A Strategic Overview:

US Food & Energy Supply Chain Security Through Distributed Fertilizer, Fuel and Electrical Power Production

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INTRODUCTION

Since 9/11, the issue of domestic security has come to the forefront of the consciousness of the American people more than at any time since December 7, 1941 and perhaps more than that as there have been a steady barrage of news reports of incidents or near misses since then. While there are many domestic strategic vulnerabilities facing the United States today, specifically addressed within this document are five (5):

- Food supply
- Fuel supply
- Electricity supply and distribution
- Environment
- Terrorism

One of the means for addressing these vulnerabilities lies with new methods of manufacturing anhydrous ammonia, NH_3, that is both:

- produced domestically &
- from a "clean" technology

This little known, yet second most widely produced chemical in the world, has the ability to address, directly or indirectly, each of the above listed vulnerabilities.

- **Food Supply - Directly** – By some estimates, over 50% of the protein consumed in the U.S. and over 60% of the processed/packaged foods sold in the U.S. have NH_3 in their supply chain. Over 70% of the NH_3 used to support the U.S. food supply is imported, with over half of that coming from China and Russia.

- **Fuel Supply – Directly** – Currently the U.S. imports over 75% of its fuel energy needs, most of which comes from countries with dramatically differing philosophies. Nearly 100% of the ethanol produced in the US is dependent on NH_3 in its supply chain and manufacturing process.

- **Electrical supply and distribution – Directly and indirectly –** The grid in the U.S. is in a vulnerable state from both its age and its susceptibility to attack from hackers and EMP (electro-magnetic pulse). Expansion of supply has been dramatically curtailed due to environmental concerns over the use of fossil fuels and nuclear energy. Wind and solar, while growing, provide only a tiny fraction of the requirement.

- **Environment – Directly** – The burning of fossil fuels releases into the atmosphere such green house gasses (GHGs) as CO_2, NOx, SOx, and particulates such as fly ash and mercury that are said to cause acid rain

- **Terrorism – Indirectly –** Petrodollars going to the Middle East have been tracked to funding terrorism activities. Further, as mentioned above, our electric grid is vulnerable to cyber and direct attack. Further, the ability to project and cost of projecting our military force across the globe is directly impacted by our dependence on other nations' providing our energy requirements.

Issue: The US food chain security is at greater risk than at any time in our history as a country, even without the ever present threat of sabotage/terrorism.

In the last few years, agricultural producers – farmers – have seen dramatic swings in the prices of fertilizer ($300-$1200/ton), diesel ($2.50-$5.00/gal) and natural gas ($4 - $14/M Btu). Those dramatic and unpredictable swings in the costs to producers have driven many out of business and driven up the prices of some of the food stocks to such a point that we witnessed food price protests on a global scale.

The synthesis of NH_3 using solid oxide fuel cell process technologies in development now and the deployment of small distributed manufacturing facilities holds the potential to stabilize the agri-business model and turn it from a centralized model to a distributed model with the result of greater independence for the producers and greater security of the food supply chain.

This paper provides a pragmatic approach to applying new technologies to provide significant improvements for:

- the localized, distributed manufacture and use of green fertilizer produced with renewable energy,
- distributed energy generation including fuels and electricity and
- distributed energy storage and retrieval of renewable sources of electricity on demand

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STRATEGIC IMPERATIVES

From both production and use standpoints, "clean-tech" anhydrous ammonia technology has direct strategic applications for the supply of food, fuels, and electricity and lessens the impact of these activities on the environment.

Properly viewed, the little known, but second most common chemical in the world, is a strategic resource for which increased availability has far reaching and potential national security implications. The following chart (larger version at end of document) reflects some of those interdependencies and issues:

Food – Not readily recognized nor discussed in any visible manner is the simple fact that *we are dependent on foreign suppliers for a very large part of our food supply*. More than half of our food production is dependent on our ability to import NH_3 (for use as fertilizer for such crops as corn and wheat). A disruption in this supply chain portends rapid increases in the cost of food and likely decreases in its availability. The ability to manufacture (with no CO_2 emissions) on a local, distributed, cost-effective manner is a potential remedy for the vulnerability that U.S. agriculture currently faces. This capability also relieves the agri-business from the wild price fluctuations ($300-1200/ton) that NH_3 has seen over the past 3 years due to the speculative nature of fossil fuel pricing, specifically natural gas.

Fuels - In terms of fuels, there are major initiatives underway in the US to lessen its dependence

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on imported oil with the oft-cited goal of energy independence. In the search for alternative fuels, the late Matt Simmons, the founder of the world's largest private energy investment banking firm, Simmons and Company, identified and advocated that only one potential fuel fills the need in the foreseeable future – anhydrous ammonia. "NH_3 (Liquid Ammonia) is [the] only realistic solution that makes sense." (Ammonia Fuel Conference Keynote Address, Kansas City, October 2009) While that might appear to be a viable solution near term as it can be burned alone or mixed with other fuels in an internal combustion engine (ICE), it only shifts the problem as 75% of the US's current consumption of NH_3 is imported (for fertilizer), just from different countries, including Russia and China. In addition, while ethanol for fuel is being touted as a viable alternative for use as a fuel, missing from the radar screen of the media is that nearly 100% of the ethanol for fuel produced in the US from corn is dependent on NH_3. Bio-diesel, depending on the source, may also be dependent.

The potential strategic threat from importing such high percentages of our fuel and fertilizer is real. What these new technologies provide is a clean, reliable, distributed, locally produced and cost effective solution to both. While as a nation the US could build more of the 100-year-old technology currently used, Haber-Bosch (H-B) plants, there are several factors that preclude this from happening: these plants are capital intensive, production is tied to the use and price of natural gas, and the process generates massive amounts of GHG's, including ~2 tons of CO_2 for every ton of NH_3 produced. The US EPA has just (2010) ruled that CO_2 is a toxic substance subject to its soon to be released regulations. Taking these factors into account, it is highly unlikely that any new H-B NH_3 plants will be built in the US.

Electricity Distribution and Production– Much has been written recently about the age and vulnerability of the grid in the U.S. Our ability to use renewable sources of electricity are hampered by the vagaries of the wind and sun, the physical location of the grid vis-à-vis the best locations for wind, solar, hydro, or geothermal, and the peak loading/leveling concerns of the grid distribution system. Ammonia can help alleviate the issues in all areas by using excess electricity supplied from wind and solar, when not matched to demand, to generate ammonia, which can be stored for later processing via a fuel cell or ICE to generate electricity when needed. This "Energy Storage & Retrieval" system is more efficient than batteries and significantly enhances the profitability of wind and solar farms, likely increasing the overall investment and yield from these approaches to renewables. It also allows for better use of the grid and flattens the variability of wind and solar generation. Storing energy as ammonia as an "Environmentally Benign Battery™ also decouples generation from distribution allowing for the capture of "stranded" power, such as hydro and wind, in areas not near the grid.

Greater distribution of power generation provides less vulnerability of the population to grid failure and lower impact should failure occur, and the lower the impact, the less attractive an attack becomes. An alternative to the central generation and distribution of power is the construction and deployment of 'Digital Distributed Micro-Generators ™ (DDMG). Under this concept, standard-sized engines driving generators are installed in multiples and distributed throughout the grid nearer to the point of electrical consumption. While distributed power generation is not a new concept, what is new is the potential to use engines with new technology to come on line in a few seconds, burn NH_3, and be deployed in multiples so that "digital" (quickly turning on and off by ones to balance load) becomes feasible. Because the engines are commercially available sizes, they would not, for the most part, require specialized components for repairs. These engines and the resultant 'Digital Distributed Generation™' (DDG) facilities would be designed to burn NH_3 but could also burn natural gas and would lessen the need to upgrade the massive transmission part of the grid, as well as grid interconnects, that are so vulnerable.

DDG's have the following advantages:

- Lower capital cost to deploy
- Lower transmission losses
- No CO_2 (easier air permits)
- Less noise than large installations (easier permitting)
- Increased reliability
- Flexibility to demand response
- Cost efficiency
- Simpler maintenance

Agriculture: The second strategic imperative is derived from the fact, as noted above, that we import 60-75% of the anhydrous ammonia for fertilizer: *we are dependent on foreign suppliers for a very large part of our food supply*. And several of those countries present thorny political, trade and military issues, namely Russia and China. Those sources in particular cannot be deemed secure suppliers. And pressure on China to revalue its currency will have a negative effect strategically as it weakens our agriculture sector with higher costs. The ability of the US to respond to any interruption in the supply chain from overseas has been further diminished by the shuttering of plants in the US leaving almost no idle capacity. Not readily recognized is that, according to some sources, 50% of the protein consumed in the US is directly dependent on the use of NH_3. The interruption of these sources of NH3 for any length of time represents an unacceptable security risk to the US.

Environment: As discussed earlier, the combustion of fossil fuels generates significant amounts of GHG's and harmful particulates. Ammonia as a direct replacement for fossil fuels is achievable and would reduce the pollution generated from fossil fuels. The one caveat is that the current H-B process for making ammonia is unacceptably polluting as it uses CH_4 or coal as its raw material, generating 2 tons of CO_2 per ton of NH_3. Therefore, a process to produce NH_3 in a "green" manner, such as SOFC synthesis, would help address the environmental concerns that are currently impacting today's fuels and processes.

Terrorism – There are some additional aspects of domestic security not discussed above. The first is the wide recognition that exporting petrodollars to nations that do not have strategic interests aligned with those of the US constitutes a security issue at some level which we need not elaborate on and which the use of domestically produced NH_3 can impact.

The second issue is the vulnerability of our increasingly “smart” but aging and overloaded electrical grid. Most Americans are aware of the more and more frequent news reports of foreign sources hacking both our grid and the industrial infrastructure of the US. Less reported is the concern of some experts that the grid could be ‘taken down’ in a destructive manner, and as we saw happen accidentally in the ‘80’s in the Northeast, creating the potential for a cascading wave of failures across the US. At the same time, the April 2008 Congressional Commission on the threat of an EMP attack (Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack) lays out unthinkable consequences of a single Electro Magnetic Pulse bomb attack that include a cascading of grid failures. According to some, the result would be wide spread fatalities from lack of food, water and heating. The connection between the two is that a coordinated assault by a few terrorist cells (or even a few individuals) could potentially accomplish the same thing as an EMP attack. As the Commission points out, besides the vulnerability of electronics that control the grid, there are about 2,000 transformers, nominally around the 345kV range, that support the grid a large portion of which would be destroyed in an attack. Taken down destructively, they point out that it could take years to get the grid back up as the total annual world production (100% off shore) is only 100 units and delivery time is roughly 3 years in a benign environment.

In either case, the results are beyond the frequently used term in the study of “catastrophic”. An alternative to this scenario is the construction and deployment of ‘Digital Distributed Micro-Generators ™ (DDMG) as discussed above.

SOFC Ammonia Synthesizer Technology - SOFC technology solutions better addresses these very real strategic imperatives. The current 100 year old production technology is tied to the price of natural gas and electricity. This process uses 3-4% of the world’s natural gas to manufacture and is a polluter to the effect of 2 tons CO_2 per ton NH_3 produced. It is also affected by the currency value of the US dollar (75% is imported) and can potentially be threatened by disruptions in the supply chain. Smaller, distributed ammonia plants (µ-hubs) of all types can be powered by renewable resources such as hydroelectric, wind, or solar, and **<u>when produced in this manner, ammonia is classified as an advanced bio-energy fuel by the USDA</u>**. An additional benefit is the potential for creating carbon credits/offsets as carbon regulation or taxes are anticipated to start with the new administration.

Ammonia as Fuel

While the use of NH_3 in agriculture alone argues for an exceptional opportunity for new production methods to be commercialized, it is the use of NH_3 as a fuel that demands a technology breakthrough that is both distributed (close to point of use to reduce transportation costs and supply chain disruptions) and green to eliminate GHG’s including CO_2. The new solid oxide fuel cell technologies for producing NH_3 such as those of the Aetodyne solution achieve all of that. In addition, it is anticipated that the processes will require 1/10 the capital cost of current methods. While the business case for agriculture stands on its own, even as the nascent market for ammonia as a fuel develops, ammonia as a fuel will not likely get legs under it as long as: 1) it is tied to the price and use of natural gas 2) creates CO_2 in its production and 3) has high

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capital costs (think refineries). Under those conditions, it is unlikely that new ammonia plants will be built in the US in the foreseeable future, thus requiring the US to import ammonia, putting it in the same predicament as it is with imported oil today.

Our national electrical 'smart' grid is faced with serious challenges that demand resolution in the near term. First, as more renewable power generation sources come on line, the grid will need new transmission lines and substantial upgrades as well as new methods of energy storage all of which are seeing legislative, environmental and financial hurdles. At the same time, the grid has encountered an increasing and unprecedented level of cyber attacks well publicized in the media over the last few years. Those attacks have the potential to bring down significant portions of the grid, and some worry in a destructive manner. From an agri-business perspective, the disruption of electrical power equals a disruption of agricultural production on an exponentially magnified basis as it leads to the loss of crops and livestock – both of which take extended time to replace.

At a time where excessive pressures on the earth's land resources are of growing concern, there is a massive new demand emerging for cropland to produce fuel for the transportation sector. Although this situation had been developing for a few decades, it was not until Hurricane Katrina in 2005, then oil prices jumped and U.S. gasoline prices climbed, that the situation came into focus. Suddenly investments in U.S. corn-based ethanol distilleries became hugely profitable, unleashing an investment frenzy that will convert one fourth of the 2010 U.S. grain harvest into fuel.

The price of grain is now tied to the price of oil. In this new situation, when the price of oil climbs (which is inevitable) the world price of grain moves toward its oil-equivalent value.

While not a panacea, new NH_3 production technologies such as the SOFC technology are positioned to play a significant role. It is pragmatic, here-today and part of the puzzle that constitutes a significant part of the solution that directly addresses these strategic imperatives.

THE AMMONIA RELATIONSHIPS

The series of new technology solutions discussed will address the following areas as shown in Figure 2 below. While there are other methods to potentially produce anhydrous ammonia regionally (smaller facilities using the current technology), none provides the parallel advantages of a green approach that also facilitates the security of the food supply chain through distributed production of fertilizer, fuel and electrical power (DDG) with the added benefit of economic development at the local level.

Local Economic Development Impact - At the same time, the extra benefits of this type of distributed production of energy include local economic development and greater local control of energy and its development and use in those areas. The economic development impact centers on the installation and operation of thousands of micro-hubs™ across the US that produces NH_3 for local agricultural consumption initially and, as the associated technologies are deployed, for

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fuel and generating electricity.

As these micro-hubs are modular, the local entity that operates them can install units that produce 10 tons of NH_3 per day and scale it, as demand increases, to 1000 tons/day. The micro-hubs are particularly attractive when matched with local wind and solar farms to change intermittent renewable energy such as wind and solar to dispatchable or base load constant power. This is achieved by converting those renewable electricity sources to ammonia as an “Environmentally Benign Battery™” and also increases their profitability and efficiency.

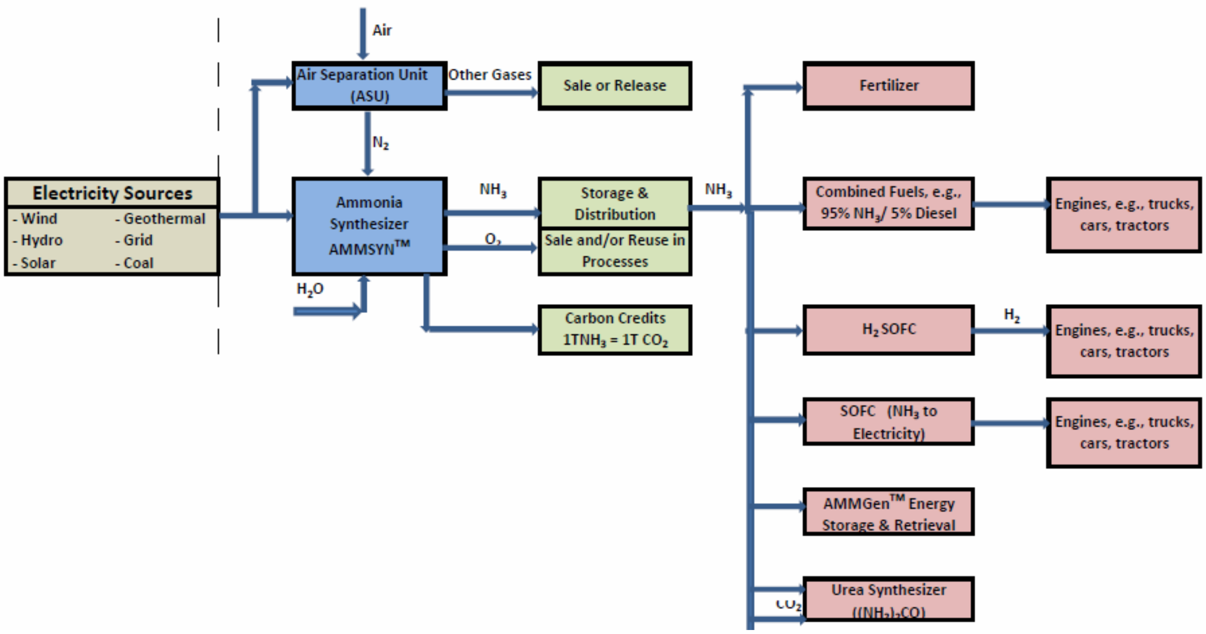

Figure 2

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THE FLIP SIDE OF THE COIN

The flip side of the coin is the argument against the need to respond to the above scenario based on the newly discovered natural gas reserves in the US and its current low price (about $4.32/mm BTU). Certainly natural gas will play an increasingly important role in the US energy supply going forward and is a key to helping achieve energy independence. It is one of the three “fuels of the future” that holds real promise in the US achieving those goals. However, the price and availability of natural gas in the US has **little impact on the strategic vulnerabilities** of the US as outlined <u>unless</u> one assumes that:

1. The strategic vulnerabilities are recognized immediately by the agricultural and power generation industries **and** the federal government <u>AND</u>

2. The re-commissioning of existing and the construction of new US-based "brown" (Haber-Bosch) NH_3 manufacturing facilities are started immediately <u>AND</u>

3. The construction of new DDMG is started immediately <u>AND</u>

4. The cost of production of "brown" NH_3 is subsidized by the US government or tariffs are imposed to combat the lower cost of imports <u>AND</u>

5. The price of natural gas stays at or below its current spot price of $4.32, yielding a current price of NH_3 of $550/ton at point of use. IF natural gas stays below $8.00/mm BTU (an estimate by some based on the new gas discoveries, NH_3 would rise in price to between $800-$1,000/ton (unsustainable to the farming community) <u>AND</u>

6. New NH_3 manufacturing sites will be able to get the air permits <u>AND</u>

7. The EPA will be reversed by Congress or the next administration after 2012 on its CO_2 ruling so there are no “high cost of carbon” (which would add $15 - 40/ton to the cost of "brown" NH_3) <u>AND</u>

8. There are no competing methods of NH3 that do not produce CO2 and other GHG’s <u>AND</u>

9. Those other methods do not achieve their goals of production costs at substantially below current methods <u>AND</u>

10. The public will go along with the building of new ‘brown’ NH_3 facilities in the US <u>AND</u>

11. The trends started and accelerating in California to reduce or eliminate more CO_2/GHGs in the agriculture sector will not propagate across the US <u>AND</u>

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12. The ethanol and other agricultural industries will reverse their initiatives on reducing CO2/GHGs in their supply chain AND

13. There are no adverse effects discovered in the foreseeable future from the 'fracking' technology now being used to improve yields from shale gas deposits AND

14. The current and expected public concerns over 'fracking' will be successfully addressed AND

That is just a start on the strategic implications of relying on the current 100+ year old process and the status quo of depending on imports or even thinking the US can manage with the current strategy. It is true that the current system lets everyone make money in the supply chain and as long as the pain of generating CO_2 does not get any worse, the system will function – until there is an 'event' that induces a crisis.

A simple scenario would begin with another petroleum crisis that (1) drives "brown" NH_3 back to $1200/ton, and (2) causes more farmers to (a) go out of business and/or (b) purchase the NH_3 at the inflated prices, thereby causing (3) both the price of food to skyrocket, and wide-spread food shortages. In addition, because ethanol production is tied directly to NH_3 prices, the cost of ethanol will rise dramatically and there will, likely, be shortages based on reduced corn production/acre.

Under this scenario, it is also expected that the NH_3-producing countries (that supply over 60% of current US NH_3 consumption) will either increase their prices even more or possibly curtail production as their own internal demands increase. Either outcome exacerbates a difficult US situation. In this crisis environment expeditious decisions will be made to relieve the political and economic pressures through the commissioning of "brown" NH3 plants producing more CO_2 , but no one will care.

The competitive SOFC 'green' technologies can drive the needed change on their own, avoiding the looming crises in food, fuel, and electricity with the added benefit of elimination of carbon emissions. As these technologies hit their cost projections, the financial incentive WILL be there to make the transition.

Creative destruction of old paradigms - it is the way of disruptive technologies.

And the probabilities? Given that all 14 above are "AND's", one can concatenate the probabilities to show the probability of the macro-event happening, given its dependence on all 14 singular events happening. Thus, if we were to assign a very high probability of 80% to each event, the probability of the macro-happening is 4.4%. A more probable is, at best, 60% yielding less than a 0.1% chance of the macro, or a **99.9% probability that we will need an alternative ammonia-producing process.**

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If any single event approaches zero probability, it is even worse.

Probability of each event	Probability of all 14 events with each at x %
90%	22.88%
80%	4.40%
70%	0.68%
60%	0.08%
50%	0.01%

Reducing the number of events and increasing the probabilities of the remaining events happening perhaps stretches the believability factor.

As good of a solution as natural gas is in the near term for a wide variety of applications, NH3 and H2 (the other two "fuels of the future") both hold promise because they move the US much further forward in terms of eliminating GHG's. And the impetus for getting the world off fossil fuels will continue for a wide variety of reasons.

For the US, it is a win-win situation – there is no benefit to setting up any win-lose dynamics.

Using domestic natural gas instead of imported foreign oil is a win for the US (and maybe for the world if it can extract itself from the Middle East).

Using an SOFC or other new technology process to manufacture clean, green NH3 instead of natural gas that produces 2 tons of CO2 for every ton of NH3 is a win for the US and the world trying to reduce GHG's.

The bottom line: the rational strategic choice is to seriously examine the potential for developing an alternative NH_3 producing process as quickly as possible. The consequences of inaction or delay pose an unacceptable security risk for the US.

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The Strategic Imperatives

Finally, the inescapable conclusion that demands the attention of anyone concerned about the security of the supply chains of food, electricity and fuels in the US is that all three pose unacceptable security risks for the people of the US and most of the rest of the industrialized world.

What is needed is a revolution in thinking and pragmatic steps to resolve the issues in the shortest time possible, which, given the magnitude of the problems will take a substantial amount of time. Whether the solutions can be found and implemented in time to prevent a crisis is really the issue. The level of risk is high and there appears to be little on the horizon that indicates any mitigating steps are in process. In fact, just the opposite seems to be the case as more and more vulnerabilities are uncovered on an almost daily basis.

The strategic vulnerabilities that have been considered in this paper were:

- Food supply
- Fuel supply
- Electricity supply and distribution
- Environment
- Terrorism

The three Strategic Imperatives that are proposed and the actions that need to initiated to address them are:

Food:
Accelerate the development and deployment of distributed green NH3 production facilities in the US to serve the agricultural market. Use renewable resources where feasible to make the production completely green.

Fuel:
Accelerate the development and deployment of distributed green NH3 production facilities and the development of ICE and SOFC technologies to burn NH3 and deploy those beginning with stationary applications and moving to mobile applications.

Electricity:
Use the other two developments to deploy DDMG facilities throughout the US to power micro-grids, reduce the dependence on the larger grid infrastructure and accelerate the use of renewable where feasible.

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BACKGROUND INFORMATION:

USES OF ANHYDROUS AMMONIA

The NH_3 – anhydrous ammonia – is the second most common chemical used in the world and has numerous advantages in this environment. It can be used:

1.A Directly as a fertilizer in farming operations

1.B (If used to remediate CO_2 sources, by making urea,) as a pelletized form of fertilizer and animal feed that is easily transported, stored and applied in a wide variety of applications

2.A As part of a mixed fuel (e.g. 95% NH_3 5% diesel) for reciprocating engines or turbines

2.B As a high-density, safe store for hydrogen applications including fuel cells, engines, etc.

2.C As a direct fuel for new technology ICE's under development

3.A As a fuel in solid oxide fuel cells directly or

3.B As an "environmentally benign battery ™" for the storage of power from intermittent and/or stranded sources including wind and solar, and to support co-generation, and distributed power generators

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NH_3 APPLICATIONS

1.A Fertilizer

NH_3 is commonly stored in large tanks in rural areas where farming technology facilitates it use directly.

The product is distributed in tanks that are pulled behind tractors and injected into the soil behind wide plows where it attaches to soil moisture and the nitrogen is absorbed by growing plant roots.

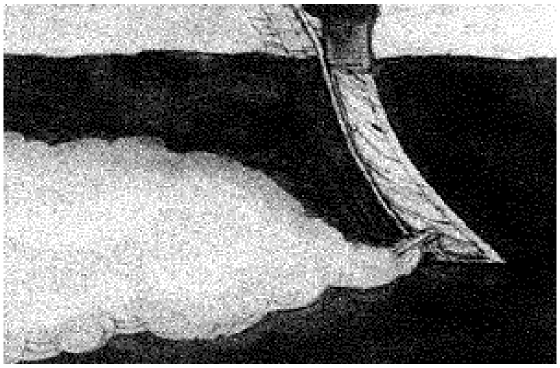

Figure 3. Anhydrous ammonia expands into a gas as it is injected into the soil where it rapidly combines with soil moisture

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For instance, as a rough rule of thumb, where corn is the crop of choice, 200 lbs of NH_3 per acre would yield 160 lbs of N per acre and typically would result in 160 bushels of corn grown per acre.

<u>In addition, the production of NH_3 for fertilizer is totally green in the proposed process as opposed to the current method (Haber-Bosch) which produces ~2 tons of CO_2 per ton of NH_3</u>.

Applying NH_3 directly is the most efficient use of the product.

There is also a global market for NH_3 that is rapidly growing. These new SOFC methods of production holds out the possibility of manufacture at below market rates, while being a totally green process, which has a market advantage for countries and agriculture working to reduce their carbon footprint.

1.B Urea Manufacturing

Urea $((NH_2))_2CO$ today is produced using CO_2 and NH_3. The advantage of urea is that it is pelletized, can be bagged, easily transported, and spread with a wide variety of means, even in soil that would not be amenable to the use of plows and a trailing NH_3 tank. For farming or horticulture applications that do not permit the direct application of NH_3, urea is the fertilizer of choice.

Again, there is a large and growing world-wide market for urea. This method promises to produce it a cost below market when produced as a method to remediate CO_2 and has the marketing and pragmatic advantage of being totally green for those markets working to reduce their carbon footprint.

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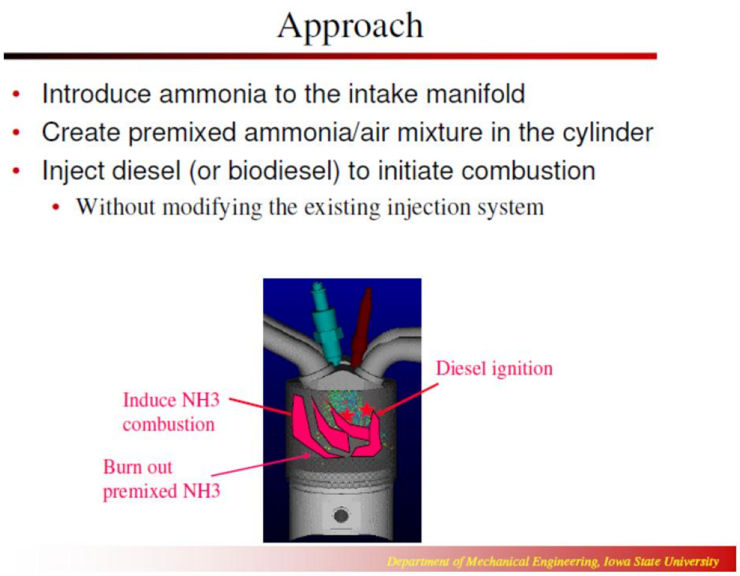
2. A Mixed Fuel Engines and Generators

Current work is underway to optimize the use of NH_3 in mixed fuel reciprocating engines and turbines for power generation. NH_3 has a long history of being used in engines stretching all the way back to a small fleet of buses in Belgium in 1943 which logged thousands of hours of trouble free operation and the US's X15 Rocket Plane of the 1960's and 70's.

The impediment to wider use has been the lack of a more cost effective method to produce NH_3 that would make its use economically feasible in engines and turbines. The new technology of this application makes the achievement of that goal achievable.

Given the achievement of this milestone, transporting NH_3 to any desired location where electrical power is needed without the need to build expensive interconnecting power grids as a first priority becomes an economically feasible solution. Generators powered by engines that burn NH_3 can be 'ganged' to produce power on micro-grids closer to the point of consumption.

A number of options for generators exist, including burning ammonia with diesel or **biodiesel** in addition to the direct fueling of engines, an approach that is currently in the development stages in a number of companies.



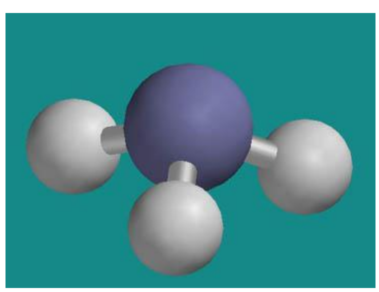
Diesel generators can be converted to burn a mixture of diesel and anhydrous ammonia, significantly reducing the production of green house gases and other pollutants.

Today, there are major efforts underway to burn anhydrous ammonia in both SOFC's – Burlington Northern Railroad (now owned by Warren Buffett), and in mixed fuels – Caterpillar and John Deere, the Merchant Marine Academy and US DOE among them.

2.B High Density Store of H_2

Ammonia is the preferred method of storing H_2 due to its density of H compared to the gas itself. A wide variety of Hydrogen applications are on the market today and more are being fielded every year. Currently a sample of Hydrogen applications include: automobile and truck engines, home heating, cooling and cooking, power generation, fuel cells for power generation, etc. Ammonia can be easily cracked at the point of use and is much safer to transport and use than Hydrogen.

Of the fuel cells on the market today, the most common are the hydrogen fuel cells. Storing the hydrogen as NH_3 and cracking it at the point of use for Hydrogen fuels cells, considering the costs throughout the entire supply chain, is the most economical approach available.



NH_3 Molecule

As the world adopts more Hydrogen technology applications, having extremely cost effective methods of producing its precursor in the form of NH_3 becomes extremely attractive. It also makes the feasibility of this country as a leader in the deployment of the commonly used 'hydrogen economy' a reality.

Hydrogen gas is extremely light, requires high pressure to store and is widely regarded as extremely hazardous due to its explosive qualities. NH_3, on the other hand, is commonly handled worldwide by a very large and diverse group of users.

In the US, it is not uncommon for teenagers in the farming communities to use the product in unsupervised situations as it is normally considered as safe or safer than gasoline or propane (a common fuel for homes and farming equipment as well as camping gear for recreation.)

Anhydrous ammonia is toxic if directly applied to the skin or inhaled, but then, so are gasoline and other fuels. The accident rate with NH_3 is below other fuels and chemicals.

2.C Direct Fuel for Engines

Recently, a number of entrepreneurial companies have launched efforts to burn NH_3 in ICE's directly through various methods including the use of a 'cracker' at the intake manifold to produce a small amount of hydrogen to act as a flame accelerant in the piston chamber. Others are known to be using a new liquid form of NH_3 while others are using modifications to standard engine technologies to achieve the direct combustion of NH_3.

Those efforts have also spawned interest by larger companies such as Toyota and others who have attended the annual Ammonia Fuel Conferences renamed the NH_3 Fuel Conference in the fall of 2010.

Undoubtedly, there will be breakthroughs in the technologies to burn NH_3 as a fuel for engines and the deployment will follow, initially in stationary and industrial applications. Whether it makes the leap to mobile applications including trucks, busses and autos will depend on a combination of public and private initiatives to clear infrastructure and regulatory obstacles. But the impetus is clearly on the side of the NH_3 as fuel alternative.

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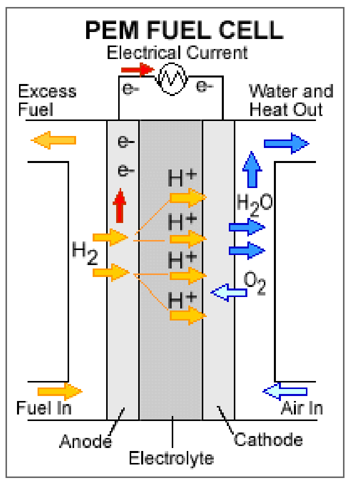
3.A Fuel for SOFC

A great deal of research has gone into the development of solid oxide fuel cells as a way to circumvent the cumbersome and inefficient current designs of fuel cells.

New developments have yielded encouraging results for SOFC's operating in the 200-400C range vs the previous 1200C range. With slightly more work, those SOFC technologies can be brought to market for the direct use of NH_3 in the generation of power.



As a store of power, NH_3 and the use of SOFC's is estimated to have an overall efficiency of 50-70%, substantially higher than lithium ion batteries. For electricity that is being produced at US $.015 per kWhr, and stored in the form of NH_3 and then generated on demand, the potential cost of US $.030 is extremely attractive compared to the generation of electricity by natural gas generators that is typically 4-5 times as expensive, and exhausts massive amounts of CO_2 and NOx.

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3. B An "Environmentally Benign Battery ™ "

In the case where NH_3 is being produced in abundance over its ability to be used locally, it can be used as a way to store power.

Its use as a fuel for electrical power generation is discussed separately. But in areas not connected to a larger power grid where electricity can be generated and is essentially 'stranded', such as wind farms, co-generation facilities or turbines, NH_3 becomes an environmentally and safe store of power. It can be subsequently piped, trucked or used locally to generate electricity on demand via a number of methods discussed separately.

Grid flexibility is the ability of power output, or capacity, to change over a given period of time. One can speak about the flexibility of a single power plant or the combined flexibility of all power plants on the grid. Flexibility is critical for accommodating changes in electricity supply and demand that occur, often unexpectedly, as power plants go offline or as consumers turn appliances on and off. Demand for electricity can vary by a factor of three or more depending on the weather and the time of day and year, which means that hundreds of Gigawatts (GW) of flexibility must be built into the power system. Wind power does not currently have the flexibility to increase power output, only the ability to lower power output on demand. Anhydrous ammonia can help us change this.

Using about 1/6th of the power produced by a wind turbine during off-peak times, storing it as NH_3 and then reversing the process during peak periods would yield an average of 10% more revenue from a wind turbine. This is mainly due to the pricing structure of electricity. During off-peak hours (overnight) power is sold at voided cost whereas during peak hours it is sold a market value to the highest bidder. Using NH_3 as an energy storage-medium it is now practical and economically viable to install wind energy merchant plants.

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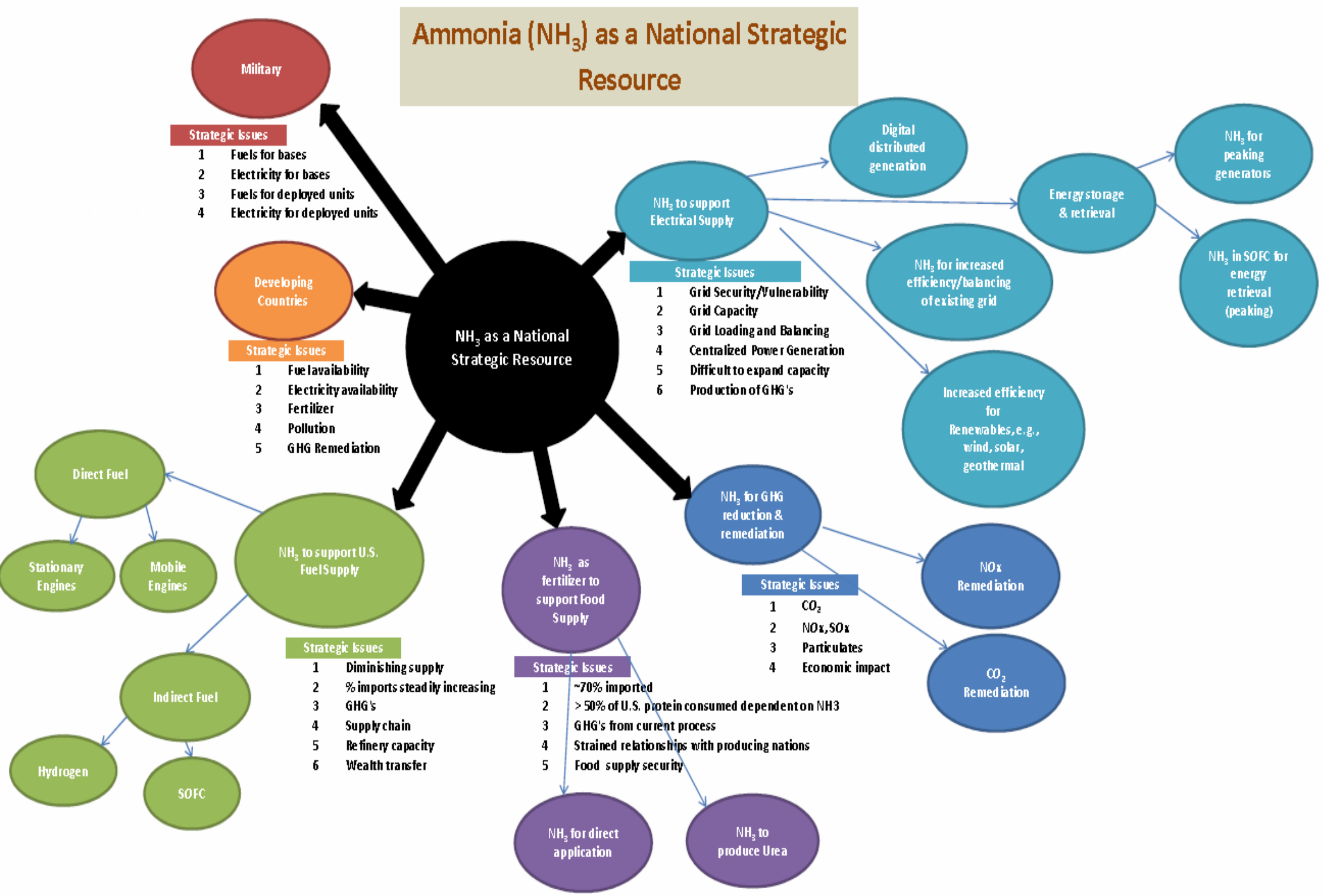
Ammonia (NH_3) as a National Strategic Resource
NH_3 as a National Strategic Resource
Military
Strategic Issues
1 Fuels for bases
2 Electricity for bases
3 Fuels for deployed units
4 Electricity for deployed units
Developing Countries
Strategic Issues
1 Fuel availability
2 Electricity availability
3 Fertilizer
4 Pollution
5 GHG Remediation
NH_3 to support U.S. Fuel Supply
Strategic Issues
1 Diminishing supply
2 % imports steadily increasing
3 GHG's
4 Supply chain
5 Refinery capacity
6 Wealth transfer
Direct Fuel
Stationary Engines
Mobile Engines
Indirect Fuel
Hydrogen
SOFC
NH_3 as fertilizer to support Food Supply
Strategic Issues
1 ~70% imported
2 > 50% of U.S. protein consumed dependent on NH3
3 GHG's from current process
4 Strained relationships with producing nations
5 Food supply security
NH_3 for direct application
NH_3 to produce Urea
NH_3 for GHG reduction & remediation
Strategic Issues
1 CO_2
2 NOx, SOx
3 Particulates
4 Economic impact
NOx Remediation
CO_2 Remediation
NH_3 to support Electrical Supply
Strategic Issues
1 Grid Security/Vulnerability
2 Grid Capacity
3 Grid Loading and Balancing
4 Centralized Power Generation
5 Difficult to expand capacity
6 Production of GHG's
Digital distributed generation
Energy storage & retrieval
NH_3 for peaking generators
NH_3 in SOFC for energy retrieval (peaking)
NH_3 for increased efficiency/balancing of existing grid
Increased efficiency for Renewables, e.g., wind, solar, geothermal

ABOUT AETODYNE

Aetodyne is focused on the development, commercialization, and deployment of new SOFC technologies for the production of anhydrous ammonia (NH_3) and its derivatives, including combination fuels and hydrogen.

The Aetodyne solution is a process technology that is transformative to the market: the production of anhydrous ammonia from air, water and electricity. This is a significant breakthrough as the production of NH_3 has required the use of natural gas or coal for nearly all of its production globally for the past 100+ years, consuming approximately 4% of the world's natural gas. Initial discussions with Camco, an internationally recognized validation authority in carbon credit methodologies, indicates that the Aetodyne process will be eligible for carbon credits as well.

The Aetodyne approach is to use new emerging technologies to build and sell widely distributed µ-hubs for the production of NH_3. In particular, Aetodyne has licensed a solution to address both of these concerns using state-of-the art technology to produce anhydrous ammonia for use as both fuel and fertilizer from air, water, and electricity. **When renewable electricity is used, the USDA has classified NH_3 as an advanced bio-fuel, made with no pollution whatsoever.**

In summary:

1. The Aetodyne process is completely green
2. The Aetodyne process produces carbon credits
3. If renewable electricity is used, is classified as an advanced bio-energy fuel

Our strategy is to provide unique sustainable solutions to the alternative energy market in the form of anhydrous ammonia compounds and their derivatives for the production of fertilizer, fuels and electrical power.

This totally "green" process can produce NH_3 for 50-70% of the average price that NH_3 has been selling for over the last few years. Aetodyne's business is to manufacture and sell µ-hubs (micro-hubs) on a turn-key basis to end-users for localized production and consumption of NH_3.

The process produces oxygen as a by-product and is completely free of greenhouse gases.

Please direct any inquiries to David Leis, Vice President, Business Development at david.leis@aetodyne.com or to the following in the footer.

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