Transforming Electricity

A paradigm shift to avoid new transmission wires, cut fuel and costs in half, reduce vulnerability and mitigate climate change

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Profound changes in the US production of heat and power are underway that will dramatically improve the economy, improve air quality, mitigate climate change, improve balance of payments, reduce system vulnerability and save consumers $170 billion per year. The 80-year paradigm of centrally generating most electric power is yielding to a hybrid system that will locate new electric generation plants near users. Distributed generation plants will avoid new transmission lines and, by combining generation of heat and power, will operate at twice the efficiency of the present system.

The electric power system has seldom made the news. Real electricity prices declined for sixty years, power was available for a growing economy and the public focused on other issues. When OPEC twice raised prices in the 1970's, public concern was largely diverted to automobile efficiency, even though heat and power production consumes 68% of US primary energy. In 1978, the federal government modified laws to allow non-utility power generation, but the public paid little attention, until now. Recent headlines have trumpeted rolling blackouts in California and nationwide electric and gas price spikes. In the past four years, North American electric grids have been broken by ice storms in Quebec and the American Midwest and over-taxed by heat waves in New York, Chicago and California. In 1998, Illinois wholesale electric prices rose 80 times, from a range of 1.5 to 9 cents to over $7.00 per kilowatt-hour. California electric price increases and blackouts created economic and political chaos. Suddenly the public is concerned about the electric power system. Titanic headlines hint at the iceberg beneath.

The era of undisputed central generation is ending, accompanied by dramatic changes.

That iceberg is the growing illogic of primary reliance on centrally generated electricity. The US power system burns too much fuel, invests too much in transmission and distribution, pollutes too much and stifles innovation.

The era of undisputed central generation is ending, accompanied by dramatic changes. Real electric prices have dropped by 32% since 1984. Thanks to gradual easing of regulations and elimination of barriers to efficiency, a wave of pent-up technology – some of it 40 years old – will soon provide multiple benefits.

Power Problems

To understand current power related problems, consider the following:

- *Cooling towers discard prodigious amounts of waste heat at a coal-fired power plant in Lemont, Illinois. Across the street, a CITGO refinery burns 8% of its crude oil feed-stock to produce the heat just thrown away.*
- *In 1999, US industry flared enough tail gas to generate 5% to 8% of annual US electric production, roughly equal to the annual electricity consumption of California.*
- *Steel, glass and chemical plants burn fossil fuel and consume electricity to melt scrap iron, iron ore, sand and produce new chemicals. Recycling this heat would produce five percent of US electric needs without added fuel.*
- *Methane removed from underground coalmines is largely vented, when it could support several thousand megawatts of new electric capacity.*[1]
- *Two refineries in Gothenburg Sweden (Shell and Prem) provide all of the heat for over 200,000 of the 450,000 residents via a district-heating network.*[2] *None of the 150 operating refineries in the US recycles any significant portion of their waste heat.*
- *The Pacific Princess, a casino cruise ship, generates its heating, cooling and electricity with half of the fuel per guest of land-based casinos.*
- *Potomac Electric Company sought to recover heat from a coal fired generating plant for the federal government's Washington DC steam systems. If the plan went ahead, despite saving money and pollution, environmental rules would void the air permit and require the plant to install expensive pollution controls. The project was canceled.*
- *A recent study by the Electric Power Research Institute concluded that power quality cost the US $119 billion last year.*[3] *This is more than a 50% addition to the $229 billion paid for all electricity in 1998.*

Taken in isolation, any one of these items could be interpreted as a minor market failure. Taken in combination, they hint at a larger problem. The authors' combined 30 years of experience has found thousands of similar anecdotes throughout the energy industry. The sheer number of these incidents coupled with their assault on conventional wisdom – "can the power system be that far from optimal?" – suggests something is wrong with the current energy system worldview.

The broad causes of US power problems are 1) inadequate transmission, 2) failure to recycle heat, 3) rules and regulations that enshrine yesterday's approaches and block innovation and 4) the increased power quality needs of a digital economy.

Power Problem #1—Transmission

The US is completely wired, but has used up most of its spare transmission and distribution (T&D) capacity. Since 1990, when federal law allowed wholesale electric competition, both independent power producers and utilities have built new generation plants to supply the growing electric load, but no one has built significant new T&D. The system has become transmission and distribution limited, and the country has experienced increasingly frequent power outages. Power developers build new generation capacity near interstate gas pipelines (for fuel) and near transmission wires with spare capacity (to deliver their power to local markets). The spare transmission capacity of 1990 has nearly all been absorbed. Peak US loads have risen by 17.5% in the decade, but transmission capacity has barely grown. New central plants will become harder to locate without major and expensive T&D expansion.

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There are deep concerns about how, or indeed whether, society will build new transmission and distribution. The public universally takes a "not in my back yard", or NIMBY, approach. People simply detest new transmission lines, and regularly mobilize to stop or delay their construction. Lynn Draper, Chairman and CEO of American Electric Power, one of the nations largest utilities, says that it is easier to obtain a permit to build a new coal fired generating station than to obtain the approvals and right of way to build new transmission lines.[4] Most recent US power problems were caused by lack of adequate T&D, and nobody close to the industry believes enough new transmission can be built. Federally granted eminent domain might speed permitting of T&D right of way, but won't solve the problem. The problem is economics.

Consulting firm Arthur D. Little found that new transmission and distribution cost about $1,260 per kilowatt of new capacity.[5] While today's preferred central plant technology – combined cycle gas turbines – cost only $500 per kilowatt to build, someone must pay another $1,260 to build new T&D to deliver the power. As spare delivery capacity is used up, consumers can expect real electric rates to rise by about 3.5 cents per kWh to cover T&D expansion. New urban power delivery can cost much more – up to $10,000 per kW – if one can obtain rights of way. The US needs a fresh approach.

Beyond the problems with permitting and financing new T&D, there is a tremendous uncertainty in the market. Over the past decade, energy market competition has been introduced in stages. While most states are now heading towards full deregulation, none have yet presented a clear "road-map" with respect to the T&D system. The result has been a market-wide reluctance to make major investments in T&D, since utilities do not know whether they will ever be able to recoup their capital investment.

These seemingly intractable problems are greatly eased by moving to distributed generation – smaller generating plants, located at or near users and connected to the grid. By meeting load growth with new distributed plants, **no new T&D will be needed**.

Furthermore, distributed generation avoids the attendant 7.6% power losses[6]. At central generation plants, power is transformed to high voltage and then moved through miles of transmission wires, transformed down to distribution voltage, moved through distribution systems, then again transformed down to user voltage levels. Power is lost in each transformation. Distributed generation avoids most of the losses. Distributed plants at user sites lessen power demand on the grid and eliminate related T&D losses. If the on-site plant produces excess power, then regardless of the contract of sale, that power will flow backwards through existing distribution wires to the nearest node, and then flow to nearby power users, again in existing wires. The power loss caused by moving on-site power to nearby neighbors is less than one third of the losses moving power from central plants.

Each time a new distributed power plant is commissioned, the load on T&D wires is reduced. The remote

T&D is only needed if a distributed power generator is out of service during peak loads. Given that today's plants have average forced outage rates of 2%, one hundred new distributed generation plants with 10 megawatts each, will supply 1,000 megawatts of load, but only require 20 megawatts of the existing transmission capacity. These new distributed plants will release 980 megawatts of existing T&D capacity.

Power Problem #2 – Failure to Recycle Heat

Early electric plants were poor at producing electricity from fuel but good at using waste heat. Edison extracted only 6% of the fuel's energy as electricity, with 94% left over as heat, but he sold much of the heat. Today, the US electric system converts 33% of the energy in fuel to electricity - more than five times better than 1880 – but recycles little waste heat. How did the electric pioneers recycle the heat? In 1885, the Illinois Northern Hospital for the Insane said, "Since the exhaust steam from the engine has been turned into our heating mains and made to do double duty, namely, light and warm our building at the same time, the actual cost of the light has been reduced to a mere bagatelle."[7]

The early central generation plants were located in city centers and fed waste heat into local steam systems. But there were good economic reasons to build larger plants, which could no longer be located in urban areas. Electricity from a small plant based on 1910 technology was an absolute luxury. Typical prices were over 20 cents per kilowatt-hour, equivalent to $4.00 per kWh today, or sixty times today's average US price per kWh. These high electric prices were caused by the need to recover all of the capital investment from plants operating at only 15% of capacity. Each streetcar company built a generating plant to power trams during the morning and evening commute, but produced little power during the rest of the day. Other generating plants supplied office buildings during the day, but produced little power at night. Street lighting had its own generating plants that produced no power during the day. Rural areas had no electric power. Early power entrepreneurs built thousands of isolated generation plants, each serving one building or one factory. Recycling waste heat saved fuel costs, but isolated generation plants, designed for the peak load, had very low load factors, making electricity a luxury.

Enter Samuel Insull, principal creator of Chicago's Commonwealth Edison. With a goal of affordable power, he interconnected different loads, increasing the daily output from each generating plant. He sold power to the streetcar companies, adding morning and evening load to his plants that supplied office buildings. Insull connected some rural communities to increase his summer sales of power. He bought and interconnected the street lighting generators to gain night loads. With each step, he reduced the price of electricity and increased the demand.

By 1925, Insull's success caused universal embrace of central systems. The economic lesson seemed clear: central generation of electricity was cheaper than distributed generation. **But the real lesson was that grid-connected generation is superior to isolated generation, regardless of size of generation plant**.

As the optimal economic size of electric generation plants grew, plants had to be located further from population. Steam cannot be moved economically more than about five miles, and it became impossible to recycle the heat. Consider the 4000-megawatt generating station near the point where Colorado, Utah, New Mexico and Arizona meet. The station vents enough thermal energy to heat all of the buildings in Manhattan, Philadelphia, Boston and Washington DC, but the nearest town is Farmington, New Mexico, 60 miles away with a population of 37,844. The result? All of this heat – all of this potential value – simply warms the air.

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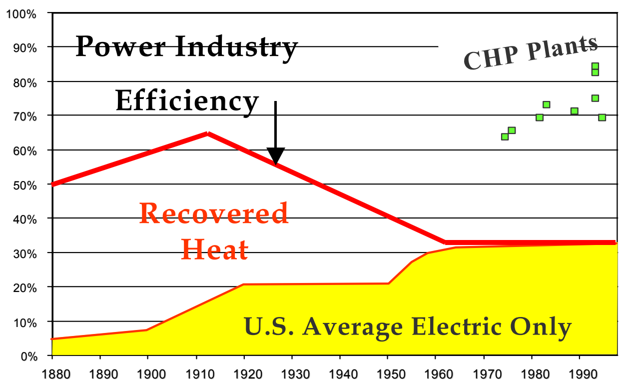
First, overall efficiency dropped, as the remote central plants could no longer recycle heat. Figure 1 shows the ninety-year drop in overall efficiency of the US electric system. The bottom area shows the improvement in generating technology. Early plants only converted 6% of the energy in fuel to power, and the average rose to 33% by 1959, a six-fold gain. The data for the total efficiency is not available, as no national records are kept even today of the amount of recycled heat. The upper line is the authors' estimate of recovered heat from the early isolated plants, connected with an arbitrary straight line to 1959, when combined heat and power had declined to 4% of total US production.

Figure 1. Energy Generation Efficiency Curve



The squares show a sample of the 150 distributed combined heat and power (CHP) plants the authors' companies have installed based on gas, oil, coal and biomass, and employing piston engines, combustion turbines, steam turbines and boilers. The CHP plants all achieve at least twice the average efficiency of the US power system.

The second negative effect of the long reliance on central generation was the enactment of a series of laws and regulations that assumed central power would always be optimal. Over time, technology and fuel availability changed, removing the negatives of small power plants. Coal, oil, natural gas and biomass can all be burned in on-site plants that are clean and approach 80% efficiency – 2.5 times the US average efficiency. Given that these distributed plants do not need new T&D, their total cost is the cost of the plant – about $1000 per kilowatt of capacity. A large new central plant can be built for $500 per kW but will require two to three times that much more money for new T&D, and will burn twice as much fuel.

Power Problem #3 – Impediments to Innovation and Efficiency

Given the fuel efficiency and capital cost advantage of today's distributed power plants, why aren't more of these efficient plants built? Why hasn't someone like Michael Dell (Dell Computer founder), Craig McCaw (cell phone pioneer) or Herb Kelleher (Southwest Airline founder) transformed the industry and built many of these cheaper plants? First, the power market is not free, and second, many obsolete laws, based on the central generation worldview, block innovation.

The Market is Not Free

The local monopoly has unique rights to: 1) move power across the street, 2) approve interconnection designs and installations and 3) sell backup power. Utilities want to keep their customers and have no reason to assist on-site generation. They lobby for "postage stamp rates" to move power, charging each on-site generator the average cost for moving power across the state, when the actual flow is next door. They generally demand expensive facilities to interconnect on-site generation to their wires.[8] The utilities ask regulators to approve backup rates based on the assumption that each distributed plant will fail at the time of system peak, so that the charges pay for 100% spare generation and transmission capacity. State commissions allow such high rates, even though the probability of outage is roughly 2%.

In layman's terms, this would be equivalent to setting the annual premium for house insurance to the full replacement price of the house. The insurance industry has built a profitable industry on the mathematics of probability, but this math is ignored when setting electric backup charges. The typical backup rates represent a 50 to 1 overcharge and discourage on-site power.

Obsolete Laws Block Innovation

Other rules block efficient new plants. At the start of the electric age in 1880-1920, every government wanted to speed electrification. The average legislator was receptive to the local monopoly's suggestions, often buttressed with campaign contributions, that electricity was a natural monopoly and would expand faster with protection from competition. By 1920, private wires had been banned everywhere, and none of these bans have been lifted.

Fifteen states went so far as to ban electric sales from an on-site plant to its host. These states said non-utility generators could only sell to the local utility, who then offered less than one third of the retail value of the power, effectively killing the economics of distributed power. Federal laws blocked non-utility generation until 1978 and blocked wholesale sales of power until put into effect in 1996. The laws still make it illegal for anyone but the monopoly to move the power.

When a power entrepreneur overcomes utility opposition, high backup prices and high interconnection costs, and develops a project so good that it can earn a profit selling at wholesale, there are still more barriers. Ohio, Maryland and other states have empowered boards to determine whether a new power plant is needed. These boards consider themselves responsible for preserving the monopoly and often take two years to render their decisions. They block new plants that would force old plants to close. These boards have successfully blocked several plants proposed by the authors of this article. They have no doubt blocked untold numbers of other entrepreneurs from even entering the industry.

Finally, even well intentioned environmental regulations have played a roll in preventing increased energy efficiency. First, the current regulatory approach places most of the burden for cleaning the air on new plants, giving the old plants a competitive advantage. Second, current EPA rules seldom recognize efficiency as a pollution control strategy. Third, the old plants have been prevented from modernizing to increase efficiency or recycle heat, because this would be considered a major modification under new source review rules, which then force the plant to lower its emissions to those of the best new sources – something the old plants cannot do.

> Old power plants have been prevented from modernizing to increase efficiency or recycle heat.

The state public service commissions, to prevent monopoly profits by their protected utilities, base regulations on a cost of service plus allowable rate of return philosophy. This has the perverse effect of requiring utilities to give their customers 100% of efficiency gains. This rate approach has dampened enthusiasm for efficiency investments.

Power Problem #4 –Power Quality

A digital economy demands superb power quality. Today's power system was built to serve yesterday's needs. The old industry relied on large motors and human control. A short power outage caused by a falling tree branch touching two distribution wires was not terribly disruptive. The lights flickered, motors slowed and power was restored.[9] Several seconds of power outage was tolerable and users could manage minutes of outage with relatively small costs. In fact, the electric industry statistics ignore outages under five minutes and acts of God, such as ice storms and high winds. Utility industry "reliability" data are extremely good, but not relevant to today's digital economy.

Ubiquitous computer chips manage industrial processes, telephone traffic, Internet communications and financial transactions. They can tolerate only eight milliseconds of power outage before losing memory. For householders, a brief flicker of lights has become annoying. Clocks, video recorders and computers demand resetting. The same flicker can shut down a modern industrial plant for hours or even days. Financial sector losses can be catastrophic, and for medical researchers, one flicker can destroy a lifetime of work. Genetech's Boston research center would lose over $100 million if power were interrupted.[10]

Operators of critical applications now demand a power supply with 99.9999% probability of not being interrupted, (Six nines). They demand years of operations between probable power interruptions. The probability analysis predicts that a central system can achieve, at most, five nines of reliability. The practical limit for grid only reliability is 4 nines, or 99.99% reliability – two orders of magnitude below digital power quality needs.

Two technical solutions to power quality issues have emerged. One draws primary power and first backup from two grid feeders, and then adds costly banks of batteries, flywheels, and slow-to-start standby generators to achieve five nines of reliability. The second approach takes primary and secondary power from on-site generation, using the grid for tertiary backup. The second approach profits by selling power to the grid, and can achieve six nines of reliability. Adequate digital power quality can only be achieved through primary reliance upon on-site power, backed up by the grid.

Collateral Issues

The way society produces heat and power production impacts several collateral issues including 1) power prices, 2) system vulnerability, 3) balance of payments, 4) pollution and 5) global warming.

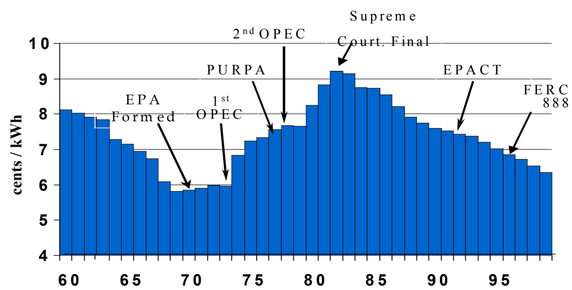
Collateral issue #1 –Power Price

Real electric prices rose 60% between 1969 and 1984. Several factors contributed. Environmental controls lowered efficiency and added capital cost to power plants. Most investor owned utilities embraced nuclear generation, but nearly universal cost overruns increased electric prices. Costs to acquire rights of way for new T&D began increasing. Profligate government spending on Vietnam and domestic social programs drove up inflation and interest rates. Surging oil use emboldened OPEC to quadruple prices in 1974 and then to increase prices again in 1979.

Something had to be done. Sharply rising prices led governments to question the worldview of electricity as a natural monopoly. In 1978, Congress enacted the Public Utility's Regulatory Policy Act or PURPA, which allowed generation competition from "qualified cogenerators" and "small power production" that was based on waste fuels. Fourteen years later, Congress passed the National Energy Policy Act or EPACT allowing more non-utility generation. **Since 1984, real electric prices have declined every year – a 32% reduction.** Figure 2 traces the average real US electric prices in 1996 dollars, and notes the timing of key actions. Including:

- EPA founded in 1970
- OPEC oil price increases in 1974 and 1978
- Passage of Public Utility Regulatory Policy Act in 1978 (PURPA) allowing generation competition
- Supreme Court final decision that PURPA was constitutional in 1984
- National Energy Policy Act (EPACT) allowing electric competition for wholesale customers
- Federal Energy Regulatory Commission Order 888 in 1996 implementing EPACT

Figure 2, Real US Prices of Electricity (1996 dollars)



The new competition encouraged utilities to control spending. After PURPA, most new generation was competitively bid. The industry continued to cling to its central generation worldview, but embraced efficient combined cycle plants. Overturning the worldview and moving to distributed power has the potential to reduce power prices by a further 50% or $110 billion per year, and simultaneously address power quality issues, saving another $60 billion per year.

Collateral issue #2 – System Vulnerability

Since the events of September 11, 2001, the power industry and its regulators have focused on system vulnerabilities.

The nation's T&D systems can absorb a failure of any major component and still deliver required power, but are not built to withstand double failures. Cities are fed through transformers that step down high voltage power from transmission lines to distribution voltage. If a giant transformer were disabled by one armor-piercing bullet, the system would switch to the alternate transformer and continue service. If two transformers are disabled, the city will go black. The transformers take weeks to repair. In freezing weather, buildings could not be heated and water pipes would burst. Furnaces could not operate, since they need power for their controls, blowers and pumps.

Transformers can be "hardened" – surrounded by concrete walls or placed below ground. But each city still depends on transmission lines that stretch through miles of rural and even wilderness areas. It is not feasible to guard every transmission tower. The vulnerability inherent in total reliance on remote, central power generation must be addressed.

One way to reduce this vulnerability is by interconnecting distributed power – allowing it to operate in parallel with the grid. Many high-rise buildings already have standby generators for elevators and emergency exit lighting. Hospitals have standby generators for life-support and other critical loads. But utilities, fearing loss of load, have not allowed standby generation to operate until the load has been disconnected from the grid. The resulting standby systems are hard-wired to specific emergency loads. Utilities have structured their rates to provide disincentives to systems that export power to the grid. As a result, much of the distributed generation that exists today can serve on-site loads but cannot act to enhance the reliability of the larger electricity system.

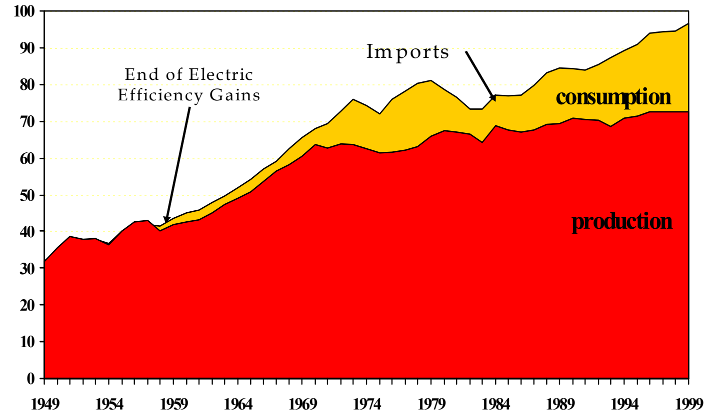
There are 80,000 megawatts of isolated standby generation in the US, representing about 12% of system peak load, but these generators cannot be used to decrease vulnerability without interconnection.[11]

Grid interconnection is key. If distributed power is interconnected, it can supply power during transmission failures. Power generated at distribution voltages inside the city does not flow through the big transformers. This power can be called on by the wires utility, enabling them to ration power and keep buildings warm. The controls on existing standby generators can be cheaply modified to operate in parallel with the grid, enabling central dispatch. Utilities have prevented interconnection to discourage competition. In addition, safety regulations often prohibit use of standby generation except for emergency on the mistaken notion that this will increase reliability.

Collateral issue #3 – Balance of Payments

Figure 3 shows the US consumption of primary energy from 1949 to 1999. Primary energy consumption rose 2.3 times over the fifty years while the economy grew 5.6 times. Thus, the US economy now creates 2.4 times more product with each unit of energy then it did 50 years ago. This "dematerialization" trend is likely to continue. But energy consumption still outgrew domestic production of energy. This growing gap has been filled by imports. In 1999, 28% of all US energy was imported. The US paid $1.7 trillion for energy imports over the 42-year period, worsening the US balance of payments.

Figure 3, US Production and Consumption of Energy (Quadrillion BTU's)

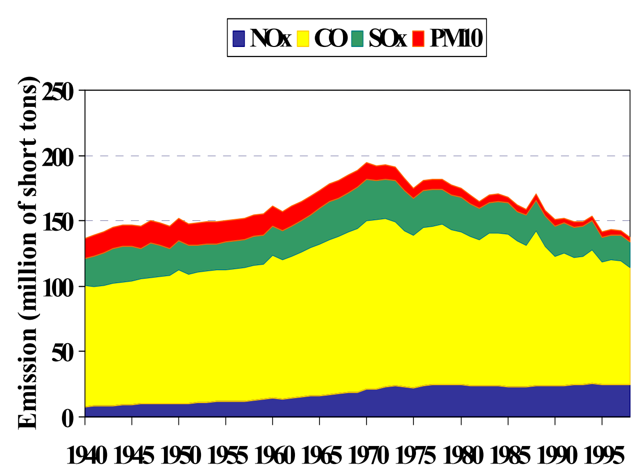


Collateral issue #4 –Pollution

In the 1970's, environmental problems took center stage. Ecological systems could not handle growing emissions. Total tons of US air pollutant emissions (CO, NOx, SO_2 and particulates) had risen 41% since 1940, leading to smog, unacceptable air quality and acid rain. In July of 1970, President Nixon asked Congress to establish the Environmental Protection Agency to administer, among other things, stringent rules for new power plants.

Figure 4 shows the total emissions of four criteria pollutants since 1940 and traces the return of total emissions back to 1940 levels. The economy grew 8.5 times over the same sixty years, so the US is now producing only one-sixth as much pollution per dollar of gross domestic product as it did in 1940,[12]

Figure 4, Million Tons US Pollutants



This progress was welcome, but could have been faster and cheaper. The original environmental control methodology, limited by available technology to monitor emissions, has two problems. First, it grants "grandfather" rights to existing plants to emit at historic levels unless there is a major modification. Secondly, new plants are permitted based on then best available control technology, and given "grandfather" rights to continue emitting at that level forever, unless there is a major modification. This methodology creates no incentive to increase efficiency or to add new technology to reduce pollution, once a plant is built. And it effectively block modifications.

Today, it is feasible to continuously monitor emissions from all plants and therefore possible to adopt a new environmental control methodology, and this is happening.

The EPA is asking Congress to replace the new source rules with a cap on total emissions of three pollutants -- oxides of nitrogen, sulfur dioxide and mercury. Under the proposed rules, every producer of heat and power will be on equal footing, forced to purchase permits for each ton of pollution they emit, regardless of the age or technology of their plants. The likely result will be a move away from end-of-pipe controls in favor of more efficient approaches that reduce both emissions and cost by burning less fuel. Distributed generation that recycles heat will benefit from such new rules.

Collateral Issue #5 Global Warming

Many people believe global warming is the biggest challenge facing the human race. Others are skeptical. Both sides agree about one thing – lowering carbon dioxide emissions will disrupt the economy. Both sides assume the power system is optimal, so any changes to lessen CO_2 emissions must raise costs. Given this assumption, the debate pits those who are willing to disrupt the economy to mitigate climate change against those who feel the evidence does not justify economic sacrifice.

But the power system is not optimal. Distributed power that recycles heat or produces power with waste heat or waste fuel can cut fuel use in half and lower power prices. The atmospheric bonus is a significant reduction in carbon dioxide emissions. **The best way to emit less carbon dioxide is to burn less fuel.**

In public debates on global warming, it is commonly assumed that there are only two tools available: 1) reduce consumption, whether it be via "consumption taxes" or President Carter's sweater and 2) shift to more ecologically and/or national security-friendly fuels, like natural gas, ethanol and hydrogen. The debate ignores a third solution that will save money and achieve other political/environmental goals; use fuel more efficiently. Distributed power that recycles waste heat, is powered by waste industrial heat or uses industrial flare gas for power is more than twice as efficient as conventional central generation, and it saves money by burning less fuel.

The New Economic Calculus

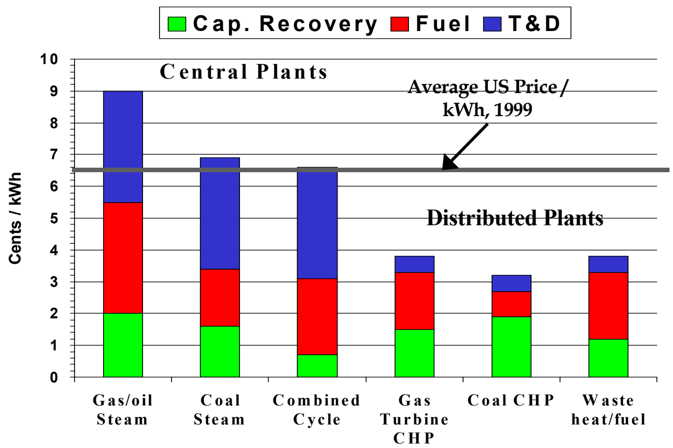
The analysis below suggests that future electric prices can drop by 50%, saving US consumers over one trillion dollars per decade.

Five other network industries (interstate rail, trucking, telephone, gas, and air travel) had monopoly protection rescinded between 1970 and 1984. Ten years after competition was allowed, real prices had dropped between 27% and 58%. Although many predicted that service to low-income and remote customers would deteriorate under competition, exhaustive studies have concluded that service has improved, real prices have dropped to all classes of consumers and new services have emerged.[13]

How far can electric prices fall? With competition allowed in generation and some deregulation in 25 states, US prices have already dropped 32% from their 1984 peak. A comparison of delivered power costs from six types of new plants – three central generation approaches and three distributed generation approaches – shows a further 50% price drop is possible.

Figure 5 shows six different new generation plants and what each must charge per kilowatt-hour to earn a fair return on capital. The chart depicts the three main central plant technologies, all of which require T&D, and the three distributed plant technologies, which do not require T&D.[14]

Figure 5, New Power Plants – Price per kWh to Earn a Fair Profit



In 1999, 61% of US utility power was generated in the first two types of plants,[15] the most expensive of current technology options. The first burns gas and/or oil and the second burns coal. Both waste two-thirds of the fuel's energy. To build a new gas/oil fired steam plant and earn a fair profit would require nine cents per kWh, 35% more than current retail prices. No one builds them anymore. A new coal fired steam plant has lower fuel costs but still must charge more than today's average electric prices to earn a fair return on capital.

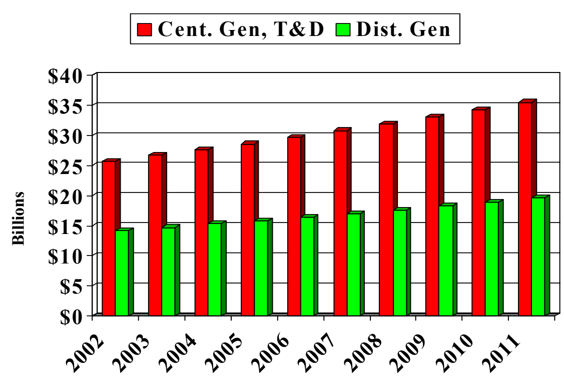
The third central plant burns expensive gas, but has a low capital cost and achieves better fuel efficiency by combining two cycles. A combustion turbine driven generator produces some electricity, and then hot exhaust gas produces more electricity by powering a steam turbine, hence, the name "combined cycle." These plants only waste 45% of the fuel's energy. They need to charge current average prices to earn a fair return unless they are built near spare transmission lines, which lowers the T&D costs. Many combined cycle plants and a few new coal plants are being built near spare, and increasingly rare, transmission capacity.

The distributed generation plants use the same fuels plus waste fuel in some cases, and use the same technology as central plants. But they produce power at or near the user of the power, and they recover and sell heat. All three distributed plants achieve 70% to 90% efficiency, greatly reducing emissions, especially of carbon dioxide. These plants can earn a fair return selling power for about half of current prices.

Future US Capital Investment in Electric Generation and Transmission

Figure 6 projects total US capital costs for two approaches. The analysis assumes the US will need to build 137,000 new megawatts of capacity in the next decade[16]. Satisfying all load growth with central plants will require $84 billion for the generating plants and $220 billion for new T&D; a total of $304 billion.[17] Satisfying all load growth with distributed generation will cost $168 billion for new plants, but not require any new T&D. A distributed plant future would save $136 billion of capital investment and reduce the cost of new power by about 3 cents per kWh.

Figure 6, Central Versus Distributed Generation Capital



Savings from Distributed Generation

What is the economic calculus of moving from total reliance on centrally generated power to a hybrid system with most new power generation from distributed plants? Distributed plants that can earn a fair return at half of current average prices will attract load from older central plants, once barriers are removed. Until average prices drop to half of present levels, more distributed plants will be built, which will cause existing central plants to be closed or dramatically modified.

Distributed generation built near high power quality users and connected to parallel with the local grid, can deliver the 99.9999% reliability those users demand. By aggressively deploying distributed power, the US could halve the $119 billion costs from inadequate power quality.

Bottom line -- power prices can drop by 50% over the next ten years and cut power quality costs in half. The annual savings could reach $170 billion per year.[18]

Good Questions

Several questions can be raised about the future described above.

First, are there adequate opportunities to build distributed power plants that recycle heat?

The US currently generates only 7% of its total power in combined heat and power plants. By contrast, Denmark generates 59% of its total electricity in CHP plants. The US DOE has estimated that 125,000 megawatts of combined heat and power plants could be built to supply existing steam systems on industrial and institutional campuses. This would represent an additional 20% of US power from CHP. The DOE study did not count opportunities to recover power from waste heat or waste fuel, which we have internally estimated to exceed 100,000 megawatts. DOE did not include combined heat and power to service new thermal distribution networks or to supply direct thermal energy to dryers and chemical processes. These additions could increase US generation at CHP plants to over 50% of total power.

What if large users leave the utility system? Isn't this "cherry picking" and won't it cause rates to small users to rise?

Yes, this is cherry picking; no, it will not increase rates to small users. Power entrepreneurs will seek market niches, just as Herb Kelleher of Southwest Airlines pursued vulnerable segments of air travel.

Cherry picking causes prices to drop. Faced with customer loss, incumbent suppliers struggle to cut costs and offer better value. Managers close inefficient plants and adopt best practices. Economist Joseph Schumpeter called this process "creative destruction," and argued it was how capitalism increases the standard of living.

If distribution competition is allowed, will there be more wires?

Power from distributed generation either stays home or goes next door, never reaching transmission systems. Furthermore, allowing private wires will not necessarily lead to more local wires. Independent power producers will use the threat of installing a private wire to obtain a fair price for use of existing wires. Government allowed private natural gas pipes to bypass the local gas distributors, but few new pipes have been built. The Philadelphia Gas Company cut prices for transmission by 88% when Trigen threatened to build a bypass in 1997. The resulting savings made it feasible to build a $175 million CHP project, supplied through **existing** gas pipes, and the gas company has profited as well.[19] Wires seem no different.

Conclusions

Total reliance on central generation is causing power problems and is negatively affecting other collateral issues. Governments at every level have eased monopoly protection and removed some barriers to efficiency.

Several results are encouraging. Real electric prices have fallen in each of the last 17 years and are now only 68% of the prices charged in 1984. Total tons of regulated air pollution began to decline in 1971 and have dropped to 1940 levels, in spite of the economy being 8.5 times larger.

In other areas, the US power system is not optimal. Heat is seldom recycled; transmission lines are full and will be difficult and expensive to expand. The digital economy demands higher power quality than central systems can deliver. The power system's frozen efficiency results in excessive fuel use which exacerbates environmental and balance of payments problems. Finally, the central power system is needlessly vulnerable.

There are still obsolete laws and regulations that impede efficiency and stunt distributed generation. The rewards from removing these barriers can be enormous, cutting in half both fuel use and electricity prices and significantly reducing air pollution. Eliminating barriers and embracing interconnected distributed generation can, within ten years, save the US economy $170 billion per year.

The US has long enjoyed a high standard of living, thanks to a free market economy that rewards entrepreneurs who do more with less. The challenge is to extend this winning formula to electricity.

[1] EPA is working to promote recovery because methane is a potent greenhouse gas.

[2] Cities of the future – European Comparison, Part II: Case Studies – Göteborg, ICLEI 1998, pages 1,13, and 14

[3] Electric Power Research Institute's Consortium for Electric Infrastructure to Support a Digital Society (CEIDS). The study involved interviews with what the study authors noted was a "statistically representative sample" of 985 firms in three sectors of the US economy that represent 40 percent of the US gross domestic product - and which show particular sensitivity to power disturbances. http://ceids.epri.com/ceids/home1.html.

[4] Discussions at advisory board meeting of Haddington Ventures Inc in August, 2001, (Author Thomas Casten is a board member and was attending the meeting)

[5] Arthur D. Little, Preliminary Assessment of Battery Energy Storage and Fuel Cell Systems in Building Applications, Final Report to National Energy Technology Laboratory, US DOE, August 2, 2000, page 43. Author Sean Casten led this study.

[6] Energy Information Agency, Energy Review 2000

[7] Morris Pierce, "The History of Cogeneration – the dawning of the age of electricity," Cogeneration and On-Site Power Production, July-Aug, 2000, Vol 1, #4.

[8] US Department of Energy, Making Connections – Case Study of Interconnection Barriers and their Impacts on Distributed Power Projects.

[9] Distribution systems are designed to open the electric breakers briefly then re-close. The branch or squirrel that temporarily shorts two circuits is literally blown off the wire by the current surge, eliminating the short circuit.

[10] Personal conversations of author Thomas Casten in 1999 with Al Forte, then energy manager for Genetech parent American Home Products.

[11] There are exceptions. Southern Company encourages standby systems to operate in parallel with the grid and offers users savings in return for agreeing to operate their standby systems to shave peak system loads. A further problem impacts the reliability of the standby systems. The only way they can be exercised under load is to interrupt power, connect the standby generators, operate through the exercise period, then interrupt power again to reconnect to the grid. With so many systems relying on computer chips, two power outages every time the standby generator is exercised are unacceptable. Standby systems are therefore not exercised, lowering the chances that they will start in emergency.

[12] Bureau of Economic Analysis, US Department of Commerce, National Income and Product Account Tables, Table 1.2, Real Gross Domestic Product in 1996 dollars.

[13] Robert Crandal and Jerry Ellig, Economic Deregulation and Customer Choice: Lessons for the Electric Industry (Fairfax, Va.: Center for Market Processes, 1997).

[14] These examples cover the technical options for generation based on combustion of fossil fuel or biomass. Solar energy from photovoltaic panels, windmills, hydropower, wave power and nuclear are other options that will also compete.

[15] EIA, Energy review, 199, Page 213.

[16] US summer capacity was 782,000 mW in 1999. The growth of demand from 1989 to 1999 averaged 1.63% per year. Projecting the same growth for the decade ahead results in a need for 137,000 megawatts of new demand. See US DOE, Energy Information Agency Annual Review, 1999, page 218.

[17] The analysis assumes T&D costs of $1260 per kW in 1997, central generation costs of $500 per kW and distributed generation costs of $1000, both in 2000. Inflation of 3% is added each year to all numbers and assumed load growth is 1.63% per year, same as the prior 11 years.

[18] 3400 Billion kWh @ 6.74¢ per kWh per EIA Annual Energy Review, 1999, Pages 227 & 235.

[19] Author Thomas Casten was CEO of Trigen at the time and relates this story from personal involvement.