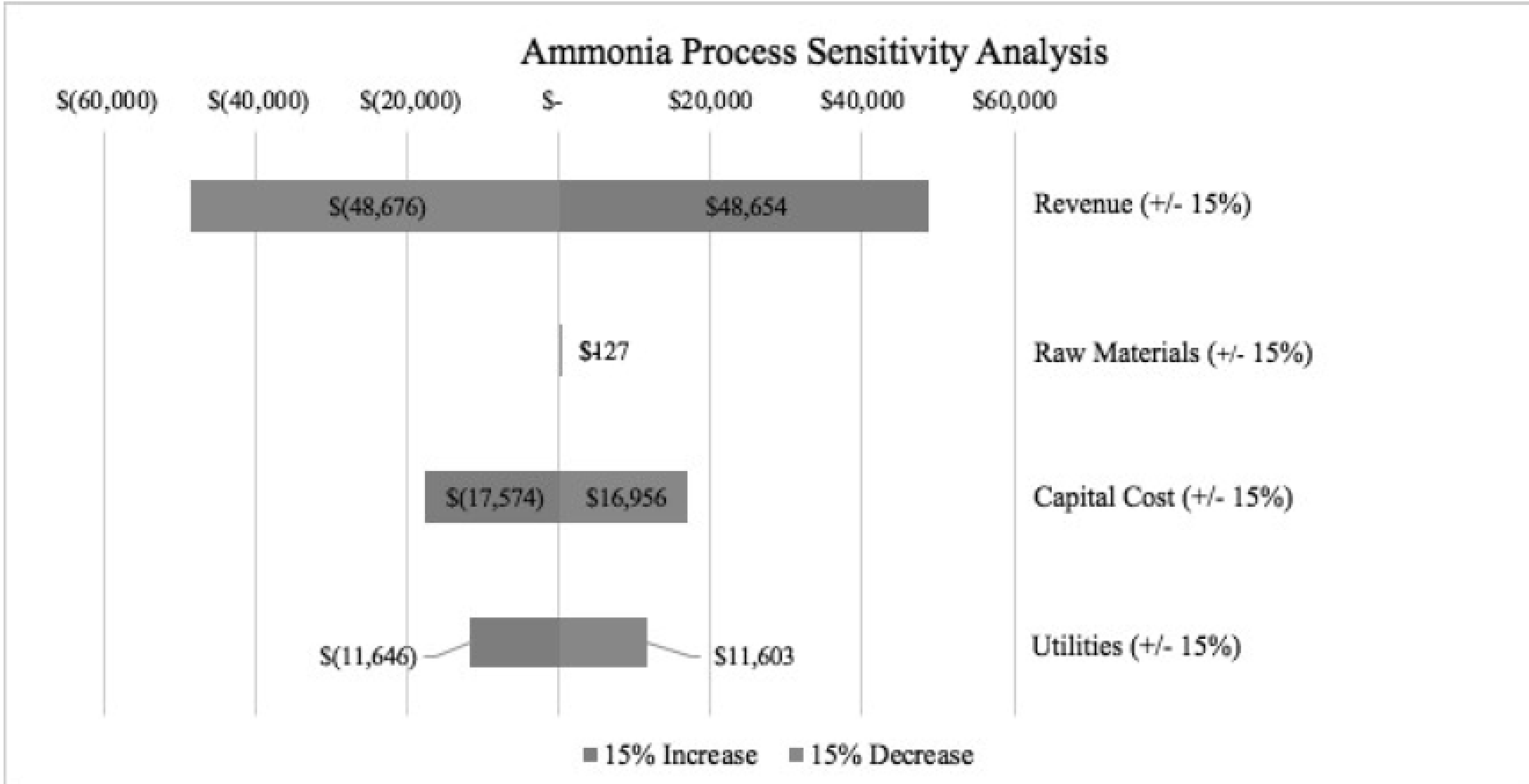


Utility Consumption Costs



Utility Costs by Process

Sensitivity Analysis



Multiplication
Factor: 1 = 1000

Conclusions and Recommendations

- At typical ammonia sales prices, the present design is not profitable
  - A sale price of approximately $3,000 per ton is necessary for an 8% DCFROR

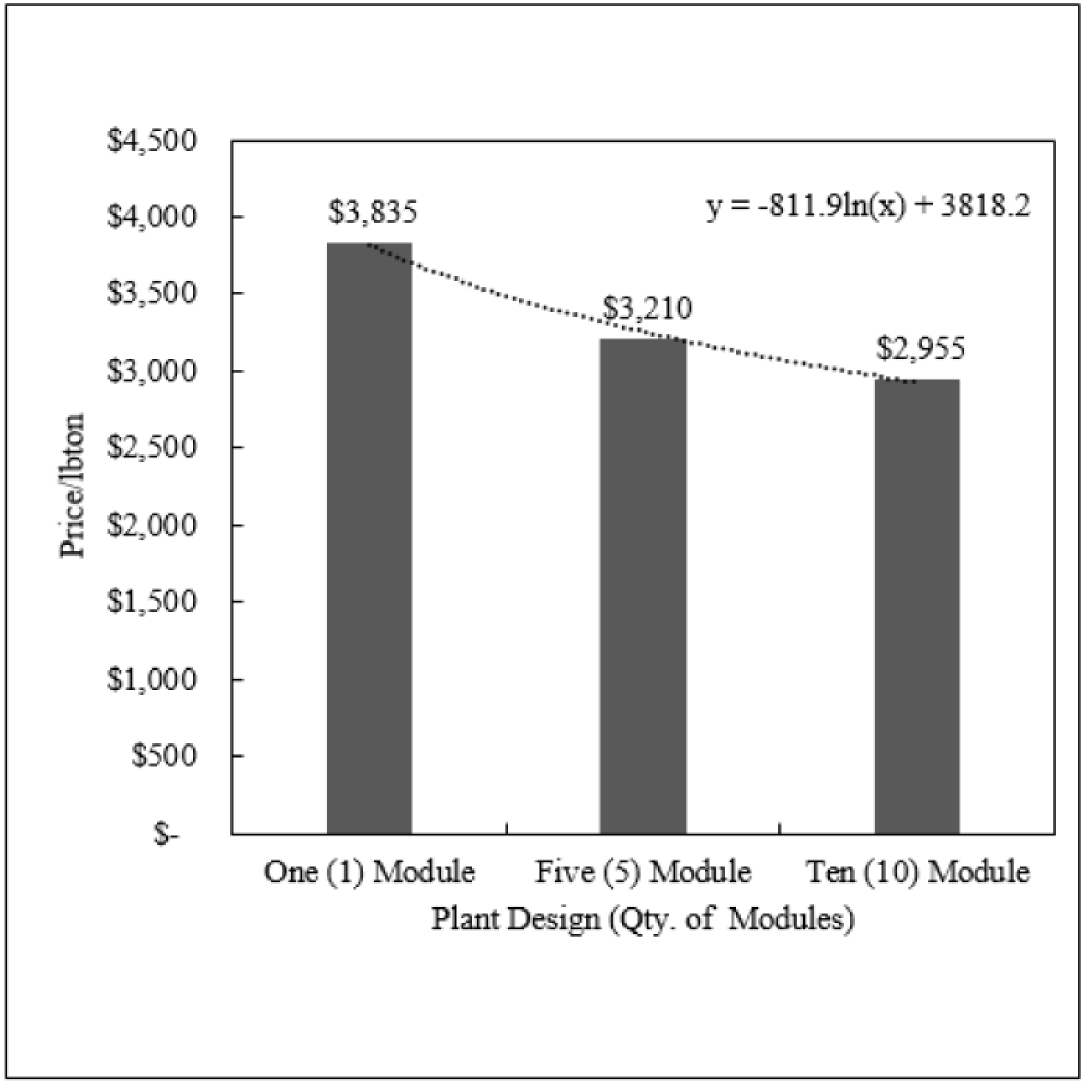
- Large fixed capital and continuous costs arise from electrolysis

- Methane reformation may allow for profitable operations, but runs counter to the push for green design

- In the event that the project is continued in an alternate form, automated emergency deluge systems may prove integral to safety

Questions

Considering More Modules



Balances

PSA Unit					
Stream or Equipment	$Enthalpy_{in}$ (Btu/hr)	$Enthalpy_{out}$ (Btu/hr)	Energy Flow (Btu/hr)	Total Energy Difference (Btu/hr)	Percent Difference
PSA Feed, 1	-101000.	-	-	-	-
Compressor C-101	-	-	15000.	-	-
Cooler E-101	-	-	-3060.	-	-
Compressor C-102	-	-	-8430.	-	-
Cooler E-102	-	-	-8510.	-	-
KO Drum V-102	-	-11300.	-	-	-
Compressor C-103	-	-	16500.	-	-
Cooler E-103	-	-	-10600.	-	-
KO Drum V-103	-	-41100.	-	-	-
Compressor C-104	-	-	16200.	-	-
Oxygen Adsorber V-105/106	-	-17400.	-	-	-
Nitrogen to Process, 17	-	-14800.	-	-	-
Totals	-101000.	-84600.	17100.	700.	0.69%

Balances

Haber-Bosch Synthesis					
Stream or Equipment	$Enthalpy_{in}$ (Btu/hr)	$Enthalpy_{out}$ (Btu/hr)	Energy Flow (Btu/hr)	Total Energy Difference (Btu/hr)	Percent Difference
Nitrogen Feed, 17	-15000.	-	-	-	-
Hydrogen Feed, 19	-6300.	-	-	-	-
Compressor C-105	-	-	54000.	-	-
Cooler E-104	-	-	-38200.	-	-
Compressor C-106	-	-	59900.	-	-
Cooler E-105	-	-	-60100.	-	-
Compressor C-107	-	-	59600.	-	-
Cooler E-106	-	-	-60000.	-	-
Compressor C-108	-	-	59900.	-	-
Compressor C-109	-	-	509000.	-	-
Reactor R-102	-	-	620000.	-	-
Heater H-101	-	-	733000.	-	-
Cooler E-109	-	-	-1540000.	-	-
Chiller E-(110-112)	-	-	-580000.	-	-
Ammonia Product, 37	-	-796000.	-	-	-
Recycle, 38	-584000.	-	-	-	-
Total	-605300.	-796000.	-182900.	7800.	1.28%

Balances

Refrigeration Unit			
Stream or Equipment	Energy Flow (Btu/hr)	Total Energy Difference (Btu/hr)	Percent Difference
Process Fluid Chiller, E-110	6040000.	-	-
Compresssor C-110	770000.	-	-
Compressor C-111	959000.	-	-
Cooler E-111	-990000.	-	-
Compressor C-112	971000.	-	-
Cooler E-112	-7750000.	-	-
Total	0.	0.	0%

Utility Costs

Cooling Water Costs Per 1,000 Gallons (Note 1)	
Industrial Costs	$ 2.79
Industrial Electricity Costs Per Kilowatt-Hour (Note 1)	
Monthly Fee	$ 57.75
Charge Per kWh	$ 0.05
Demand Charge July, August & September Per kW	$ 19.58
Demand Charge January, February & March Per kW	$ 16.49
Demand Charge Other Months Per kW	$ 13.65
Natural Gas Costs Per 1,000 ft^3 (Note 2)	
Industrial Costs	$ 4.42

PSA Utilities

Designation	Single Module		Whole Project (Ten Modules)	
Equipment	**Electric Power (kW)**	**Annual Cooling Water Make-up (gpy)**	**Electric Power (kW)**	**Annual Cooling Water Make-up (gpy)**
C-101	3	-	30	-
C-102	3	-	34	-
C-103	3	-	34	-
C-104	3	-	33	-
E-101	-	34	-	183
E-102	-	95	-	510
E-103	-	118	-	634
P-101 A/B	1	-	5	-
P-102 A/B	1	-	5	-
P-103 A/B	1	-	5	-
Total	**15**	**246**	**147**	**1327**
Cost	**$7,000**	**$0**	**$75,000**	**$0**

Electrolysis and Haber Bosch Utilities

Designation	Single Module			Whole Project (Ten Modules)		
Equipment	Electric Power (kW)	Annual Cooling Water Make-up (gpy)	Natural Gas (ft3/hr)	Electric Power (kW)	Annual Cooling Water Make-up (gpy)	Natural Gas (ft3/hr)
R-101	1,719	1,079,369	-	17,192	10,793,685	-
C-105	16	-	-	165	-	-
C-106	18	-	-	182	-	-
C-107	18	-	-	181	-	-
C-108	18	-	-	182	-	-
C-109	272	-	-	2,720	-	-
E-104	-	425	-	-	4,251	-
E-105	-	360	-	-	3,600	-
E-106	-	668	-	-	6,676	-
E-109	-	30,861	-	-	308,613	-
P-104 A/B	1	-	-	5	-	-
P-105 A/B	1	-	-	5	-	-
P-106 A/B	1	-	-	5	-	-
P-108 A/B	68	-	-	678	-	-
H-101	-	-	964	-	-	9,643
T-101	35	48,649	-	350	486,487	-
Total	**2,167**	**1,160,331**	**964**	**21,665**	**11,603,311**	**9,643**
Cost	**$1,010,000**	**$3,200**	**$35,000**	**$10,100,000**	**$27,400**	**$350,000**

Refrigeration Utilities

Designation	Single Module		Whole Project (Ten Modules)	
Equipment	Electric Power (kW)	Annual Cooling Water Make-up (gpy)	Electric Power (kW)	Annual Cooling Water Make-up (gpy)
C-110	23	-	232	-
C-111	29	-	289	-
C-112	29	-	292	-
E-110	-	6723	-	67235
E-111	-	1106	-	11061
E-112	-	8619	-	86187
P-109 A/B	19	-	189	-
P-110 A/B	2	-	24	-
Total	**103**	**16448**	**1027**	**164483**
Cost	**$48,000**	**$500**	**$480,000**	**$5,000**

PSA Compressors

Compressor Parameters	**C-101**	**C-102**	**C-103**	**C-104**
Type	Reciprocating, Electric Drive			
Discharge Pressure (barg)	.7	1.8	3.6	6.6
Discharge Temperature (°C)	75.	113.	128.	113.
Volumetric Flow rate (gpm)	.6	.6	.6	.6
Hydraulic power (hp)	3.	3.	3.	3.
Compressor Efficiency (%)	75.	75.	75.	75.
Brake Horsepower (bhp)	5.	7.	7.	5.
Motor Size (hp)	10.	10.	10.	10.
Motor Efficiency	80.	80.	80.	80.
Material of Construction	Carbon Steel			

PSA Heat Exchangers

Heat Exchangers	E-101	E-102	E-103
Type	Floating Head Interstage Cooler	Floating Head Interstage Cooler	Floating Head Interstage Cooler
Area (m2)	0.4	0.8	1
Duty (kJ/h)	3,230	8,970	11,200
Shell			
Temp. (°C)	75	115.0	115.0
Design Pres. (barg)	5.0	5	7
Phase	Vapor	Vapor	Vapor
Materials of Construction	Carbon Steel	Carbon Steel	Carbon Steel
Tube			
Temp. (°C)	40.7	40.7	40.7
Design Pres. (barg)	4.9	4.9	4.9
Phase	Liquid	Liquid	Liquid
Materials of Construction	Stainless Steel	Stainless Steel	Stainless Steel

PSA Cooling Water Pumps

Pump Parameters	**P-101 A/B**	**P-102 A/B**	**P-103 A/B**
Type	Centrifugal, Electric Drive		
Discharge Pressure (barg)	5.1	5.1	5.1
Flow rate (gpm)	.3	.9	1.
Hydraulic power (hp)	.01	.04	.05
Pump Efficiency	.73	.73	.73
Brake Horsepower (bhp)	.02	.05	.06
Design Power (kW)	.75	.75	.75
Motor Size (hp)	1.	1.	1.
Motor Efficiency	.9	.9	.9
Material of Construction	Carbon Steel		

PSA Knockout Drums

Knockout Drums	**V-101**	**V-102**	**V-103**
Orientation	Horizontal		
Design Pressure (barg)	4.1	5.2	7.
Volume (m3)	.14	.14	.14
Diameter (m)	.6	.6	.6
Length (m)	1.5	1.5	1.5
Process Temperature (°C)	50.	50.	50.
Material of Construction	Carbon Steel		

Ammonia Loop Compressors

Compressor Parameters	**C-105**	**C-106**	**C-107**	**C-108**	**C-109**
Type	Reciprocating, Electric Drive				
Discharge Pressure (barg)	13.	27.	51.	97.	187.
Discharge Temperature (°C)	106.	138.	138.	137.	84.
STD. Volumetric Flow rate (gpm)	3.	3.	3.	3.	3.
Hydraulic power (hp)	21.	24.	24.	24.	201.
Compressor Efficiency (%)	75.	75.	75.	75.	75.
Brake Horsepower (bhp)	25.	27.	27.	27.	210.
Motor Size (hp)	25.	30.	30.	30.	250.
Motor Efficiency (%)	80.	80.	80.	80.	80.
Material of Construction	Carbon Steel				

Interstage Heat Exchange

Heat Exchangers	E-104	E-105	E-106
Type	Floating Head Interstage Cooler	Floating Head Interstage Cooler	Floating Head Interstage Cooler
Area (m2)	5	5	10
Duty (kJ/h)	40,300	63,460	63,300
Shell			
Temp. (°C)	40.7	40.7	40.7
Design Pres. (barg)	4.9	4.9	4.9
Phase	Liquid	Liquid	Liquid
Materials of Construction	Carbon Steel	Carbon Steel	Carbon Steel
Tube			
Temp. (°C)	106	138	137
Design Pres. (barg)	15	32	55
Phase	Vapor	Vapor	Vapor
Materials of Construction	Stainless Steel	Stainless Steel	Stainless Steel

Ammonia Loop Knockout Drums

Knockout Drums	**V-108**	**V-109**	**V-110**	**V-111**
Orientation	Horizontal			
Design Pressure (barg)	18.	31.	55.	101.
Volume (m3)	.4	.4	.4	.4
Diameter (m)	.6	.6	.6	.6
Length (m)	1.5	1.5	1.5	1.5
Process Temperature (°C)	50.	50.	50.	50.
Material of Construction	Carbon Steel			

Ammonia Loop CW Pumps

Pump Parameters	**P-104 A/B**	**P-105 A/B**	**P-106 A/B**	**P-108 A/B**
Type	Centrifugal, Electric Drive			
Discharge Pressure (barg)	5.1	5.1	5.1	5.1
Flow rate (gpm)	4.	6.	6.	1400.
Hydraulic power (hp)	.2	.3	.3	60.
Pump Efficiency	.73	.73	.73	.73
Brake Horsepower (bhp)	.2	.4	.4	82.
Design Power (kW)	.75	.75	.75	75.
Motor Size (hp)	1.	1.	1.	100.
Motor Efficiency	.9	.9	.9	.9
Material of Construction	Carbon Steel			

Ammonia Loop Heat Integration

Heat Exchangers	**E-108**	**E-109**
Type	Floating Head Reactor Effluent Exchanger	Floating Head Reactor Effluent Cooler
Area (m2)	22	55
Duty (kJ/h)	1,150,000	1,620,000
Shell		
Temp. (°C)	250	40.7
Design Pres. (barg)	205	4.9
Phase	Vapor	Liquid
Materials of Construction	Carbon Steel	Carbon Steel
Tube		
Temp. (°C)	450	282
Design Pres. (barg)	205	205
Phase	Vapor	Vapor
Materials of Construction	Stainless Steel	Stainless Steel

Ammonia Loop Separator

Pressure Vessels	V-113
Orientation	Vertical
Design Pressure (barg)	202.
Volume (m3)	.1
Diameter (m)	.3
Length (m)	1.4
Process Temperature (°C)	- 5.
Material of Construction	Carbon Steel

Ammonia Storage Tank

Pressure Vessels	**V-114**
Orientation	Horizontal
Design Pressure (barg)	17.
Volume (m3)	247.
Diameter (m)	5.
Length (m)	14.
Process Temperature (°C)	- 5.
Material of Construction	Carbon Steel

Refrigeration Compressors

Compressor Parameters	**C-110**	**C-111**	**C-112**
Type	Reciprocating, Electric Drive		
Discharge Pressure (barg)	3.	7.	17.
Discharge Temperature (°C)	46.	124.	131.
STD. Volumetric Flow rate (m3/h)	10.	10.	10.
Hydraulic power (hp)	3.	3.	3.
Compressor Efficiency (%)	75.	75.	75.
Brake Horsepower (bhp)	5.	7.	7.
Motor Size (hp)	10.	10.	10.
Motor Efficiency	80.	80.	80.
Material of Construction	Carbon Steel		

Refrigeration Pumps

Pump Parameters	**P-109 A/B**	**P-110 A/B**
Type	Centrifugal, Electric Drive	
Flow rate (gpm)	387.	50.
Hydraulic power (hp)	17.	2.
Pump Efficiency	.73	.73
Brake Horsepower (bhp)	23.	3.
Design Power (kW)	19.	2.2
Motor Size (hp)	25.	3.
Motor Efficiency	.9	.9
Material of Construction	Carbon Steel	

Refrigeration Knockout Drum

Knockout Drum	**V-112**
Orientation	Horizontal
Design Pressure (barg)	10.
Volume (m3)	.4
Diameter (m)	.6
Length (m)	1.5
Process Temperature (°C)	50.
Material of Construction	Carbon Steel

Inherent Safety

Hazard	**Inherent Safety Concept**	**Application in Process**
Production of Waste and Possible Environmental Pollutants.	Minimization	Eliminate all unnecessary usage of fossil fuels to power and heat the process for less CO_2 emissions.
Complex operating procedures plant wide, increasing chance for operator error.	Simplification	Modular ammonia synthesis trains greatly simplify the lineup of process units, as well as their operation plant wide.
Storage of large amounts of ammonia in tankage increases severity of potential accidents.	Moderation	With each modular ammonia train being its own entity, tankage is also split between the trains to accommodate for less ammonia in a mass storage setting.
Equipment failure can lead to downstream process trips and upsets, leading to a potentially costly and hazardous situation.	Minimization	With the modular setup, if there is a process unit that must come down for maintentnace in one train, the remaining 9 trains may continue to operate normally, minimizing costly plant downtime and hazardous process stoppage.
Possible exposure to poisonous gasses such as H_2S is likely when utilizing sulphur recovery and methane reforming units to produce hydrogen.	Substitution	With the usage of water electrolysis and pressure swing adsorption, methane reforming and hydrocarbons are not necessary to produce process feedstocks.

Project Title:	**AICHE Senior Design Project - 50 mtpd Ammonia Production**																				
Corporate financial situation:	Expense																				
Minimum rate of return I* =	8.0%		Tax rate = 25%				*Annual Ammonia production (mtpy)=* 17,340														
Other relevant project info.	Multiplication Factor: 1 = 1000						Cost per ton (2000 lb)= $2,955														
End of Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Production																					
Ammonia Annual Revenue	-	-	-	28,200	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500
Sales Revenue	-	-	-	28,200	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500
Net Revenue	-	-	-	28,200	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500	56,500
- Raw Material Costs	-	-	-	(15)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)
- Other Op Costs	-	-	-	(10,450)	(28,800)	(28,800)	(28,800)	(28,800)	(28,800)	(28,800)	(28,800)	(28,800)	(28,800)	(28,800)	(28,800)	(28,800)	(28,800)	(28,800)	(28,800)	(28,800)	(28,800)
- Utilities	-	-	-	(5,500)	(11,000)	(11,000)	(11,000)	(11,000)	(11,000)	(11,000)	(11,000)	(11,000)	(11,000)	(11,000)	(11,000)	(11,000)	(11,000)	(11,000)	(11,000)	(11,000)	(11,000)
- Operating Labor	-	-	-	(3,850)	(7,700)	(7,700)	(7,700)	(7,700)	(7,700)	(7,700)	(7,700)	(7,700)	(7,700)	(7,700)	(7,700)	(7,700)	(7,700)	(7,700)	(7,700)	(7,700)	(7,700)
- Depreciation	-	-	-	(7,200)	(12,900)	(10,300)	(8,300)	(6,600)	(5,300)	(4,700)	(4,700)	(4,700)	(4,700)	(2,400)							
-Working Capital Writeoff	-	-	-																		
- Depreciation Writeoff	-	-	-																		
Taxable Income	-	-	-	1,185	(3,930)	(1,330)	670	2,370	3,670	4,270	4,270	4,270	4,270	6,570	8,970	8,970	8,970	8,970	8,970	8,970	8,970
- Tax @ 25%	-	-	-	(296)	983	333	(167)	(592)	(917)	(1,067)	(1,067)	(1,067)	(1,067)	(1,642)	(2,242)	(2,242)	(2,242)	(2,242)	(2,242)	(2,242)	(2,242)
Net Income		-	-	900	(2,900)	(1,000)	500	1,800	2,800	3,200	3,200	3,200	3,200	4,900	6,700	6,700	6,700	6,700	6,700	6,700	6,700
+ Depreciation	-	-	-	7,200	12,900	10,300	8,300	6,600	5,300	4,700	4,700	4,700	4,700	2,400	0	0	0	0	0	0	0
+ Working Capital Writeoff	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	700
+ Depreciation Writeoff	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
- Working Capital	-	-	-	(700)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
- Fixed Capital	(12,000)	(23,900)	(23,900)	(12,000)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cash Flow	(12,000)	(23,900)	(23,900)	(4,600)	10,000	9,300	8,800	8,400	8,100	7,900	7,900	7,900	7,900	7,300	6,700.00	6,700.00	6,700.00	6,700.00	6,700.00	6,700.00	7,400.00
Discount factor (P/Fi,n)*	1.000	0.926	0.857	0.794	0.735	0.681	0.630	0.583	0.540	0.500	0.463	0.429	0.397	0.368	0.340	0.315	0.292	0.270	0.250	0.232	0.215
Discount Cash Flow		(22,130)	(20,490)	(3,652)	7,350	6,329	5,545	4,901	4,376	3,952	3,659	3,388	3,137	2,684	2,281.09	2,112.12	1,955.67	1,810.80	1,676.67	1,552.47	1,587.66
NPV @ i* =	**12,028**	Although the NPV is greater than zero at a discount rate of 8%, this is not an economically attractive option because the cost/lbton to reach an 8% DCFROR was $2955. When compared to a traditional ammonia plant cost/lbton of ~$700 this ammonia plant design incorporating electrolysis is not feasible.																			
DCFROR =	**8.01%**																				

Notes:

1 Purchase and apply for operating permit July 2021

2 36 months later production starts