

**Economics of Using Flared vs. Conventional Natural Gas to
Produce Nitrogen Fertilizer: A Feasibility Analysis**

**Thein Maung
David Ripplinger
Greg McKee
David Saxowsky**

**Department of Agribusiness and Applied Economics
Agricultural Experiment Station
North Dakota State University
Fargo, ND 58108**

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Table of Contents

1. Introduction	1
2. Availability and Economics of Flared Natural Gas	3
2.1. Economics of Capturing and Collecting Flared Gas	3
2.2. Other Factors Influencing the Capture of Flared Gas	7
2.3. Summary	7
3. Feasibility of Producing Nitrogen Fertilizers Using Conventional Natural Gas	8
3.1. Geographic Location of Ammonia Production Capacity and Ammonia Production Process	9
3.2. Methodology, Assumptions and Data Need	11
3.3. Ammonia Cost Estimation Results	13
3.4. Ammonia Cost Sensitivity Analysis	13
3.5. Ammonia Cost Estimation Based on Mix Products	15
3.6. Summary	16
4. Business Models	17
4.1. The Value Proposition	17
4.2. Justification of Capital	17
4.3. Path for Scaling Firm Operations	18
4.4. Ownership and Associated Control Rights	18
5. Cooperatives	18
5.1. Traditional Cooperative	18
5.2. New Generation or Closed Membership Cooperative	19
5.3. Hybrid Cooperative	21
6. Limited Liability Company	22
7. Income Taxation	23
8. Facility Siting	24
8.1. General Siting Considerations	24
8.2. Plant-Specific Requirements	25
8.3. Utilities Infrastructure	26
8.4. Transportation Infrastructure	29
8.5. Preliminary sites	30
8.6. Summary of Siting Considerations and Next Steps	31
9. Summary of Findings	32

List of Tables

Table 1. Top 20 Flaring Countries by Volumes (in Billion Cubic Feet), 2007-2011	2
Table 2. Amount of Gas Flared in North Dakota.....	3
Table 3. Baseline Assumptions Used in Estimating Ammonia Cost.....	12
Table 4. Total Capital Cost for Ammonia Production	12
Table 5. Baseline Levelized Cost for Ammonia Production	13
Table 6. Percent of Total Levelized Cost for Baseline Case	13
Table 7. Total Capital Cost of Producing Ammonia, Urea, ANS and UAN and Anhydrous Ammonia Levelized Cost.....	16
Table 8. Shovel Ready Checklist.....	24

List of Figures

Figure 1. Concentration of Flared Gas in Western North Dakota	4
Figure 2. Oil and Flared Gas Production Patterns for Four Sample Wells.....	4
Figure 3. Amount of Gas Flared in North Dakota	5
Figure 4. Flare Gas Based on 13 Oil Well Observations.....	5
Figure 5. Average of 13 Well Observations from Figure 4 (Straight line represents the trend).....	6
Figure 6. Optimal Way to Connect and Capture Flared Gas	6
Figure 7. Pipeline Connection Cost for Capturing Flared Gas	7
Figure 8. Historical and Forecasted Henry Hub Natural Gas Spot Price.....	8
Figure 9. Total Dry Natural Gas Production in North Dakota.....	8
Figure 10. Historical Natural Gas Price in the United States	9
Figure 11. Ammonia Production Capacity in North America	10
Figure 12. Ranking of Ammonia Production Capacity in the U.S.	10
Figure 13. Steam Methane Reforming Ammonia Production Process	11
Figure 14. Impact of Changes in Natural Gas Price on Ammonia Cost.....	14
Figure 15. Impact of Changes in Electricity Price on Ammonia Cost.....	14
Figure 16. Impact of Changes in Capital Cost on Ammonia Cost.....	15
Figure 17. Impact of Changes in Real Discount Rate on Ammonia Cost	15
Figure 18. Business Models Mediate between Technical and Economic Domains	17
Figure 19. Traditional Cooperative (CHS, CoBank)	19
Figure 20. New Generation Cooperatives.....	20
Figure 21. Hybrid Cooperatives.....	22
Figure 22. Limited Liability Companies.....	23
Figure 23. Northern Plains Natural Gas Pipelines (International)	27
Figure 24. North Dakota Glacial Aquifers.....	28
Figure 25. U.S. Power Transmission Network	28
Figure 26. North Dakota State Highway Performance Classification System	29
Figure 27. Burlington Northern Santa Fe and Canadian Pacific Rail Lines.....	30

Executive Summary

The feasibility analysis begins by examining the economic potential of using flared natural gas as a feedstock to produce a low-cost, reliable, and sustainable supply of nitrogen fertilizer for North Dakota farmers. Specific objectives include

- Determining the most profitable facility size, location, and configuration for a natural gas nitrogen fertilizer production facility in North Dakota.
- Calculating the financial returns and capital requirements of gas-based nitrogen fertilizer production.
- Identifying possible business structures for the fertilizer production facility.

Project objectives are achieved by evaluating the technological and economic feasibility of alternative nitrogen fertilizer production and distribution systems.

- Flared Gas Collection: the economics of flared gas collection in western North Dakota analyzes the availability of flared gas supplies.
- Ammonia Plant Preliminary Design: several ammonia production plants based on commercially available technologies are used to estimate capital and operating cost.
- Business Structure: the effect of alternative business structures, including new generation cooperatives, on incorporation, capitalization, taxation, and fertilizer marketing are investigated.
- Facility Siting: factors in determining optimal plant site include fertilizer form (e.g. ammonia, urea), technological and economies of scale, transportation and utility infrastructure, and nitrogen fertilizer demand. The use of natural gas in western and eastern North Dakota and co-location by existing coal-fired power plants or refineries are considered.

Topics originally intended to study but not yet completed or are no longer relevant include

- Preparing a financial pro forma, including pro forma balance sheet, income and cash flow statements for the nitrogen fertilizer production plant to demonstrate the financial viability of the enterprise.
- Incorporating a supply chain model to estimate storage and transportation costs and efficiencies, including capturing and retaining value, and reducing cost and risks.
- Determining the willingness of food manufacturers, bioenergy producers, and other current and potential buyers of North Dakota crops to pay the premiums for green inputs.
- Estimating the impact of using of green fertilizer on farm profit.

The focus of the study was refined when initial findings revealed that initiating an enterprise to capture and process flared gas was not economical at this time, but that relying on the energy industry to supply conventional natural gas for fertilizer manufacturing is more feasible at the present time. However, a premium for crops produced with green inputs and need for carbon sequestration in the future should be subsequently studied at appropriate times.

Economics of Using Flared vs. Conventional Natural Gas to Produce Nitrogen Fertilizer: A Feasibility Analysis

Thein Maung, David Ripplinger, Greg McKee and David Saxowsky¹

1. Introduction

Flared gas (that is, the gas associated with the production of crude oil in western North Dakota) consists of different types of gases including methane natural gas, propane, butane, ethylene, propylene and butadiene. On average, methane gas constitutes 55% of total gas composition (USEPA 1991). The Global Gas Flaring Reduction Public-Private Partnership (GGFR), a World Bank-led initiative established in 2002, supports governments, development agencies and oil industries worldwide in their efforts to reduce the flaring and venting of associated or flared gas during the crude oil extraction. The GGFR's mission is to promote effective regulatory frameworks and solve the issues related to gas utilization such as lack of access to energy infrastructure, markets and services especially in developing countries. According to the data in Table 1 obtained from the World Bank's GGFR website, globally Russia is the top gas flaring country with 1.32 trillion cubic feet (TCF) of gas being flared in 2011. The United States ranks fifth in 2011 with 0.25 TCF of gas being flared. Gas flaring in the United States has rapidly increased in recent years partly because of the boom in oil and gas industries in the Bakken and Three Forks formations in western North Dakota.

In 2007, the GGFR funded the PFC Energy to conduct study on gas flaring in the Russian Federation. The goal was to promote developing policies and regulations on gas flaring and utilization in Russia. The study (see PFC Energy 2007) suggests that there are four major factors that inhibit energy producers from capturing and utilizing flared gas. They are 1) lack of infrastructure such as gas processing plants and pipelines needed to transport flared gas, 2) lack of policy frameworks that provide sustained incentives for producers to better utilize flared gas, 3) large volumes of flared gas come from small fields in less populated and remote areas far from major local energy markets which make pipeline connection costs prohibitively high, and 4) prices of natural gas, propane and butane extracted from flared gas.

In addition to wasting valuable resources, gas flaring also contributes to a significant anthropogenic source of greenhouse gas (GHG) emissions (GGFR 2005). In North Dakota, most of the flared gas is wasted due to insufficient infrastructure which has not expanded at the same pace as rapidly growing oil production (USEIA 2011). The state has lax regulations on gas flaring. For example under North Dakota regulations (see NDDMR 2011), gas flaring from an oil well is allowed during the first year of production without paying penalties in the form of taxes or royalties. After one year, gas flaring is still permissible given that an oil company pays taxes or royalties on the flared gas. If an oil company can show that connection of a well to a natural gas gathering line is economically infeasible, it can be exempted from the prohibition against gas flaring. In recent years because of improvements in natural gas drilling and hydraulic fracturing technologies, there has been an oversupply of natural gas in the market which brings down gas

¹ Maung and Ripplinger are research scientists and McKee and Saxowsky are Associate Professors.

prices. Low natural gas prices provide little incentives for private investments in flared gas reduction.

The objective of this study is to investigate the viability of using flared natural gas to produce nitrogen fertilizer in North Dakota. We begin by looking into the availability and economics of flared natural gas in Section 2. We found that flared natural gas supply could become unstable over the long term and that at the current time it is not economically advantageous to use flared gas to manufacture nitrogen fertilizer. Thus in Section 3, we look into the feasibility of using conventional natural gas to generate nitrogen fertilizer. Sections 4 and 5 discuss business models and cooperative structures for a nitrogen fertilizer firm. Sections 6 and 7 illustrate the structure of limited liability company and income taxation for the firm. Section 8 examines facility siting for a potential nitrogen fertilizer plant. Finally, Section 9 concludes this study.

Table 1. Top 20 Flaring Countries by Volumes (in Billion Cubic Feet), 2007-2011

	2007	2008	2009	2010	2011
Russia	1,846	1,483	1,645	1,257	1,320
Nigeria	575	547	526	530	515
Iran	378	381	385	399	402
Iraq	237	251	286	318	332
USA	78	85	116	162	251
Algeria	198	219	173	187	177
Kazakhstan	194	191	177	134	166
Angola	124	124	120	145	145
Saudi Arabia	138	138	127	127	131
Venezuela	78	95	99	99	124
China	92	88	85	88	92
Canada	71	67	64	88	85
Libya	134	141	124	134	78
Indonesia	92	88	102	78	78
Mexico	95	127	106	99	74
Qatar	85	81	78	64	60
Uzbekistan	74	95	60	67	60
Malaysia	64	67	67	53	56
Oman	71	71	67	56	56
Egypt	53	56	64	56	56
Total (20 nations)	4,660	4,377	4,483	4,165	4,271
Rest of the world	777	777	706	706	671
Global flaring level	5,436	5,154	5,189	4,871	4,942

Source: <http://go.worldbank.org/G2OAW2DKZ0>

2. Availability and Economics of Flared Natural Gas

In recent years, gas flaring in the United States has increased rapidly as indicated in Table 1. On average, North Dakota accounts for as much as 21% (Table 2) of the total gas flared in the United States. Most of the gas flared in North Dakota is heavily concentrated in the western part of the state such as Williams, McKenzie, Dunn and Mountrail counties (Figure 1). Flared gas generally follows oil production pattern (Figure 2). As the production of petroleum crude oil increases, so does the amount of gas flared (Figure 3). Figures 4 and 5 indicate that usually the amount of gas flared declines over time as oil production declines. This variation in flared gas production and the cost of capturing and processing flared gas (discussed below) suggest that relying on flared gas alone over the long term to produce nitrogen fertilizers may not be practical.

Table 2. Amount of Gas Flared in North Dakota

Year	Billion Cubic Feet (BCF)	% of US Total**
2006	6.65	-
2007	13.73	18%
2008	26.83	32%
2009	23.79	21%
2010	30.81	19%
2011	45.98*	18%
Average	28.23	21%

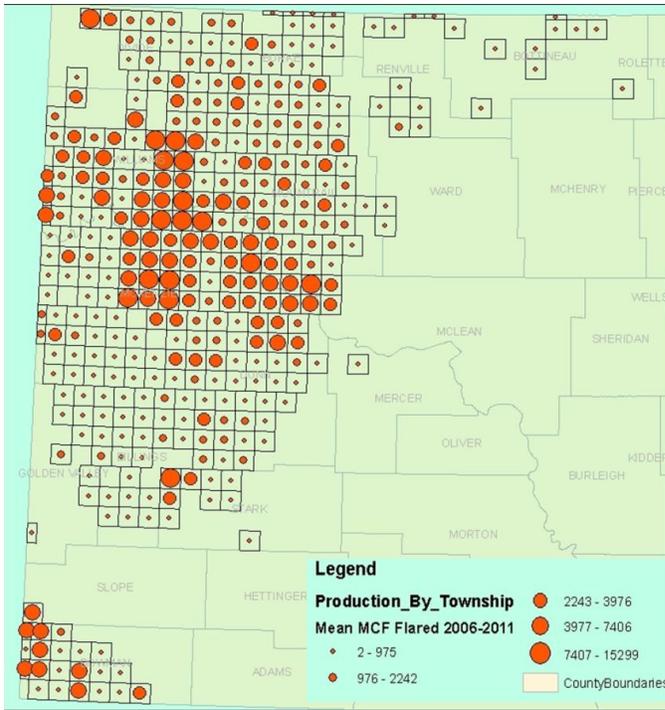
*Due to some missing data, the amount of gas flared maybe higher than this in 2011.

**Computed using the total amount of gas flared in the United States (Table 1) and the amount of gas flared in North Dakota.

Source: NDDMR

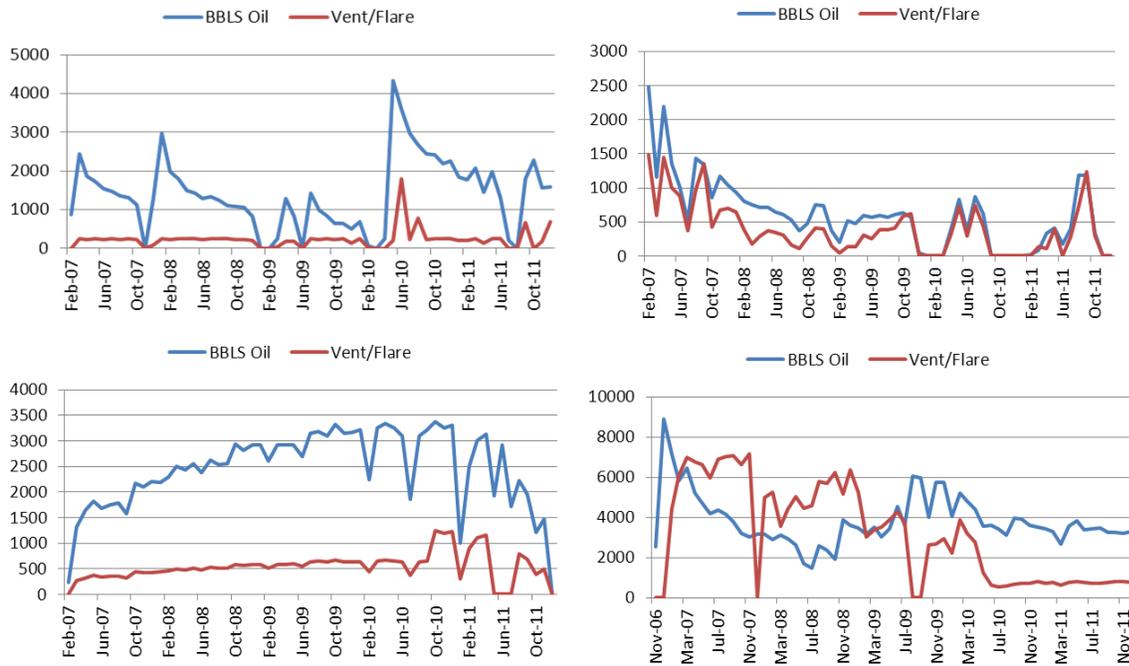
2.1. Economics of Capturing and Collecting Flared Gas

To the best of our knowledge, with the exception of the study by PFC Energy (2007), few or no studies have examined comprehensively the economics of collecting flared gas. According to PFC energy (2007), an optimal way to collect flared gas is to connect oil well fields to a gathering center located in the middle and transport flared gas from the center to a gas processing plant (GPP) (see Figure 6). Using this optimal approach, PFC energy estimated pipeline connection costs from fields to a gathering center and then to a GPP. Generally, it would cost as much as \$4/MMBtu (Million Btu) to collect all the flared gas through a pipeline infrastructure using the aforementioned approach (Figure 7).



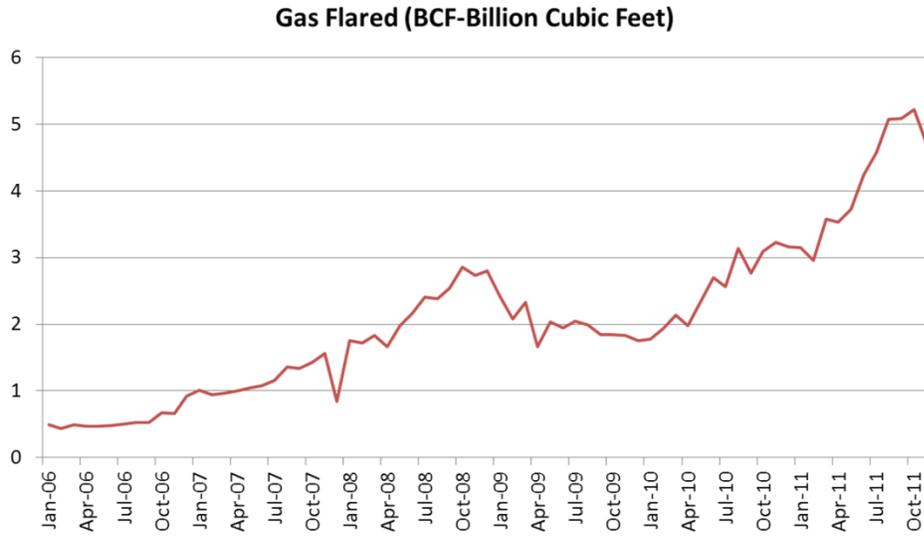
Source: NDDMR

Figure 1. Concentration of Flared Gas in Western North Dakota



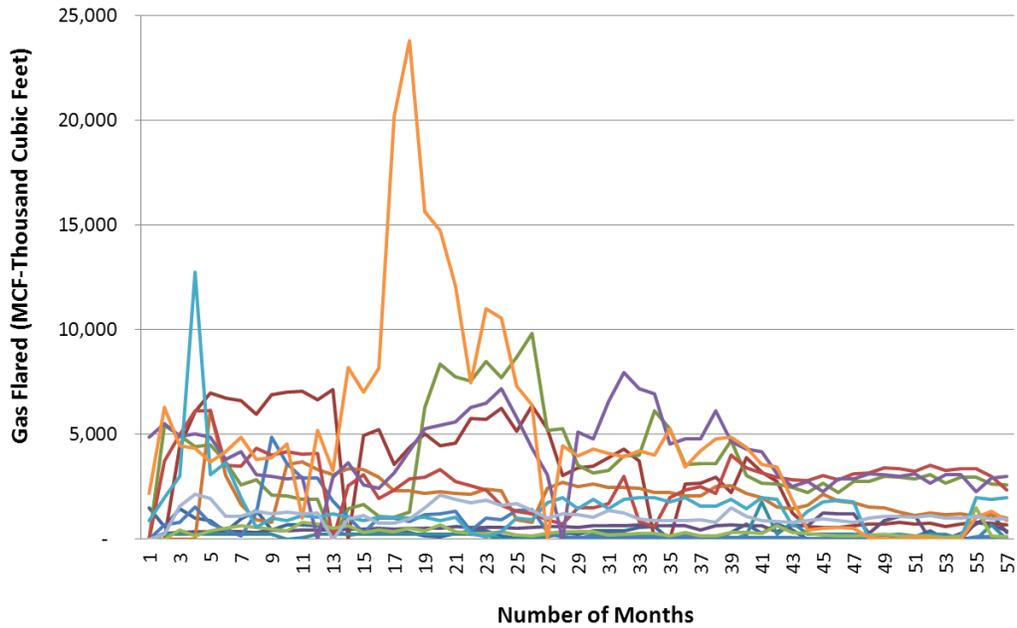
Source: NDDMR

Figure 2. Oil and Flared Gas Production Patterns for Four Sample Wells



Source: NDDMR

Figure 3. Amount of Gas Flared in North Dakota



Source: NDDMR

Figure 4. Flare Gas Based on 13 Oil Well Observations

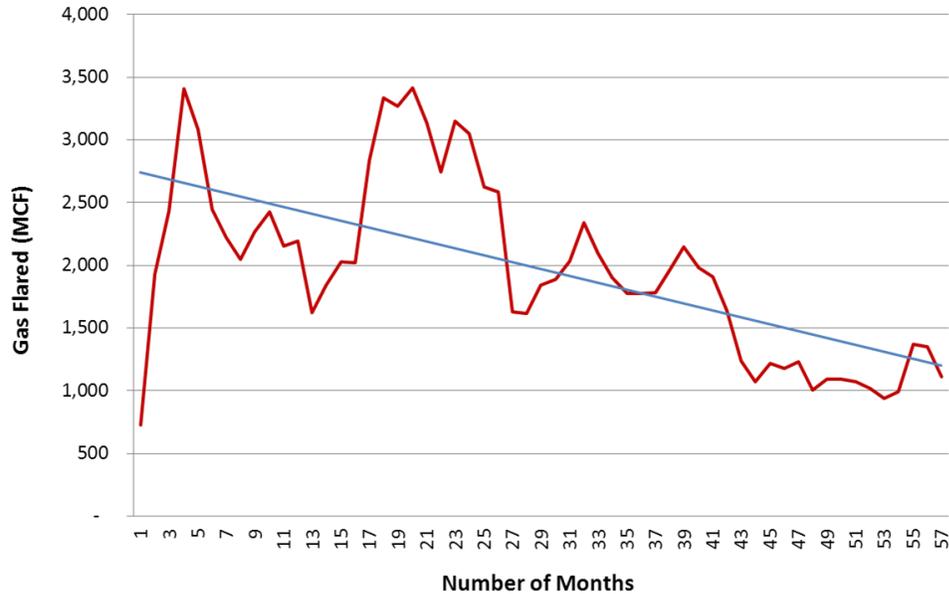
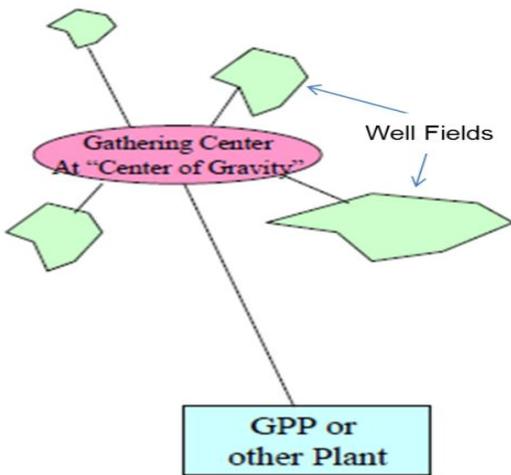


Figure 5. Average of 13 Well Observations from Figure 4 (Straight line represents the trend)

The total cost of producing flared natural gas could sum up to at least \$7.57/MMBtu², assuming that payment to oil producers for capturing flared gas is \$0.57/MMBtu (PFC Energy 2007), pipeline connection cost is \$4/MMBtu (PFC Energy 2007) and processing cost is \$3/MMBtu (Blanton 2010). At present, the spot price of conventional natural gas at Henry Hub is about \$2.88/MMBtu. As long as the price of conventional natural gas is lower than the cost of flared natural gas, energy producers have little incentive to capture and process flared gas for use.

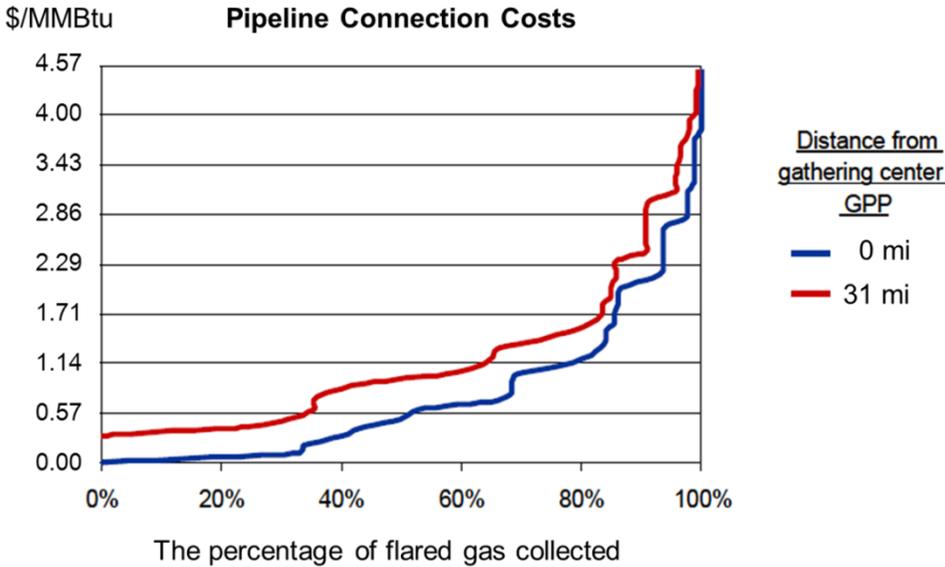


GPP – Gas Processing Plant

Source: PFC Energy (2007)

Figure 6. Optimal Way to Connect and Capture Flared Gas

² Storage, transportation and marketing costs are excluded.



Source: PFC Energy (2007)

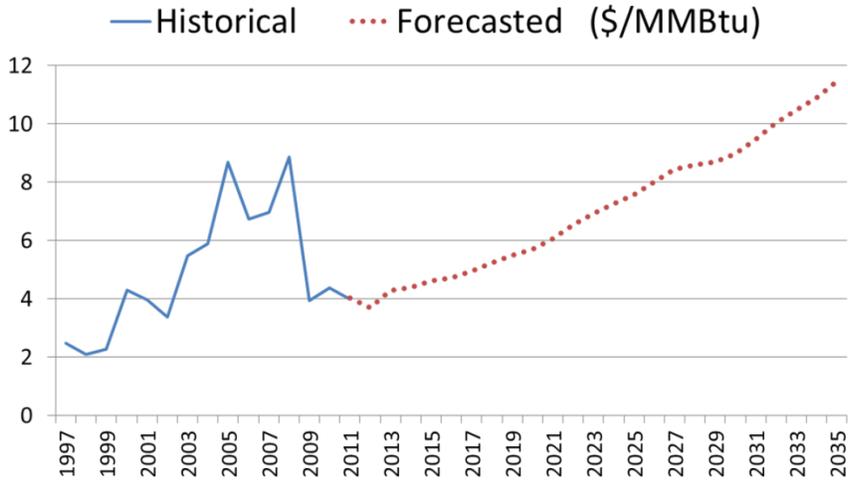
Figure 7. Pipeline Connection Cost for Capturing Flared Gas

2.2. Other Factors Influencing the Capture of Flared Gas

Two factors may provide energy producers with incentives to capture and collect flared gas: 1) an increase in conventional natural gas price and 2) federal policy inducement. The U.S. Energy Information Administration (EIA) predicted that natural gas price would likely rise in the future (Figure 8) as demand catches up with supply. Beginning January 1, 2015, the U.S. Environment Protection Agency (EPA) requires that oil refineries capture flared gas and make it available for use. This mandate will prevent methane natural gas from going to waste and reduce greenhouse gas emissions. These two factors will likely make flared gas available for commercial use in the near future.

2.3. Summary

Presently, the conventional natural gas price is lower than the presumed flared natural gas cost and consequently, energy producers do not have incentives to capture the flared gas and make it available for use. However, this will change if the price of natural gas increases as predicted and as EPA's regulations on capturing flared gas take effect on January 1, 2015. It may not be in the best interest for nitrogen fertilizer producers to depend solely on flared natural gas as the major feedstock because the supply of flared gas could become unstable in the long run.

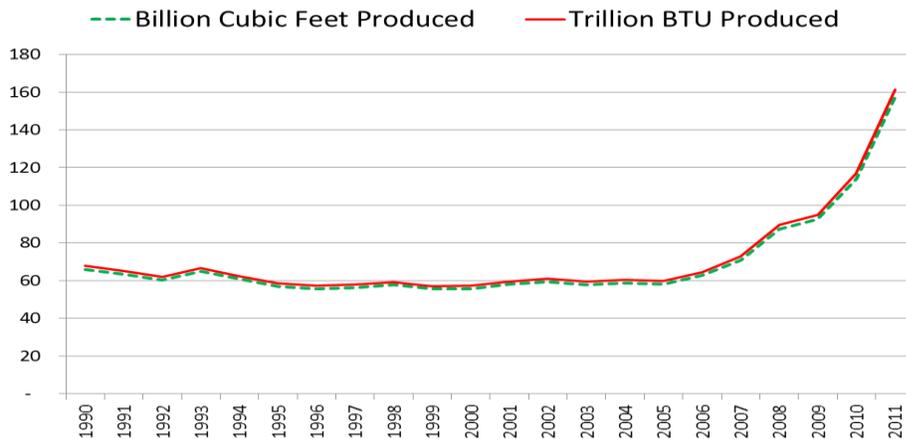


Note: This is based on the reference case.
 Source: <http://www.eia.gov/oiaf/aeo/tablebrowser/>

Figure 8. Historical and Forecasted Henry Hub Natural Gas Spot Price

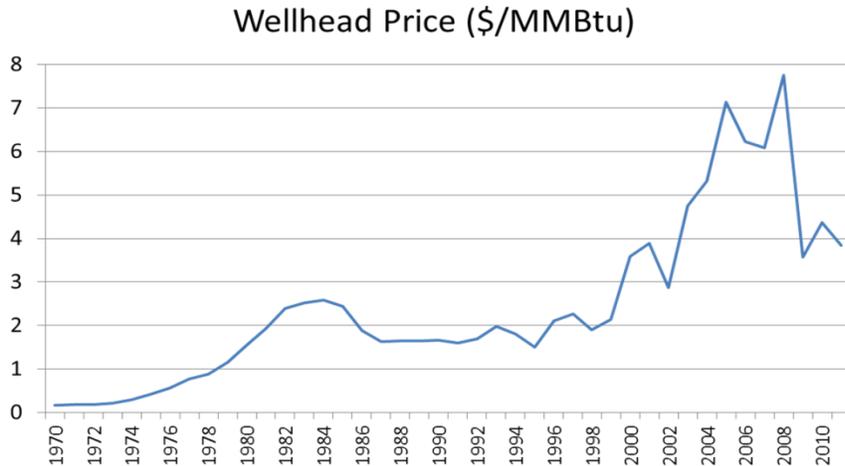
3. Feasibility of Producing Nitrogen Fertilizers Using Conventional Natural Gas

Since early 2005, natural gas production has been on the rise in North Dakota due to improved horizontal drilling and hydraulic fracturing technologies. In 2011, total natural gas production in North Dakota reached 160 trillion Btu (Figure 9) which is enough to generate approximately 4.8 million tons of anhydrous ammonia. In recent years because of advancement in natural gas production technology, there has been a national surplus of gas supply and the price has declined sharply (Figure 10). At present, both spot and future prices of natural gas at Henry Hub are close to \$3 per MMBtu. Low natural gas prices are driving interest in nitrogen fertilizer production investment.



Source: NDDMR

Figure 9. Total Dry Natural Gas Production in North Dakota



Source: http://205.254.135.7/dnav/ng/ng_pri_sum_dcu_nus_m.htm

Figure 10. Historical Natural Gas Price in the United States

3.1. Geographic Location of Ammonia Production Capacity and Ammonia Production Process

In North America, most ammonia production takes place in Louisiana, Oklahoma, and Alberta (Canada) (Figure 11). Trinidad and Tobago in the southern Caribbean also have a large ammonia production capacity. In the United States, North Dakota ranks twelve in terms of production capacity (Figure 12). The state has the capacity to produce 400,000 tons of ammonia each year. Globally, about 75% to 80% of ammonia is produced using Steam Methane Reforming process (Kramer 2004). The ammonia production process illustrated in Figure 13 includes the following steps: 1) desulfurization of natural gas, 2) primary reforming, 3) secondary reforming, 4) shift conversion, 5) CO₂ removal, 6) methanation, and 7) ammonia synthesis through the Haber-Bosch process.

In the first step, sulfur content in natural gas is removed to prevent damaging the catalysts in the primary reformer. In the second step, sulfur-free natural gas is mixed with process steam and reformed to convert methane into hydrogen, CO₂ and CO (carbon monoxide). Then the gas mixture is sent to the secondary reformer where it is combined with compressed air that has been preheated. Air is added to generate a synthesis gas having a hydrogen-to-nitrogen mole ratio of three to one. The gas leaving the secondary reformer is then cooled in a waste heat boiler (USEPA 1996). In the fourth step, the cooled gas mixture enters a CO shift converter where CO is converted into CO₂. The CO₂ is removed in the fifth step. The remaining trace amounts of CO and CO₂ are removed during the methanation process step. What remains is a mixture of nearly pure hydrogen and nitrogen which is then converted to anhydrous ammonia in the final step using the Haber-Bosch process.



Source: http://www.energy.iastate.edu/renewable/ammonia/ammonia/2005/Hutchison_transport.pdf

Figure 11. Ammonia Production Capacity in North America

State	Capacity (Tons)	Rank
LA	4,514,000	1
OK	2,515,000	2
AK	1,416,000	3
IA	791,000	4
GA	758,000	5
KS	695,000	6
TX	680,000	7
MS	669,000	8
OH	598,000	9
VA	584,000	10
TN	409,000	11
ND	400,000	12
IL	306,000	13
NE	292,000	14
AL	193,000	15
WY	192,000	16
OR	111,000	17
FL	86,000	18
Total	15,209,000	

Source: http://www.energy.iastate.edu/renewable/ammonia/ammonia/2005/Hutchison_transport.pdf

Figure 12. Ranking of Ammonia Production Capacity in the U.S.

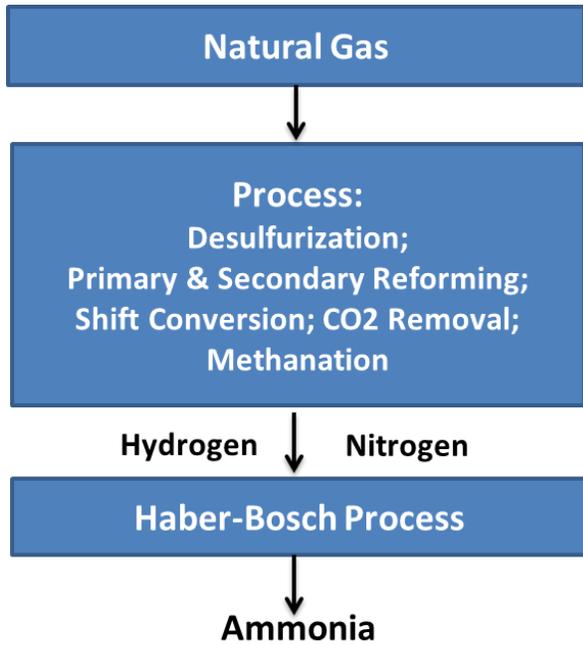


Figure 13. Steam Methane Reforming Ammonia Production Process

3.2. Methodology, Assumptions and Data Need

This study utilizes levelized cost to investigate the feasibility of producing anhydrous ammonia using natural gas. According to the USEIA (2010),

“levelized cost represents the present value of the total cost of building and operating a generating plant over an assumed financial life and duty cycle, converted to equal annual payments and expressed in terms of real dollars to remove the impact of inflation”.

Mathematically, the present value of the total cost can be expressed as

$$PV(\text{total cost}) = \frac{LC * F_1}{(1+i)^1} + \frac{LC * F_2}{(1+i)^2} + \dots + \frac{LC * F_N}{(1+i)^N} = \sum_{n=1}^N \frac{LC * F_n}{(1+i)^n} \quad (1)$$

PV is defined as the present value. Total cost includes capital (K), natural gas (NG), electricity (E), and operation and maintenance ($O\&M$) costs. LC and F are, respectively, denoted as levelized cost and the amount of fertilizer (in short ton) produced each year (n). i represents a real discount rate. Since annual NG , E and $O\&M$ costs are assumed to be constant, equation (1) can be written as

$$PV(K) + NG + E + O\&M = \sum_{n=1}^N \frac{LC * F_n}{(1+i)^n} \quad (2)$$

Because LC and F are fixed, the levelized cost in equation (2) can be expressed as

$$LC = \left\{ \left[\frac{PV(K)}{\sum_{n=1}^N \frac{1}{(1+i)^n}} \right] + NG + E + O\&M \right\} / F \quad (3)$$

Baseline assumptions used to estimate the levelized cost of anhydrous ammonia production are shown in Table 3. We investigate the levelized cost of anhydrous ammonia production for five different plant sizes. The plant sizes along with their capital costs are described in Table 4. Operation and maintenance (O&M), electricity and capital costs were obtained from our industry source³. Capital costs include both ISBL (Inside Battery Limits) and OSBL (Outside Battery Limits) costs⁴.

Table 3. Baseline Assumptions Used in Estimating Ammonia Cost

Natural Gas Cost (\$/MMBtu)	5
Plant Efficiency Rate (%)	100
Electricity Cost (\$/kWh)	0.06
Electricity Requirement for Small Plant (kWh/ton)	950
Electricity Requirement for Large Plant (kWh/ton)	100
O&M Cost for Small Plant (\$/ton)	40
O&M Cost for Large Plant (\$/ton)	30
Natural Gas Requirement (MMBtu/ton)	33
Real Discount Rate (i) (%)	8
Lifetime Financing (n) (years)	20
Number of Operating Days	340

Table 4. Total Capital Cost for Ammonia Production

Plant Size (tons/year)	Total Capital Cost (Million \$)
3,400	24
50,000	138
516,000	630
1 Million	968
1.5 Million	1,261

³ The source cannot be revealed due to non-disclosure agreement.

⁴ ISBL costs include the costs of main process units such as compressors, heat exchangers, electrical wires and hardware, computer control systems, drainage and sewers, and foundations and structural supports etc. OSBL costs include the costs outside of the main process units such as steam generation, water treatment systems, water cooling and piping systems, electrical supply, general utilities, site development etc. (Netzer 2006).

3.3. Ammonia Cost Estimation Results

Levelized cost for ammonia production is estimated by plant size and reported in Table 5. The table shows that as the plant size increases the cost declines due to economies of scale. The rate of cost decline is steeper when the plants are smaller, but as the plant size increases, the rate of cost decline gradually flattens. It would cost \$325/ton to generate ammonia using a 516,000 tons/year plant. Storage and transportation costs were not considered in estimating this cost. The share of capital cost as percent of total cost declines as the plant size increases (Table 6). But, the share of natural gas cost as percent of total increases significantly as the size of plant increases. The natural gas cost accounts for more than 50% of total cost as the plant size reaches or surpasses 516,000 tons/year production capacity.

Table 5. Baseline Levelized Cost for Ammonia Production

	Ammonia Plant Size (tons per year)				
	3,400	50,000	516,000	1 Million	1.5 Million
	\$/ton of Ammonia				
Capital Cost	721	281	124	99	86
Natural Gas Cost	165	165	165	165	165
Electricity Cost	57	57	6	6	6
O&M Cost	40	40	30	30	30
Total Ammonia Cost	983	543	325	300	287

Table 6. Percent of Total Levelized Cost for Baseline Case

	Ammonia Plant Size (tons per year)				
	3,400	50,000	516,000	1 Million	1.5 Million
	Percent of Total Cost				
Capital Cost	73%	52%	38%	33%	30%
Natural Gas Cost	17%	30%	51%	55%	58%
Electricity Cost	6%	10%	2%	2%	2%
O&M Cost	4%	7%	9%	10%	10%
Total Ammonia Cost	100%	100%	100%	100%	100%

3.4. Ammonia Cost Sensitivity Analysis

Because natural gas cost accounts for more than 50% of total cost, changes in natural gas prices will impact the cost of ammonia production. Figure 14 shows that as the natural gas price increases from \$5/MMBtu to \$12/MMBtu, the cost of ammonia production increases substantially (for example from \$325/ton to \$556/ton for a 516,000 tons/year plant). Other factors, such as changes in electricity price, capital cost, and real discount rate have relatively

smaller impact on ammonia cost (see Figures 15, 16 & 17). The figures show that changes in electricity price, capital cost and real discount rate have a much larger impact on small plants than large plants.

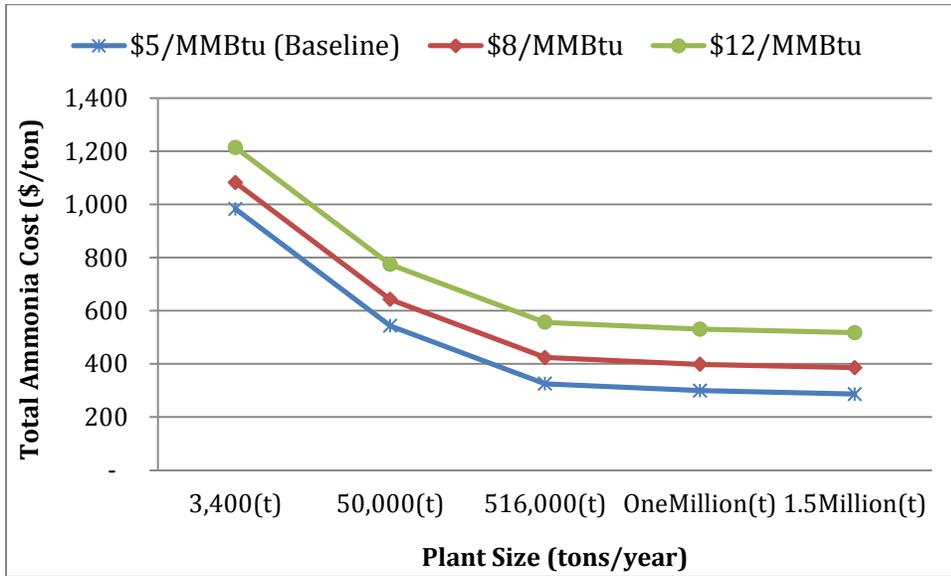


Figure 14. Impact of Changes in Natural Gas Price on Ammonia Cost

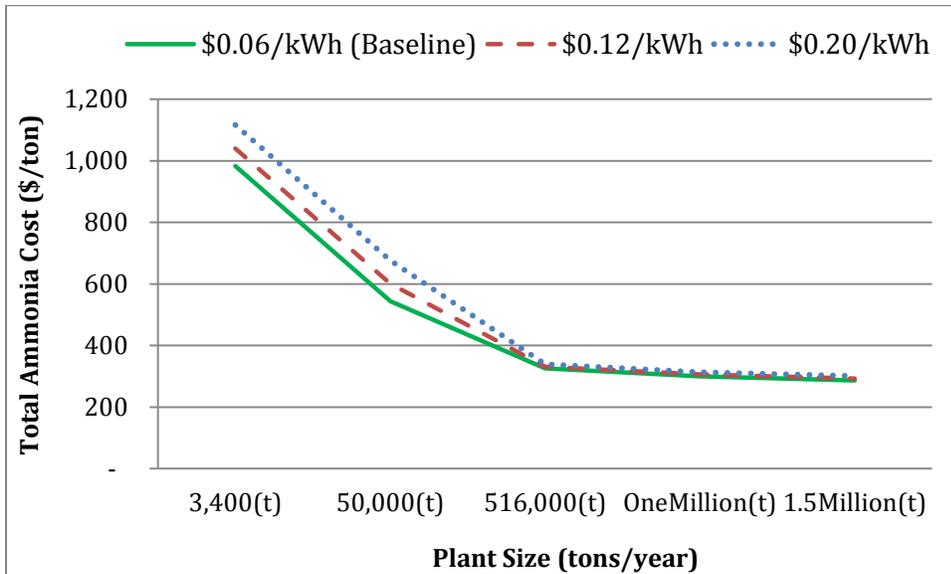


Figure 15. Impact of Changes in Electricity Price on Ammonia Cost

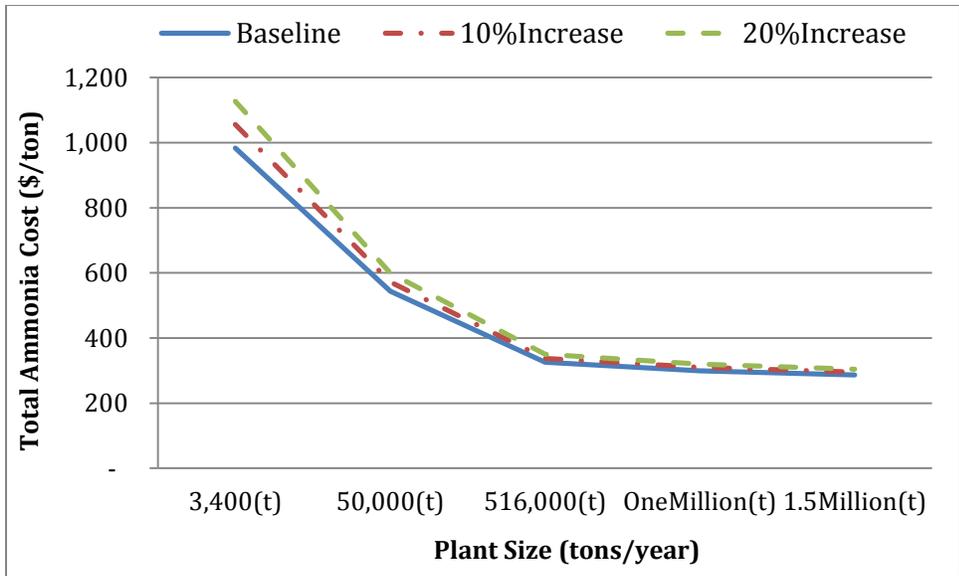


Figure 16. Impact of Changes in Capital Cost on Ammonia Cost

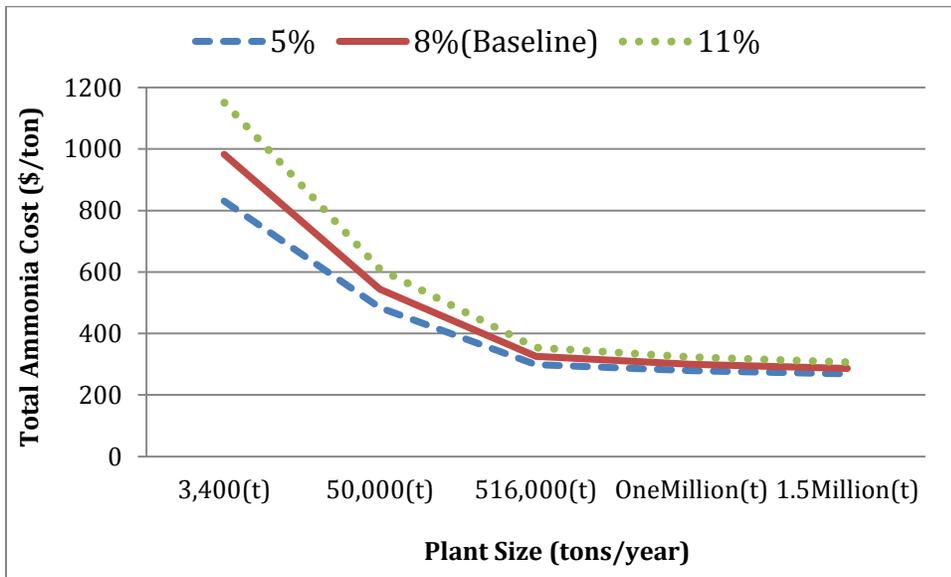


Figure 17. Impact of Changes in Real Discount Rate on Ammonia Cost

3.5. Ammonia Cost Estimation Based on Mix Products

The estimated ammonia costs do not include costs of producing other fertilizer products such as Urea, ANS and UAN. According to our industry source, the total capital cost of producing ammonia, Urea, ANS and UAN varies from \$516 million to \$1.34 billion for the plant sizes shown in Table 7. Using our baseline assumptions, we estimated anhydrous ammonia levelized cost associated with this product mix. Results reported in Table 7 show that the ammonia cost ranges from \$383/ton to \$571/ton for this mix-product case.

Table 7. Total Capital Cost of Producing Ammonia, Urea, ANS, and UAN, and Anhydrous Ammonia Levelized Cost

Plant Size (tons/year)	Total Capital Cost (Million \$)	Ammonia Levelized Cost (\$/ton)
170,000	516	571
510,000	1,044	409
748,000	1,336	383

3.6. Summary⁵

Because of advancement in horizontal drilling and fracking technologies, natural gas production has sharply increased in North Dakota in recent years. As the gas supply outstrips the demand, the market price declines rapidly. This low cost for natural gas creates a major incentive for local firms to invest in nitrogen fertilizer production. Results in this research indicate that ammonia production costs vary by plant size. Initially as the plant size increases, ammonia cost declines sharply but when the plant size reaches 516,000 tons/year, the rate of cost decline flattens. For a 516,000 tons/year plant, ammonia cost is estimated to be \$325/ton, excluding storage and transportation costs. Natural gas feedstock cost can account for more than 50% of total production cost. The sensitivity analysis shows that ammonia cost increases significantly as natural gas price rises. Other factors, such as changes in electricity price, capital cost, and real discount rate have relatively minor impact on ammonia cost especially for a large fertilizer plant.

⁵ Note: The analysis does not include preparing a financial pro forma to demonstrate the financial viability, that is, pro forma balance sheets, income statements and cash flow statements for a nitrogen fertilizer production plant. The study does not determine the willingness of food manufacturers, bioenergy producers, and other current and potential buyers of North Dakota crops to pay the premiums for green inputs, nor does it estimate the impact of using of green fertilizer on farm profit because the fertilizer produced from this a project would not likely meet a definition of being “green”. In addition, the study does not develop a supply chain model to estimate storage and transportation costs and efficiencies, including capturing and retaining value, and reducing cost and risks. These detailed analyses will be prepared as part of developing a business plan, as necessary.

4. Business Models

A business model is a tool that describes how physical and technical inputs interact with a marketplace and investors to generate economic output. Understanding the functions of a business model may aid the selection process of the legal structure of the business model for this project. The functions of a business model are summarized in four ways, described below. The relationship among these functions is illustrated in Figure 18.

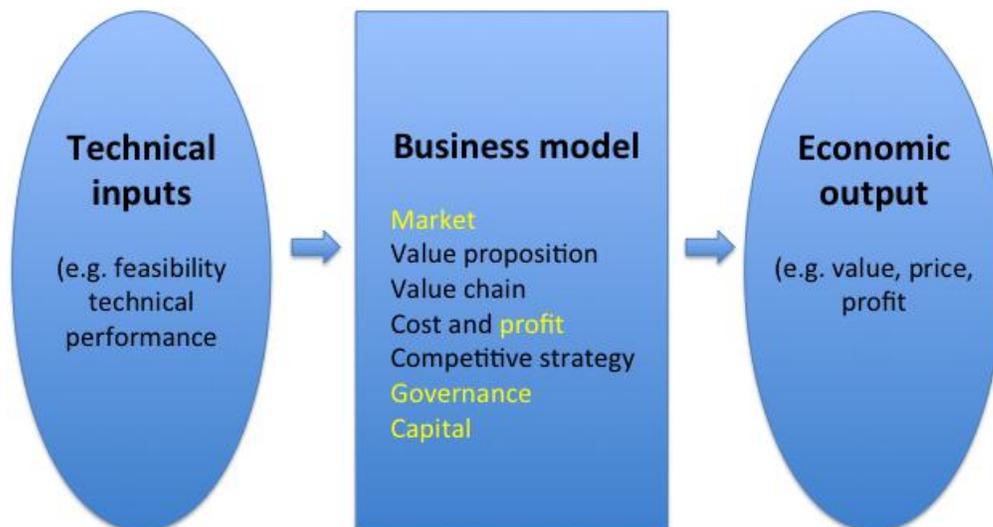


Figure 18. Business Models Mediate between Technical and Economic Domains

4.1. The Value Proposition

The first function of a business model is to articulate the value created for the corporation's users. The value proposition is targeted at users for which the firm's technology achieves a purpose. A firm's decision makers identify sources of inputs for creating and distributing output. Users then exchange money for the output, generating revenue for the firm. The difference between expected revenues and expected costs of using the selected inputs determines the firm's profit potential.

4.2. Justification of Capital

In order for the firm to obtain the assets necessary to produce output, it requires financial capital. Equity capital comes from investors who perceive the firm's profit potential. Debt capital comes from lenders who also perceive this potential. The firm justifies capital investment when it demonstrates that the probability of achieving the value proposition, during the life of the investment, is greater than the risks of failure.

4.3. Path for Scaling Firm Operations

The relationship between investors and the firm determines how the firm obtains capital for changing the scale of output over time. Income generated by the firm can be reinvested into itself or investors may contribute equity directly. Alternatively, the firm may obtain additional capital through borrowing.

4.4. Ownership and Associated Control Rights

Given that income provides investment incentives, business models also describe the nature of income distribution and the process by which distribution decisions are made. Investors in the company, both equity and debt, make their investment contingent on having rights to the firm's value. Since the likelihood of generating that value is subject to risk, investors require control over the firm's decision making process so as to increase the likelihood the firm will survive.

Investors of equity and debt have rights to different sources of the firm's value. Lenders provide capital in exchange for rights to the firm's assets. Should the firm fail, lenders will be the first to be repaid on their investment. In contrast, equity investors provide capital in exchange for rights to the net income of the firm. Since lenders will be paid regardless of the profitability of the firm, equity investors bear relatively more risk of not being repaid than lenders. In exchange for this increased level of risk, equity holders are granted the greatest right to control the decisions of the firm.

5. Cooperatives

Cooperative corporations are a type of business model. They are unique relative to other business models in terms of control, ownership, and distribution of income. The unique aspects of control, ownership, and income distribution are 1) democratic control by the users of the company, 2) ownership by the users, and 3) net income distribution to company users in proportion to patronage. A user who both patronizes the firm and has made an equity investment in it is said to be a member. Note that the connection between the rights of control and ownership are placed in the hands of members. There are three principal types of cooperatives. They differ based on the composition of the membership.

5.1. Traditional Cooperative

The value proposition and justification of capital. A traditional cooperative contains a value proposition and justification for capital similar to any other type of corporation. The equity holders can be comprised of common and preferred stockholders. All common stockholders must be users of the cooperative. Subject to bylaws, a person can become a member of a cooperative at any time when they both use its services and make an equity investment. A person ceases to be an active member by no longer patronizing the firm. Lenders also play an active role in financing cooperative businesses.

Path for scaling firm operations related to ownership and control rights. Since a person can become a member of a traditional cooperative at any point in time, the path for scaling up the

business depends on, among other things, patronage volume. Capital for asset purchases in traditional cooperatives is obtained from lenders and members. Since members are the only equity investors, they control the rate of investment and have rights to its net income. After making an initial direct investment in the cooperative, a common way for members to continue making equity investments is to retain the net income and allocate retained income to each member in proportion to use. Members make a policy establishing this procedure through an elected body of member representatives, called a board of directors. As a result, the value of equity increases over time, assuming positive net income, and the cooperative is able to increase the scale of its operations. Member equity in a traditional cooperative is redeemed at the discretion of the board of directors. Lending has no unique features in a traditional cooperative. The relationship among these features is illustrated in Figure 19.

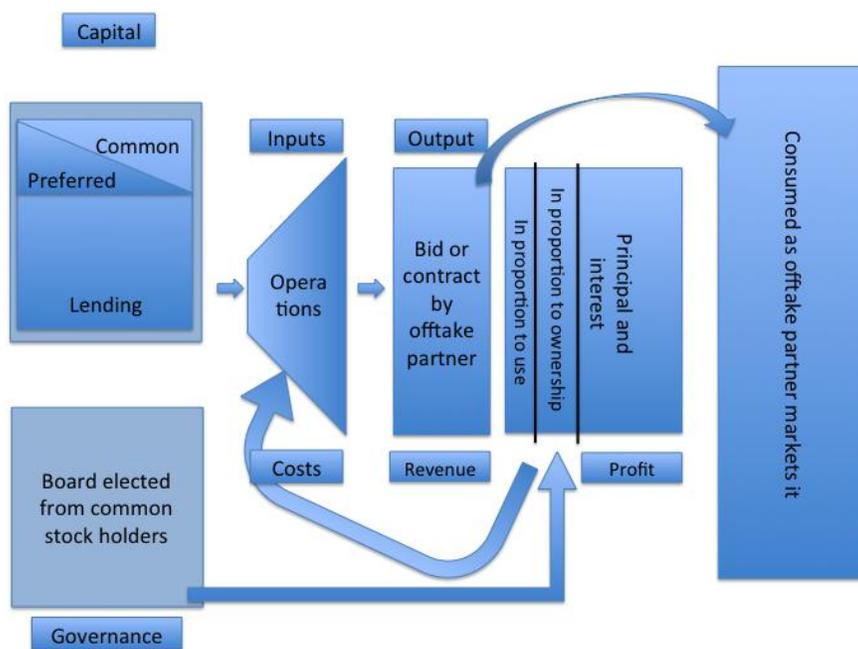


Figure 19. Traditional Cooperative (CHS, CoBank)

5.2. New Generation or Closed Membership Cooperative

The value proposition and justification of capital. A new generation cooperative contains a value proposition and justification for capital similar to any other type of corporation. The equity holders can be comprised of common and preferred stockholders, and lenders play an active role in financing new generation cooperatives. All common stockholders must be users of the cooperative. Although membership in a new generation cooperative is obtained when a person both uses the cooperative and makes an equity investment, new generation cooperatives restrict access to using the cooperative. For this reason, new generation cooperatives also are sometimes called closed cooperatives.

Two examples demonstrate how this model works in practice. In the case of the CALAMCO, a fertilizer purchasing cooperative, total membership is restricted by California state law to a maximum number of shares. Each share represents an allocation of fertilizer for member

purchase. Since statewide fertilizer requirements exceed the fertilizer volume provided by the shares, the maximum membership size is less than the total farmer population in California. In the case of a marketing cooperative, like American Crystal Sugar Company, each share represents a right to market a fixed area of harvested acreage through the cooperative. Since the physical capacity of the cooperative is less than the capacity of the cooperative's service territory to produce sugar beets, membership in this cooperative is restricted. In both cases, a person ceases to be an active member by no longer patronizing the firm.

Path for scaling firm operations related to ownership and control rights. Since a person can become a member of a new generation cooperative only when shares are available, the path for scaling up the business is relatively stable in this type of cooperative. Capital for asset purchases in new generation cooperatives (as in traditional cooperatives) is obtained from lenders and members. Members make an initial direct investment in the cooperative by purchasing shares. The shares grant a right to use the cooperative for a period of time. Net income is usually returned at the end of the fiscal year in the form of dividends (marketing cooperatives) or rebates (purchasing cooperatives). Income distribution policy is made by the board of directors. Member equity in a new generation cooperative is redeemed when stock can be sold to another active or potential member, with oversight by the board of directors. Lending has no unique features in a new generation cooperative. The relationship among these features is illustrated in Figure 20.

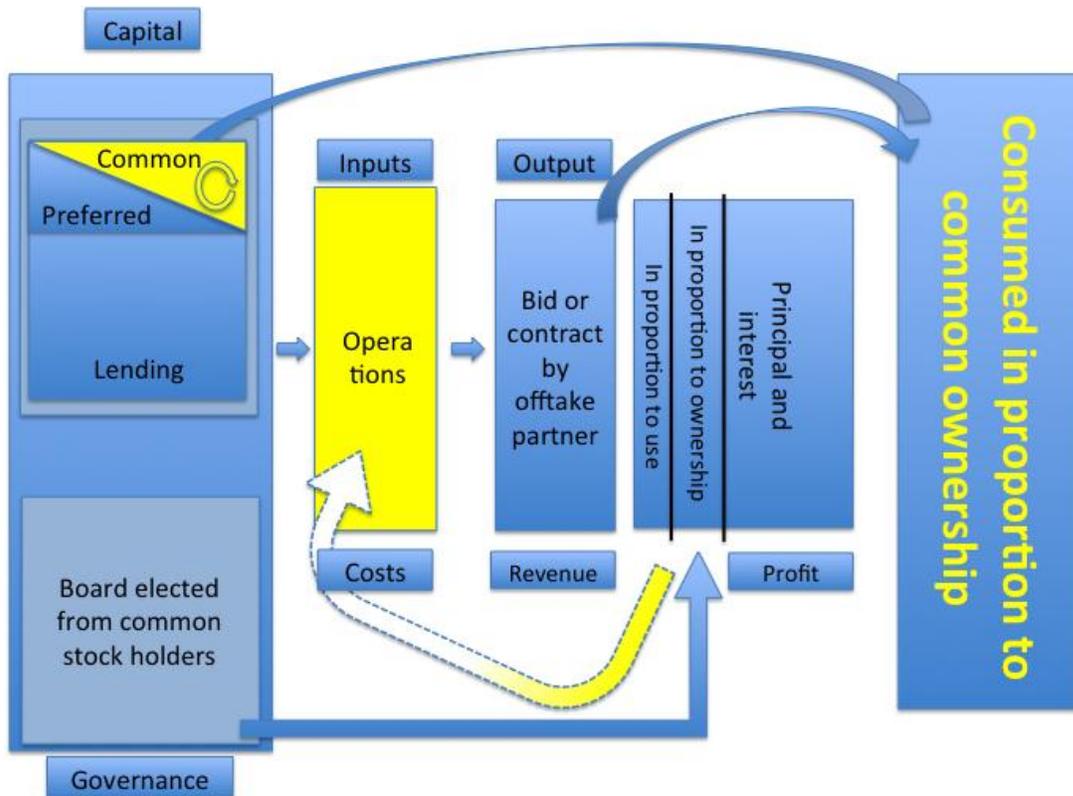


Figure 20. New Generation Cooperatives

5.3. Hybrid Cooperative

The value proposition and justification of capital. A hybrid cooperative contains a value proposition and justification for capital similar to any other type of corporation. In 2003, Minnesota amended its cooperative business incorporation statute, affecting sources of equity capital. Wyoming and Iowa have adopted similar statutes. The central feature of this amendment is to allow equity investment in a cooperative by non-users. Hence, the equity holders can be comprised of common and preferred stockholders, but common stockholders are NOT required to be users of the cooperative. Membership in a cooperative is obtained EITHER when a person uses the cooperative and makes an equity investment in it, OR simply when they make an equity investment in it. This kind of cooperative takes advantage of features of traditional investor-owned corporations as well as traditional cooperatives. For this reason these are called hybrid cooperatives.

Path for scaling firm operations related to ownership and control rights. Since a person can become a member of a hybrid cooperative through investment and/or use, the path for scaling up the business may be relatively stable in this type of cooperative when compared with traditional cooperatives. Capital for asset purchases in traditional cooperatives is obtained from lenders and members. Members make an initial direct investment in the cooperative by purchasing common shares. Since investors comprise the board of directors, distribution of net income is subject to the preferences of the board, subject to certain constraints. Non-members may contribute as much as 99.99% of the equity, but cannot receive more than 85% of the income. Also, patrons must comprise at least 50% of the voting power of “general matters of the cooperative.” Lending has no unique features in a hybrid. The relationship among these features is illustrated in Figure 21.

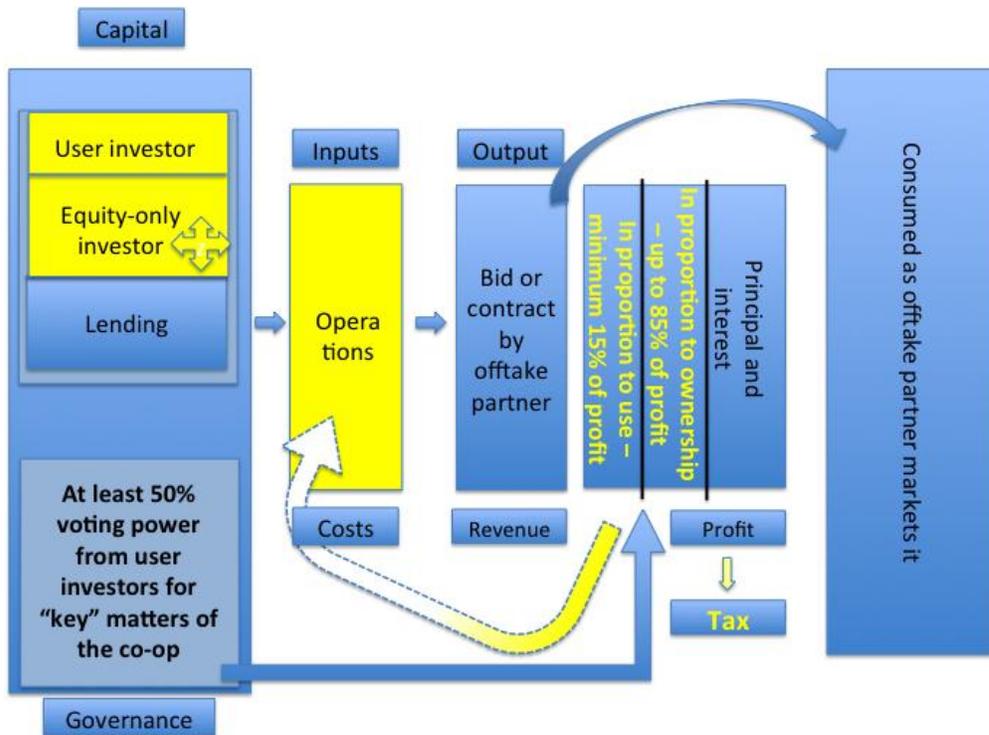


Figure 21. Hybrid Cooperatives

6. Limited Liability Company

A limited liability company (LLC) decouples the relationships between use, control, ownership, and income distribution, as in a cooperative. A limited liability company contains a value proposition and justification for capital similar to any other type of corporation. One or more owners, also termed “members”, may contribute equity to the company. The board of directors is comprised of members. The bylaws of the corporation establish the relationship between ownership and voting rights. Member equity in a limited liability company is redeemed when stock can be sold to another active or potential member. The relationship among these features is illustrated in Figure 22.

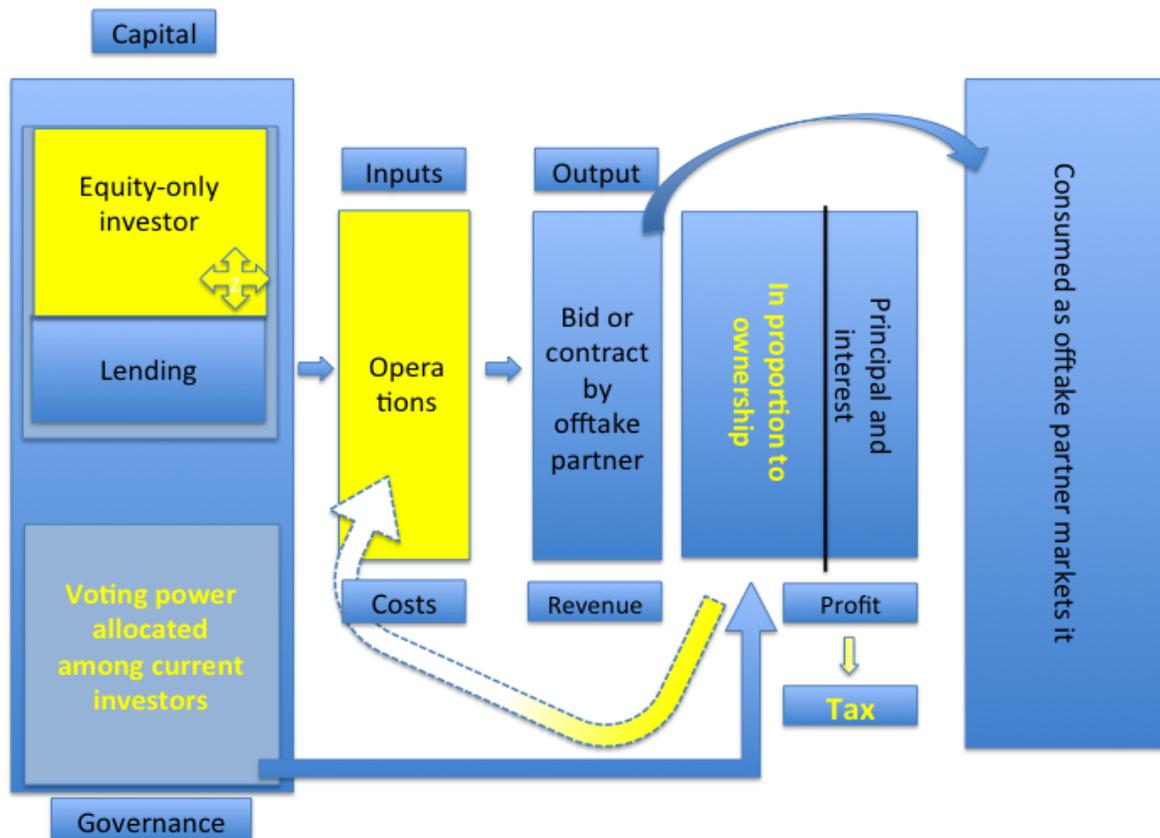


Figure 22. Limited Liability Companies

7. Income Taxation

The net income of traditional and new generation cooperatives is generally taxed according to the single-tax principle. The principle is based on the concept that cooperatives are nonprofit extensions of the business enterprises of the patrons who own them. Consequently, the net income of cooperatives is generally taxed only once.

The taxation of hybrid cooperatives varies depending on the choice of the co-op; it may choose to be taxed based on cooperative tax statutes (Subchapter T) or partnership statutes (Subchapter K). One criterion for selecting the tax treatment is the optimal taxation of income from non-member business. Under subchapter T, income from non-member business is taxed based on the double-tax principle, whereas under subchapter K, it is not. The net income of LLCs is generally taxed according to the single-tax principle. The principle appears to be based on the concept that LLCs are nonprofit extensions of the owning member(s).

8. Facility Siting

The site of a manufacturing facility gives shape to the entire supply chain. It impacts capital and operating costs and the ultimate success of a business. Siting is sometimes determined by a single dominant factor while in other cases, a number of alternatives are weighed (Ballou 2002). The goal of the nitrogen fertilizer production facility siting task is to identify siting criteria and determine, at a high level, the existence of at least one suitable site in the northern plains, the absence of which would raise questions about the feasibility of the entire project. The study identified and evaluated four preliminary sites. Although no location was found to be the obvious site for the facility, sites that meet required and preferred criteria are expected to be readily identified during the business planning process based on the preliminary review. This section describes general siting considerations, plant-specific requirements, a review of North Dakota utilities and transportation infrastructure, and preliminary sites.

8.1. General Siting Considerations

The North Dakota Department of Commerce’s Shovel Ready Checklist is used to provide a general overview of siting considerations. It includes an outline of site characteristics developers should consider as well as activities or documents that may need to be conducted or prepared in conjunction with site selection and development. The Checklist was developed to assist businesses and site selectors make their decisions more quickly, correctly, and with fewer hassles. Of interest to the siting task was the list of site characteristics and suitability. The Shovel Ready Checklist is presented in Table 8.

Table 8. Shovel Ready Checklist

Characteristics and Suitability	Surveys, Studies, and Tasks
Site ownership	Archeological and historical survey
Developable acres	Archeological and historic mitigation
Acres free of wetlands	Conceptual site plan
Suitable shape and configuration	Environmental assessment
Suitable topography	Floodplain boundaries
Surrounding land use	Park covenants/rules/regulations
Transportation access	Protected and rare species survey
Zoning	State environmental quality review
Real estate transaction	Site survey
Community support	Soils survey
Electric service	Special district approval
Water	Stormwater management
Wastewater	Traffic impact study
Telecom service	Wetlands avoidance and minimization
Natural gas service	Wetlands avoidance and minimization plan
Rail service	Wetlands mitigation plan

8.2. Plant-Specific Requirements

Plant-specific requirements for the nitrogen production fertilizer plant were identified independent of the Shovel Ready Checklist. However, they align and include many of the characteristics identified. Before discussing site selection criteria, the geographic area considered for the siting of the plant bears mention. The northern plains nitrogen fertilizer market targeted to be served by the facility includes North Dakota, South Dakota, western Minnesota, eastern Montana, Manitoba, and Saskatchewan. Most nitrogen is expected to be consumed in this region; however, unique market conditions may lead to export at times. Consequently, siting was focused on North Dakota due to its central location in this market. In addition, North Dakota has abundant, low-cost, and in some cases stranded natural gas (the original motivation for the study); and significant acreage planted to nitrogen-demanding crops. These latter two considerations provide a significant strategic advantage to locating another nitrogen fertilizer plant in the state.

Nitrogen production plant-specific siting criteria identified include land, transportation and utility infrastructure, and labor.

- **Land** - The desired site is expected to be as much as 160 acres (one-quarter section) in size. This provides adequate space for construction of the initial plant and expansion that may occur. Isolation from residential and commercial areas is preferred. Nitrogen production is an industrial process which makes it a poor fit for non-industrial or non-agricultural areas. A one to two-mile buffer is preferred. Flat land is desired to minimize site preparation costs.
- **Utility Infrastructure** - Natural gas and water availability are paramount. Natural gas is the primary feedstock for nitrogen fertilizer production and also is used as fuel for the plant. The amount of natural gas needed is dependent on the plant's output. A world-scale 2000 metric ton/2200 short ton plant requires approximately 80,000 MMBTU's daily. This is a significant amount of feedstock that weighs siting a location in proximity to a natural gas plant or large interstate natural gas pipeline.

Water is needed as part of the fertilizer production process as well as for cooling. Water requirements for processing and cooling vary. High-end estimates of water needs are 5,000 gallons per minute. In the absence of sufficient water supplies, electrical-powered cooling can be utilized. Waste water disposal (up to 1,500 gallons per minute) and power line transmission (up to 15 MVA) access also are necessary.

- **Transportation Infrastructure** - Markets will be accessed by shipping product by highway and rail. Rail access also is needed to move building supplies during construction.
- **Labor** - A large workforce of up to 2,000 people will be needed to construct the plant. Proximity to a community of 20,000 or more will aid in housing during construction and avoidance of costly man camps.

8.3. Utilities Infrastructure

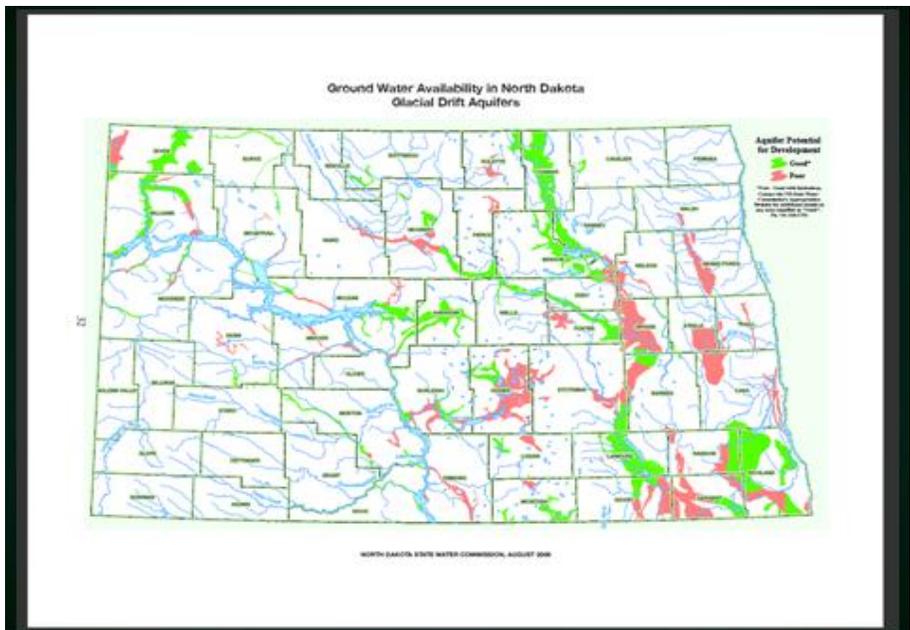
Two large international natural gas pipelines -- Alliance and Northern Border -- transect North Dakota. These pipelines historically moved natural gas from Alberta to the Chicago market. The Viking Pipeline follows North Dakota's eastern boundary a few miles into Minnesota. The Williston Basin Interstate Pipeline serves much of the state of North Dakota, western South Dakota, as well as eastern Montana and Wyoming, but ships much smaller quantities than the Alliance, Northern Border, or Viking. Recent development of the Bakken formation in western North Dakota has led to the release or collection of large amounts of associated gas. This has led to the expansion or construction of natural gas plants in the area which use the Alliance and Northern Border to reach market. A map of major international natural gas pipelines is presented in Figure 23.

Ground and surface water is available in many areas of the state. However, few locations have adequate supplies available to meet the process and cooling requirements of a world-scale nitrogen fertilizer production plant. Even if water is available, use is permitted by the State Water Commission and much of the water has already been secured for various municipal, agricultural, and industrial purposes. A map of North Dakota glacial aquifers is presented in Figure 24. Also shown on the map is the location of the Missouri River which is home to more than 80 percent of the state's surface flow. The Red River, which forms the eastern border of much of the state, also is sizable, although much of its available water is already spoken for by municipalities and industry.

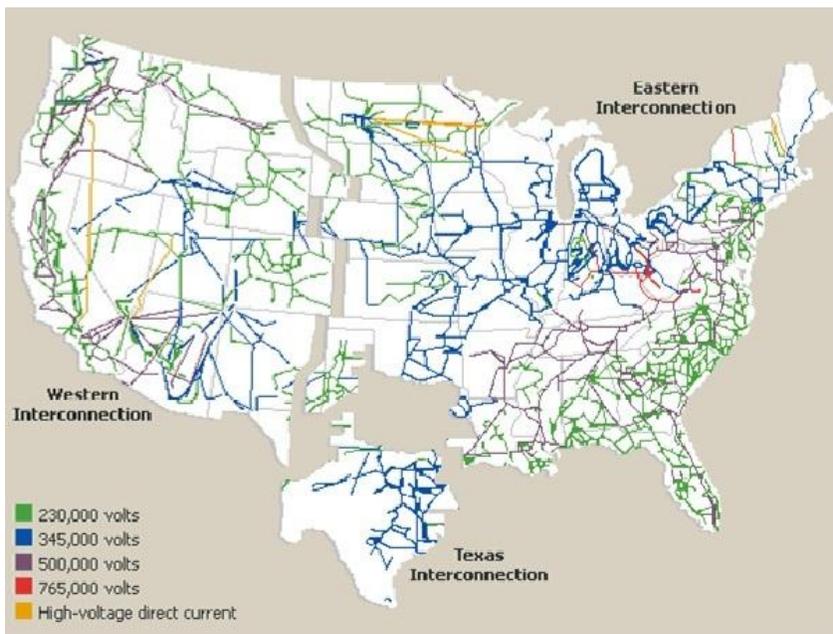
As a major power generation state, North Dakota is transected by a number of major and minor power transmission lines some of which correspond to highway and rail corridors. This alleviates concern for power availability, somewhat. Figure 25 shows the location of major power transmission lines in the state and nation.



Figure 23. Northern Plains Natural Gas Pipelines (International)



Source: North Dakota Water Commission
 Figure 24. North Dakota Glacial Aquifers

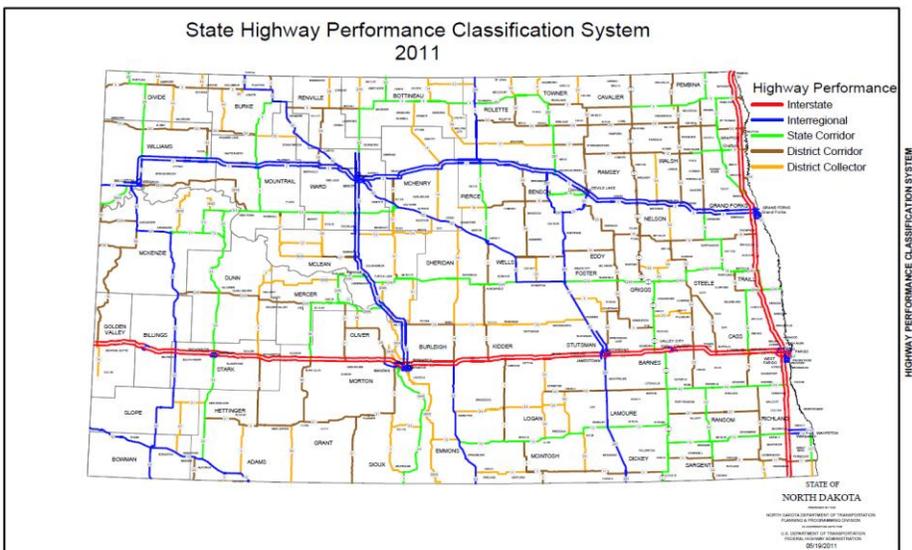


Source: Energy Information Administration
 Figure 25. U.S. Power Transmission Network

8.4. Transportation Infrastructure

Highway and rail infrastructure is needed to deliver building materials to the site and to transport nitrogen products to market. As most fertilizer is expected to be sold within the region, highway access is critical. While location on an interstate or interregional highway is not mandatory, it would reduce concerns about road conditions and maintenance. North Dakota's State Highway Performance Classification System is presented in Figure 26. Interstate highways appear in red and interregional highways in blue. Double lines indicate four-lane highways.

Many North Dakota locations are served by the Burlington Northern Santa Fe (BNSF) or the Canadian Pacific (CP) railroad. These railroads align with many of the state's highway corridors. A map of these systems is presented in Figure 27 with the Canadian Pacific being the lighter shaded line.



Source: North Dakota Department of Transportation

Figure 26. North Dakota State Highway Performance Classification System



Figure 27. Burlington Northern Santa Fe and Canadian Pacific Rail Lines

8.5. Preliminary sites

Four preliminary sites were identified as part of the feasibility analysis prior to and during the application of siting criteria.

Dakota Gasification, Beulah, North Dakota – is the location of the state’s only existing nitrogen fertilizer plant. The coal gasification complex has a 400,000 ton per year ammonia production capacity. The complex also captures and ships CO₂. The site is located adjacent to the Bakken play making construction costs and labor availability a major concern while providing immediate access to natural gas. There is limited room for adjacent to the site for development. The site is served by the Burlington Northern Santa Fe Railroad and is located on North Dakota Highway 49 and just south of North Dakota Highway 200. The Missouri River is located 20 miles to the east.

Spiritwood Energy Park, Stutsman County, North Dakota – is the location of Great River Energy’s new 99 MW coal-powered plant just south of the Burlington Northern Santa Fe mainline and 10 miles east of Jamestown on Interstate 94. The Alliance natural gas pipeline comes closest to the site near Wimbledon 15 miles northeast. The location is above the Spiritwood aquifer which currently supplies the nearby Cargill malting facility.

Hankinson, North Dakota – was initially identified because of its location on the Alliance Pipeline, the only delivery point in North Dakota. The city is located on the Canadian Pacific mainline and just a few miles west of Interstate 29. Wahpeton is 25 miles northwest and Fargo is

60 miles north. Water may be available from the Hankinson Aquifer, Milnor Channel, or Brightwood Aquifer.

Nashua, Minnesota – was identified because of its location near an intersection of the Burlington Northern Santa Fe and Canadian Pacific railroads which coincides with Minnesota Highways 9 and 55. The undeveloped location is approximately 70 miles southeast of the Fargo-Moorhead Metropolitan Area and 25 miles away from the nearest cities of Wahpeton, North Dakota, and Fergus Falls, Minnesota. The area is 50 miles south of the Viking pipeline and 30 miles northeast of the Alliance pipeline.

8.6. Summary of Siting Considerations and Next Steps

While no site was officially identified, a number of prospective spots were reviewed. Water availability may play a key role in finding the ultimate location. The next step will be to work with the North Dakota Department of Commerce, other state agencies, and local economic development agencies to review sites in greater detail.

9. Summary of Findings

The crop mix of the northern plains is not likely to change dramatically in the next several decades and the associated use of nitrogen fertilizer is more likely to increase than it is to remain stable or decrease. Nitrogen is being used to meet increased food, feed, and energy demand. Nitrogen wholesalers expect an ongoing transition away from anhydrous ammonia use due to issues of safety and environmental impact. Natural gas is a key component in the manufacture of nitrogen fertilizer and it is currently the lowest cost source of hydrogen for ammonia production. Since oil and gas drilling in North Dakota is expected to continue for years with production lasting decades, the availability of natural gas in the northern plains will be stable into the future.

Few studies have conducted research on the economics of flared gas collection. The market price of capturing and processing flared gas is not yet established but there is opportunity to work, and possibly partner with natural gas companies to predict long-term prices and lay-in a long-term supply to manufacture fertilizer. Despite the significant capital and expertise required, oil and gas companies are finding a way to collect and clean the gas associated with oil production. They are planning to build gas gathering pipelines and processing plants in western North Dakota (Bentek Energy, 2012).

A fertilizer production facility located near an area where the fertilizer is consumed creates a competitive advantage in transportation cost. The technology to manufacture fertilizer is proven and commercially available. There may be an opportunity to manufacture several related industrial products. The northern plains offers necessary infrastructure and business resources, such as natural gas pipelines, rail, interstate highways, brown field and green field industrial sites, off-take partners, manufacturing partners, natural gas supply partners, lenders who are willing to consider providing debt capital, and agricultural producers throughout the region who may be willing to invest equity as well as purchase the final fertilizer product.

Our feasibility study shows that a start-up business can manufacture fertilizer at a competitive cost. The technological economies of scale suggest a relatively large scale facility. Due to the surplus of natural gas supply and low natural gas prices in the United States, it is highly likely that additional fertilizer manufacturing capacity will be built in North Dakota and other states. Expansion of existing facilities in other states and provinces has already been announced.

A fertilizer manufacturing business needs to develop a long-term vision and prepare for times when fertilizer prices decline and natural gas prices increase. Supply and price risks are of concern to nitrogen marketers and farmers. Long-term supply (natural gas) contract and off-take partners will reduce the risks. It may take four years of construction time to begin manufacturing nitrogen fertilizer. A new generation cooperative as well as a hybrid cooperative may offer tax advantages over other business models. For example, CALAMCO, a California-based ammonia production and marketing new generation cooperative, has been successful. There is a need to work closely with producers to understand their willingness to invest equity as well as commit to the purchase of the final fertilizer products. Prioritization of goals, including profitability, governance, and consumption, can be used to identify the appropriate business model. Subsequent business planning with accountants, attorneys and other professionals will test each of these points.

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