Addressing Energy Supply Vulnerabilities

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Can a mega-worldwide energy interruption occur? The perfect storm may be brewing with such events as natural disasters, acts of terrorism and international disputes. This article explains how your company can prepare to effectively handle an energy disruption.

The world's energy demands and supplies form an extremely integrated system with a high-speed feedback loop— any change, anywhere in the energy supply side quickly affects all users. Production and transportation of oil and gas are being interrupted by accidents and weather-related events throughout the world. Unfortunately, international disputes are ongoing, and terrorist activities outside of the U.S. are becoming more frequent, more sophisticated and more severe. These terrorist activities will strongly exacerbate energy shortages. Given the international geopolitical situation and the current energy infrastructure weaknesses, suddenly arising long-duration disruptions should be expected, together with extremely large increases in fuel and electricity costs. It appears to be extremely risky and imprudent for any company to not prepare to handle this situation. This article focuses on immediate credible threats, and offers specific suggestions for industrial companies to implement immediately.

Natural disasters

The world's primary energy supply and delivery system may be disrupted be numerous unfortunate and unplanned factors such as hurricanes and earthquakes. These may occur anywhere in the world and, if sufficiently severe, will impact the energy situation in all countries.

While not at all minimizing the tragedies that arose from the 2004 tsunami in Southeast Asia, the entire world would have suffered greatly from an extreme fuel shortage if it occurred further east at the Straits of Malacca, through which 25% of the seaborne crude oil flows by tanker. The Straits are also quite important for coal shipments as well as other dry materials such as grains.

Floods and severe thunderstorms routinely interfere with railroad shipments. A thunderstorm in Topeka, KS, on Oct. 1, 2005, for example, washed out a railroad bridge and several hundred feet of tracks. For the next five days, Union Pacific had 116 coal trains staged at various points awaiting ways to make deliveries, or to return to coal mines for loading. It took about 10 days to return to normal.

Hurricanes fall between storms and tsunamis with respect to the damage they can cause. On Aug. 29, 2005, Hurricane Katrina struck the Gulf of Mexico, damaging the shipping channel at Louisiana through which much of the Mideast crude oil flows, as well as much of the nation's oil and gas production and transportation infrastructure. On Aug. 30, the day after the storm (by which time 645 platforms and 90 rigs had been evacuated) 1,428,000 bbl/d of oil (95% of the Gulf of Mexico's daily production) and 8,798 million ft^3/d of gas (88% of the Gulf of Mexico's daily production) were shut-in (*1*). Two weeks later, 841,000 bbl/d of oil (56% of the Gulf of Mexico's daily production) and 3,383 million ft^3/d of gas (34% of the Gulf of Mexico's daily production) remained shut-in (*2*).

One month later, on Sept. 24, Hurricane Rita struck Louisiana, leading to the shut-in of additional oil and gas production. As of Dec. 29, 411,000 bbl/d of oil (27% of the Gulf of Mexico's daily production) and 1,954 million ft^3/d of gas (20% of the Gulf of Mexico's daily production) remained shut-in (*3*).

Unusually cold weather can lead to fuel supply disruptions on an international basis. For example, as shown dramatically in mid-January 2005, when temperatures in Russia and Eastern Europe fell to –20°F to –30°F, the coldest since 1927, demand for gas naturally rose. Attempting to cope with its own internal needs and weath-

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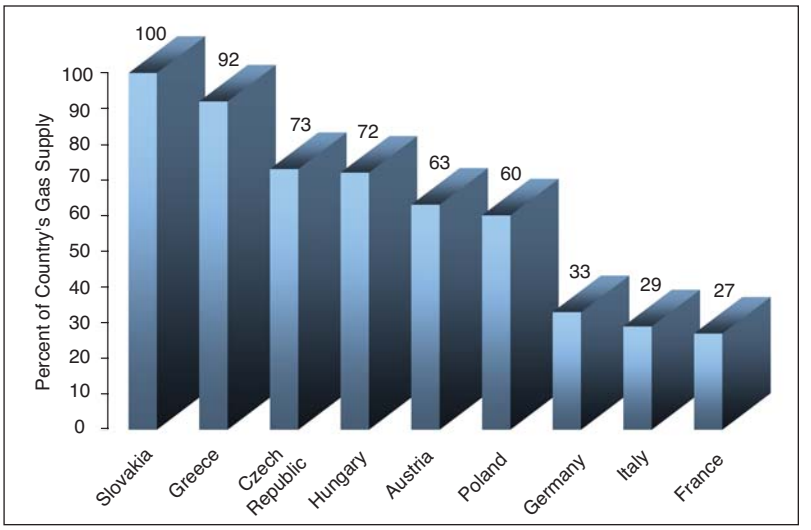
er-related production difficulties, Russia had to reduce its exports to various European countries by 5–20%.

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. They have also been subject to anti-government protests, violent civil wars and separatist movements, and inter-ethnic tensions in Algeria, Chechnya, Georgia, Indonesia, Iran, Sudan, Iraq and Nigeria. Killings in Nigeria have, in fact, led Royal Dutch/Shell and ChevronTexaco to withdraw personnel and shut-in approximately 818,000 bbl/d (40%) of Nigerian oil production. Similarly, Baluchi nationalists recently attacked the Sui Gas Plant that supplies 22% of Pakistan's gas needs; eight people were killed, and the plant was shut down for about a week.



■ Figure 1. Countries dependence on Russian gas in 2005.

Several unresolved boundary disputes are potentially serious problems. In the Far East, these include disputes between China and Japan concerning natural gas rights to the Chunxiao gas field in the East China Sea. Japan and Russia each claim sovereignty over several islands, called the "Northern Territories" by Japan and the "Southern Kurils" by Russia. In the Mideast, Iran and the United Arab Emirates each claim ownership of three islands in the Strait of Hormuz, and Iran, Saudi Arabia and Kuwait each claim partial ownership of a huge offshore gas field, called "Arash" by Iran and "Dorra" by the other two countries. One-third of the common border between Georgia and Russia has not been defined. There are numerous other disagreements and undefined borders throughout the world.

Russia now provides 25% of Europe's fuel gas and noticeable amounts of crude oil. It thus has enormous, but not necessarily decisive, leverage in its international relationships. This was displayed in January 2006 when Russia reduced gas supplies to Moldova, which quickly agreed to a 100% price increase. Simultaneously, Russia attempted to quadruple the gas prices it charged Ukraine. While Ukraine disputed the claim, Russia continued to deliver it gas for further transport to Western countries, but reduced the total by the amount that Ukraine claimed it was due. Ukraine, however, continued to take its full share, leading to a shortfall in Europe's gas supply. After several days, a complex somewhat opaque compromise was reached within which Ukraine agreed to pay almost twice its previous rate for the Russian gas, but also will receive a 47% higher transit fee from Russia for gas transportation. Shortly thereafter, Ukraine's Parliament fired the President's cabinet, causing much political turmoil. Whether the cause was a simple commercial dispute between the Russian and the Ukrainian gas companies, or a reaction to Ukraine's election of an independent Prime Minister, the fact remains that it and the Moldavian situation also happened.

Russia is, moreover, a major supplier to many European countries, as seen on Figure 1. Recent events have made several countries uncomfortable with their levels of dependence, leading them to consider increasing subsidies for renewable fuels and, led by France, to revisit their anti-nuclear-power positions.

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 many groups.

Oil and gas fields. Crude oil and natural gas fields throughout the world, while guarded and protected to various degrees, are tempting targets for dissident and terrorist groups. Crude oil and natural gas recovery requires availability and operation of computers, pumping and compressor systems, purification processes, and storage and blending systems. Water or inert gas injection is often used to sweep additional oil out of the basin. Large oil–water separators and water treatment facilities are therefore increasingly important components of crude oil production. Fields, production staff and production facilities are vulnerable to accidents or attack. Rational, well-informed attackers would be unlikely to destroy production capabilities; they are more likely to try to coerce governments by withholding supplies from the international market. Kuwaiti oil fields, nevertheless, were deliberately dam-

aged by Iraqis at the end of the invasion in 1991. Several oil wells in the Bay Hassan oilfield in Iraq were bombed in April 2005. Irrational or unknowledgeable attackers certainly exist throughout the world.

There have been several terrorist attacks in the Saudi Kingdom, including that of May 2004 on the ABB Lummus office in Yanbu during which seven employees were killed and that on the Khobar Towers which resulted in 22 deaths, as well as several others during the first two weeks of June 2004. Russian facilities and citizens have been, and presumably remain, targets of various separatist groups who have demonstrated a willingness and ability to take violent murderous and destructive actions.

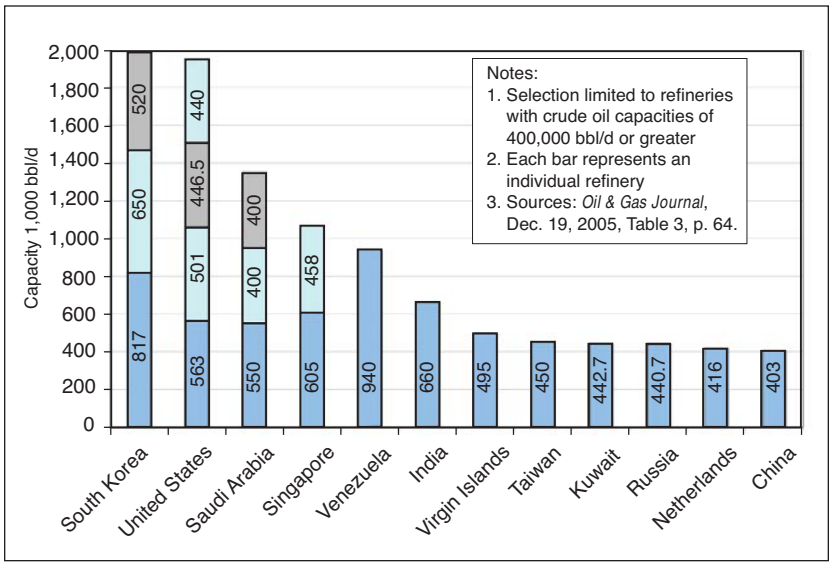


Figure 2. The world's largest refineries by country and capacity.

Pipelines and pumping stations. Many attacks have been perpetrated on pipelines, generally leading to local oil or gas shortages. These have been serious within countries such as Pakistan that lack alternative supplies and redundant infrastructure. Insurgents in Columbia, likewise, have frequently bombed pipelines that supply crude oil to refineries. Approximately 40% of the feed to the world's largest refinery, Paraguana in Venezuela, was cut off by sabotage in December 2005. In the same month, terrorists also bombed a crude oil pipeline in Nigeria, killing eight people and leading Royal Dutch/Shell to shut-in 180,000 bbl/d of crude oil production. This was followed a month later by an attack on the Shell Beneside pumping station that led to 16 people being killed or wounded, and the evacuation of the area. The pipelines supplying natural gas from Russia to Georgia and Armenia were severely damaged by terrorists' explosions in January 2006. This action was quite serious, interrupting virtually all of Georgia's supply during an unusually deep cold spell. Initial assessments were that repair efforts might not be completed for four weeks. During the same month, separatist militants attacked three natural gas pipelines in Assam, India. This action affected operations in an oil field, leading to an interruption of crude oil supply to four refineries and an electric power plant.

If attacks on pipelines are sufficiently frequent, they can certainly interfere with a country's ability to export product. Iraq, for example, shut its 600,000 bbl/d crude oil export pipeline after it was subjected to more than 15 terrorist attacks in early 2005. Within the context of this article, however, such attacks have not yet had any major effect on the international energy situation. Repairs of land-based pipelines have usually, but not always, been straightforward and generally performed rapidly. Nevertheless, larger-scale attacks could be more damaging. The concern is high enough for the U.S. and Georgia to have created a special military unit to guard the pipelines carrying oil from the Caspian Sea to the Black Sea, with Northrup Grumman Corp. providing aerial surveillance.

Damage to sub-sea pipelines, such as those that bring gas from Algeria and Russia to Europe, would be far more difficult and time-consuming to repair. Construction of the deep sub-Black Sea portion of the Blue Stream pipeline, for example, took approximately eight months without fear of attacks.

Although railroad trains, barges and trucks offer diversity of transportation of liquids such as crude oil and refined products, there are currently almost no alternatives to pipelines for transporting gases; LNG capacity, while growing rapidly, is still a minor factor. Attacks on the world's gas pipeline system could thus certainly be quite disruptive, particularly throughout Europe and Asia.

Terminals and storage facilities. Since Saudi Arabia is an exceedingly important crude oil supplier, the operation of its export terminals is critical. The primary export facilities are located on the Persian Gulf at Ras Tanura (6 million bbl/d) and at Ras al-Ju'aymah (3 million bbl/d), and on the Red Sea at Yanbu (5 million bbl/d). These collectively can handle approximately 14 million bbl/d, which comfortably exceeds the Kingdom's production capacity of 10.5 million bbl/d. Loss of any one of these would, however, lead to very serious consequences; loss of two of them would be exceedingly serious.

Russia has become an important crude oil supplier to Asia and Europe, with major terminals at Primorsk (880,000 bbl/d) on the Baltic Sea, Novorossiysk (900,000 bbl/d) and South Ozerereyevka (600,000 bbl/d) on the Black Sea, Pivdenny (180,000 bbl/d) near Odessa, Poland, and several smaller facilities. Loss of any one of these would have serious adverse impacts on Europe and on the Asian and Russian economies.

Similarly, the Israeli oil ports and terminal facilities at

Ashkelon on the Mediterranean Sea (9.4 million bbl) and Eilat on the Gulf of Aqaba (8.5 million bbl) have become important. Connected to each other by a high capacity pipeline, they allow crude oil arriving at the Mediterranean Sea from Black Sea ports to bypass the Suez Canal, alleviating its tanker size limitation, or alternatively the long route around Africa for delivery to the east. This pipeline, moreover, is rather unique in being able to transport oil in either direction. Both of these Israeli facilities, however, are within range of Palestinian and South Lebanese rockets.

Refineries. Twenty large refineries with capacities of 400,000 bbl/d of crude oil or more are sited in 12 countries, as shown in Figure 2. While terrorist groups may attempt to attack facilities anywhere, seven of the large refineries are located in countries (Kuwait, Saudi Arabia) that are clearly in unstable regions or in which terrorists have already been active (India, Russia, Netherlands). The loss of production from a major refinery would lead to lowered product exports and a reallocation of crude oil. Since only Saudi Arabia and Russia have meaningful spare crude oil production capacities, a successful attack in these countries would have a noticeable impact on the worldwide energy balance. In addition to availability issues, prices would undoubtedly rise beyond normal supply and demand considerations because of psychological factors.

Only four of the largest refineries are located within the U.S. (the 563,000 bbl/d ExxonMobil facility in Baytown, TX, the 501,000 bbl/d ExxonMobil facility in Baton Rouge, LA, the 446,500 bbl/d BP facility in Texas City, TX, and the 440,000 bbl/d facility at Lake Charles, LA). These are the sixth, ninth, thirteenth and sixteenth largest refineries in the world, each processing approximately 3–4% of the crude oil refined in the U.S. Since the U.S. refineries are currently operating in excess of 90% of their capacities, the loss of any one or more of these would cause serious energy problems, not only throughout the Southwest, but also throughout North America.

Shipping. The biggest and most likely immediate threat by far is terrorist attacks on shipping (*4*). Much of the crude oil supplied to the highly industrialized countries such as the U.S. and Japan are transported in very large crude carriers (VLCCs; capacities of 200,000–399,999 tons or approximately 1.25–2.5 million bbl) or the larger ultra large crude carriers. During the first nine months of 2005, 141 ships were boarded, 15 fired upon, 11 hijacked, and 256 crewmembers taken hostage. This, however, is actually an 18% reduction over the same period in 2005. The waters off Somalia, conversely, have become exceedingly dangerous, and "Ships not making scheduled calls at Somali ports are advised to keep at least 200 nautical miles from the Somali coast" (*5*). During the first nine months of 2005, there were 61 pirate attacks reported on ships in Indonesia, 10 in the Malacca Straits, and 13 in Nigerian waters (*6*). Most of these attacks were small-scale ventures of two or three "pirates" who stole an anchored ship's stores such as paint, lines, tools and the like. Many larger ventures resulted in the kidnapping of officers and engineers for ransom. As with automobile accidents, a substantial number of events are not reported because of concerns that insurance premiums will rise or adverse publicity will occur.

More ominous than piracy for financial gain were attacks by as many as 20 persons on three to five well-equipped speedboats, armed with machine guns, who steal ships' documents (*7*). Possibly an even more ominous situation is the hijacking of tankers by pirates who demand that crews teach them how to steer, but had no interest in docking operations. Ten armed men, for example, hijacked the chemical tanker Dewi Madrim in March 2003, steered it through the Strait of Malacca, and left with equipment and technical documents. More recently, on March 12, 2005, a group of 35 pirates, displaying machine guns and rocket-propelled grenade launchers, seized the 1,289-tonne tanker MT Tri Samudra. This vessel was carrying methanol through the Strait of Malacca from Borneo Island to Belawan, Sumatra, but was ordered by the pirates to sail to another port (Dumai, Sumatra), and the ship's captain and chief engineer were kidnapped. The ship's owners believe the pirates were, in fact, terrorists from the Free Aceh Movement that is fighting for independence. At least one authority, however, is skeptical of terrorist involvement, noting that "…hijacking would be a very inefficient way to get training, which would be good only for an identical ship in identical conditions. And in any case, the sobering reality is that no specialized training is needed to drive a ship into a bridge, a port facility, or another ship" (*8*). While accepting these points, future cooperation between pirates and terrorists is certainly plausible.

Various international and U.S. agencies have identified many locations as critical to the worldwide flow of oil, coal and many other items (Table). These have narrow inlets and 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.

While the focus of this article is on energy, many other materials pass through these points, such as grains, metals, ores, industrial equipment and consumer products. An interruption would curtail delivery of these and impact shipping traffic in each direction. It would, moreover, lead to a demand for more tankers to compensate for the use of non-optimum routes, thus increasing delivery times and shipping costs. Premiums for shipping insurance, if available, would also dramatically increase.

Table. Crude oil shipping chokepoints. Source: (*9*)

Chokepoint	Location	From/To	To/From	Million bbl/d
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

The duration of a blockage would obviously depend on its nature. A blockage of the Suez Canal provides one benchmark. During the 1956 war between Egypt and Israel, the Egyptians blocked the Suez Canal with shipwrecks and with mines. After the war, it took more than one year of multinational effort to clear it sufficiently for traffic to resume. While ship-mounted cranes and mine-sweeping abilities have improved since then, the ability to cause damage has also increased. A one-year effort to restore traffic appears to be plausible.

As bad as an attack on any of these would be, it must be remembered that terrorist groups frequently attack several points simultaneously. Recent examples include the Sept. 11, 2001, attack by four teams (three successful) on the U.S., the May 16, 2003, simultaneous attacks on five sites in Casablanca, Morocco, the Nov. 15, 2003, bombing of two synagogues in Istanbul, Turkey, and the Mar. 11, 2004, attacks on three train stations in Madrid, Spain.

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 class (capacities of 126,000–199,999 tons or ~790,000–1,250,000 bbl) or the Panamax class vessels (capacities of 50,000–79,999 tons or ~314,000–503,000 bbl). Transit time and cost would, of course, increase if smaller tankers and non-optimum routes had to be used. Although the loss any of these routes may be somewhat mitigated by using trucks, smaller tankers and barges and increasing flows through pipelines, the adverse impact would, nevertheless, be substantial.

Antiterrorist measures

Although the oil-producing countries and companies spend tens of millions of dollars on security, piracy and terrorist attacks continue. International initiatives have not led to impressive results.

The United Nation's "Convention of the Law of the Sea" defines the conditions under which hot pursuit of a foreign ship, arrest of persons, seizure and disposal of property, and imposing penalties are permissible. It is, unfortunately, relatively easy to repaint and slightly alter the outward appearance of a hijacked ship and reregister it in Liberia, Malta or Panama for operation under a "Flag of Convenience." The United Nation's International Maritime Organization has adopted "Measure to Prevent the Registration of Phantom" ship (*10*). This, however, 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. In 2004, however, Indonesia, Malaysia and Singapore began coordinated patrols of the Malacca Strait, with Japan participating in drills. A more intense structured "Regional Maritime Security Initiative" (RMSI) has been discussed within which the U.S. would provide military assistance upon request. Although it has been resisted by various countries as an intrusion into their national sovereignty, discussions continue.

After numerous discussions, four countries (Indonesia, Malaysia, Singapore and Thailand) agreed that they would jointly implement an "Eye in the Sky" program to enhance the security of the Malacca Strait. The countries provide sufficient resources so that one or two aircraft now patrol the Strait every day, providing timely information to naval vessels (*11*).

Japan hosted a Ministerial Conference on International Transportation Security in Tokyo in January 2006. With 14 countries and four international organizations participating, its concluding joint communiqué states: "We recognize that acts of terrorism pose a serious threat to international transport and that acts of piracy and armed robbery against ships recur with alarming consequences. We therefore believe that it is essential to reduce the vulnerability of international maritime transport to such unlawful acts." The Ministers present agreed to adopt various Conventions and Protocols that, if truly implemented, should enhance maritime security.

Several groups collect information about successful and attempted piracy incidents and disseminate details to the maritime community. These include weekly reports from the U.S. Office of Naval Intelligence, monthly reports from the International Maritime Organization (a division of the United

Nations) and daily status bulletins and weekly reports from the Piracy Reporting Centre (a group within the International Maritime Bureau, which in turn is part of the International Chamber of Commerce).

Planning for disruptions

Supranational planning. 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) (*12*). These present numerous requirements related to emergency energy self-sufficiency through national oil storage, demand restraint, and oil allocation to each country. The measures would be triggered when an international disruption produces a 7% loss of supply. 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 tested (*13*).

The European Union has developed a parallel emergency response system (*14*) that provides guidance when stocks exceed IEA minima. No central coordinating authority, however, yet exists within the European Union, although new initiatives continue to be considered.

The U.S. has proposed an international nuclear fuel reserve, partly as a way to assure Iran, North Korea and other countries that their nuclear power plants will be able to obtain fuel without developing an indigenous uranium-enrichment or plutonium-reprocessing capability. Many basic issues will need to be resolved before this reserve becomes a reality. For example: Who would own the fuel? How and by whom would the reserve be administered? How would the receiving country's spent fuel be handled? Who is responsible for transportation? Until these and other matters are resolved, this internationally oriented reserve will not be established. Based on the history of other international efforts, it appears unlikely that it will be realized within the next five years.

Decisions about international cooperation, of course, always have major political components. The largest crude oil and natural gas suppliers to Asia are, as noted above, 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.

While reactions to disruptive events cannot be precisely predicted, there are clues to be assessed. Russia, for example, has recently announced that a major new, although environmentally controversial, 2,500-mile trans-Siberian pipeline (the Eastern Pipeline) will originate from Taishet near Lake Baikal and go eastward in two phases. During the first phase, 600,000 bbl/d will travel 1,800 miles to a point near the Chinese border, and 400,000 bbl/d will then be diverted to a direct pipeline to China, The remaining 200,000 bbl/d will be sent by railroad to the Pacific Ocean for delivery to Japan. In the second phase, the capacity will be increased to 1.6 million bbl/d, and a line extended 1,200 miles to the Pacific coast, from which the Japanese market can be readily served. This approach appears to demonstrate Russia's confidence in the Asian future and mitigates the risks of having only one country as a customer for this oil.

Governmental planning. Each government will, of course, respond to a fuel emergency in its own way. The U.S. government, for example, requires that federal agencies prepare emergency conservation plans for 10%, 15% and 20% reduction compared to the previous fiscal year in gasoline, other oil-based fuels, natural gas or electricity for periods of up to 12 months (*15*).

Many state governments have developed and enacted detailed plans enumerating specific measures to be taken when an energy emergency is declared. New Jersey's Energy Emergency Plan (*16*), for example, provides authority to declare that, among many other actions:

- Temperatures maintained by heating shall not exceed 65°F during business hours or 55°F during nonbusiness hours.
- Nighttime professional sports, entertainment and recreational activities shall be curtailed, suspended or rescheduled.
- Retail establishments shall be closed from 7:00 pm to 9:00 am and all day on Sunday.
- All outdoor flood and advertising lighting shall be eliminated.
- Gas deliveries may be reduced or suspended to defined classes of users, prioritized by daily rate of use.
- Electric loads may be interrupted on a rotating basis every two hours.
- Prime suppliers of regulated products (*i.e.,* utility companies) shall maintain a store (a "set aside") of 5% of that product it sold in New Jersey during the same month of the previous year. The 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. They, therefore, contain numerous exemptions, and the Board may also issue exemp-

tions for "extraordinary hardship" and "public welfare."

All states have emergency energy plans with greater or lesser specificity of details. In the event that any of them 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 and commercial companies to prepare for modifying their operations.

Individual company planning. 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. The two "big picture" questions that management must answer are:

• Will the demand for our products probably remain unchanged or even increase (*e.g.,* pharmaceuticals) or probably decrease, possibly close to zero (*e.g.,* SUVs), immediately after an energy emergency?

• The cost of making and distributing our products will increase noticeably. Considering contractual, public relations and political issues, how much of the increase will we be able to pass on to our customers, and how much must we absorb?

If demand is likely to remain unchanged or even increase, planning for energy shortages and interruptions longer than heretofore encountered is important. The pharmaceutical sector is an example of one for which demand for many of its products will not change; patients simply need them to maintain their lives. Although demand may be constant or even increase during an energy emergency, the ability to meet it may be reduced by constraints in the availability of energy, raw materials, production staff and the distribution chain.

If, conversely, demand is likely to decrease, planning for orderly shutdowns, storage and maintenance is important. An example is the widespread mothballing of planes in the airline industry.

Possible changes in processes and/or equipment have traditionally been examined as a conceptually simple balance of invested capital versus the resulting savings in operating costs. A new paradigm must, however, now be used for evaluating possible energy-storage and energy-reduction projects. The new framework is:

• "Past performance with respect to blackouts and fuel shortages is no guarantee of future results." We have had a new set of challenges thrust upon us.

• If our company has a limited amount of fuel and electricity available, how should we best use them? Evaluations of alternative courses of action must now consider the possibility that energy resource limitations might cause significant production curtailments or plant shutdowns. Self-generation of electricity, fuel storage and energy efficiency may now be significantly more cost-effective than in safer times.

While all energy efficiency improvements will be helpful, it is unlikely that major energy reductions will arise from measures that are even now frequently implemented such as adding oxygen trim controllers to existing boilers, operating them at lower pressures, replacing fixed or two-speed drives with variable-speed drives, changing to premium-efficiency motors, or replacing light bulbs with more efficient ones. More drastic steps will frequently be appropriate.

Large energy conservation results are more likely to arise from process changes and/or major revisions to lighting and HVAC systems. These, of course, are process- and building-specific. Importantly, even though the impetus for process revisions or for installing additional energy conservation equipment is to better contend with curtailments, the efficiency benefits will continue to be realized during non-emergency periods.

In addition to process considerations, a basic industry-wide issue that companies must address is keeping computers functioning in a major energy crisis where electricity might be curtailed or rationed for longer periods than previously encountered. Access to many of a company's vital records, process control and process safety systems depends on functioning computers. Loss of these will cause massive production and business disruptions. Emergency and standby generating systems have been installed widely to accommodate electrical outages lasting from milliseconds to a few hours; they, however, have not generally been designed to allow operations for days or weeks. Moreover, they rarely have sufficiently large fuel storage tanks.

While recognizing that each company's situation is unique, there are a number of steps that should be taken immediately by all production companies. Several of these will require environmental permits and/or other governmental approvals. Obtaining permits is frequently time-consuming and may be contentious. The process should be started as soon as possible.

1. Assess the steps that governmental agencies and your energy supplier will take. As noted above, the U.S. government, state governments and many municipalities have developed energy emergency plans. In order to assess the realistic probability of obtaining priority status with respect to energy allocations, it is necessary to understand the criteria and process. Seek information 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. Discuss their contingency plans with them to ascertain their views of how, to what

extent, and under what conditions your 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.

2. Examine your business fundamentals. Develop business scenarios for reacting to severe energy emergencies. Evaluate the options of maintaining or changing the current product slate. Reducing or suspending production of certain products to reallocate scarce energy resources may be appropriate.

3. Understand your current technical situation. It is necessary to set goals and priorities; therefore, tabulate every energy-consuming activity, together with information about type, rate and quantity of energy used. The rates and quantities should be reconciled with utility company and fuel supplier invoices. Process energy uses will usually be evident. Discrepancies, however, may arise from overlooking common items such as cooling tower fans and pumps. Simultaneously gather data about the temperatures and flowrates of all streams in order to assess potential heat recovery possibilities.

4. Examine your spare parts inventory practices. Evaluate the condition and reliability of critical equipment and control systems because forced unscheduled outages damage equipment. Since, particularly in an emergency situation, obtaining replacements will be slow and expensive, upgrade equipment where necessary. The types of spare parts kept and their inventory levels should also be reexamined. The cost impact of increasing spare-part inventory levels may be lessened by establishing cooperative approaches with equipment suppliers and/or other local production companies.

5. Examine your current processes. Companies in many industrial sectors have found it very cost-effective to reduce off-specification product rejection rates that unnecessarily consume raw material, energy and plant capacity. These wastes may be reduced to very low levels by employing more-stringent quality control and inspection measures than normally used for raw materials and intermediate products.

Providing for increased storage of raw materials, intermediates and final products will help if intermittent production becomes necessary. Shelf-life and storage temperature requirements must, of course, be considered. Additional storage capability will also provide flexibility in dealing with railroad, trucking and related transportation issues that may arise.

Perform high-electric-demand operations during off-peak periods. This is commonly recommended to reduce peak demands and obtain lower rates. It will not change the amount of electrical energy used, but may help if rationing or allocations are instituted. In the event of an energy emergency, fuel flexibility will be important. Investigate the possibilities of using alternative fuels, and implement them where practical.

6. Revisit heat recovery operations. Reactor design and operation, as well as separation processes, are usually key proprietary technologies that have taken considerable time and resources to develop. They are the last things to consider changing. There are, nevertheless, steps that might reduce energy consumption to the lower levels justified by maintaining operations without impacting the process streams.

Where heat recovery is currently practiced, investigate increasing it by taking low-cost steps that are frequently marginally economical when reviewed within conventional energy accounting scenarios. Condensate return from steam traps represents a simple example. Storage of heated or cooled streams (*i.e.,* thermal storage) for later use is another.

Somewhat more costly steps include installing additional or larger heat exchangers to increase the amount of energy recovered from compressor intercoolers, refrigerant condensers, distillation system condensers or other process streams. A process review might show that some pump and piping systems might also have to be changed, and that corrosion from condensation of flue gas streams might establish the technical limits to additional heat recovery.

Cogeneration (concurrent production of electricity and steam or chilled water) has probably been examined by every production company in the world by now, and most often rejected based on a narrow balance of capital costs versus energy cost savings. A fresh look based on effectively using the limited amount of energy that would available to continue operations might indicate that it is, in fact, justified under this new scenario. Realistic possibilities should be implemented where practical, since the new driving force is maintaining an ability to continue operation.

7. Consider moderate incremental process changes. Several incremental steps might reduce energy usage by modifying the process streams' compositions and/or time-temperature profiles. Investigate using recycled products as raw materials. Since the compositions of these partially match those required in the finished products, a substantial energy savings is often possible. Several industries, such as pulp and paper, iron and steel, and hot-mix asphalt production, routinely use recycled materials. These, of course, are not trivial changes. They might require laboratory and pilot plant testing, and interaction with such agencies as the Food and Drug Administration.

8. Install a truly adequate backup electrical generator system. It is very important to have an oil-fired emergency backup electrical generator of sufficient capacity installed and available within seconds to supply power to all critical equipment and operations. When energy emergencies arose in the past, such as the U.S. East Coast blackout of August 2003, there was a sudden demand for emergency electricity generators, which quickly became unavailable. The situation will again be severe with respect to the generators sought by

industrial companies, since they employ higher capacity units, more complex startup and control systems, more durable construction, and varied fuel supply systems. These are usually custom-designed and use many components that are not normally kept in generator suppliers' inventories.

Battery-operated starting systems are among the key components of emergency electricity systems, and have been found to be surprisingly unreliable. Dynalytics notes that nickel-cadmium batteries, although somewhat more costly, offer many advantages over the low-cost common lead-acid batteries, and should always be preferred. In fact, fuel cell systems are often an even better choice based on careful evaluations of their reliabilities and lifecycle costs.

Given the nature of the emergency under consideration, the amount of fuel oil stored onsite must also be adequate. Each company must assess the frequency and quantity of fuel oil that it might obtain during an emergency. Any substantial increase in oil storage will probably need review and approval of the local building, fire and health departments, and possibly of the company's insurance company.

Environmental permits must be secured for installing and operating diesel-engine-driven electricity generators, possibly an arduous process. Although the anticipated use of these units is for emergency backup generation, permit restrictions that are commonly agreed to may not be appropriate, given the long operating times that may be required. It is important to establish whether the desired operating scenarios are limited to emergency generation only, or also include non-emergency periods.

9. Examine your employee situation. Assess the minimum operating staff level, by function, that is necessary for continued operation. Then establish ways that this need will be met.

Employees will react to an energy emergency in a variety of ways, depending on its nature, expected duration, and their personal and family situations. Meet with employees and, if there is a union, its representatives for an honest discussion of employee and company needs. They may want a flex-time policy, car pools, temporary child-care operations, expanded meal preparation and service, relaxed rules for personal telephone calls, expanded telecommuting, or undoubtedly other unforeseen items. Decide which requests can be reasonably met and prepare a plan in sufficient detail so that lead times are minimized and it can be quickly implemented. Sick leave, absence and lateness provisions of normal personnel policies should be reviewed and altered if necessary. Present the plan to the staff, consider their further input, and revise it as necessary. Keep them informed; their cooperation will be critical.

10. Prepare to communicate. If your company produces critical items such as pharmaceuticals and finds itself faced with substantially higher costs and reduced production, irresponsible charges of price gouging and conspiring to withhold product or manipulate the market place will inevitably be leveled. Develop a fact-based presentation, including handouts and contact information, that explains the situation, how and why you are reacting as you are, and what steps are being taken to improve the situation. The audience will be public officials and the affected users.

Develop a professional relationship, through tours, briefings or lunches, with reporters of the print and broadcast media to establish the mutual trust necessary for discussing situations candidly. Public support will be particularly important if, as is the case with the recent flu vaccine shortage, any segment of the public believes its health is at risk. CEP

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