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Vulnerabilities of the International Energy Supply for the Ammonia Industry

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Ammonia production is very energy-intensive, leading the producing companies to be particularly vulnerable to several feedstock-related issues including more restrictive environmental constraints, a sudden unavailability of sufficient amounts of feedstock and fuel, and relentless, occasionally suddenly large, cost increases. Reasons these might arise are discussed below, together with an overview of actions governments are taking to reduce vulnerabilities and actions ammonia producers can take to reduce their impact.

The Ammonia Industry

The Ammonia Industry is large. On a world-wide basis, approximately 550 plants in 80 countries produce ~170,000,000 tons per year of ammonia, having a value of U.S. $40,000,000,000. Many of its modern plants are large, with capacities exceeding 1500 tons of ammonia per day. Its companies produce a limited number of products all of which are commodities with standardized properties; competition is based on price and service. Approximately 85 percent of the ammonia is used to produce fertilizers.

Although some ammonia is produced as a byproduct from manufacturing other chemicals, 97 percent is produced by reacting hydrogen and nitrogen. Feedstocks and energy supplies are virtually always natural gas, light hydrocarbons, heavy residual oils, coke or coal. Natural gas, where available, is most often used as the source of the hydrogen and as the fuel for economic and environmental reasons. This usage accounts for approximately 4 to 6 percent of the natural gas consumption in North America and Western Europe, and 40 percent in India. Natural gas typically represents 70 to 90 percent of the variable operating cost of ammonia production.

Technology is important. Today's dominant production technology is steam/methane reforming, to produce the required hydrogen, accounting for approximately 85 percent of the world's ammonia production. Coal-, coke- and residual oil-based ammonia production using partial oxidation processes for hydrogen production is also operational. In fact 60 percent of China's ammonia production is coal-based. Although there are continual evolutions, the technologies are generally considered to be mature. While recognizing the technical and economic challenges, there still remains a theoretical potential for using substantially less feedstock for ammonia production.

Paper studies of nuclear-based ammonia production have also been carried out. This route, while technically viable, is many decades away from commercial operation.

Energy Issues

Ammonia production is an international business with respect to sales and to sources of feedstocks and fuels. The producing companies are exposed to many of the same factors all businesses face, such as retaining experienced staff, cyclical and unpredictable product demand, and governmental regulations. They, however, are particularly vulnerable to several feedstock-related issues including more restrictive environmental constraints, a sudden unavailability of sufficient amounts of feedstock and fuel, and relentless, occasionally suddenly large, cost increases.

Today's technology permits ammonia to be economically produced only from coal or hydrocarbons. These primary[1] fuels are produced and sold internationally as commodities from a handful of countries. By far the largest uses of these are for transportation fuels and for space heating, followed by electricity generation. The production of many materials on which modern economies depend is highly energy-intensive. These include chemical products and intermediates such as ethylene, ammonia, methanol, chlorine and paper as well as major construction materials such as iron and steel, aluminum and cement. A relatively small fraction of the world's primary energy (~6 percent) is used as a feedstock and energy source for producing these; production of ammonia uses approximately 1 percent of the world's hydrocarbons and coal. While these magnitudes are noticeable, they are relatively small factors in the international gas, oil and coal trade. Understanding the world's energy market is therefore a prerequisite to assessing vulnerabilities the ammonia producers face. Although there are numerous economic interactions, nuclear energy will not be touched on herein; this paper will concentrate on hydrocarbons and coal.

The Worldwide Feedstock / Fuel Picture

Current Fuel Usage

On an overall basis, the mixture of primary fuels used throughout the world is as follows.[2]

Primary Fuel	***Percent of Total Use***
Oil	36.4
Coal	27.8
Gas	23.5
Nuclear	6.3
Hydro	6.0

Each country, of course, has its unique primary fuel use profile. In the more developed countries, the largest use (after conversion losses) of primary energy is for transportation, followed by industrial uses, then for residential and commercial buildings. The dominance of transportation needs has led to numerous efforts throughout the world to develop economically viable gas-to-liquids and coal-to-liquids processes.

[1] Primary Fuels are those used directly or converted to other types of energy such as gasoline or electricity
[2] BP Statistical Review, June 2006

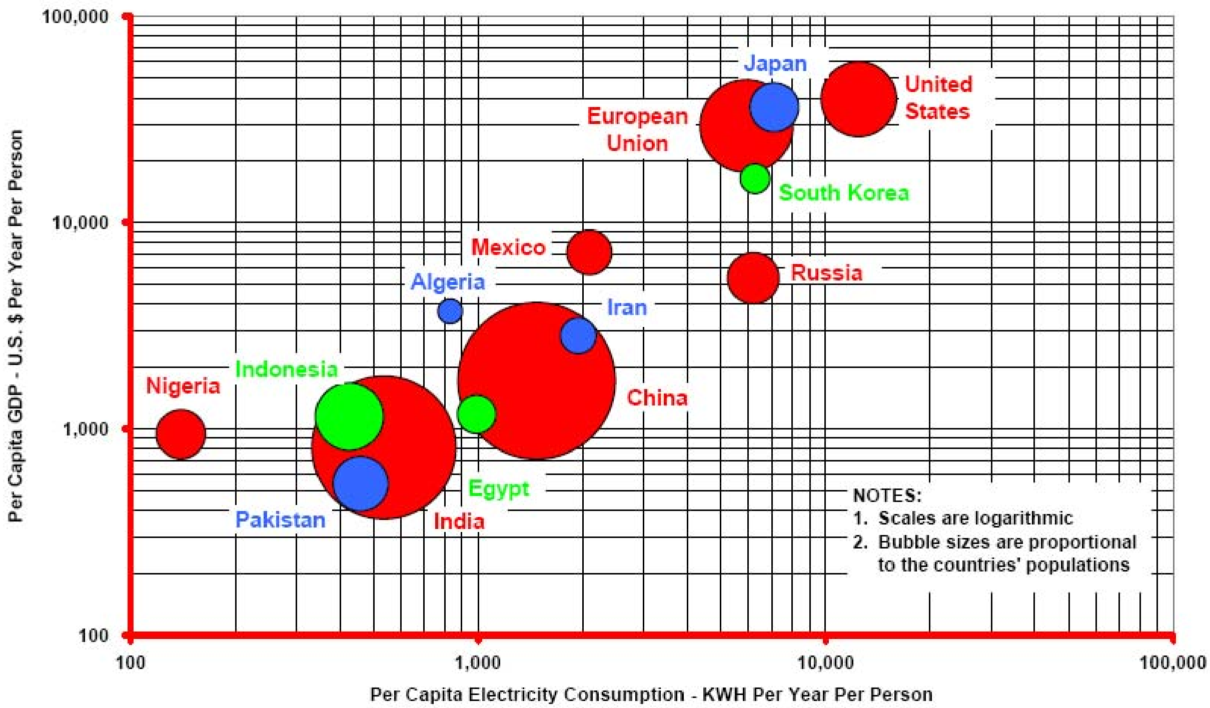
Primary Fuel Usage Will Increase

Many countries' populations are large and growing, their populations are poor (as measured by per capita gross domestic products) and they lack modern society's amenities such as television sets, air conditioning, refrigerators, computers and the like (as measured by per capita electricity generation.) See Table 1 and Figure 1.

Table 1
Economic Development

Country	Population	Annual Per Capita Electric Generation KWH/ Yr/Person	Annual Per Capita Gross Domestic Product $/Yr/Person
Canada	32,800,000	15,879	34,446
China	1,306,300,000	1,475	1,707
India	1,095,400,000	537	812
Indonesia	245,500,000	427	1,145
Japan	127,400,000	7,112	36,102
Mexico	107,400,000	2,091	7,157
Nigeria	128,800,000	140	940
Pakistan	162,400,000	459	542
Russia	142,200,000	6,200	5,371
United States	298,400,000	12,455	39,538
Venezuela	25,400,000	3,409	5,005

Figure 1
Gross Domestic Product vs. Electricity Consumption



It is certain that world energy use will increase as populations increase. Those of China, India, Indonesia and Pakistan, for example, are increasing at 0.6, 1.7, 1.6 and 2.4 percent annually,[3] leading to an additional 34,300,000 people each year in these countries alone who will need energy. Further, the per capita energy use in developing countries must also increase to provide the higher standard of living people will demand. These factors will certainly affect ammonia producers by leading to increased international competition for fossil and nuclear fuels, while many currently exporting countries will have to use more energy internally, leading to less being available for export.

The international oil trade and shipping profile is undergoing dramatic changes, with China, whose economy grew 9 percent in 2005, becoming a major oil and coal importer. In fact, imports by China have accounted for 40 percent of the increase in oil exports since 2000. India, Indonesia and Pakistan are also countries with growing economies (6.9, 5.5 and 8.4 percent per year increases in gross domestic product, respectively), large populations and currently low per capita energy usages that will undoubtedly increase. Conversely, the member countries of the European Union, unlike most other countries are experiencing strong declines in birthrates. Not a single one (including new members Bulgaria and Romania, but excepting Ireland) is at the 2.1 births per woman that it takes to sustain a population level other than by immigration. Even with a declining population rate, however, the European Union's demand for oil, gas and coal is forecasted to increase by 2.0, 2.7 and 1.7 percent per year, respectively.[4]

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[3] Population Reference Bureau, Washington, D.C. [www.prb.org]
[4] IEA Forecast

Fossil Fuel Sources

Proven gas and oil resources are found throughout the world, as indicated on Figure 2. Relatively few countries, however, have reserves in sufficient quantity, quality, concentration and accessibility to make it economically practical to produce and export them. The most important countries, from an energy viewpoint are listed in Tables 2 and 3, and they are part of a multi-billion dollar international trade business. Importantly, national oil companies, including all of the top ten reserve owners, control 77 percent of the global oil and gas reserves. Implications of this are discussed below.

Figure 2
Proven Gas and Oil Reserves
01-Jan-2007

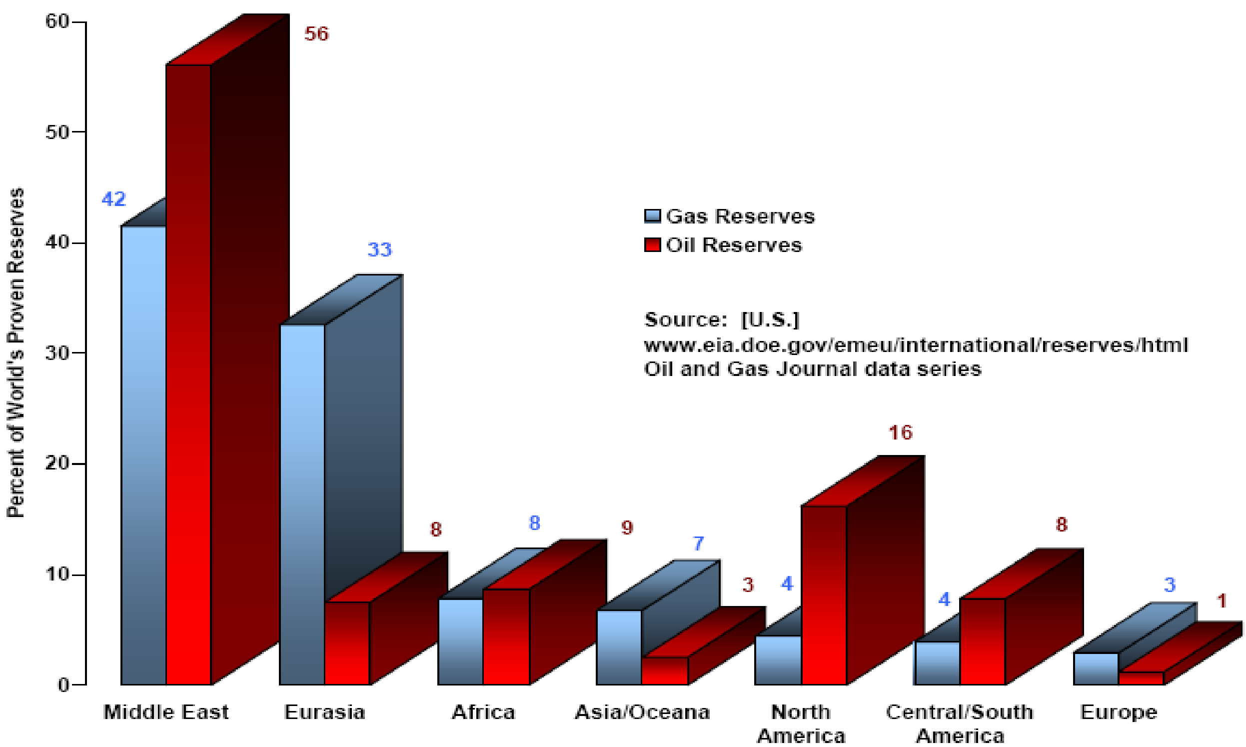

Table 2
Oil Reserves, Production and Consumption

Country	Reserves Million Barrels	Consumption Million Barrels per Year	Production Million Barrels per Year
Algeria	12,300	103	775
Canada	178,800	846	1,150
China	18,300	2,518	1,389
European Union	7,527	5,379	1,063
India	5,600	960	309
Indonesia	4,300	420	403
Iran	125,800	561	1,555
Japan	59	1,911	46
Mexico	12,900	757	1,367
Nigeria	36,200	108	895
Pakistan	300	128	22
Russia	60,000	1,042	3,531
Saudi Arabia	259,800	766	3,905
U.S.A.	21,900	7,592	2,738
Venezuela	79,700	211	1,022

Table 3
Gas Reserves, Production and Consumption

Country	Reserves Billion Cubic Meters	Consumption Billion Cubic Meters per Year	Production Billion Cubic Meters per Year
Algeria	5,177	21.8	89.6
Canada	1,812	102.8	208.1
China	1,706	43.2	44.8
European Union	3,640	546.5	263.2
India	1,217	34.9	31.9
Indonesia	3,131	41.6	86.4
Iran	30,090	89.3	89.6
Japan	44.8	94.4	3.3
Mexico	512.2	57.0	48.0
Nigeria	5,826	10.4	25.6
Pakistan	903	31.0	31.0
Russia	53,780	512.2	726.7
Saudi Arabia	7,680	74.3	74.3
U.S.A.	6,051	717.1	605.1
Venezuela	4,847	30.8	30.8

Note: Multiply cubic meters by 0.03201 to obtain cubic feet

Renewable Energies

Although their direct role in the ammonia industry is currently miniscule, renewable energies do have noticeable indirect effects on the world's demand for fossil fuels. They are therefore briefly touched on in the following.

Renewable energy is a growing, but still quite minor, factor in the world's energy system. Many States in the United States require utility companies to generate increasing amounts of electricity from renewable fuels. The European Union, as another example, has set a specific target[5] of increasing the share of green electricity from 14 percent in 1997 to 22 percent in 2010.

Biofuels: Throughout much of the world biomass (wood waste, straw, animal and vegetable wastes) are used. Use of these, with appropriate pollution control technologies, is being encouraged to reduce net CO_2 emissions.

Ethanol is increasingly being blended with gasoline to produce gasohol that is purported to promote cleaner combustion in engines and reduce greenhouse gas emissions. Most importantly, in the United

[5] Directive 201/77/EC

States it is largely produced from corn therefore yielding additional revenues to farmers in a few States. These have led to politically inspired tax credits[6] and mandates to use corn-based ethanol in gasohol leading this to be a rapidly growing fuel additive. During 2006 the United States produced 4.85 billion gallons from corn. Ethanol may be obtained more economically from other cellulosic materials such as sugar cane grown in appropriate climates. Brazil, a major producer of ethanol from sugar cane, produced 4.80 billion gallons from sugar cane during 2006.

One major positive outcome, for ammonia producers, of the drive to increase production of biofuels will be an increase in the demand for fertilizers, and therefore an increased demand for their ammonia. This is, however, already being partially offset by increases in food prices as land, farmers, corn and sugar cane are diverted from food production to ethanol production.

Other Renewables: Hydropower is a major source of electricity throughout the world. It, however, leads to many difficult environmental and social problems and therefore, with the exception of China, will not have an important role in new electrical generation for many years. Geothermal energy, solar and wind energy sources, although increasingly used, will also not have major roles in the energy picture for many years.

Coal: Although coal is widely scattered throughout the world, 81 percent of the currently economically recoverable reserves are found in six countries; the United States (27 percent), Russia (17 percent), China (13 percent) and India (10 percent), Australia (9 percent) and South Africa (5 percent.)

The use of coal has declined very substantially in Western and Eastern Europe. The European Union, as a whole, is nevertheless a net importer of coal for producing electricity and steel. Although China has vast coal reserves, their use has increased and it has become a net coal importer. India, likewise, has large coal reserves, but is also a net importer.

The coal mining industry is experiencing various problems related to production such as improving safety performance and shortages of specialized equipment. The major long-term issue is environmental performance. Combustion of coal unfortunately produces 80 percent more carbon dioxide (a greenhouse gas) per unit of energy than from natural gas and 20 percent more than from residual fuel oil. Much theoretical and research effort is underway to develop practical processes to capture and sequester carbon dioxide; to date, however, except for a few applications to enhanced oil recovery[7] no large-scale processes have been shown to be technically or economically practical. Additionally, there are increasing requirements for removing mercury from flue gases to extremely low levels. Targets can be technically met, but at high operating costs ranging between $8,380 and $153,300 per kg of mercury removed ($3,810 to $69,500 per pound) at 70 percent removal.[8]

Energy Imports and Exports

Crude Oil: As a group, the OPEC countries have the world's largest hydrocarbon reserves and are the largest exporters, producing approximately 30 million barrels per day or 40 percent of the world's total crude oil supply; non-OPEC oil and gas-liquids production is at approximately 50 million barrels per day. As critical as OPEC is however, crude oil and hydrocarbon products are produced and marketed by

[6] Currently (March 2007) U.S. $0.51 per gallon in the U.S., and an import duty of U.S. $0.54 per gallon
[7] Weyburn project in Canada, Schliepner field in North Sea, In Salah project in Algeria, Louden Field, Illinois U.S.
[8] U.S. Department of Energy, Clean Coal today, Issue 68, fall 2006, p. 8

many other countries. Importantly, these include Canada, Mexico, Norway, Oman and Russia, none of which are members of OPEC.

Natural Gas: Many countries with large and/or growing economies are net importers of natural gas. These include member states of The European Union which imports approximately 53 percent of its gas needs. Of the imports, 40 percent comes from Russia, 30 percent from Algeria and 25 percent from Norway. The United States is also a net importer of natural gas, only producing 85 percent of its demand. Gas extracted from gas shale and coal beds, termed "unconventional gas" is becoming an increasingly large factor; it now represents 16 percent of U.S. production. The shortfall was compensated for by importing gas, primarily from Canada.

Liquefied Natural Gas: Liquefying natural gas is only a way to way to help lower the cost of transporting it; it does not increase the amount of available gas. Liquefied natural gas (LNG) production, now approximately 180 million tons per year, is the fastest growing segment of the energy sector throughout the world, averaging 14 percent per year. The world's major LNG producing countries are Qatar, Indonesia, Malaysia, Algeria and Australia, and significant new liquefaction facilities are under construction in several countries including Equatorial Guinea, Iran, Norway, Russia and Yemen. The major destinations for the product are the European Union, North American and Asian markets; Japan and Korea have been completely dependent on LNG imports for many years. Unlike natural gas delivered by pipelines, LNG delivered by ships can be readily diverted to another destination for operational or financial reasons, subject to meeting navigational constraints, obtaining an unloading time window, securing gasification, pipeline and storage capacities at the intended terminal, and obtaining regulatory approvals. Scheduling operations of a multiple-user terminal is quite complex.

Have Crude Oil And Natural Gas Production Rates Peaked?

While there is general agreement that hydrocarbon production will eventually peak, or has already peaked, there is much controversy about the timing of the peak and the subsequent rate of decline. Certainly, crude oil production from Prudhoe Bay in the United States has fallen by approximately 5.4 percent per year since 1988,[9] from the North Sea by approximately 5.9 percent per year since 1999,[10] from the Oseberg complex on the Norwegian Continental Shelf by 6 percent per year since 1996,[11] from Oman's giant Yibal oilfield by approximately 60 percent since 1997,[12] and from the Samotlor and Romashkino fields in Russia by 83 percent and 90 percent, respectively, since the late 1970s[13] and from the UK's Continental shelf by 6 percent from 2005 to 2006.[14] Gas production from wells that were active within the continental United States in 1999 has fallen by more than 50 percent.[15] There are many more examples of declining production.

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[9] Calculated from data presented in Energy Information Administration, Office of Oil and Gas, U.S. Department of Energy, Future Oil Production for the Alaska North Slope, May, 2001

[10] U.S. Department of Energy, Country Analysis Brief - North Sea, August 2004

[11] Calculated from data presented in Energy Information Administration, Country Analysis Briefs – Norway, August 2005, p. 3
Department of Energy, Future Oil Production for the Alaska North Slope, May, 2001

[12] Gerth, J. and S. Labaton, Oman's Oil Yield Long in Decline, Shell Data Show, New York Times, 2004/04/08

[13] Laherrere, J., Estimates of Oil Reserves, International Energy Workshop, Laxenburg, June 19, 2001

[14] Oil & Gas Journal, March 12, 2007, p. 25

[15] Oil & Gas Financial Journal, March 2007, p. 14

Although there is only a 36 percent success rate in making commercially viable discoveries, upcoming increases in the world's oil and gas supply from new discoveries will nevertheless partially offset these declines. In addition to increased supply from new sources, technological advances in extraction practices and reservoir control have increased production and recovery of a reservoir's oil-in-place. Importantly, technology improvements are not considered in the well known Hubert's predictive methodology.[16] A recent analysis[17] of actual production data shows very poor agreement between reality and predictions based on Hubert's technique. Predictions consistently understated, by 50 to 80 percent, the amount of oil that can be recovered from two large U.S. oil basins for which there are many decades of data.

Production of any nonrenewable material such as crude oil or natural gas comes initially from the sources that are easiest and most economical to develop and then, as these are depleted, from sources that are more remote, deeper and in increasingly harsh environments, and/or by use of more complex technologies. In time technological and economic barriers to developing underutilized sources of fuels such as sub-sea hydrates will be overcome. This will, however, not occur within the immediate future that is the focus of this presentation. The world will not "run out" of oil or gas in the foreseeable future; prices will simply increase, perhaps dramatically, to compensate for higher extraction, transportation and refining costs.

The Energy-Related Issues

Supply Chain Vulnerabilities

The supply chain for providing feedstocks and energy to ammonia producers includes the following links. Damage of any link damages the entire chain.

- Extraction of crude oil / gas / coal
- Storage of crude material and then refined products
- Transportation of crude oil / gas / coal to refinery / fuel processor, and then transportation of the refined products
- Refining / fuel processing

These links may be damaged by many events within the categories discussed below.

Strikes, Anti-Governmental Actions and International Disputes

Refineries and pipelines have been shut down by strikes and protests due to economic disparities in many countries including Bolivia, Mexico and Venezuela. In September 2007, for example, saboteurs blew up a liquid propane and four natural gas pipelines in Mexico, affecting 25 percent of Mexico's gas supply. These high visibility criminal activities affect thousands of businesses and employees and cost hundreds of millions of dollars.

Anti-government protests, violent civil wars and separatist movements, and inter-ethnic tensions are prevalent in Algeria, Chechnya, Georgia, Indonesia, Iran, Iraq, Nigeria, Pakistan and Sudan. Several

[16] Hubbert, M.K,, Energy from Fossil Fuels, Science, February 4, 1949, p. 103
[17] Nehring, Richard, Hubert's Unreliability, Oil & Gas Journal, April 3 2006, April 17 2006, April 24, 2006

unresolved boundary disputes are potentially serious problems in the Far East, the Mideast, Eurasia and North Africa.

Natural Disasters

Floods and severe thunderstorms routinely interfere with railroad shipments of coal and oil. Hurricanes and cyclones certainly cause much damage to the fuel chain. Hurricanes Ivan, Katrina and Rita struck the major gas and oil producing and processing regions of the United States, leading to massive losses and shut-ins. Similarly, during 2006 there were precautionary suspensions of oil and gas production in Australia due to cyclones Claire and Hubert. Enormous powerful cyclones in the Mideast are unusual, but do occasionally occur. Cyclone Gona, for example, struck the Arabian Sea in June 2007 with wind speeds of 213 km/h (133 MPH), wave heights of 12 meters (40 feet.) It missed major offshore oil fields in the Persian Gulf but led to the shutdown of Omani ports and refueling operations in the United Arab Emirates. If its path were only slightly further north, the damage to Mideast production facilities would have been quite severe.

Unusually cold weather can also lead to fuel supply disruptions on an international basis. In mid-January 2005, temperatures in Russia and Eastern Europe fell to -29^{O}C to -34^{O}C (-20^{O}F to -30^{O}F), the coldest since 1927, and demand for gas naturally rose. Attempting to cope with its own internal needs and weather-related production difficulties, Russia had to reduce its exports to various European countries by 5 to 20 percent.

Earthquakes and tsunamis are potential disasters that will probably cause major problems to the world's energy chain. Indonesia, for example, provides Singapore with 600 million cubic feet of gas per day through sub-sea pipelines, is the world's first or second largest LNG exporter, and the second largest coal exporter. It experienced a series of earthquakes off of its western border in September which fortunately were relatively minor, and also fortunately did not affect the Straits of Malacca. But it points to a vulnerability to natural and uncontrollable events.

Accidents

Ammonia plants handle feedstocks, fuels, products and byproducts that are explosive, flammable, toxic and corrosive, and production is carried out at high temperatures and pressures. They nevertheless have an unusually good safety record, brought about in large part by their managements' willingness to share "lessons learned" and "best practices' at meetings and symposia, and in various publications.

The hydrocarbon supply chain is subject to occasional accidents, notably including fires at refineries or pipelines. Additionally, ocean-going shipments of crude oil or LNG flowing through crowded narrow passages such as the Bosporus between the Black Sea and the Mediterranean Sea via the Aegean Sea are vulnerable to accidents.

Fuel Processing

Newly produced crude oils often contain high percentages of sulfur and therefore can not be processed in many refineries. Although distillation capacity has been increased throughout the world, desulphurization capacities in refineries definitely remain as constraints. Other problems with many newly produced crude oils include high amounts of water and salts which can overwhelm crude oil desalters, and high acid contents, leading to unacceptable corrosion rates. These and other problems limit the usefulness of many crude oils.

Additionally, refineries throughout the world are operating near 95 percent of their capacities, which leaves little room for accommodating problems. A simultaneous outage of two or three of the larger refineries would seriously reduce the availability of liquid fuels, causing higher costs to ripple throughout the energy supply chain to the gas sector and then onward to chemical, including ammonia, plants.

Fuel Transportation

Although promising new oil and gas fields continue to be discovered throughout the world, often in remote and harsh locations, they will be useless unless their raw products can be moved to refineries. Crude oil and liquid products are transported from the oil wells to refineries by combinations of pipelines and ocean-going tankers, and to a smaller extent by trucks, railroads and barges. Each mode has a critical role.

Although the international shipping industry has a history of boom and bust cycles, it appears that trans ocean shipping will not be a weak link in the energy supply chain in the near future.

Pipelines: Pipeline transportation is extremely important and usually the only economically feasible possibility for moving large amounts of crude oil or gas from interior wells to ports. These frequently transport between 400,000 and 1,000,000 barrels of oil per day and cross several countries. From both economic and geopolitical perspectives, control of pipelines is at least as important as controlling oil and gas wells and refineries. Major oil pipelines connect Western Siberia to the Gulf of Finland, Kazakhstan's Northern Caspian Sea basin to Novorossiysk on the Black Sea, Kazakhstan to Western China, Azerbaijan to the Eastern Mediterranean coast of Turkey.

Natural gas is also transported internationally and within most countries through a series of large pipelines that often carry 80 million cubic meters (2.8 billion cubic feet) per day. Currently, the world's largest gas exporter, Russia, delivers gas to European customers using pipelines that pass through Ukraine, Belarus and Turkey. Gazprom and its partners have started construction of the *Nord Stream Pipeline* that will connect an existing Russian gas pipeline network to the port of Vyborg on the Gulf of Finland, then pass under the Gulf and the Black Sea to Greifswald in Northeastern Germany. An important strategic consideration for Russia is that this route bypasses Belarus, Estonia, Poland, Latvia, Lithuania and Ukraine.

Continental Europe also receives large amounts of natural gas via pipeline from two other sources. *The Enrico Mattei Pipeline*, (formerly the Trans-Mediterranean (Transmed) Pipeline) carries natural gas from Algeria via Tunisia, passing under the Mediterranean Sea to Sicily and then to mainland Italy. The *Pedro Duran Farell (PDF) Pipeline*, (formerly the Maghreb-Europe Gas (MEG) Pipeline) carries natural from Algeria via Morocco, passing under the Strait of Gibraltar to Cordoba, Spain.

Additionally, Norway delivers gas through France to Calahorra Spain through the *Trans-Pyrenean Pipeline.* It also delivers gas to the United Kingdom through the new *Langeled Pipeline* which originates in Nyhamna, Norway and terminates at Easington, UK. The 1,200 kilometer (745 mile) long pipeline is the longest offshore unit ever constructed and will provide 20 percent of the UK's consumption.

An important issue from an energy security viewpoint is that some of these pipelines bypass Russia and some do not. Several additional new pipelines are actively being considered throughout the world. Many, such as the proposed Nabucco gas pipeline, have strong geopolitical and economic components. This particular one would bring gas from Azerbaijan through Romania, Bulgaria and Turkey to Austria. Since it would reduce dependence on Russia, Gazprom naturally opposes it, favoring an extension of its Blue Stream Pipeline to transport gas through the Balkans to Hungary.

North America is one of the few regions in which pipelines are not currently a major constraint. This may change in the future as demand increases.

Terrorist Attacks

A relatively new concern is that a terrorist group will deliberately interfere with production and/or international transportation of fuel. Given its importance to the world's economy and indeed civilization itself, it is a tempting target for fanatical groups. Many international terrorist groups have indicated that they consider all Westerners and their properties to be legitimate targets, and in fact have proclaimed it a duty to attack them.

Components of the energy infrastructure have, in fact, been sabotaged by terrorist attacks in many countries notably including Kuwait, Nigeria, Pakistan, Saudi Kingdom and Yemen. Damage to the sub-sea pipelines such as those that bring gas from Algeria and Russia to Europe could be difficult and time-consuming to repair. There was, in fact, an explosion in the sub-sea TransMed Pipeline in 1997 that has been labeled as a terrorist act. Very little detailed information has been made public, but it is estimated that the gas flow to Italy through this pipeline was interrupted for 45 days.

Russia has become an important crude oil supplier to Asia and Europe, with major terminals at Primorsk on the Baltic Sea, Novorossiysk and South Ozerereyevka, both on the Black Sea, Pivdenny near Odessa, Poland, and several smaller facilities. Loss of any one of these would have serious adverse impacts on the European, Asian and Russian economies.

Various international agencies have identified many locations as critical to the world-wide flow of oil, coal and many other items; Table 4 presents six of them. These have narrow inlets/outlets that could be blocked by accidents or terrorist attacks. If they were closed the economic result would be staggering. Costs of shipping, security and insurance would undoubtedly greatly increase, driving up costs substantially.

Table 4
Crude Oil Shipping Chokepoints[18]

Chokepoint	Location	From / To	To / From	MM[19] Barrels Per Day
Strait of Hormuz	Oman / Iran	Persian Gulf	Gulf of Oman (Arabian Sea)	16.5 – 17.0
Strait of Malacca	Malaysia / Singapore	Indian Ocean	South China Sea (Pacific Ocean)	11.7
Bab el-Mandab	Djibouti / Eritrea/Yemen	Red Sea	Gulf of Aden (Arabian Sea)	3.0
Bosporus/Turkish Straits	Turkey	Black Sea	Mediterranean Sea	3.1
Suez Canal	Egypt	Red Sea	Mediterranean Sea	1.7
Panama Canal	Panama	Pacific Ocean	Caribbean Sea (Atlantic Ocean)	0.5

Loss of any of the first three of these chokepoint routes could not be accommodated by simply diverting tankers to the Bosporus, Suez or Panama Canals; the largest tankers they can handle are the Suezmax[20] class or the Panamax[21] class vessels. Although the loss any of these routes may be somewhat mitigated by using trucks, smaller tankers, barges and increasing flows through pipelines, the adverse economic impact would, nevertheless, be substantial.

Antiterrorist Measures

Although the oil producing countries and companies spend tens of million dollars on security, piracy and terrorist attacks continue; international initiatives have not led to impressive results. Among the many efforts are the United Nations "*Convention of the Law of the Sea*" which defines the conditions under which hot pursuit of a foreign ship, arrest of persons, seizure and disposal of property, and imposing penalties is permissible. Additionally, the United Nation's International Maritime Organization has adopted '*Measures to Prevent the Registration of "Phantom" ships.*'[22] This, however, "*invites governments to…*" and "*urges governments to…*" It is a very weak document.

Law enforcement within territorial waters is, of course, the responsibility of each nation. Several South Asian countries, however, do not have the naval and military resources to perform satisfactorily; informal cooperation has helped on an ad hoc basis. While slowly improving, enforcement is spotty; piracy continues to be a concern throughout Asia and Africa.

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[18] World Oil Transit Checkpoints, Country Analysis Briefs, [U.S.] Energy Analysis Briefs, November 2005
[19] MM: million (1,000,000)
[20] Suezmax Class Crude Carriers: Capacities of 126,000 to 199,999 tons (~790,000 to 1,250,000 barrels)
[21] Panamax Class Crude Carriers: Capacities of 50,000 to 79,999 tons (~314,000 to 503,000 barrels)
[22] Resolution 923(22), 22nd Assembly, November 2001

Environmental Issues

Although the production and use of fuels leads to environmental challenges with respect to solid and liquid discharges, the major long-term issue is that there is overwhelming evidence that global warming is occurring at an alarmingly dangerous rate, that carbon dioxide is a major contributor, and that emissions of it must be reduced. These have lead to the Kyoto Protocol, which has been ratified as a binding obligation by 166 countries, not including The United States. China and India, with large and growing carbon dioxide emissions, have ratified the Protocol but, being classified as developing nations do not need to commit to specific targets. Multinational companies operating within their borders are nevertheless finding themselves under pressure to reduce greenhouse gas emissions. It is, moreover, likely that in the near future public pressure will lead China, India and the United States to increasingly comply with the terms of the Kyoto Protocol.

Ammonia production is accompanied by substantial CO_2 production, ranging from 1.6 tons of CO_2 per ton of NH_3 from natural gas to 3.3 tons of CO_2 per ton of NH_3 from coal. Given today's technical and economic situations, ammonia producers have only three practical options for addressing upcoming CO_2 emission limitations that appear to be inevitable. They can:

- use fuel and feedstocks more efficiently
  While recognizing the technical and economic challenges, there still does remain a theoretical potential for using substantially less hydrocarbons for ammonia production. Given the efforts being devoted to energy matters, it is possible that a breakthrough will occur in a corporate, academic or national laboratory.

- capture CO_2 from flue gas and process streams for producing other chemicals such as urea, methanol or dimethyl ether, or for injection into wells for enhanced oil recovery, or for storing it indefinitely. Much theoretical and research effort is underway to develop practical processes to capture and sequester carbon dioxide; to date, however, except for a few applications to enhanced oil recovery[23] no large-scale processes have been shown to be technically or economically practical.

- pay for inevitable carbon taxes or for CO_2 allowances if a cap-and-trade system is adopted.[24]

Implementing any of these choices will be expensive. Since transactions take "a willing seller and a willing buyer" to consummate, producers can not raise their prices beyond the point where the buyer no longer believes the benefits outweighs the costs. Ammonia producers are particularly vulnerable to this reality.

International Political Dimensions

Although maintaining relations with all countries in today's globalized energy network is important, those with Russia, Algeria, Iran and China are of particular concern for the immediate future. These will be discussed in turn.

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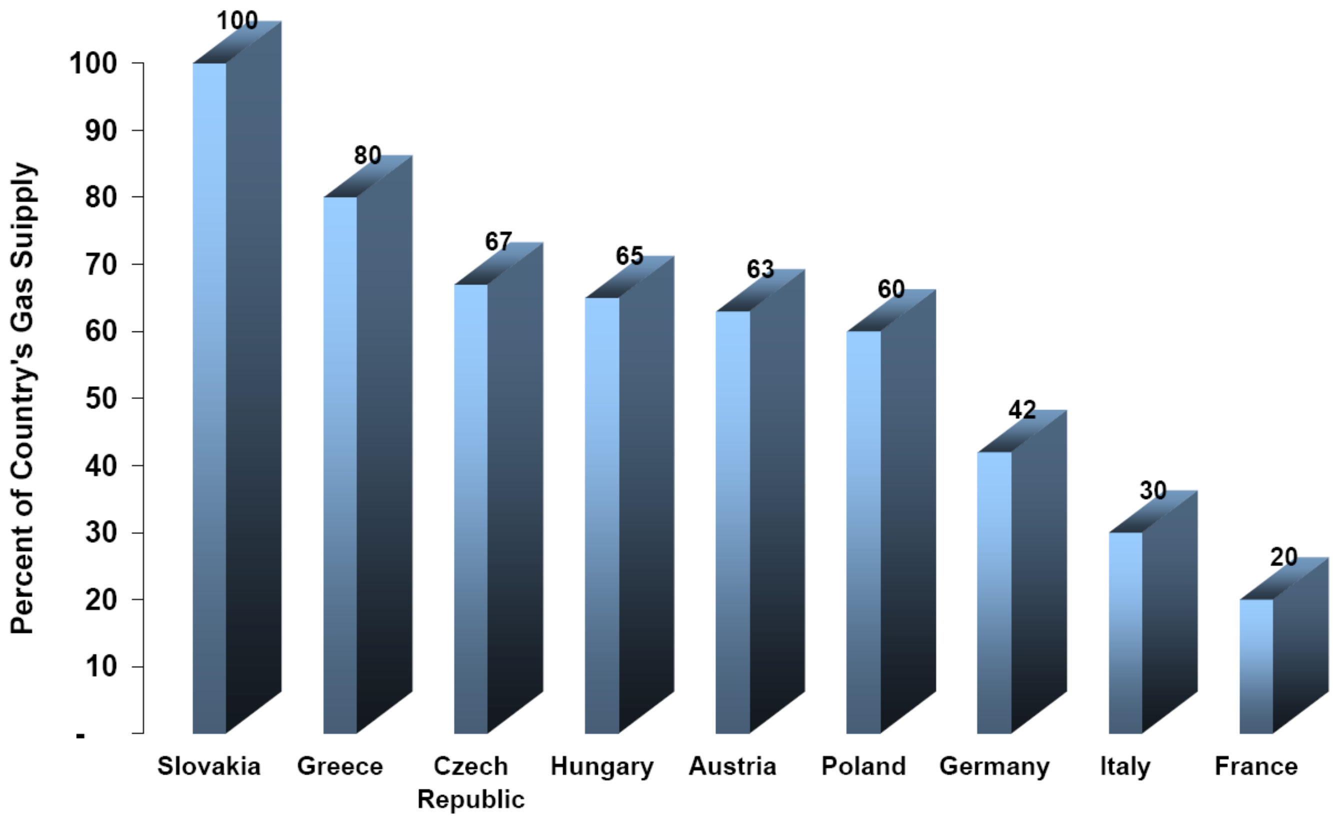
[23] Weyburn project in Canada, Schliepner field in North Sea, In Salah project in Algeria, Louden Field, Illinois U.S.
[24] Currently (March 2007) trading at \$2.00-\$5.00 per ton of CO_2 in the U.S. and \$15.00 - \$20.00 in Europe

Russia is clearly a major gas supplier to many European countries, as seen on Figure 3, and therefore its activities are exceedingly important. Russia now sees a major opportunity to greatly enrich itself through its energy resources, and simultaneously sees dangers from various Islamic fundamentalist groups in its Southern neighboring countries. In reaction to various decisions, statements and slights, both perceived and real, made by Western leaders, Russian policies have fundamentally changed.

> *"Until recently, Russia saw itself as Pluto in the Western solar system, very far from the center but still fundamentally part of it. Now it has left that orbit entirely: Russia's leaders have given up on becoming part of the West and have started creating their own Moscow-centered system.*[25]*"*

Figure 3
EU Countries Dependence on Russian Gas
- 2006 -



The general Russian energy position may be summarized by two points.

- Why should we subsidize other countries with below market-price gas or oil?
- If we do not control energy resources and distribution, others will.

One new set of issues is thus centered on the prices that Russia is charging other countries for its gas, and in particular the ways in which they have been increased. Examples include Russia's doubling the gas price to Moldova unilaterally, and then reducing gas supplies to obtain quick agreement. Similarly Russia announced a doubling of gas prices to Georgia and then imposed bans on importing various

[25] Trenin, Dmitri, Russia Leaves the West, Foreign Affairs , July/August 2006

products and additionally suspended air and railroad traffic. Georgia had no choice and agreed to the new prices.

The Ukrainian episode has been widely cited as an example of a country using its position as a major gas and oil supplier as a political weapon. Russia caused much alarm when it attempted to quadruple the gas prices it charged Ukraine, through which 20 percent of Europe's gas flows. After several days of seriously adversarial moves by each party, a complex somewhat opaque compromise was reached.

These, of course, may be viewed as cases where Russia was simply exercising its rights in rather straightforward commercial matters.

Russia, however, is now exhibiting even more troubling behavior by actions that are clearly directed to placing all aspects of oil and gas production and their transportation under governmental control. During the European Union-Russian Summit in October 2006, Vladimir Putin stated

> *"I'll remind you that some European countries, members of the European Union, cover 90 percent of their gas needs with Russian hydrocarbons. Ninety percent! And no one's complained so far."*

Sakhalin-2 presents an example of a very troubling Russian approach to increasing its control of gas and oil supplies by forcing renegotiation of an existing agreement. This is the world's largest LNG liquefaction plant, with a capacity of 7 percent of world's LNG supply. Gazprom had been negotiating for 25 percent ownership of the consortium plus a blocking vote on its Board of Directors. As part of its negotiating strategy, Russia claimed environmental problems, withdrew an environmental permit, threatened to stop work and even publicly threatened criminal charges. Diplomatic responses, including those from Japan, the UK and the European Union, were verbal, but contained no substance. After many tense months, Russia succeeded in obtaining the share and control it sought, in exchange for $7.45 billion ($4.00 per barrel of reserves). A more reasonable market price would have been $4.90 per barrel of reserves, or a total of $9.13 billion.

As still another example, in a somewhat surprising move, given a previously close relationship, Russia suddenly demanded that Belarus pay more than twice as much as it previously paid for gas. This lead to a series of increasingly hostile verbal exchanges between Belarus and Gazprom, partly because of the price aspect and perhaps more importantly because Gazprom indicated that if Belarus could not pay with cash (which it could not), it was willing to take a 50 percent share of the Belarusian gas pipeline company. This is of major strategic importance to Russia since approximately 20 percent of gas sold to Europe flows through Belarus. Unlike the Ukranian situation, Belarus was not be able to resist and ultimately agreed to a settlement that is close to Gazprom's terms. This, like other Russian moves, will even further increase the European Union's dependence on Russia for its gas supply.

In another disconcerting situation, Lithuania attempted to sell its Mazeikiu Nafta Refinery through an international bidding process, which was won by a Polish company, PKN Orlen. Subsequently to losing the bid, Transneft (Russia) shut the pipeline that supplies oil to the town of Mazeikiai and the refinery claiming the pipeline was unsafe, using metals from 40 years ago that are now not allowed (but it continued using the pipeline to supply Belarusian refineries.) After much tense maneuvering, the sale to PKN Orlen was finally consummated in December 2006, becoming the largest investment ever made by a Polish company.

Russia, however, is not without its own problems. In spite of its increasing wealth, much of its infrastructure is outmoded, its political relations with many countries are deteriorating, and its health situation is poor. Moreover, Russia's economy will be somewhat dependent on the European Union for several years. Currently approximately two-thirds of its oil and gas is purchased by European Union members and, although it is taking steps to broaden its oil and gas pipeline transportation situation, it does not yet have any capacity to divert gas to North America or Asia. Given the decline in per-well gas production, many analysts are uneasy with the relatively low level of investments Gazprom is making in exploration and production activities.

Algeria is important since, as noted above, it provides the European Union with 30 percent of its gas. A concern has arisen from Vladimir Putin's visit to Algeria in March 2006 at the invitation of President Bouteflika to strengthen the "Strategic Partnership" signed in Moscow in 2001. Subsequently Gazprom and Sonatrach (the Algerian gas company) signed a *Memorandum of Understanding* in August 2006 to cooperate on:

- Exploration for new gas supplies in the Sahara
- Sharing markets for gas in North America and Europe
- Sharing LNG technology
- Jointly bidding for foreign assets

This is potentially a serious problem for the European Union and particularly for Italy which imports 80 percent of its gas, of which 32 percent comes from Russia and 37 percent from Algeria.

Algeria, however, also faces many internal problems such as high unemployment and a lack of housing. Since its economy depends almost entirely on oil and gas exports, Algeria clearly needs the European Union which takes 63 percent of Algeria's exports and provides 58 percent of its imports.

Algeria has to date acted in a cooperative and responsible manner, honoring agreements and issuing no threats. In 2006 it, however, did pass a law requiring Sonatrach to keep a 51 percent share of energy projects, and has now taken over complete control of the $7 billion Gassi Touil gas project being developed. Its two Spanish developers, Repsol YPF SA and Gas Natural YPF SA, are seeking arbitration claiming their 80 percent share was taken illegitimately. It would be unfortunate if Algeria is starting to seek short term advantages by following the Russian model of using de facto expropriation; the temptation does exist.

Iran is certainly a major supplier of crude oil, exporting approximately 2,700,000 barrels per day, with Japan and China as its largest individual customers. It, however, is involved in several well known disputes with its neighboring and many western countries that can charitably be described as tepid at best. Obviously, Iran's strongest bargaining tool is its ability to withdraw a substantial amount of its crude oil from the international marketplace. This would lead to a worldwide inability to satisfy current demands, even if all other producers maximized their production, a politically difficult decision to expect. Even without secondary effects such as increased shipping and insurance costs, oil prices would probably rise by approximately 20 percent. In 2006 Iran unilaterally repudiated a price clause in an Iranian-Indian LNG project, leading to a loss of confidence in its reliability. In March 2007 Iran requested that payments for its oil be made in Euros rather than U.S. dollars. Since no other producer has done this, it appears to have been politically motivated.

The most direct way that Iran can affect ammonia and urea producers would be to increasingly move up the natural gas value-added chain to produce and market increasing amounts of these products. This, as indicated below, appears to be currently underway.

China has a rapidly growing economy with a manufacturing sector that requires large increases in fuel supplies; it is currently importing 3.85 million barrels per day of crude oil and products, which is 53 percent of its demand. The country is aggressively pursuing fuel supply agreements with many countries throughout the world. Among other items, the China National Petroleum Corp. owns 40 percent of Sudan's Greater Nile Petroleum Operating Company that produces 350,000 barrels per day of crude oil; in fact, 10 percent of China's oil comes from Sudan. Currently, another 12 percent of China's crude oil imports come from Iran. Looking to insure its future, the Chinese oil and gas company (Sinopec) and the National Iranian Oil Co. (NIOC) have agreed to explore for oil and gas in central Iran, and the China National offshore Oil Corp (CNOOC) is in talks with NIOC to develop the offshore North Pars field which is estimated to have 1.4 trillion cubic meters[26] of gas reserves. Other significant steps include China and Venezuela recently forming a joint venture to explore for and develop gas and oil deposits in both countries, to increase the supply of oil to China, and to build a fleet of tankers.

These aggressive steps to assure its fuel supply, while certainly understandable, will leave less gas and oil available throughout the world for chemical production. China's approach to satisfying its oil and gas needs, however, has certainly influenced its stance on various issues brought to the United Nation's Security Council, including measures related to Sudan and Iran.

Economic Vulnerabilities

Natural gas, oil and coal prices, which dominate the costs of producing ammonia and urea, vary greatly throughout the world. Will production of these increasingly migrate to production from lower cost heavy oils or coal, and/or to low hydrocarbon- cost regions? Perhaps, perhaps not. These will be considered in turn.

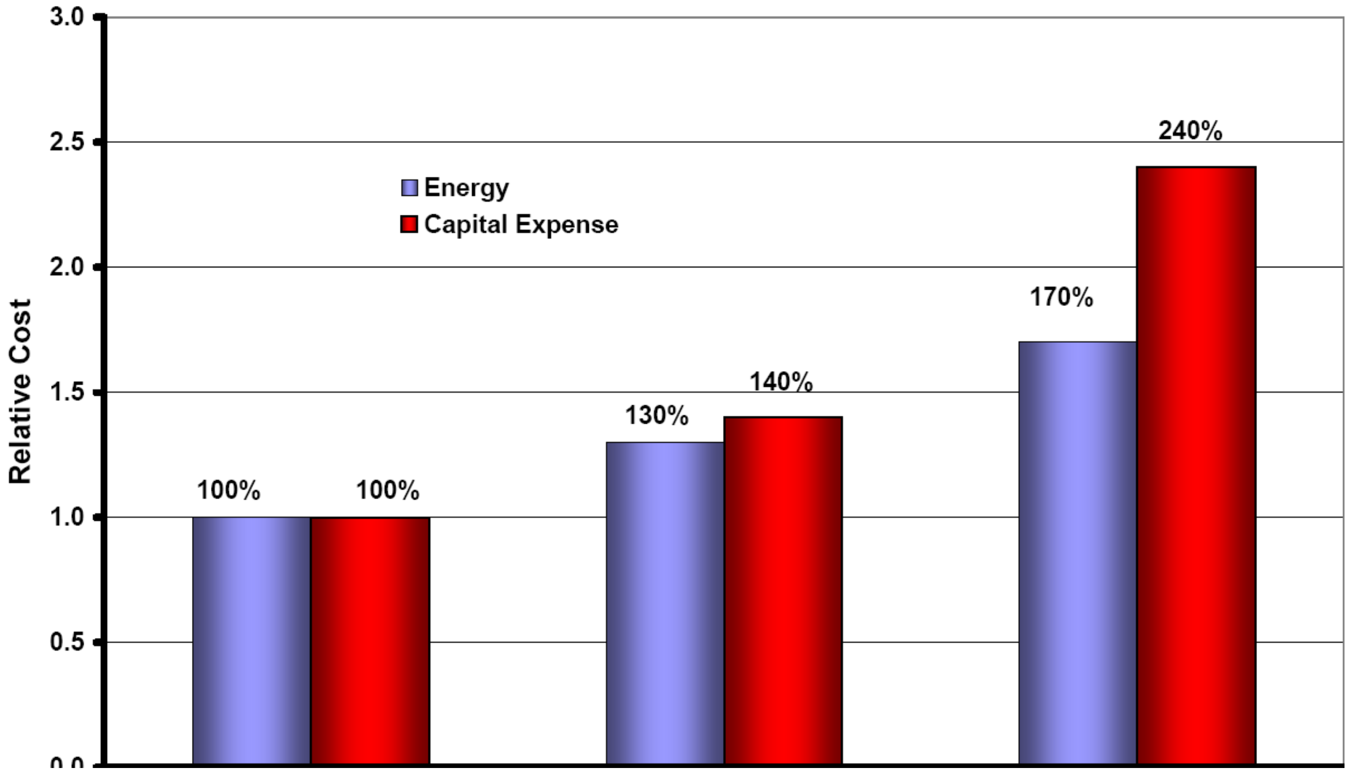
A superficial view is that heavy and residual oils cost less than natural gas, and coal costs even less. This is narrowly true, but ignores the higher handling, storage, and environmental costs as you go from gas to oil to coal. On an all-in basis, operating costs do in fact favor natural gas. Similarly, going from natural gas to oil to coal leads to substantial increases in capital expenses. These factors are shown on Figure 4.[27]

Coal-based ammonia producers are faced with an additional difficulty. Their operation often produces significant amounts of other products such as phenols, cresylic acids, naphtha and possibly liquid nitrogen and inert gases from an air separation unit. Their plants may, in fact, be designed and operated primarily to produce a synthesis gas for other products or, more recently, a fuel gas for electricity production via a combustion turbine/generator cycle; the ammonia and other chemicals are actually byproducts from these plants. The economic issue is that, while the byproducts may yield significant revenues, they are most often sold in spot markets rather than within long-term supply agreement frameworks. The production companies therefore face demands for several products that are not

[26] Multiply normal cubic meters by 37.33 to obtain standard cubic feet (includes different temperature bases)
[27] Source: IFA Statistics – Western Europe

completely predictable and may not be in phase with each other. The market prices obtainable, moreover, are also not predictable. These factors lead to numerous operational and financial challenges.

Figure 4
Relative Operating and Capital Expenses



Oil- and coal-based ammonia production may make sense within a larger framework of preferring to use natural gas for other purposes, or to utilize a waste product, or to maximize use of indigenous resources perhaps to provide employment. Dynalytics Corp. does not foresee any major migrations to oil-or coal-based ammonia production except for cases in which revenues from byproducts are substantial.

Evaluating the possible migration to low gas cost countries is more complex. As noted above national oil companies, including all of the top ten reserve owners, control 77 percent of the global oil and gas reserves. One implication of this is that decisions are based on many factors; production economics are less important to many governments than they are to investor owned companies. Their focus is frequently more on geopolitical and social matters.

Additionally, as part of their internal political considerations, national oil and gas companies often tend to have much larger numbers of employees than companies in the private sector, and are often forced to sell their products within their countries at highly subsidized prices. This then leave them with less money available for reinvestment into their plants. Underinvestment is now limiting exploration, plant upgrades and even routine maintenance in many countries. It certainly makes it difficult to justify taking on new investments in downstream projects such as ammonia or urea production.

The projected economic performances of new facilities are sensitive to assumptions about numerous factors such as fuel costs, product prices and their changes, none of which can be accurately predicted for the expected lives of the plants. It is not at all clear that the current fuel cost advantage several countries have is sufficient to justify major capital investments required for new ammonia or urea plants; many alternate economic possibilities may be more attractive to owners of gas or oil reserves or contracts.

One scenario for companies or countries that are willing to risk capital is to invest in facilities that produce other energy-intensive exportable products such as aluminum, petrochemicals, or possibly in gas-to-liquids plants. Recently, however, the degree to which capital costs are increasing is substantially higher than predicted by experienced staffs, showing that all large investments are somewhat problematic. This has led to cancellations of at least two[28] planned gas-to-liquids projects.

Another scenario is that gas and oil producers simply sell their products at market-prices without risking capital. A relevant situation was encountered by companies in the United States that produced aluminum via electrolytic refining. Although electricity represents "only" 1/3rd of their production cost, and even though their plants had been built, were fully staffed and were operating, the producers elected to shut down their facilities during the 2001 power shortage since they could sell their electricity more profitably than their aluminum. There are many good reasons to pursue this risk-averse strategy.

Dynalytics corp. does not expect LNG trade, although growing rapidly, to have a dramatic impact on gas prices. Financing the liquefaction plants and the regasification terminals, which often cost 0.5 to 1.0 billion dollars, is not feasible without having long-term purchase agreements from large creditworthy customers. These typically are utility companies that can rely on fuel cost pass-through provisions to insulate themselves from large swings in costs; very few ammonia producers can or would be willing to risk such a commitment. The LNG that will be available to North America and Europe, moreover, will generally only compensate for declines in per-well gas production.

What can be expected, considering that *"All predictions are dangerous; especially those about the future!"*

What is the upcoming ammonia landscape probably going to look like? Consider what has been publicly announced for ammonia, as summarized on Figure 5.[29] Importantly, almost all of the announced projects in the Middle East are from Iran, all of those from Asia / Pacific are from China, and none (except some revamps) are from Russia. The total announced increase is 34,930 tons per day, or ~7.5 percent of current production by 2010. If those "in engineering" are discounted by 25 percent and those "in planning" by 75 percent, the increase would be 6.0 percent.

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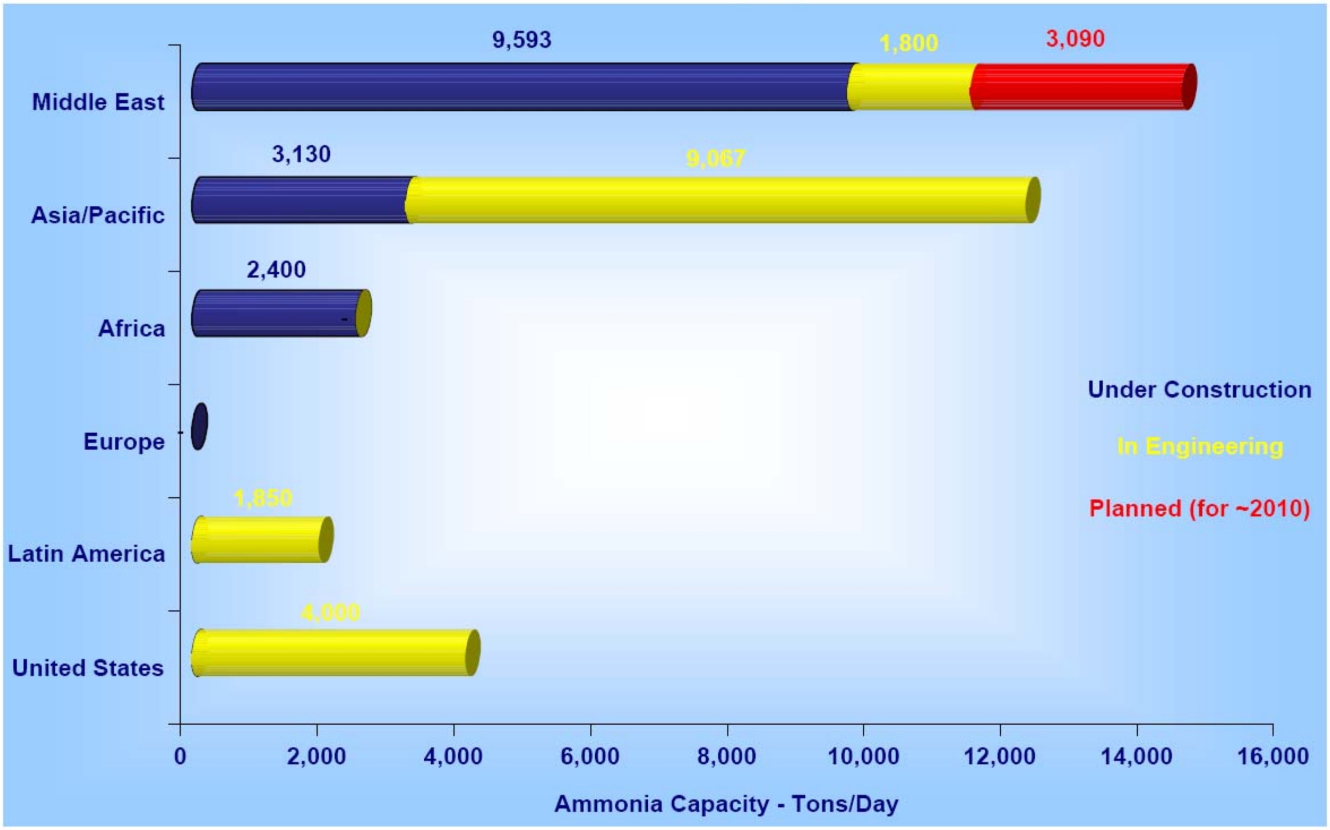
[28] Tinhert - 36,000 barrels per day gas-to-liquids for Sonatrach, initial budget of $2.5 billion; Ras Laffan - 154,000 barrels per day gas-to-liquids by Qatar/Exxon Mobil, initial budget of $7 billion

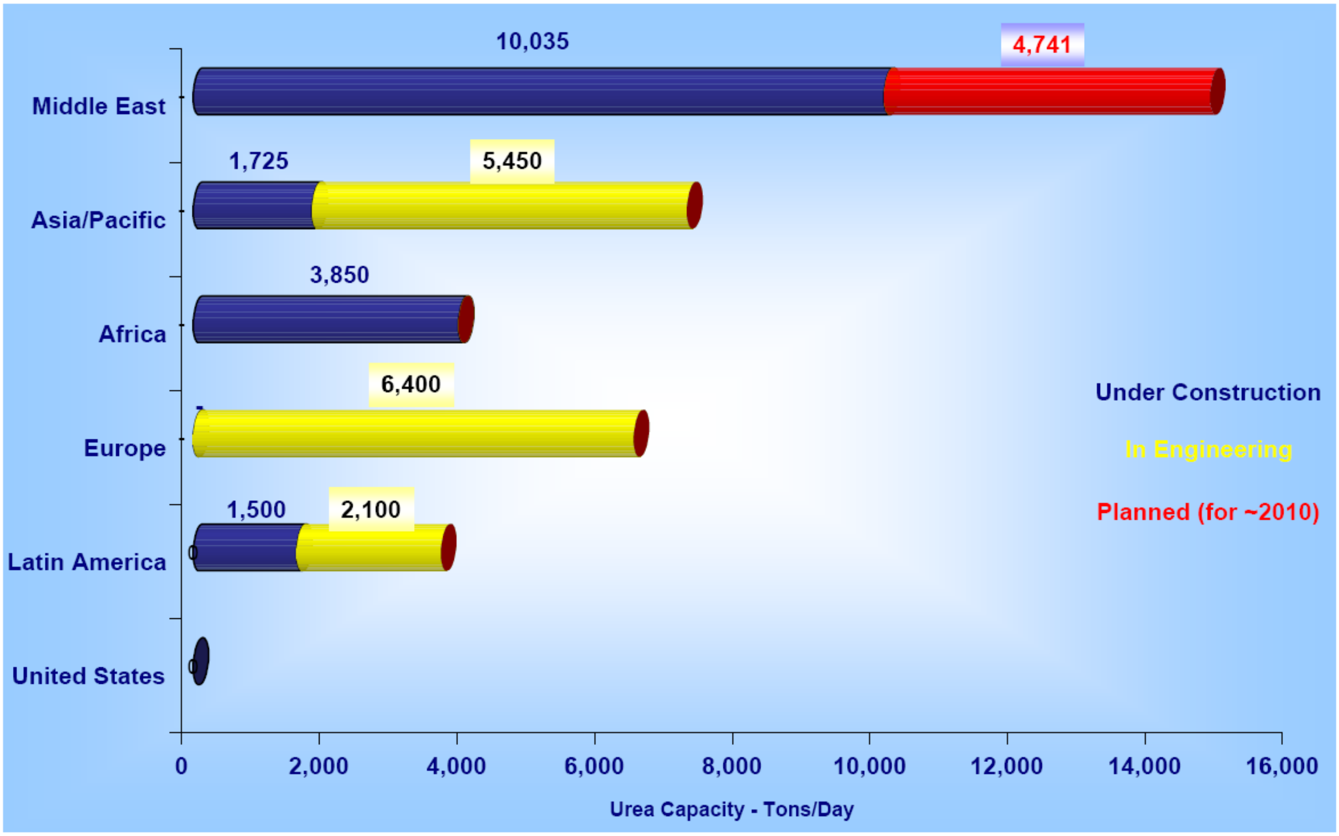
[29] Boxscore, Hydrocarbon Processing, June 2007. Note that these do not include revamps.

Figure 5
Possible Future Ammonia Capacity Additions



The situation with respect to urea, as shown on Figure 6, is similar.[29] Again, almost all of the announced projects in the Middle East are from Iran, all of those from Asia / Pacific are from China (except some under construction in Indonesia.) The major difference is that in Europe, Belarus, France and Russia have some urea plants "in engineering."

Figure 6
Possible Future Urea Capacity Additions



Considering likely demand growth, hydrocarbon availability and cost, and various countries' strategic viewpoints, it appears that during the next ten years major growth in ammonia and urea production capacity will be based on natural gas or, to a lesser extent, oil, and will primarily occur in the Middle East and Asia / Pacific; China and India will probably increase their heavy oil-based ammonia production capacity. Since The United States and the European countries are net importers of natural gas, economic production of ammonia and urea from these regions will become increasingly untenable. In the longer term of perhaps 20 years from now, it appears likely that the fuel cost to capital cost ratio will increase to the point of making heavy oil- and coal-based ammonia production economically attractive in a wider range of situations than now encountered.

In the near future, new natural gas-based ammonia and urea production capacity is expected primarily from such countries as Iran, Egypt, and possibly Saudi Arabia and Sharjah (UAE) where natural gas is priced at approximately 10 to 20 percent of that in North America and Europe. Additionally, mothballed plants in Nigeria and Venezuela will also be restarted, and China is bringing new heavy oil-based ammonia production capacity online.

Russia appears to be concentrating on the alternate scenario of selling gas and oil, perhaps for economic reasons and perhaps for political reasons. Although Russia has 4,000 tons per day of urea production "in engineering," based on its energy-related actions throughout the world, it would be surprising if it significantly expanded its already large international ammonia and urea trade.

Planning For Disruptions[30]

Supranational Planning: The essential elements of planning for energy disruptions are:

- providing an acceptable mechanism for coordinating the use of stocks, and redirecting supplies
- having adequate reserve stocks in place

These are meant to alleviate the effect of interruptions; they are not intended for short-term management of high energy prices.

Oil and Natural Gas Reserves are stored by governments and private industry in many countries, generally (but not in all cases) meeting the terms of international agreements requiring a 90 day supply. The United States Strategic Petroleum Reserve is the premier example of this, with 690 MM barrels in storage. Japan has a generally similar amount. These, however, are pricey endeavors. At ~$70 per barrel, these can require about $50 billion to fill. China has a Strategic Petroleum Reserve of about 25 days of imports, and is discussing increasing this to cover 70-75 days. Financing this is very problematical.

Each government will, of course, respond to a fuel emergency in its own way. Coal (and nuclear fuel) reserves appear to be adequate for at least a year of operation at 100 percent capacity throughout the world; oil and gas reserves are more limited. Member countries[31] of the International Energy Agency have agreed to maintain emergency oil stocks of at least 90 days of import and appear to be doing so. These stocks may be any combination of public and private reserves.

While cooperative sharing under emergency conditions is envisioned, this has not yet been extensively tested; they have actually been used only twice, in 1991 on the eve of the Gulf war and in 2005 after Hurricane Katrina. Additionally, the system had been put on alert before January 1, 2000 because of concerns about computer problems affecting energy supplies, in 2002 in response to the shutdown of production in Venezuela, and in 2003 prior to the invasion of Iraq.

The major international system for responding to an energy emergency is embodied in the International Energy Agency's International Energy Program (IEP) and Coordinated Emergency Response Measures (CERM.)[32] Although much of the IEP is clearly defined and self-executing, many of the credible threats to the international oil supply such as strikes or major accidents are specifically excluded from the activation triggers. Importantly, much of the CERM requires unanimous agreement of member nations, each of which has different political, fuel demand and supply situations. These programs have not yet been extensively tested.[33]

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[30] The following material is discussed more completely in: Cooper, H.W., "Vulnerabilities of The United State's Energy Supply: The International Context", June 2006 – Available at www.dynalytics.com.

[31] Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Republic of Korea, Luxembourg, The Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States

[32] OECD/IEA, 2003

[33] See Willenborg, R., C. Tonjes and W. Perlot, Europe's Oil Defences, Clingendael International Energy Programme, CIEP 01/2004, The Hague

Decisions about international cooperation, of course, always have major political components. The largest crude oil and natural gas suppliers are Saudi Arabia and Russia, both of which have been subjected to terrorist attacks by fundamentalist and separatist groups. They are the only two countries with any noticeable spare production capacity, but they have large Muslim populations they might fear offending by openly cooperating with the Western countries when important. Moreover, they might decide that, while the West now provides the largest market for their crude oil and gas exports, their future might be better served by favoring the rapidly growing Asian economies when allocating their suddenly limited production. Nations' reactions to disruptive events simply can not be precisely predicted.

Since energy supplies are vital to the wellbeing of many industrialized nations, another reaction to a severe shortage might be for one or more of the importing countries to undertake military actions. Other than to note that a coordinated response would be difficult to organize, and the risks of escalation and irreversible damage to supplies would be high, and the political and military outcome uncertain, this possibility will not be discussed further in this paper.

Governmental Planning: Each government will, of course, respond to a fuel emergency in its own way. Many state governments have developed and enacted detailed plans enumerating specific measures to be taken when an energy emergency is declared. Many provide authority to declare that, among many other actions:

- ❑ *Gas deliveries may be reduced or suspended to defined classes of users, prioritized by daily rate of use.*
- ❑ *Prime suppliers of regulated products shall maintain a "set aside" of "X" percent of that product it sold during the same month of the previous year.* A Board of Public Utilities may redirect some or all of the "set aside" to a specified end-user.

The rules recognize that many groups such as communication companies, utility companies, hospitals, and emergency vehicles face special situations. Plans therefore contain numerous exemptions and possible relief for "extraordinary hardship" and "public welfare." In the event that any emergency plan must be implemented, intense and probably acrimonious fighting for priority and exemptions will undoubtedly occur. Since requested exemptions will not all be granted, it is prudent for all industrial companies to prepare for modifying their operations.

Individual Company Planning: Based on the energy vulnerabilities described above, Dynalytics believes the following represent realistic planning boundaries.

- ❑ A moderately serious interruption: a 10 percent reduction in all types of energy, plus occasional sporadic rolling two-hour blackouts, lasting for a one-month period. Fuel prices will triple.

- ❑ An extremely serious interruption: a 20 percent reduction in all types of energy, plus many sporadic rolling two-hour blackouts, lasting for a twelve-month period. Fuel prices will increase to seven times their then-current values.

Strategic Management Issues

Each company's situation is, of course, unique with respect to the totality of its operations, including its production facilities and available space, staff, supply and distribution chains, product and customer requirements, and financial strength.

Faced with serious energy interruptions, corporate management must first answer a threshold question:

> *Given the characteristics of our customer base, should we continue producing ammonia and/or other products?*

If an objective analysis leads to a positive answer, decisions can then be made about whether or not is would be appropriate to invest in plant efficiency upgrades and, more fundamentally, whether it would be economically sensible to invest in technologies for using alternate feedstocks such as heavier hydrocarbons, coke or coal. These are certainly not trivial issues.

National, State and Municipal governments have developed energy emergency plans. In developing answers to these big-picture issues, it is particularly important to assess the steps that these agencies and individual energy suppliers will take. Assessing the realistic probability of obtaining priority status with respect to energy allocations requires an understanding of the criteria and process. Information should be sought from the staff of all agencies that will be involved with energy use and allocation matters. Application forms, if available, should be filled out to the extent practical, and stored, thus saving critical time when they might need to be filed.

Utility and fuel supply companies have certainly developed contingency plans for managing various levels of supply and delivery interruptions. It is important to discuss their contingency plans with them to ascertain their views of how, to what extent, and under what conditions a company will be impacted by their problems. It is important to understand the conditions under which, regardless of Agreements or Contracts, Force Majeure clauses will be invoked and service suspended.

Other less momentous steps that should be taken are those related to basic industry-wide issues, including keeping computers functioning, reviewing spare parts inventory practices, assuring that the employee situation will permit continuing operation, and preparing to communicate to governmental agencies, employees, customers and suppliers.

Conclusion

The international energy chain that leads feedstocks and fuels to ammonia plants is vulnerable to various interruptions that may be arise from natural causes, from geopolitical factors such as terrorist and other anti-government activities or the use of resources to influence other countries' foreign policies, or from inadequate processing and transportation capabilities. Fuel costs may increase suddenly and sharply from supply chain interruptions or from cartel actions or other revenue-enhancing actions by individual producing countries.

The international, national and local governmental plans to deal with major long duration shortages assume high levels of cooperation between many stakeholders and are largely untested. It is therefore prudent for ammonia producers to carefully assess their individual situations and options, to plan for major fuel interruptions, and to start critical path activities as soon as possible.

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Dr. Herbert W. Cooper has over forty years of experience with economic, technological and environmental aspects of power production, hydrogen production, steel mills, petrochemical production, oil refining and similar industrial facilities. He has been the president of Dynalytics Corp. since 1969; a company whose clients have included governmental entities, major engineering firms, equipment vendors, oil & chemical, and aerospace companies throughout the world.

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