Energy Recycling, the Missing Link

Written by Thomas Casten, WADE Chairman

The US faces severe energy related problems including over taxed transmission, high natural gas prices, regional air quality problems, and concerns about greenhouse gas emissions. The economy is increasingly vulnerable to OPEC, extreme weather and terrorists. Power quality, appropriate for the last century’s electric motors, is inadequate for today’s digital economy. An Electric Power Research Institute (EPRI) study, done before the August 14, 2003 blackout, put the cost of power quality problems to the US economy at $119 billion per year\(^1\). US industry is concerned.

Currently Proposed Solutions

EPRI says it will cost $226 billion to shore up the electrical transmission system. Faced with dwindling low cost gas fields in the continental US, the gas industry proposes more drilling in Alaska with long pipes to the US and LNG terminals to handle expensive gas imports. State and Federal environmental agencies, seeking cleaner air, mandate expensive scrubbers for the nation’s aging fleet of central generation plants. President Bush refuses to set limits on greenhouse gas emissions, claiming this will cause economic disruption. These conventional approaches start with the same flawed worldview – that central generation of electricity is optimal. Instead of improving electric generation efficiency, each group urges government to throw money at their problem, raising energy prices and causing further loss of industrial jobs. We need better solutions.

Energy recycling is the missing link – a fresh approach that addresses all energy related problems while saving money, reducing pollution, reducing vulnerability, and providing industrial jobs by creating new revenue streams to basic industries for sale of their waste energy. And government can induce energy recycling with no cost to

taxpayers by simply modernizing regulations and removing current barriers to efficiency.

Energy Recycling Basics

Manufacturers of most products, including electricity, vent significant byproduct energy. Much of this waste can be economically recycled into electricity and useful thermal energy. Recycled energy adds no pollution and displaces the pollution and cost from fossil fuel that would have been burned to produce the same energy. Average US central generation delivers end users one unit of energy for every three units of input fuel; this miserable 33% efficiency has not improved in 43 years. The collective energy thrown away by US central electric generation plants could displace nearly half of the nation’s boiler fuel, but it is uneconomic to transport heat over long distances. Each decision to build new, isolated central generation is a 25-40 year decision to waste energy.

The US electric industry wastes 20 quadrillion Btu’s each year, equal to 20% of the nation’s 100 quads of total energy use. Simply building new electric generation plants near thermal users would allow the plants to economically recycle at least ½ of this waste, cutting the nations total fuel use by 10%. In spite of many barriers, US energy innovators have managed to build about 65,000 megawatts (8% of total generation) of decentralized plants that recycle waste heat. A recent study sought the best way to meet the expected US 43% electric load growth over the next two decades and compared serving the new load with decentralized or with central generation. The conclusion: decentralized generation cut power costs by 40% versus central generation.

Decentralized CHP plants cost more per kilowatt of generating capacity than new central plants, a seeming disadvantage. But this comparison yields the wrong conclusion. Total capital costs for new central generation includes both the generating plant and new T&D investments. Centrally generated power must be transformed to higher voltages, travel through long, leaky wires, and then be transformed back to user voltages. This process ‘eats’ one kilowatt hour in ten. Since only 90% of centrally generated power reaches end users, society must build 1.1 megawatts of central generation and 1.1 megawatts of new T&D for each megawatt of load. An alternative is to simply build 1 megawatt of distributed generation at the load. The study referenced above found that decentralized generation would avoid nearly $400 billion of capital investment over the next 20 years, reducing needed capital investment from $900 billion to $500 billion.

Decentralized generation, by recycling waste energy and avoiding line losses,

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2 Casten, T. & Collins, M., Cogeneration and On-Site Power Production, Optimizing Future heat and Power Generation, Nov-Dec 2002 (3) 6, pp 71-77.
dramatically reduces air pollution versus central plants. Emissions of NO\textsubscript{x}, SO\textsubscript{2} and particulate matter (PM 10) are respectively 58%, 68% and 43% lower in the decentralized generation scenario versus the central generation scenario. Carbon dioxide emissions dropped by 49% with decentralized power. Recycling energy is the missing link.

### Recycling Industrial Waste Energy

A second option is to recycle industrial waste heat, waste fuel, and pressure drop into heat and power. Visit a steel mill, refinery, chemical or glass factory on a cold day and see vast clouds of vapor -- wasted energy. EPA gas flare data identifies roughly 88,000 MWh of wasted energy every hour. Recycling this waste could power 22,000 megawatts of electric generation, the equivalent of 22 nuclear plants. Produce combined heat and power with flare gas to net 66,000 megawatts of heat and power. We estimate 10,000 megawatts could be produced without any new fuel by extracting power from the steam and gas pressure drop found throughout industry and on university and medical campuses. Recycling hot exhaust might yield 10,000 to 50,000 MWh.

**Recycled Energy is Clean Energy**

No incremental fossil fuel is burned and no incremental air pollution is produced when waste energy is recycled into heat and power. Consequently, recycled energy is every bit as environmentally friendly as heat and power from renewable energy sources including solar energy, wind and biomass. Recycled energy should qualify for every renewable energy incentive.

**Recycled Energy Case Studies**

Building recycled energy projects has been incredibly difficult, because utilities typically oppose on-site generation, fearing loss of revenue and potential weakening of the “electric monopoly” logic. But in 1994, NiSource, parent of Northern Public Service Company, or NIPSCO, took a more enlightened view. NIPSCO’s steel customers were in trouble. Legacy costs for retirees’ health and pension, intense foreign competition, and aging production facilities had combined to slash steel industry profits and cash flow. There were, in every steel plant, huge waste energy flows that could be recycled to cut costs, but the steel industry had more urgent demands for capital in core production facilities.

NiSource formed a subsidiary, Primary Energy, and invested $300 million between 1994 and 2003 in six energy projects with capacity to recycle roughly 900 megawatts of heat and power from steel plant waste heat and blast furnace gas. Myriad rules stood in the way, but Primary Energy persevered. Indiana law prohibits any third party from selling electricity to a host, so Primary Energy crafted tolling arrangements under which US Steel, International Steel Group (ISG) and Ispat Inland pay to convert their waste energy to heat and power, which they use. NIPSCO offered electricity buy/sell arrangements at fair prices instead of demanding predatory backup power charges. When steel company credit was insufficient to support financing, NiSource bet on its customers and guaranteed loans. Union steelworkers were hired by the steel companies to operate each project, with Primary Energy providing supervisory engineers.

All three steel companies are much healthier today and currently produce and sell every possible ton of steel. Recycled energy has played an important role in this economic turnaround. The steel companies are collectively saving $70 million per year
and have reduced their emissions and improved their power reliability.

The six recycling projects eliminate 19,000 tons of NOx, 22,000 tons of SO$_2$ and seven million tons of carbon dioxide emissions per year and have won several environmental awards.

Herewith thumbnail sketches of the projects:

Three projects, one at each company, burn blast furnace gas to make high-pressure steam, which drives extraction/condensing steam turbine generators. The projects are capable of 50MW to 160MW of electric generation and supply most of the mills requirements for process and heating steam.

A conventional GE gas turbine feeds US Steel’s cold rolled tin plant. The gas turbine exhaust is recycled to produce high-pressure steam that drives a steam turbine. Then the remaining energy is recycled again to heat 1,600 gallons per minute of softened water used to wash the steel. By recycling waste heat, the plant achieves 2.5 times the efficiency of average central generation and saves money.

Hot exhaust from 368 coke ovens is converted to high-pressure steam by 16 heat recovery steam generators to drive an 95-megawatt electricity generator and provide 300,000 to 600,000 pounds of process steam.

Blast furnace stove exhaust contains significant amounts of energy, but is not hot enough to economically recycled as electricity. Instead, Primary Energy uses the heat to dry coal for injection into North America’s largest blast furnace. This has enabled Ispat Inland to significantly reduce natural gas and coke usage.

There are myriad energy recycling opportunities in the kilowatt size range. Turbosteam of Turner Falls, Massachusetts installed a 50kW backpressure turbine to recycle steam pressure drop at the Suffolk County Jail in Boston, Massachusetts. The jail purchases medium pressure steam from Trigen Boston’s district steam system and historically deflated the steam to low pressure with a valve. Since the 1997 installation of a backpressure turbine generator, the jail has enjoyed free electricity. They purchase no added steam, but send cooler condensate to the sewer.

Are $20 Bills Lying on the Ground?

Economists assert that there are no $20 bills lying on the ground in a free market. Under this theory, it will be impossible to repeat what Primary Energy has done, since recycling energy innovators must have already captured all of the economic opportunities to recycle waste energy. Policy makers who support massive
expenditures to fix energy problems must believe that there are no options that reduce pollution and vulnerability and save money. We think they are wrong.

The electric market is anything but free, and obsolete regulations make it largely illegal and/or uneconomic for would be energy recycling innovators to pick up the “$20 bills.” These barriers are artifacts of the history of the 120-year-old electric industry.

Electricity, arguably the most important invention of all time, became a commercial reality in 1880 in NYC and San Francisco. Word spread rapidly and every community wanted to electrify as quickly as possible. Early technology favored remote generation (hydroelectric plants and yesterday’s coal plants) and there were, in the early days, substantial economies of scale. Assuming technology would always favor remote plants and that there would always be economies of scale in generation, governments all over the world decided to restrict competition and made Faustian bargains with electric entrepreneurs. In exchange for a monopoly in perpetuity, the entrepreneurs agreed to rapidly electrify each community. They were allowed fair returns on capital on the condition that they would pass all efficiency gains to the public in order to prevent excessive profits. This protected status lowered the cost of capital, making electricity more affordable. Everyone was expected to live happily ever after, and for years, real prices per kilowatt-hour declined.

For years, the industry worked hard to lower costs to lure customers away from self-generation, gas lighting, and muscle power; and a worldview grew that central generation is the optimal way to produce and deliver power.

But technology marched on, resulting in ever more reliable, efficient and cost-effective smaller generation plants. Add the advantages of energy recycling; avoidance of line losses, reduced vulnerability and improved power quality, and the conclusion is inescapable -- decentralized generation wins.

Netherlands, Finland, and Denmark each recognized the value of decentralized generation 20 years ago and each country now generates over 40% of their nation’s power on-site with maximum energy recycling. These countries use 50% less fuel per kWh than the US and have consequently maintained robust industrial production. Portugal saw the light and now offers prices for power from decentralized plants that include avoided central plant fuel and capital, avoided T&D capital and line losses, and avoided pollution. India just reversed 50-year-old policies and now offers long-term contracts at over 6 cents per kWh for power made at sugar cane factories from bagasse.

The US, in spite of modest deregulation, remains unintentionally hostile to recycled energy. Fifteen states retain laws that ban the sale of electricity to anyone but the utility, even if the power is generated on the site of a user. All fifty states ban private wires that cross public roads, thus denying energy innovators any leverage in
negotiating the prices their distribution monopoly charges for moving power across the street to the nearest retail customer. Public service commissions regularly approve backup charges that assume 100% failure at system peak of all decentralized generation. No commission currently gives DG any credit for avoided T&D capital, avoided line losses, or avoided pollution. State and federal environmental rules require new generation to be up to 50 times less polluting than existing generation, while allowing old, inefficient central generation to emit at historic pollution levels. Commissions deny rewards to utilities for efficiency gains.

Bottom line: The US suffers from needlessly inefficient and dirty use of energy. Outmoded regulations prevent energy recycling innovators from picking up $40 to $60 billion per year of “$20 bills,” that are lying on the ground. Policy makers have a golden opportunity. By modernizing the regulations and regulatory approach and removing barriers to efficiency, they can unleash a flood of recycled energy that will pay US industry for its waste energy, reduce dependence on fossil fuel use, cut pollution, and cut future electric prices by 40%. Recycled energy is the missing link to sensible energy policy.

Cokenergy at Ispat Inland Steel, East Chicago, Indiana

Note: City of Chicago across Lake Michigan

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