Reducing Industrial Pollution

The term "industry" scarcely captures the richness and diversity of the activities that it encompasses, as well as their importance. Were it not for "industry," America would lack not only cars and trucks, but also roads on which to drive them. There would be no books or newspapers, for lack of not only paper, but ink as well. Crops would still grow, but more slowly, due the absence of fertilizers.

Figure 1 In Japan, where energy efficiency is a mania, "campaigns" are mounted about once every five years to examine every step in the production processes of industries, searching for ways to cut fuel consumption and reduce air pollution. Japan uses one-half as much energy per person as the United States. (Source: Knight Science Journalism Tracker.)

"Industry" starts with a uranium mine two miles deep into the hills of New Mexico and runs to mills tucked into snowy valleys of New Hampshire. It includes everything from the extraction of natural resources to their ultimate shaping into finished products.

Because industrial activities are so different, one from the other, it is impossible to arrive at any single solution—or even any single set of solutions—to the variety of pollution challenges that they present. What might work to reduce emissions in the cement industry—blended cement, for example—is utterly meaningless to a producer of steel. This is not to say, however, that there are not ways to reduce emissions of Kyoto and non-Kyoto pollutants alike. There are, and many of them can save money as well.

Indeed, there are so many opportunities to eliminate pollution from industries—and for these purposes, that includes agriculture, because the days of Mom, Dad and the kids working a few acres are long gone—that they cannot possibly be listed and explained in the space here. There are literally thousands of improvements that could be made. Indeed, much of the challenge lies in the reality that, as engineers are fond of saying, "the Devil is in the details."

The Japanese, however, have developed a novel and very effective way of eliminating as much pollution as possible out of making cars, smelting steel, refining oil and other industrial activities: every few years, the government mounts industry-wide efficiency "campaigns," in which engineers and others examine every process, machine, boiler, step—in short *everything*—for the purpose of increasing efficiency and reducing emissions.

The Swedes have taken a different approach. For emissions of oxides of nitrogen, or NO_X, a major cause of ozone or smog, the government has adopted a "feebate." Polluters pay into a fund based on how much they emit, then the contributions are rebated to low polluters. The calculation is very simple: reducing pollution saves money. The system has worked so well that some companies began offering bonuses to workers who reduced emissions during their shifts, something that can be accomplished by simple adjustments to burners, boiler doors, and the like.


Figure 2 In the Swedish town of Vaxjo wood chips from nearby forests provide electricity, and the ash is returned. Throughout Sweden and much of Europe, taxes on emissions of carbon dioxide have spurred hundreds of new ways to reduce emissions of greenhouse pollutants. (Source: Wordpress.)

For carbon dioxide, the Swedes have taken a different approach: one half of the general tax that funds government programs was repealed, then replaced with an economy wide levy on emissions of CO_2.

In short, there are many approaches that can be adopted, but generic measures to provide financial or other incentives at the plant level seem to work the best. However, there are opportunities for improving machines and other devices that many different factories and industries use—motors, for example, and lights.

STEAM HEAT

Industrial Boilers and Motors

Industrial boilers burn coal, oil and other fossil fuels or very often gases that are byproducts of the production process, to generate hot water or steam used in a variety of ways. Chemical plants, for example, use the heat to change one substance into another. Paper mills will use it to "pulp" wood, which creates the raw material for paper. Because boilers are common to so many industrial processes, boosting their efficiency will sharply reduce emissions.

Similarly, electric motors are widely used in industrial applications, so increasing their efficiency will also reduce pollution. Motors that have been used most commonly in the past have efficiencies ranging from 60 to 90 percent, but versions are now available to reach 95 percent.

Boilers account for about one-third of manufacturing energy use in the U.S., while electric motors, represent another 10 percent.

Better Boilers

One specific way of improving the efficiency of boilers deserves special mention because is can be used so widely, but isn't in the U.S.

Cogeneration of heat and power

In the vast majority of cases, the largest single improvement in efficiency and reduction in air pollution that can be made at an industrial facility is through the adoption of cogeneration—also known as combined heat and power, distributed generation, or recycled energy—which is the simultaneous production of two or more forms of energy from a single fuel source. Most often, fuel is burned to generate electricity and the leftover heat, which otherwise would simply be released into the air, is used to make chemicals, process food or the like.

Figure 3 The Joffre Cogeneration facility is the largest cogeneration power plant in Canada. Located east of Red Deer, Alberta, in Western Canada, the power station produces steam, heat and electricity for the NOVA Chemicals petrochemical facility. The surplus electricity of 290 megawatts is sold to the grid. (Source: NOVA.)

Cogeneration facilities can extract 80 to 85 percent of the energy in fuel, significantly reducing the air pollution compared to facilities where electricity and heat are produced separately. The engine used to generate electricity can vary from large diesels to giant turbines, but the approach is the same: make the electricity and use the heat that would otherwise be wasted. The heat can also be used to provide air conditioning, using absorption chillers in which heat is used to run a compressor instead of electricity, in which case it is called trigeneration.

Whatever the name, cogeneration is used widely in Europe, but is the exception not the rule in the United States. Most of the nation's CHP stations are small facilities, operated on college campuses, military bases or offices, hospitals and other commercial facilities.

Increasing boiler efficiency

Increasing boiler efficiency, thus reducing air pollution, can be accomplished in a variety of ways:

- Proper maintenance, which can include a wide range of options, such as blowing soot from surfaces, tuneups, and reducing excess air.

- Reducing the need for steam and, thus use of the boiler, by eliminating leaks, insulating pipes, recovering heat. These can boost system efficiency by 5 to 40 percent, and costs are usually recovered in one to two years.

- Improving the operating system by, for example, installing devices that allow loads to be automatically controlled, which also saves money by reducing fuel consumption.

- Switching from coal or oil to natural gas, which reduces operating costs and extends the plant's lifetime by eliminating corrosion and other damage from pollution-rich fuels.

Figure 4 OK, keeping soot out of boiler tubes isn't the most scintillating of subjects, but it is one of the keys to heightened efficiency, which, in turn, lowers both operating costs and air pollution. (Source: Conformaclad.)

Electric Motor Systems

Motors produce air pollution indirectly using electricity, so the emission reductions that result from improving efficiency will depend on the type of fuel used by the generator. The amount of electricity consumed by these motors can be huge. In California, for example, one-third of the electricity is used to move water.

Standard motors operate with an efficiency of 60 to 70 percent for small devices of a few kilowatts, to 92 percent for large motors of 100 or more kilowatts. High-efficiency motors operate in the range of 83 to more than 95 percent.

Some of the opportunities lie in improving the efficiency with which the output of a motor is used, not in the motor itself. One analysis of an industrial pumping system, for example, found that only 49 percent of the energy output of the electric motor was actually converted into work to move the liquid. Optimizing system design rather than simply choosing components can lead to improvements of 60 percent using existing technology. One study found that replacing traditional power-transmission "V" belts with modern flat belts could improve efficiency from 85 to 98 percent. Adjustable-speed electronic drives that better match mechanical load reduce electricity demand.[1]

Figure 5 Engine manufacturer Cummins replaced 296 motors ranging from 1 to 125 hp with premium-efficiency versions at its Midrange Engine Plant in Walesboro, Indiana. Although the new motors were only a few percent more efficient than the standard motors they replaced, they reduced power costs by $80,000 per year.

An energy-efficient motor costs more to buy, with a price typically 15 to 30 percent above that of a standard motor. But over a typical 10-year operating life, a motor can easily consume electricity valued at over 57 times its initial purchase price. So, for example, with the purchase of a $1,600 less-efficient motor, a buyer may be committing much larger electricity bills. In the case of the $1,600 motor, paying a bit more up front—say, $400—will reduce electricity consumption by 3 percent, saving $2,760. Purchasing new or replacement energy-efficient motors makes good economic sense.[2]

Indeed, that is generally the case. Of the many activities that produce pollution, some of those most accessible to controls are in the industrial sector. Because technologies for extracting, refining and processing raw materials and for building a variety of finished goods are extremely energy intensive, the opportunities for reducing carbon dioxide, black carbon, ozone and its precursors, as well as other toxins, is extraordinarily large. Curbing emissions by increasing efficiency invariably translates to cost savings. Moreover, unlike motor vehicles whose pollution is regulated largely by rules from Washington, (or in the case of California, Sacramento) powerplants and industries are susceptible to local and state guidance.

Now for a closer look at three specific industrial sectors that are the largest consumers of energy and sources of air pollution: cement kilns, steel making and oil refineries.

CEMENT KILNS

Manufactured commercially in at least 120 countries and almost every state in the U.S., cement is mixed with sand and gravel to make concrete, which is then used to build offices, stores, roads and, in countries where wood is in short supply, homes. There may be industries that produce more pollution per pound of product, as well as a greater variety, but there can't be many. Cement production consumes vast amounts of energy and raw materials, so what comes out of the smokestack is not pretty.

The pollutant emitted in largest quantity is carbon dioxide. Cement accounts for roughly 22 percent of the carbon dioxide emitted by the world's industries.[3] This is for two reasons:

First, the raw material for cement is limestone, or calcium carbonate—seashells deposited millions of years ago. One of the first steps in cement production is to "decarbonize" it, or drive off the carbon dioxide that it contains by burning. Older kilns do this in a huge rotating kiln in which the mass of materials is so wet that the process takes roughly 30 minutes and large amounts of energy.

Second, producing the heat for baking burns huge quantities of fuel, usually whatever is the cheapest, which means it's usually the dirtiest as well. The owners will burn whatever they get their hands on, everything from coal and used tires to hazardous wastes and city trash. As a result, for every ton of Portland cement produced, roughly one ton of carbon dioxide is emitted, as well as other pollutants such as black carbon, dioxins, mercury and the like.[4]

Because so much of carbon dioxide comes from "decarbonizing" the essential ingredient of cement, it might seem likely that cutting emissions would be tough. Not so.

Emissions can also be sharply reduced by substituting other materials for limestone to produce so-called "blended" cements. Substitute materials include blast furnace slag from steel mills and fly ash from coal-fired power plants. Blended cement sets a bit more slowly, but produces a stronger and longer-lasting concrete. In some nations (e.g., The Netherlands), all concrete is made from blended cement.

Figure 6 Lafarge's MaxCem® substitutes ground granulated blast furnace slag (GGBFS) for some of the Portland cement, which can cut air pollution from kilns by half. It is "suitable for use in virtually all concrete and concrete product applications," according to the company, providing "enhanced strength, workability, and placeability characteristics." (Source: Lafarge Corp.)

Individual states determine how much pollution is emitted from cement kilns because they are the principal customers. The state highway department sets specifications for concrete used to build highways, and their counterparts who build schools, courthouses and the like do the same for them, and those who write the building codes determine what architects and contractors do. Requiring blended cement might not be as simple as snapping fingers, but it is certainly no herculean task.

Other pollution can be cut by switching from a wet kiln to the more efficient, and hence cleaner, dry process. Then there's the question of fuel: kiln operators are willing to use any fuel that will sustain a flame, but that needn't be the case. The kilns could just as easily burn natural gas instead of coal, used tires or hazardous waste. For that matter, burning isn't required at all, just heat. That can be provided by the sun's energy or electricity (see the discussion of solar concentrating systems).

STEEL MAKING

The iron and steel industry is the largest energy-consuming manufacturing industry in the world, accounting for 10 to 15 percent of the annual industrial energy consumption. Annual world steel production has increased from about 100 million tons in 1945 to about 770 million tons in 1990, and is expected to grow further, by about 1.7 percent a year, mainly because of an increase in steel consumption in developing countries.

Figure 7 This POSCO integrated steel mill in South Korea is the world's cleanest and most efficient, employing continuous casting and a process that dispenses with "coking," which produces prodigious amounts of cancer-causing pollution. (Source: Nwsworld.)

Air pollution, sometimes in prodigious amounts, is produced at several stages in making steel:

- **Coking:** Coke is a solid carbon fuel used to melt and reduce iron ore. It is made by sealing pulverized, bituminous coal in an oven that is heated to very high temperatures for 14 to 36 hours. One option for reducing pollution—coke oven emissions are highly toxic—is to assure that the oven doors are tightly closed. But an even better option is to make steel without coke, using a process now employed in South Africa and South Korea.

- **Casting:** Historically molten steel has been poured into immense loaf pans and allowed to cool into enormous rectangular ingots. Then, the ingots are reheated and the steel is rolled. Continuous casting in which the steel is rolled immediately, thus avoiding the energy and pollution from reheating, is employed widely in other countries, especially Japan.

- **Cogeneration:** Many of the gases produced during the production of steel can themselves be burned to generate electricity. Doing so increases efficiency and eliminates air pollution.

- **Recycling:** The cleanest and least expensive steel is the ton that doesn't have to be made. Although steel is North America's number one recycled material, 50 percent of it still ends up somewhere other than at furnaces designed to smelt steel scrap.

Oil Refineries

Refining is most energy intensive industry in the United States and the source of immense amounts of air pollution. Refineries evolved from relatively simple distillation-based plants to highly complex and integrated distillation and conversion processes in which chemicals are added and removed at different times of the year and to meet the challenges posed by changing feedstocks and product needs. That said, refinery pollution and energy consumption can both be reduced through a variety of measures.

- **Process integration:** So many streams of different fluids are constantly passing through a refinery, undergoing conversions that are so complex and numerous that they inevitably reach a point where there is a "pinch" in the system that slows things down and cuts efficiency. To avoid these, analysts have developed a methodology to optimize the system called, not surprisingly "pinch analysis." In recent years, it has been extended to virtually every aspect of refinery operation, in part because it has greater potential for increasing efficiency than any of the more traditional measures, such as cogeneration.

- **Energy recovery:** At various points in the refining process fluids are lost that could be captured and used either in the refining process itself or to generate electricity. Some of these are burned, or flared, as they are vented to the air. Capturing these and using them, either by re-injecting them into the stream of refinery fluids or burning them for electricity generation, increases efficiency and reduces air pollution.

Figure 8 Throughout the world at oil and gas fields and refineries, gas is "flared," or burned. This wastes a precious resource and creates air pollution. It could be captured and stored, or converted to methanol, a liquid fuel that can easily be transported, even from remote regions such as this one in Nigeria. (Source: claimatelaw.)

- **Heat recovery:** In a modern refinery most processes operate at high temperatures and pressures alike. The crude oil that enters the process is loaded with contaminants that can and do foul pipes, furnaces and other components, reducing the efficiency with heat. By one estimate the economic value of these losses is roughly $2 billion a year.

Special Attention

Two other industrial sectors merit attention because of the size of the threats they pose and the ease with which these could be eliminated. One is applicable across a wide variety of industries and, in a sense, is a threat that was created inadvertently in an attempt to protect the stratospheric ozone layer, which blocks solar radiation. The other is the use by electric utilities and equipment manufacturers of what is almost certainly the most powerful of all greenhouse gases, a chemical called SF6, which has an atmospheric lifetime of 50,000 years.

Putting Out Fires

To reduce destruction of the stratospheric ozone layer by chlorofluorocarbons (CFCs) and halons, substitutes were developed and have been adopted that, while ozone "friendly," are powerful causes of global warming. Many of these greenhouse gases—hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs)—are used in devices to extinguish or suppress fires and explosions, and are included in the Kyoto Protocol's "bag of six" pollutants.

Just as HFCs and PFCs can replace CFCs, so too can other chemicals—which are both ozone and global warming "friendly"—be substituted. In addition, most emissions from fire-extinguishing result from leaks and "total flooding" discharges, whether accidental or to extinguish fires. Emissions can also be reduced by using different technologies and practices.

Potential options include—

Inert Gas Systems

Inert gas systems extinguish fires using argon, nitrogen, or a blend of the two, sometimes incorporating CO_2 as a third component. Inert gas systems provide both fire protection and life safety/health protection equivalent to HFCs in most ordinary fires hazards, including those in electronics and telecommunications applications.

Although inert gas systems are effective at extinguishing fires, they discharge more slowly than HFC systems (60 seconds or more compared with 10 to 15 seconds), so in areas where a rapidly developing fire is likely, inert gas systems are not recommended. Still, even in these cases, new devices that recognize and extinguish fires before they have a chance to spread can be used.

Water Mist Systems

Unlike traditional water-spray systems or conventional sprinklers, water "mist" employs extremely fine droplet sprays from specially designed nozzles to produce much smaller droplets under low, medium, or high pressure to extinguish fires, using much less water. In some applications, such as aboard ships, they can be brought into action faster than HFC systems because there is less concern about applying water mist in situations where openings to the space are not all closed—which in turn leads to reduced fire damage. In addition, unlike HFC systems, which are usually limited to a single discharge of agent, most water mist systems have an unlimited water supply in land-based operations, and at least 30 minutes of potable water discharge followed by an unlimited amount of seawater for marine applications.

Water mist systems are currently used aboard ships, in storage and machinery spaces, and combustion turbine enclosures as well as flammable and combustible liquid machinery applications.

Fluorinated Ketone (FK-5-1-12)

The name is a mouthful, but 1,1,1,2,2,4,5,5,5-nonafluoro-4-(trifluoromethyl)-3-pentanone—let's just called it FK-5-1-12—has an atmospheric lifetime of about two weeks and a 100-year

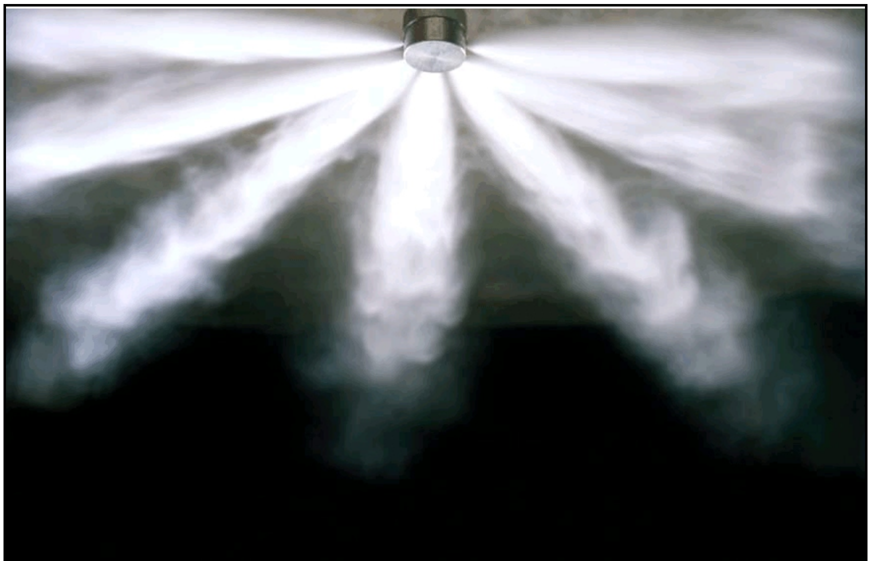

Figure 9 Fluorinated Ketone, has an atmospheric lifetime of about two weeks and a 100-year global warming potential of about 1, making it no more powerful than carbon dioxide. But it puts out fires just fine, and can substitute for the substances now used, which powerful greenhouse gases. (Source: Siemens.)

global warming potential of about 1, making it no more powerful than carbon dioxide. It has been EPA-approved since 2003.

There are other alternatives to fire suppression chemicals or systems, including—

- recovery and reuse of HFCs;
- improved detection systems;
- fine aerosols; and,
- inert gas generators.

THE MOST POWERFUL GREENHOUSE GAS OF ALL

Many pollutants that cause global warming last a long, long time. Carbon dioxide, for example, lasts 50 to 3,000 years, and after 1,000, roughly one third is still in the system. None, however, rivals the 50,000 year life of sulfur hexafloride, or SF6.

Figure 10 Japan AE Power Systems Corp. Sells vacuum circuit breakers that do not use SF6, which has an atmospheric lifetime of 50,000 years and is 23,900 times more powerful molecule-for-molecule than carbon dioxide as a cause of global warming. (Source: Japan AE Power .)

SF6 is colorless, odorless, non-toxic and, most importantly, non-flammable. Because SF6 is a dielectric, or an electrical insulator, it is used in high-voltage circuit breakers, switchgear, and other electrical equipment, sometimes replacing polychlorinated biphenyls (PCBs), which were partially banned in the 1970s by federal law.

The global warming potential of SF6 is 22,200 times that of carbon dioxide. Older equipment, such as a single circuit breaker, can contain up to 2,000 pounds of SF6—the rough equivalent of 44 million pounds of carbon dioxide—while modern breakers usually contain less than 100 pounds. Thus, one option for reducing emissions is simply to replace older devices.

Globally, the electric power industry uses roughly 80 percent of all SF6. In theory, none of it should be emitted into the atmosphere, because the uses are—or should be—totally enclosed. In reality, however, there are significant leaks from aging equipment that utilities fail to replace, and from releases during equipment maintenance and servicing.

In the words of the U.S. Environmental Protection Agency—

The electric power industry has an enormous opportunity to help reduce the nation's SF6 emissions through cost-effective operational improvements and equipment upgrades.

The options for reducing emissions are quite straight forward:

Leak Detection and Repair: if consistently and aggressively implemented in the U.S., SF6 emissions could be reduced by 20 percent;

Use of Recycling Equipment: recycling could eliminate 10 percent of total related emissions from the U.S. electric industry; and,

Employee Education/Training: by how much SF6 emissions could be reduced through training and an aggressive corporate policy of minimizing releases is unclear, but without question, it is substantial.

CONCLUSION

As in every other sector of the economy, ranging from herds of dairy cattle to fleets of cars, there is no lack of solutions in the industrial sector. They abound. But, just as in every other sector, those charged with making decisions are motivated only by making profit, as much as possible and as quickly as possible. They will not save us, so we must save ourselves.

1. Motors drive equipment such as pumps, fans, air compressors, cutters, presses, grinders, material handling systems, and other process equipment. A motor system typically consists of an electric motor, a belt or transmission device and the driven equipment. For example, a compressed air system typically includes an electric motor belt driven reciprocating or screw compressor, a storage tank, and a distribution system.

2. Bonneville Power Administration, “Energy-Efficient Electric Motor Selection Handbook,” Jan., 1993, http://64.233.169.104/search?q=cache:G9_h3UHaczwJ:www.wbdg.org/ccb/DOE/TECH/ce0384.pdf+high+efficiency+electric+motor&hl=en&ct=clnk&cd=10&gl=us

3. Price, L. & Worrell, “Global Energy Use, CO2 Emissions and the Potential for Reduction in the Cement Industry,” Cement Energy Efficiency Workshop, Organised by IEA in cooperation with WBCSD, Paris, France, Sep. 4-5, 2006, http://64.233.169.104/search?q=cache:lVdo62kbUEoJ:www.iea.org/textbase/work/2006/cement/Price_Worrell.pdf+use+of+blended+cement+globally&hl=en&ct=clnk&cd=5&gl=us

4. U.S. Energy Information Administration, “Energy Market and Economic Impacts of S.280, the Climate Stewardship and Innovation Act of 2007,” http://www.eia.doe.gov/oiaf/servicerpt/csia/special_topics.html.