Richard Munson

Recycling Energy: How Industry Is Leading a Clean-Technology Revolution

I. The Opportunities Ahead

With the Chicago skyline visible across the southern tip of Lake Michigan, Mittal Steel occupies several thousand acres of treeless grime, blazing furnaces, and mounds of black coal. It's not where you'd expect signs of an environmental revolution, yet this industrial behemoth is converting its waste heat into power and demonstrating how energy recycling can tackle the nation's power and greenhouse-gas problems.

U.S. industries increasingly realize the value in the enormous amounts of waste energy produced by their own factories. Ironically, it is manufacturers, long blasted for their pollution, who are leading the charge for clean energy. Their key motivation may be saving money rather than saving the earth, but the result is the same.

The growing drive for efficient technologies results from rising electricity prices, which are likely to double in the next five to 10 years. Recent double-digit increases have shocked Maryland, Illinois, and other states that had postponed imposing higher natural gas costs. Fuel prices, in fact, are three to five times their 1999 levels, and further electric price escalations are likely since long-term utility fuel contracts are below spot-market prices.

More ominous are the costs of building new power plants, which are needed to replace many of today's units that are well over 50 years old. The expense of building a centralized coal-fired power plant has soared from $800 per kilowatt in the late 1990s to as much as $2,500 per kW, largely because of new pollution control requirements, and additional mandates are in the wings. The Environmental Protection Agency's Clean Air Interstate Regulations (CAIR), for instance, are forcing coal plants to significantly reduce their sulfur and nitrogen-oxide emissions by 2009, and the Clean Air Mercury Regulations require substantial emissions reductions from both existing and new coal-fired power plants. Electricity company filings indicate these added pollution controls will cost $550 to $850 per kW of capacity, which often exceeds the plant's original cost.

Not included in this calculus are the costs associated with reducing greenhouse gases to mitigate global climate change. Carbon-restricting legislation is likely, and a moderate $20/ton charge would add 2 cents per kWh to delivered power costs. No doubt the United States and other countries, largely because they adopted scrubbers and other pollution-control technologies, have achieved significant reductions in sulfur dioxide and nitrogen oxides from power plants.

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Carbon dioxide, however, is different. It simply cannot be scrubbed or cleaned. This greenhouse gas, in fact, is a fundamental result of burning carbon-containing fossil fuels, including coal, natural gas, oil, and propane. Some 40 percent of U.S. CO_2 emissions come from electricity generation. Reducing electric use by using more efficient lights and appliances will reduce CO_2 emissions, but the only way power plants can reduce CO_2 emissions is to burn less fossil fuel per kWh.

Also on the horizon are additional costs for new transmission wires and transformers, since today's systems are strained. New power lines, even if they can overcome public opposition, will cost far more than the wires strung only a decade ago.

Higher electricity costs, of course, present both challenges and opportunities. Within the price-conscious industrial sector, fuel and power price increases have accelerated a drive toward energy alternatives, particularly those that manufacturers can control. Industrialists increasingly realize that their manufacturing processes emit substantial quantities of energy that can be profitably recycled.

Some manufacturers long have obtained both electricity and heat from their processes. The pulp and paper industry, for instance, burns its wood wastes to produce both electricity and useful steam. Dow Chemical has upgraded its combined heat and power (CHP) systems to save, compared with a 1994 baseline, 250 trillion BTUs of energy, equal to the annual household energy consumption of New York or Tokyo. As part of its effort to cut fuel usage and CO_2 emissions, Dow declares that cogeneration is ''significantly more efficient than purchasing power from an outside utility power plant and then separately generating steam.'' Smart industries use one fire to do two jobs. But what of industrial waste energy?

Researchers found that recycled energy already provides almost 10,000 MW of power, equal to the output of 10 large nuclear reactors.

The Lawrence Berkeley National Laboratory, in a report for the U.S. Environmental Protection Agency, examined 19 clean-energy technologies, ranging from small distributed power systems on farms to large integrated gasifiers at petroleum refineries. The researchers found that recycled energy already provides almost 10,000 MW of power, equal to the output of 10 large nuclear reactors, and they identified sufficient waste energy for another 96,000 MW, enough to provide almost 20 percent of U.S. electricity needs. This recycling of industrial waste energy would cut CO_2 emissions by nearly 400 million metric tons, more than 17 percent of the nation's current output.

The report's highlighted clean-energy technologies go by un-sexy names, such as ''back-pressure power recovery'' or ''black liquor gasification,'' but these opportunities offer energy price and climate advantages. Consider back-pressure power recovery. Many industries generate steam at high pressures in order to pack steam into distribution pipes. The pressure is then reduced at point of use in order to run their dryers and other processes. Several firms produce and market small back-pressure steam turbines that recycle the usually wasted power embodied in that pressure drop, turning pressure drop into electricity. A similar opportunity exists within natural gas pipelines, where gas pressures must be lowered at community substations, and where expansion turbines can harness the energy released as gas expands to low pressures.

Black liquor refers to the product from de-lignifying wood chips, and it usually is burned to recover the chemicals used in the de-lignification process. Facing higher costs for fuel, however, several pulp and paper firms are beginning to gasify the spent liquor and their other waste products, such as bark, in order to fuel gas turbines that efficiently generate both electricity and steam for the paper mill. Some black-liquor gasifiers recycle enough waste energy to produce a surplus of energy from the pulp

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process, allowing the mill to sell excess power.

Other clean-energy examples are the modern steam turbine plants that help chemical manufacturers and petroleum refiners recycle their exhaust or flue gas. This re-powering process allows a gas turbine to deliver up to 20 percent of the furnace heat. Producers of ethylene and ammonia also can use ''high-temperature CHP'' that converts all the fuel into power and waste heat for use in the boiler. The results are reduced power-generation costs, less sensitivity to fuel price fluctuations, and the potential to generate 44,000 MW of electricity and cut 214 million metric tons of CO_2 emissions.

Recycled energy projects can be big (several hundred megawatts, with a single megawatt supplying about 500 homes) or small (40 kilowatts). Capital costs also vary, ranging from $300 per kW for backpressure steam turbines to more than $1,800 for certain steam-turbine plants. Even the highest construction costs are still below the costs per kW of capacity from a new coal-fired unit, and the distributed generator requires no transmission wires, and, if utilizing free waste energy, no additional fuel.

In addition to recycling industrial waste heat, more clean-energy opportunities exist to capture the vented heat from most electricity generators. This thermal energy can displace the fuel burned in separate boilers and supply water heating, space heating, and absorption cooling. These cogeneration, or combined-heat-and-power, units also can provide the steam needed for several industrial processes.

Capturing such heat from electricity generation requires a shift away from centralization. Since low-temperature heat cannot be transported economically over long distances, heat recycling requires smaller, on-site electric generation plants. These local units may be smaller than central plants, but are not toys. They use the same technologies, only smaller steam boilers, steam turbines, gas turbines. The shift to local generation, however, offers enormous fuel savings. Recycling half of the heat currently thrown away by fossil-fueled central generators would save more than 15 percent of the nation's fossil-fuel consumption and greenhouse-gas emissions substantially.

Even nuclear reactors can recycle their waste heat, as seen with nuclear-power submarines and aircraft carriers.

Other benefits abound. By providing electricity close to the users, recycled energy plants reduce transmission-line losses as well as the need for additional wires. These facilities improve industrial competitiveness by reducing industrial energy costs and creating the potential to sell excess power and obtain new revenue streams. By reducing pollution, recycled energy saves public-sector costs associated with health care and environmental protection. Such dispersed generation, moreover, increases power reliability and helps to stabilize the grid.

Such a shift to decentralization is possible, as demonstrated by Denmark, which over the past two decades raised cogeneration's share of total electricity production to more than 50 percent. Netherlands, Finland, and Russia also have substantial cogeneration, while several other developed countries – including Germany, Poland, Japan, and China – have CHP rates more than twice those in the U.S. Denmark's transition required no new technologies, but simply used smaller applications of the technologies used in central generation, and then captured and utilized the wasted energy. Even nuclear reactors can recycle their waste heat, as evidenced by the fact that all nuclear-power submarines and aircraft carriers use wasted reactor heat to warm and cool the ships.

The concentration of cogeneration has much more to do with policy than any mix of energy resources and users. Regulators in California and Hawaii, for example, have worked to open the market to entrepreneurs, and each produce more than 20 percent of their power from cogeneration plants. South Carolina, in contrast, has no CHP units because it

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maintains many old laws, including one that makes it illegal for an entrepreneur to sell power, even to a manufacturer on whose property the generator sits.

II. The Limits of Power-Plant Centralization

The U.S. power system is less than optimal. The status quo, in fact, is not sufficient for the 21st Century digitalized economy that demands efficiency and reliability. The average generating plant – built in 1964, using technology from the 1950s – suffers an efficiency rate of only 33 percent, meaning that for every three ''lumps'' of fuel, it provides only one ''lump'' of electricity. This inefficiency largely results from power plants being centralized, located far from consumers, and unable to utilize wasted heat.

Inefficiency also causes pollution, and electricity generators are this nation's largest polluters, spewing tons of mercury, sulfur dioxide, CO_2, and other contaminants into America's air and waters. Despite significant government and industry effort, 46 of the top 50 emitters are power plants, and electric generators total 38 percent of U.S. CO_2 emissions.

The consequences of the system's inefficiencies are staggering, if little noticed. Unreliable supplies – ranging from millisecond fluctuations that destroy electronic equipment to the summer 2003 blackout that left 50 million people without power – annually cost Americans approximately $150 billion, essentially adding a 45 percent surcharge to the cost of U.S. electricity.

Dependent on a far-flung electricity-delivery system, the average U.S. customer also loses power 214 minutes per year. According to a recent report by Carnegie Mellon University, that number compares to 70 minutes annually in the United Kingdom, 53 in France, 29 in the Netherlands, 6 in Japan, and only 2 minutes per year in Singapore. Disturbingly, the frequency of outages in the U.S. is no less today than it was a quarter century ago. Computer-dependent businesses consider these numbers when they pick locations for their operations and factories, and the U.S. is at a distinct disadvantage.

Energy recycling also demonstrates that the economics of centralization have changed.

The myopia associated with today's status quo – centralized, electricity-only generation – is stark. It's not unusual for a power plant on one side of the street to vent enormous amounts of heat, while a factory on the other side burns additional fuel to generate the same amount of heat in order to dry plastics, bake coal, or conduct an array of other industrial operations.

The process of electricity generation is straightforward. Most power plants boil water and capture some of the steam energy to spin a generator. Like the teapot on your stove, the typical power unit simply lets the excess heat and steam vent into the air. Recycling this energy and steam can double a generator's efficiency, displacing the extra fuel that would have been burned to provide heat to warm homes or run industrial processes. Such recycling – also known as cogeneration or combined heat and power – lowers costs and cuts pollution and greenhouse-gas emissions.

Energy recycling also demonstrates that the economics of centralization have changed. No doubt it remains cheaper on a per-kilowatt basis to build one large centralized plant rather than many smaller dispersed power plants. Yet initial capital costs of generation are only part of the equation. Since transmission lines are in short supply, new centralized power will require new high-voltage wires, which cost some $1,380 per kW of capacity (ironically, more than power generator itself). New on-site generation, in contrast, avoids most transmission and distribution costs by delivering power directly to local customers. Dispersed projects also avoid most of the line losses – which average 9 percent but can reach 20 percent during peak periods when lines are loaded – associated with high-voltage lines.

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Today's transmission and distribution system, in fact, loses substantial electricity, averaging 9 percent but reaching 20 percent during peak periods when wires are loaded. Most of the problem results from remote generation having to transform its electricity to high voltages (requiring capital and losses) in order to allow the use of smaller copper wires for the tall transmission lines that cross the landscape. When the high voltage reaches a city or other large load center, it is transformed back down to medium voltages (requiring more capital and losses). Then distribution wires carry the power up every street and feed smaller transformers, often mounted on the electricity line poles, which transform the power to user voltages to power hair dryers and other appliances.

By contrast, local generation can feed power directly to the industrial user, freeing the system described above, and it can feed excess power into the distribution system, avoiding several transformer steps, as well as avoiding capital and losses. Excess locally generated power, in fact, can be transformed backwards in existing transformers and fed into the larger grid. Since all power flows to the nearest user, regardless of contract, local power generation cuts losses.

The economics of centralized generation also suffers from the requirement for redundant power. All generators, regardless of size or type, will be shut down for maintenance and equipment failures, but when a huge central station shuts down, a great deal of capacity is lost, so there must be backup stations ready to generate. The current industry standard calls for reserve capacity of 18 percent. Yet a system of on-site units, according to a recent study by Carnegie Mellon University, can obtain the same system reliability with only 3 to 5 percent redundancy. Consider that with 1,000 MW central stations, the grid needs 1,000 MW of spare capacity. In contrast, with 100 10 MW local generators providing the same total capacity of 1,000 MW, it is highly unlikely that more than 50 MW will fail at the same time. Put another way, more distributed generation means less costs associated with spare capacity. In fact, after factoring in line losses and redundancy needs, satisfying a kilowatt of new peak load requires 1.44 kW of centralized capacity to generate power or 1.07 kW of on-site generation.

Policymakers long have ignored industrial waste as an energy source. It's been a bipartisan habit.

Thus, central generation requires 228 percent more capital investment than distributed energy. Put into dollar terms, central generation would cost $46 billion to serve the projected increased demand for power by 2020, compared with only $20 billion to serve load growth with localized units. Economies of scale no longer apply to electricity production and delivery.

III. Policy Lags Technology

Policymakers long have ignored industrial waste as an energy source. It's been a bipartisan habit. Republicans tend to assume the premise that free markets fix all inefficiencies, while Democrats get distracted by the shining promises of wind turbines or solar cells. Even when rival politicians agree about the need to clean up coal-fired power plants, both camps express almost a blind faith in new and unproven technologies – such as sequestering carbon deep within the earth. Few confront the basic issues of how flawed policies create technical and financial inefficiency.

Even most environmentalists ignore industrial efficiency, preferring instead to focus on solar and wind technologies. No doubt these and other renewable energy sources are carbon-neutral and reduce dependence on fossil fuels. Yet since it's obviously bad for the environment to waste two-thirds of every coal mine, the terms of the policy debate need to broaden.

The last energy bill – the Energy Policy Act of 2005 – did little more than subsidize the favorite

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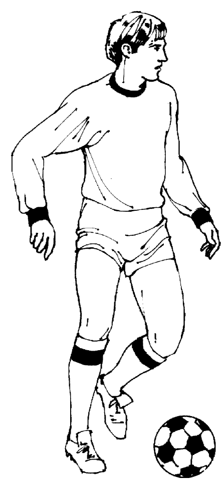
technologies of well-placed legislators and well-connected lobbyists. Billions of taxpayer dollars were showered on trying to restart the nuclear-power industry and to jump-start the use of hydrogen fuel. Today's subsidy favorite – at least among some politicians and environmentalists – is carbon sequestration, a risky and probably very expensive idea for inserting CO_2 into fissures deep within the earth.

Today's focus on the centralized generation results less from greed or incompetence than it does from the failure of policy to adapt to changing conditions. Early in the 20th Century, it made sense to encourage larger and larger power plants because turbines, boilers, and other equipment kept improving and electricity costs kept falling. The brilliant, if eccentric, Nikola Tesla also worked with George Westinghouse to utilize alternating current, allowing electricity to be transmitted over long distances. No longer did power plants need to be close to consumers, who were happy to have dirty and noisy power plants located far from urban centers.

Conditions changed, however, in 1960, although few industry leaders or policymakers noticed that centralized generation had reached its efficiency limit. No longer could new generating equipment be more efficient than the machinery it replaced, nor could the next generation of power plants convert more fuel energy to electricity. Materials seemed to have reached their natural limits. Economies of scale no longer applied to the utility industry.

Although unable to build ever more efficient generators, engineers devised an array of small applications that can be placed close to the demand for power. Most consumers today are unaware that generators operate cleanly and noiselessly in urban cores across the country.



Policy, unfortunately, has not kept pace with technology. Early in the 1900s, it made economic sense to encourage large companies to build and operate larger and larger units. A deal, reasonable at the time, allowed power companies to avoid competition in exchange for submitting to oversight by state regulators, who adopted an array of policies to encourage and protect these monopolies. Only utilities, for instance, were allowed to transmit power across public streets.

Utilities also enjoyed a unique reward system that guaranteed them a financial return on every dollar they invested. Rather than spur low-cost production, this monopoly regulation encouraged capital investment, regardless of efficiency.

Capitalism-touting politicians have long criticized Communist leaders for their multiple-year state planning, yet America's utility regulators adopted their own centralized plans, complete with five-year rate cases. After such rates were approved, utilities obtained more profit by selling more electricity. Sales, rather than efficiency, were paramount.

Efficiency, as a result, stalled in the power business, and it's been essentially stagnant for nearly 50 years. The lack of productivity gains is troubling in any industry, but particularly worrisome in the nation's largest and arguably most important industry, and when the stagnant industry spews out 38 percent of U.S. greenhouse gases.

Recent efforts to encourage efficiency have confronted this deep-seated sales orientation. Even logical efforts to advance efficiency standards face fierce opposition because they challenge the status quo, reduce throughput, and penalize utility profits. Both regulators and industry leaders fail to acknowledge that status-quo regulation is broken and cannot serve the 21st Century and that technological conditions have altered the need for inefficient centralized generators.

In addition to favoring throughput over efficiency, the status quo offers power prices that do not reflect market conditions.

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Utilities, for instance, charge an average price for electricity, even though power's true costs are much higher during peak hours in the early evening when commuters return home and turn on lights and appliances, requiring the most expensive (and least efficient) power plants to fire up and come on line. Consumers, moreover, don't see the true costs of pollution in their power rates, but pay higher taxes and insurance premiums for health and environmental damages caused by inefficient power generation.

When lawmakers accept efficiency as their goal, policies will change substantially. Pollution controls, for instance, would be based on how much power was produced rather than how much fuel was used. Such output-based (rather than input-based) standards would reward the efficient generators and force the wasteful to pay higher costs for their increased pollution.

IV. The Myth of Economic Optimization

Most economists argue that energy recycling should not be possible, that Mittal and other market-focused industrialists already must have done everything possible to increase efficiency and lower costs. The relevant joke is that an economist will refuse to pick up a $20 bill lying on the sidewalk because he ''knows'' the market doesn't allow free money to exist and that an entrepreneur would have picked it up beforehand. Yet Mittal Steel and the Lawrence Berkeley National Laboratory's report demonstrate that the joke is on conventional economists, that opportunities do exist to capture substantial quantities of energy waste.

The myth of current economic optimization leads to perverse policy choices. If lawmakers assume today's heat and power generation is economically optimal, attempts to change – such as to reduce greenhouse-gas emissions – are assumed to disrupt the current equilibrium and, therefore, increase energy costs. Yet if lawmakers believe opportunities – such as recycled energy – are available, then the debate will usefully focus on realizing those benefits.

The United States, unfortunately, forces its citizens to pay to warm the globe, largely because outmoded regulations block efficient energy generation and use. Electric prices, as noted above, do not reflect the true costs of energy, and monopoly regulation rewards sales rather than efficiency. Markets only function when there is free entry and exit, yet it is illegal for anyone other than a utility to string a wire across any street; at the same time, regulators feel obligated to ensure that utilities do not fail.

Faced with rising electricity costs, however, manufacturers increasingly see their wasted energy as a revenue stream, and they have moved to the forefront of clean-power development. Global warming, as Al Gore notes, is a reality we would rather not face, yet the convenient truth we need to recognize is this: Energy recycling profitably mitigates climate change. Recycling already provides substantial power and can generate 20 percent of U.S. electricity without burning any additional fuel or emitting any additional pollutants or greenhouse gases. Cogenerating heat and power also produces electricity with half the fossil fuel of conventional electricity generation.

Policy needs to catch up with technology. Lawmakers and regulators must recognize that today's energy system is not optimal, and that enormous opportunities exist for efficiency gains. They must encourage manufacturers and entrepreneurs to ''mine'' industrial waste energy. They also must remove the perverse incentives that motivate utilities to increase sales and retard efficiency.■

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