

Is the US Power System Economically and Environmentally Optimal?

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Economists, policy makers, and the public assume that the U.S. electric system is economically and environmentally optimal. President George W. Bush, in a major speech on climate change said, “Technology is the ticket” (2005). The Journal of the International Association for Energy Economics published a 2006 special issue exploring the costs of climate change mitigation. The lead article stated, “Almost everyone agrees that the development and diffusion of low carbon technologies will be central to stabilizing the climate...” (Grubb *et.al.*, 2006). This quote clearly assumes Energy Myth #8, that the power system is economically and environmentally optimal, given current technology.

We question this near-universal belief that new technology is the most important requirement to mitigate climate change. Significant barriers to energy system innovation largely block deployment of proven technologies that could reduce net energy costs and reduce emissions. Analyses of the likely costs of mitigating climate change largely fail to recognize the significant, worldwide barriers to energy innovation; these barriers block both existing and new energy efficiency technology, especially more efficient local generation technologies. Eliminating barriers to energy innovation is job one of anyone concerned with energy costs, fossil emissions, national security implications of fossil fuel use, or retention of manufacturing jobs.

Few assumptions that underpin government policies are as flawed as the myth that electric power system is optimal, and that industry energy use is optimal. The power industry has made suboptimal choices for at least 30 years, resulting in needless capital expenditures, excessive fossil fuel use, unnecessary pollution, and overpriced power. Nor have manufacturing industries optimized their energy production. Industrial enterprises typically treat energy as a non-core activ-

ity and then severely ration intellectual and financial resources devoted to energy efficiency projects. Industry regularly ignores energy saving projects with one to two year pay backs. The resulting opportunities should be fertile ground for third party power entrepreneurs seeking to profit by outsourcing industrial energy supply. But regulations and regulators, bent on protecting electric distribution monopolies, largely compromise the economics of such projects. The failure to optimize U.S. power systems is largely caused by power industry governance, which consists of a vast tapestry of rules and regulations that were either based on yesterdays’ technology choices or were handcrafted by electricity distribution utilities to preserve their wires monopoly.

It is instructive to quantify the magnitude of U.S. power system sub optimality. It will take the whole chapter to fully explain these conclusions:

- The U.S. economy could profitably drive 64,000 megawatts of new generation by recycling present industrial waste energy streams. Assuming this new energy recycling capacity operated 70% of the year, it would generate 392 billion kilowatt-hours/year and avoid 4 quadrillion Btu’s (quads) of fossil fuel/year.
- The U.S. could, by generating electricity locally near thermal users, profitably recycle one half of the presently wasted heat from power generation, and save 13 quads of fossil fuel.
- The 17 quads of avoided fossil fuel would reduce energy costs by \$70 billion per year and cut U.S. fossil fuel use from 85.7 quads total use in 2004 (EIA, 2004) to 68.7 quads, roughly a 20% drop in fossil fuel and in associated CO₂ greenhouse gas emissions.

- Profitably recycling this waste energy would cause many other positive benefits. The savings would preserve manufacturing jobs. All air pollution would drop by the same amount or more. The drop in demand for fossil fuel would moderate world fuel prices. There would be a sustained boom in new power plant construction. System vulnerability to extreme weather and terrorists would drop, due to the widely dispersed generation near users. Finally, the world would be economically forced to recycle its waste energy to remain competitive.

U.S. energy's inefficiency is an unfolding disaster that exacerbates many current problems including manufacturing competitiveness, jobs, national security, system vulnerability to extreme weather and terrorism, balance of payments, and global warming. We will show how regulatory/governance changes could positively address each of these problems by simply removing the regulatory barriers to efficiency and by encouraging the re-use – or as we term it, recycling – of presently wasted energy streams in both industrial production and electric power generation.

How does the myth that the power system is optimal survive? Electric power is the country's largest industry, comprised of many very large, very profitable firms that invest heavily in public relations. They say they are efficient, which reinforces the myth that they are efficient. Standard economic theory says that competition forces firms to continually improve and wring waste out of every process. Competitive markets, according to the theory, don't leave \$100 bills lying on the ground; some entrepreneur will have already picked them up. Since headlines claim that the electric industry has been 'deregulated,' the public assumes that market forces – Adam Smith's 'invisible hand' – will continue to reduce power industry waste and drive down the cost of delivered electricity. But the idea that deregulation has introduced effective true competition, especially where technology has the most to offer, fails the laugh test. Century-old grants of monopoly rights to distribute electricity remain in place and are enforced in every territory to discourage local or on-site generation.

It is time for a reality check. If deregulation has allowed true competition, markets should be working. Is the electric system becoming more efficient? Has deregulation removed key barriers to efficiency?

Sadly, the broad answer is no. A century of monopoly protection has spawned many anticompetitive rules. As far as electric distribution is concerned, these anticompetitive rules remain in force. The single most damaging barrier to competition is the universal ban on private electric wires crossing public streets. These bans force would-be power entrepreneurs to use their competitors' wires to deliver their product – electricity, to their customers. Utilities and regulators then set prices for moving power that deeply penalize local generation. A second major barrier to competition is the unique reward system that applies to monopoly-protected activities such as electric power. Regulators approve rates that are supposed to provide a 'reasonable' return on invested capital. This encourages capital investment, regardless of efficiency. By contrast, competitive markets reward low cost production. Electric power utilities present a test case scenario of assumed electric sales and then negotiate rates with their regulatory commissions for each class of customer. The market plays no role. With approved rates in place, the utility's profits hinge on throughput – how much electricity flows through their wires. More sales, more profits. Actions that lead to conservation, appliance efficiency gains, and local generation all penalize utility profits. Generation efficiency gains do not help profits, as they are passed through to customers. Society gets what these rules pay for – stagnant efficiency and endless barriers to more efficient local generation.

The record confirms this. The U.S. power system used three units of fuel to deliver one unit of electricity in 1959. Although the ensuing 46 years have seen phenomenal technology advances, which makes energy 'recycling' cost-effective, the power industry's dismal 33% efficiency level has not changed. We need look no further for proof of regulatory failure than the power industries failure to recycle waste energy streams to cut consumer costs and fossil emissions.

Deregulation has opened some parts of the industry to competition, which has worked, but only in the ways the rules reward. Regulatory changes allowed competition among centralized generation plant operators and this spawned significant improvements in labor productivity and increased availability of nuclear and coal-fired generating units. The Energy Policy Act of 1992 opened wholesale electric generation competition, *i.e.*, for power sold to the grid, and this induced electric power companies to improve labor and capital

utilization efficiencies. The U.S. power industry employed 75 persons per 100 megawatts of generating capacity in 1990 and reduced that number by 52% to 39 persons per 100 megawatts of generating capacity by 2004. The load factor for all nuclear units rose from 66% in 1990 to 88% in 2003, while coal fired load factors rose from 59% to 72% in the same period. The industry only increased its coal and nuclear electric generating capacity (407 gigawatts in 1990) by 5 gigawatts in the next thirteen years, or a 1% increase during the period, but the power output from these coal and nuclear plants increased by 26%. This improvement avoided the construction of 100 gigawatts of new generating capacity. The industry would have otherwise needed to build new coal and nuclear plants, which would have added roughly \$150 billion to the U.S. rate base, raising rates by \$18 billion per year (EIA, online). But the partial market opening, by allowing only wholesale competition failed to cause improvements in fuel efficiency.

Some pundits are ignoring these facts and claiming that since electricity prices have risen, deregulation has failed. But to believe that the price of delivered power provides insight into the impact of deregulation assumes that all other things were equal. In fact, world fuel prices have risen dramatically, tripling and even quadrupling the cost of fuel for electric power generation since 2000. These fuel price increases, with no efficiency gains, have overwhelmed the gains that limited deregulation promoted in central plant labor and capital productivity and caused electric rates to rise to consumers. To put the past in Adam Smith terms, the regulations prior to 1978 shackled both ‘invisible’ hands of would-be competitors. The Public Utility Policy Regulatory Act in 1978 and the 1992 Energy Policy Act largely untied one hand, allowing third parties, under limited circumstances, to centrally generate power and compete with other centralized generation plants. But the regulatory barriers to any local generation that bypasses the distribution grid have remained in place, keeping that ‘hand’ shackled.

Except for this limited opening of competition, today’s electric prices would be even higher. But the steady growth of electric use without any improvement in efficiency has dramatically increased the demand for fossil fuel, and has helped drive coal prices to levels four times higher than they were fifteen years ago. The power industry’s adoption of natural gas fired plants on the margin has strongly contrib-

uted to the dramatic rise in natural gas prices, all of which flows through to consumer electric prices. Nonetheless, without this modest opening of competition, electric prices to consumers would be significantly higher.

This chapter explains how the electric power industry, if faced with truly free competition, would reduce fuel use for electric power and would recycle industrial energy waste streams. Opening of competition will create a virtuous cycle of lessening the demand for fuel by efficiency gains, which will then moderate fuel price increases and lessen the fuel burned per unit of delivered power.

Part I Understanding Optimal Generation

1. Recycling Energy – A Casualty of Governance

To understand what is wrong with today’s power system, three points are sufficient. First, realize that manufacturing processes and electric power generation plants only convert a portion of available energy input to useful work and then discard the remaining potential energy. As just noted, the U.S. electric power generation system, on average, discards two thirds of its input energy as waste. Many industrial processes also discard prodigious quantities of potential energy. Second, understand that much of the waste energy from manufacturing and power generation can be profitably recycled into useful heat and power, but only if the energy recycling facility is located at or near users. Thermal energy, the form of much of present waste, does not travel far without losing its value. Third, understand that the U.S. electric power industry remains totally focused on remote central generation plants, none of which can recycle waste heat. This central generation paradigm applies to regulators, the utilities they regulate, and – of necessity – to independent power producers. As a result of this central generation fixation, the power industry burns roughly twice as much fossil fuel as would an economically optimal system using available technology.

There are many proven approaches that could profitably recycle the presently wasted 17 quadrillion Btu’s of energy¹. Comprehensive energy recycling would

¹ The US raw energy input in 2004 was 99.7 quads, of which 85.7 quads came from fossil fuel. Transportation, which is nearly all fossil fuel

save money, reduce pollution, mitigate climate change, improve the competitive position of U.S. industry, and create high skill jobs. But because recycling energy requires local power generation, it remains out of favor. *The potential to recycle energy may be societies best kept secret.*

The pervasive myth of an optimal power system creates a natural resistance to these claims. Surely, it will be argued, the utilities would recycle energy if this saved money. Surely industry would convert waste energy streams into power, if it was economic to do so. We shall show that neither assumption matches observed facts.

In order to extract useful work from waste energy, electricity must be generated locally, near users. But utilities don't like local generation because it reduces the electric power flowing through their wires, which under the present system of governance would reduce centralized utility profits. The impact of utility wires throughput on shareholder rewards – profits – is multiplied by the typical rate system. During a rate case, rates are established for each class of customers, using test year data that will, collectively, produce the target rate of return to the utility at assumed sales to each rate class. If actual sales are up by 5% over test year, profits might rise by 25%. Conversely, if local generation caused utility sales to drop by 5%, utility profits could drop by 25%. Yet the regulators have not corrected this bias. Utility governance, an unholy alliance of management and regulation, remains locked into a central generation paradigm that made technical and economic sense a century ago, but no longer makes sense. Today, the regulatory system mainly supports the central utility management's continuing efforts to block generation by local power generators and by waste industrial energy recyclers.

1.1 RECYCLING INDUSTRIAL WASTE ENERGY

It is a well established fact that a variety of industrial waste energy streams can be recycled into useful heat and electric power. These include hot exhaust gases, low grade fuels (some of which are typically flared), and high pressure steam and gas. For example, it is

based, consumed 27.8 quads or 28% of total input energy. Of the remaining 57.7 quads of fossil fuel, we estimate that 5 to 8 quads were used as a feed stock for various chemical production, and that the remaining 50-52 quads were used to produce thermal energy and electricity – heat and power. An optimal system that recycled waste energy streams would save 17 quads or 20% of all fossil fuel currently used.

feasible to use hot exhaust (600 degrees F or higher) from any process to produce steam that drives turbine generators and produces electricity. Hot exhaust is emitted by coke ovens, glass furnaces, silicon production, refineries, natural gas pipeline compressors, petrochemical processes, and many processes in the metals industry.² Another way energy can be recycled is by burning presently flared gas from blast furnaces, refineries or chemical processes to produce steam and electricity.

Pressurized gases also contain energy that can be recycled into electricity. Examples include steam, process exhaust, and compressed natural gas in pipelines. All gas pressure drops can be used to generate electricity via backpressure turbines. Remember the whirly gig, a stick with a plastic propeller? As children, we ran with the stick above our heads, and the motion through the air caused the propeller to turn. Wind turbines adopt the same idea on a much larger scale. But what about 'industrial wind' whirly gigs? Industry produces many streams of gas at high pressure that can power an 'industrial strength' whirly gig called a backpressure turbine. The turbine is connected to an electric generator to produce fuel-free power with no incremental pollution. For example, industrial and commercial boiler plants produce high pressure steam for distribution, which is then deflated (pressure reduced) at points of use by means of valves.

Nearly every college and university campus, as well as most industrial complexes, could produce some fuel-free electricity from steam pressure drop with a backpressure turbine generator (Turbosteam, online). Gas transmission pipelines burn 8% of the gas being transported to drive compressors that pack the remaining natural gas into transcontinental pipes. Pipelines then reduce that pressure at each city gate with valves, typically wasting the potential energy of the pressure drop. Simply recycling this pressure drop at every point that gas flows into local distribution systems would generate 6,500 megawatts, roughly 1% of U.S. electric power generation (Primary Energy, online). Industrial processes such as catalytic crack-

² Proven technology using organic fluids in a Rankine cycle profitably converts exhaust gases with temperatures above 600 degrees F to electricity, (see www.ormat.com) while conventional steam cycles become cost effective at roughly 900 degrees F. Promising technologies now under development could produce electric power with exhaust temperatures as low as 180 degrees F, but these approaches require further capital cost reduction to be economically attractive in replacing current average cost electricity.

ers at petroleum refineries and blast furnaces at steel mills emit exhaust at above atmospheric pressure. A top-gas recovery turbine on a large blast furnace can produce 15 megawatts of fuel-free power, while a similar device atop a catalytic cracking unit in an oil refinery can produce 35 megawatts of fuel-free electric power. There are many blast furnaces and many catalytic cracking units in operation 24/7, nearly all wasting potential energy.

Recycling industrial energy streams is well established, but only in facilities large enough to make use of the heat or power internally. There are roughly 10,000 megawatts of installed industrial recycled energy capacity in operation in the U.S., the equivalent of ten large nuclear plants. But this is only 10% of the existing potential to recycle industrial waste energy. A recent study for the U.S. Environmental Protection Agency documented another 95,000 megawatts of potential recycled industrial energy generation (Bailey and Worrell, 2004). The total savings potential remains significant, even after we trim the estimate to 64,000 megawatts, based on our development experience. Recycling this waste energy could produce an astonishing 14% of U.S. electricity without burning any fossil fuel. In 2004, 77% of U.S. electricity was produced by burning fossil fuels; recycling industrial energy streams with local generation could have avoided burning nearly one fourth of that fossil fuel and saved money.

Data on existing industrial energy recycling projects gives a flavor of the range of capacity and capital costs. Operating energy recycling projects range in capacity from 40 kilowatts to 160 megawatts (160,000 kilowatts), and capital costs have ranged from \$300 per kilowatt for large backpressure turbines to over \$1,800 per kilowatt for small steam-turbine plants. For comparison, capital costs per kilowatt of electrical generating capacity for a new coal-fired plant are roughly equal to the most expensive energy recycling plants. But the new coal plant must also purchase fuel and pay for transmission wires while the energy recycling plant converts free waste energy streams into heat and electric power and delivers the power directly to on-site users, avoiding transmission wires.

Figure 1 is a picture of Cokenergy, an energy recycling plant located on Lake Michigan, opposite Chicago. Some 268 ovens bake metallurgical coal to produce blast furnace coke – expanded lumps of nearly

pure carbon. The Primary Energy recycling plant in the picture converts the hot coke-oven exhaust gases to produce up to 95 megawatts of electricity and up to 980,000 pounds of steam for Mittal Steel's adjacent Harbor Works steel plant (Primary Energy, online). This generation burns no incremental fossil fuel and emits no incremental air pollution or greenhouse gases. In other words, this power is pristine, as clean as the power from renewable energy sources such as solar collectors. The plant's clean power production is staggeringly large. **In 2004, this plant generated more clean power than was produced by all of the solar collectors throughout the world.**³ And it earned a profit selling that power for less than half of the cost of power from the local utility.

Each dollar of investment in this energy recycling plant produced roughly 20 times more clean energy than a dollar invested in solar collectors, or 5 times more clean energy than a dollar invested in wind generation and wires.⁴ These comparisons are not intended to disparage the use of renewable energy, but to demonstrate the economic efficiency of recycling energy. Recycled energy is both clean and affordable.

Mittal Steel also enjoys significant economic benefits without capital investment. Producing the same steam with natural gas and purchasing electricity from the grid would have raised Mittal's costs by roughly \$40 million in 2005. Energy recycling thus makes industry more competitive and preserves jobs, while reducing costs, pollution, and dependence on imported fuel.

³ At the end of 2004, 650 megawatts of solar collectors were installed worldwide, which, at an annual estimated 8% load factor, would have produced $650 * 8760 \text{ hours} * .08 = 455,520 \text{ MWh}$. The 90 MW coke oven exhaust recycling plant produced 503,000 MWh in 2004, equal to an 8% load factor of all solar collectors.

⁴ The \$165 million energy recycling plant produced 431,000 MWh per million dollars of investment. New Solar PV at \$8.0 million per MW and a 12% annual load factor produces 131 MWh per million dollars of investment. The recycled energy plant thus produced 19.9 times more power per dollar of investment than new solar. New wind costing \$3,100 million per MW plus \$1.4 million per MW for T&D will produce, at a 30% load factor, 584 MWh per million dollars invested. Line losses of 9% reduce this to 531 MWh delivered per \$1.0 million of investment. The recycled energy plant thus produced 4.91 times more clean power than new wind per dollar of investment.

Figure 1. Cokenergy - Energy Recycling Plant at Mittal Steel, East Chicago, Indiana



This project is the exception that proves the rule of sub optimal electric power generation. A sister coke plant in Van Zant, Virginia has operated for 35 years without recycling the potential energy in its exhaust. Other examples illustrate current waste. The world produces roughly 3 million pounds of nearly pure silicon in smelters with exhaust gases similar to those recycled at Cokenergy, but to the best of our knowledge, none of the hot gases are recycled, even though they could produce 6.5 billion kilowatt-hours per year, nearly ten times the current production of clean power from worldwide solar energy. There are countless examples of other sources of hot exhaust that are currently wasted, but would be recycled into heat and electric power by an optimal system. **It is simply a myth that the power system is optimal.**

1.2 RECYCLING WASTE HEAT FROM ELECTRIC GENERATION

1.2.1. Saving Half of Fossil Fuel used in Electric Generation

So far, we have focused on recycling waste energy streams from industrial facilities. We have shown that recycling industrial waste heat has the potential to produce 14% of U.S. electric power with no incremental fossil fuel or pollution. Now we turn to an even larger potential for energy recycling, the copious quantities of waste heat from thermally based electric generation plants (plants using fossil fuels, biomass, or nuclear energy to produce electricity). To recycle energy from electric power generation, one must extract waste heat at slightly higher temperatures which slightly reduces electric output. This thermal energy, extracted at small cost to the electricity produced, can then be recycled for space heating, water heating, absorption cooling, and some industrial processes, thus displacing boiler fuel. But the electric generation plant must be located at or near thermal users and sized to their needs. Low temperature heat cannot be economically transported over long distances. To recycle heat from electric generation requires many smaller, on-site plants to supplement today's system consisting almost exclusively of large, remote generating stations.

We can roughly estimate the potential savings from constructing new combined heat and power generation units near thermal users. In 2003, the U.S. power industry consumed 27.5 quadrillion British Thermal Units (quads) of fossil fuel to deliver 9.4 quads of electricity. This corresponds to the 33% efficiency already cited (EIA, online). By contrast, combined heat and power plants (CHP) sited near thermal users are able to achieve anywhere from 50% to 90% efficiency, depending on configuration and local demand for thermal energy. Recycling half of the heat currently thrown away by fossil-fueled central generation plants would supply an additional 9.4 quads of useful energy for heating and process use. This would avoid burning 13.4 quads of boiler fuel, assuming 70% seasonal boiler efficiency. **This would save half of all fossil fuel used for electric generation today, or over 15% of all fossil fuel burned in the U.S..** This energy recycling potential is in addition to the savings of 4 quads of fossil fuel from recycling industrial waste energy into electric power that were noted above.

And, these approaches make sense everywhere. The global potential for reducing fuel use with local (decentralized) combined heat and power plants (CHP) could significantly reduce worldwide demand for fossil fuels. Today, 92.5% of the world's electricity is produced at remote, inherently wasteful central generation plants (WADE, online). One might ask if there are technical limits to CHP. Surprisingly, there are no technical limits, because CHP plants utilize all of the technologies and fuels used by central generation plants, including nuclear power⁵. The world can use existing proven technology to drive the percentage of power from local CHP plants to over 50% of total use. Denmark had already achieved this goal. Furthermore, inducing the power industry to use existing technology to recycle energy would stimulate technical improvements, which would further increase the potential to profitably recycle power plant waste energy. Finally, although local CHP generation facilities will be, on average, much smaller than centralized remote generation plants, they are still substantial plants, ranging from a few kilowatts to 700 megawatts.

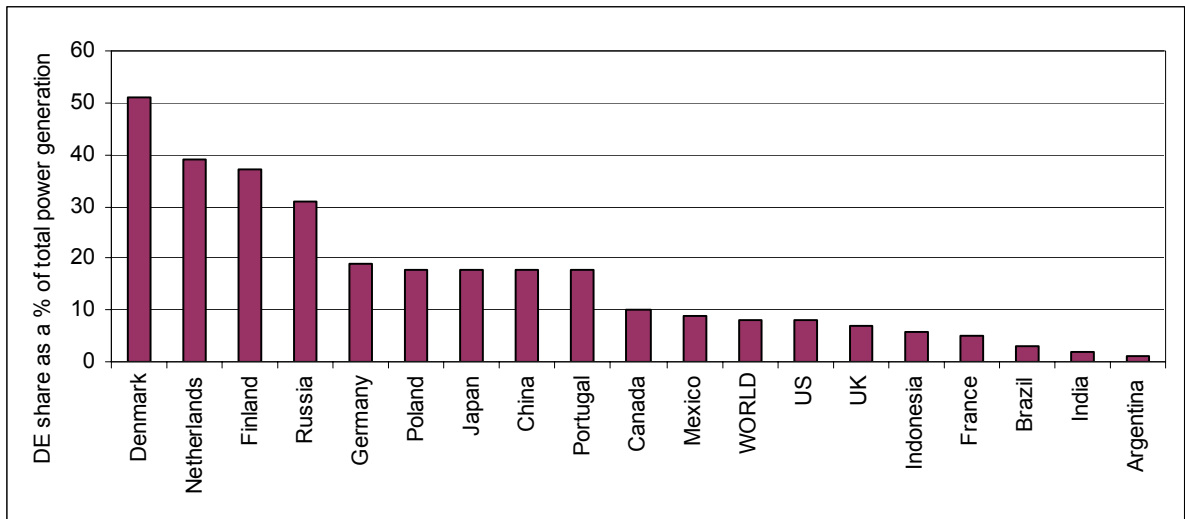
⁵ All nuclear powered submarines and aircraft carriers recycle exhaust heat from the nuclear plant steam turbines for ship's thermal energy.

Chart 1 displays the percentage of generation by local combined heat and power plants (CHP) in various countries.

The *World Survey of Decentralized Energy for 2005* by the World Alliance for Decentralized Energy (WADE) (WADE, online) found that 7.5% of worldwide electric generation was from CHP plants, but noted a great disparity among countries, as shown in the chart. The U.S. and Canada generated respectively 7.2% and 9.9% of their power with CHP plants, while some other industrial economies generated between 30% and 52% of their power with more efficient CHP plants. (The statistics are upward biased by the fact that plants are typically counted as CHP if they are capable of recycling waste heat, regardless of the amount of heat actually recycled.)

It is also interesting to note the difference in use of CHP plants between U.S. States. Three states report that they have no combined heat and power production, while California and Hawaii produced over 20% of their power with CHP plants. These differences in the use of CHP among countries and among U.S. states have little to do with the local mix of energy users. The differences can be largely explained by local power industry governance. In those countries and U.S. states that have removed some of the barriers to efficiency and begun to credit local generation with more of the value it creates, the power industry has built nearly all new generation facilities next to thermal energy users. The three states with no reported CHP plants retain old laws that make it illegal for a third party to sell power to a host, even if the generation plant is on the host property. Such governance blocks innovation.

Chart 1. CHP Production Percentage of Total Power by Country (see next end note)



2. Do Central Plants Have Economies of Scale?

Some power industry specialists will acknowledge the efficiency advantages of local CHP generation, but claim net advantages for centralized generation, because of perceived economies of scale of large plants. Indeed, there are economies of scale, if one looks only at the capital cost of the generation plant. According to the International Energy Agencies 2002 ‘World Energy Outlook’, the expected average cost of all new central generation in 2002 dollars was \$890 per kilowatt of capacity, which was 25% less than our internal estimated average cost of new decentralized plants.⁶ But this is the answer to the wrong question. It ignores the added capital costs for transmission, distribution, and redundancy.

Transmission wires in the U.S., and indeed in the world, are in short supply. Numerous recent power interruptions have flagged problems with overloaded transmission systems in the U.S. and Europe. Many developing countries, such as India, experience daily blackouts as transmission capacity has to be rationed among customers. To serve electric load growth with

new central generation plants, it is necessary to construct new transmission and distribution systems (T&D). A kilowatt of new T&D capacity has been estimated to cost on average, \$1,380 per kilowatt of capacity (Little, 2002). New T&D costs more than building new central generation per kilowatt of added capacity.

Others have confirmed the magnitude of T&D costs. The Regulatory Assistance Project did a detailed study of public information from 124 U.S. utilities over 1995-1999 and found they had average annual investments in distribution wires of \$6.4 million per year requiring increase of electric rates of \$1 to \$1.5 billion per year. RAP writes, “While generating costs may experience a decline through technological gains in efficiency, costs of the distribution system have no comparable innovations in the wings” (Shirley, 2001).

By contrast, new on-site generation avoids the T&D system by delivering power directly to local customers. A small investment in the distribution system may be required to interconnect local generation to the grid. But the added cost will seldom exceed 10% of the cost for new T&D from a new remote central generation facility.

It should be noted that utility requests for standby rates typically claim much higher costs to provide interconnection and backup power to a local CHP generator. These calculations are designed to discourage local generation that would lower utility throughput, and typically assume that the on-site gen-

⁶ The \$890 per kW of capacity is a calculation from table 3.11: New Electricity Generating Capacity and Investment by Region, page 132, World Energy Outlook 2002, International Energy Agency, and is the IEA’s estimate of the additional capacity that will be built worldwide between 2000 and 2030. The estimate of typical costs per kW of recycled energy capacity is based on internal cost records of Primary Energy, Trigen Energy Corporation, and Turbosteam. These companies are or have all been developers of recycled energy facilities managed by one of the authors (Casten).

Table 1. Capital to Serve an Incremental Kilowatt of Peak Load

	<i>Generation</i>	<i>Transmission & distribution</i>	<i>Total/kW of new generation</i>	<i>KW per kW load</i>	<i>Costs/kW of new load</i>
<i>Central Generation</i>	\$890	\$1,380	\$2,270	1.44	\$3,269
<i>Local Generation</i>	\$1,200	\$138	\$1,338	1.07	\$1,432
<i>Savings (Excess) of Central versus Local Generation</i>	\$310	(\$1,242)	(\$1,068)	-0.37	(\$1,837)
<i>Central Generation Capital as a percent of Local Generation Capital</i>	74%	1000%	170%	135%	228%

eration plant will fail at the precise moment of system peak load. Using this logic, the utilities often claim they must dedicate grid and generation capacity to supply 100% of the user’s peak load. Such analysis is deeply flawed. CHP plants often consist of multiple generators which experience random failure rates of about 2% per year. The probability of all three generators in a typical CHP plant failing simultaneously and at the exact time of the system peak load is about one in 6.25 million.⁷ Furthermore, once a reformed regulatory system encourages local power generation, any single local plant failure is likely to be lost in the noise, offset by the ability of other CHP units to increase their output. Nevertheless, electric power industry regulators have nearly always approved excessive standby charges. Such charges effectively block economically and environmentally optimal energy use. Local CHP generation avoids new T&D, reduces existing line losses, cuts air pollution, and enhances grid reliability (Alderfer *et.al*, 2000). Instead of requiring local generation to pay standby fees to the utility, regulations should require payment to local generators for the net value they create.

With this information, we can fully address the question of economies of scale by calculating the overall costs of central versus on-site or local power. Table 1 makes this calculation. The third column shows that one kilowatt of new central capacity and required T&D will cost 170% of the capital cost of building the same kilowatt of local generation capacity. In other words, the scale advantage of large central

plants is overwhelmed by the cost of new transmission and distribution.

Column 3 shows a 170% capital cost premium for centralized generation, but this is only part of the story. The fourth column of Table 1 introduces two further, very significant capital cost penalties associated with central power generation. Line losses averaged 9% in the U.S. in 2004, but the losses during peak loads were much higher. In general, line losses vary with the square of current flow and with ambient temperature, and are thus much higher during the summer when wires are hot and electric loads are high. Peak hours line losses from remote generation plants range from 20% to 30%, depending on the system and the distance that the power travels to users. In the last rate case approved by the Massachusetts regulatory commission, NSTAR, the utility serving Boston, said that peak line losses from generator to consumer were 22%. If we assume that this peak load line loss is typical, then providing one kilowatt of new peak load will require 1.22 kilowatts of new central generation capacity and 1.22 kilowatts of new T&D capacity. By contrast, net peak period line losses from local generation are about 2%. If a local plant generates power in excess of site needs, that power flows backwards towards central generation plants, which reduces system line losses.

The need for redundant capacity also penalizes central generation. The amount of redundancy necessary to achieve desired system reliability is a function of the size of the largest generating unit. The North American Reliability Council (NERC) has set a standard of 18% for reserve generation. By contrast, a recent Carnegie Mellon study found that a system comprised of smaller generation units would achieve the same reli-

⁷ The grid peak occurs over 150 hours, roughly 2% of the year. The probability of all three generators randomly failing during grid peak is .02 X .02 X .02, or .00000014, one in 6.25 million.

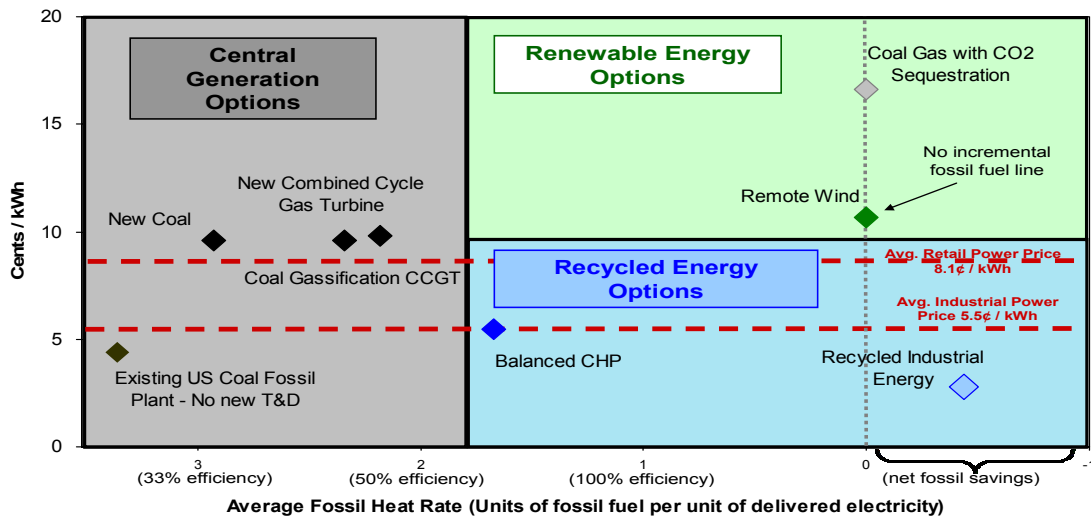
ability with only 3% to 5% redundancy (Zerriffi, 2004). Thus, as the percentage of total load generated by local CHP generators increases, the overall need for spare generating capacity and for spare T&D will diminish.

Hurricane Katrina drove these lessons home in 2005. The Missouri Baptist Medical Center was the only operational hospital in Jackson, Mississippi for 52 hours after the storm, powered by its on-site CHP plant. Meanwhile, the grid could not deliver power to other area hospitals, and lives were lost.

To account for peak line losses and redundancy needs, Table 1 shows that delivering a kilowatt of new peak load requires either 1.44 kilowatts of new central generation and T&D or 1.07 kilowatts of new local generation. The last column presents the full impact on investment cost per kilowatt of serving incremental peak load with central or local generation. Central generation requires 228% more capital investment to serve incremental load growth than is needed to serve the same incremental load from local generation.

We can extrapolate to determine the annual capital cost penalty of continuing to serve U.S. electric load growth with central generation instead of local CHP power plants. The U.S. electric load is currently growing about 14,000 megawatts per year. Serving load growth with central generation will require \$46 billion capital investment for new central generation and wires or could be built for \$20 billion with local generation, saving \$25 billion investment each year.

Chart 2: Future Generation Options



2.1 GENERATION OPTIONS FOR THE FUTURE

We now examine specific generation options for serving load growth and ask what options could be ideal: Ideal options will generate and deliver power to consumers at prices below what they pay today. Ideal options will use no fossil fuel and emit no greenhouse gases. To find these generation options, one must go beyond the typical analysis that looks only at the cost of power at the generator. Such analysis makes a false assumption that all power will need the same wires. The chart that follows answers a broader question – what retail price per kilowatt-hour must be paid to cover all of the costs of generating and delivering the power, including capital amortization, peak line losses and system redundancy requirements.

The vertical axis of Chart 2 is the cents per kWh that must be paid by industrial customers to cover all of the costs noted above. The horizontal axis tracks fossil efficiency by showing the net fossil fuel required per delivered unit of electricity, all in the same units. A line is drawn at 5.5 cents per kilowatt-hour, the 2005 average U.S. price paid by large industrial consumers, and another line is drawn at 8.1 cents, the 2005 average price paid by all retail consumers. This allows the reader to see which generation options will raise electricity prices and depress economic growth, and which generation options will lower electricity prices and accelerate economic growth.

The overall picture suggests cause for alarm. All conventional options will raise electricity prices. Small improvements in fossil efficiency come at a high price with new coal and gas fired central stations. The renewable energy options deliver a unit of electricity without burning any fossil fuel but raise delivered power costs even more.

We can see that a new conventional coal plant, after paying for emission controls and new T&D, will require 9.6 cents per delivered kWh, a 20% increase over today's average retail prices. Electric utilities and many policy makers are touting a new approach to cleaner and more efficient generation with coal, cleverly marketed as 'clean coal'. This new approach involves gasifying the coal first, which is a complicated, capital intensive process, often referred to as Integrated Gasification Combined Cycle (IGCC). The process removes all of the sulfur and mercury in coal and produces a gas that can be burned in a gas turbine, which is more efficient than the best thermal coal plants. By combining two cycles and making steam with the gas turbine exhaust to drive a second power turbine, the overall efficiency, net of gasification losses, can climb to 45%, half again as efficient as the 30% efficiency of conventional coal plants. But the process does not lend itself to smaller, local generation that could recycle waste heat. So, half of the energy in the original coal must still be vented. The current expectations for cost and performance suggest that combined cycle plants with gasification will require 9.6 cents per delivered kWh, an 80% increase over current average industrial prices

Another option is to separate the carbon dioxide in the exhaust and then sequester that CO₂ in an underground cavern, or pump that CO₂ into an oil field or into the deep ocean (a process known as carbon sequestration). This option is being hailed as a way to mitigate climate change. The Electric Power Research Institute (EPRI), which performs much of the research for utilities, has estimated that sequestering CO₂ will add 7 cents per kWh to the cost of power from a gasifier-based power plant. Gasification is an essential first step to CO₂ sequestration, because the process separates the carbon dioxide from nitrogen that makes up roughly 80% of typical exhaust. Without the gasification step, the volume of gas to sequester would be five times greater and would not be suitable for enhanced oil recovery, which is one use of the separated CO₂.

Although this integrated gasification combined cycle plant still consumes 2 units of coal for every unit of delivered electricity, it is depicted on the chart as zero fossil fuel, given that its greenhouse gas emissions have been sequestered. This is a way to produce clean energy, but it results in price increases of 100% over current average industrial prices.

Combined cycle gas turbine plants are inherently more efficient than thermal plants and can deliver one unit of electricity with only 2 units of fossil fuel, but these plants burn expensive natural gas. Delivered power, from these generators, at today's gas prices, will cost consumers 9.8 cents per kWh or 92% more than current average industrial prices. This choice is particularly worrisome, given the extreme volatility of natural gas prices.

Renewable energy options shine in terms of reducing fossil fuel. Wind, geothermal, and solar electricity use no fossil fuel. But consider the costs. Wind technology has dramatically improved, reducing the cost of the wind turbines per kilowatt of capacity and improving the ability of the turbines to operate in low and high speed winds. But even with these advances, the best wind farms achieve only a 30% load factor over a typical year. This means the cost per kWh for the turbine and T&D capital amortization is only spread over 30% of full load or 2600 hours of equivalent full load, versus fueled generation plants with up to 93% load factor – over 8000 equivalent full load hours. Furthermore, the wind farms are typically located far from electric customers. This combination of low load factor and dedicated transmission lines with equally low load factor radically increases the delivered cost of power from wind. Wind farm developers are proceeding with long term contracts for power of 4 to 5 cents per kilowatt-hour, making wind seem relatively inexpensive. But one must add federal production subsidies and amortization of the dedicated transmission lines to determine the true cost of electricity from remote wind farms, delivered to consumers. The chart uses estimates of the all in cost of wind for 2002 in Texas of 8.9 cents per kWh or 161% the current average industrial rates, including subsidies (Dobesova *et.al*, 2005).

Unfortunately, wind has one other unintended consequence. In the Southwestern U.S., the peak electrical loads occur during weather events called 'heat storms'. A high pressure zone stagnates over a wide area and drives temperatures and electric loads to sys-

tem highs. Because the zone has stagnated, there is no wind, therefore, no wind generation. So the unintended consequence is that we need to build double electric capacity, first the wind generation capacity for normal weather conditions, and then duplicate capacity to meet the peak 'heat storm' loads that occur when the wind is unavailable. Alternatively, the power must be stored during high wind generation to be available during heat storm peaks, but the storage costs remain prohibitive. The cost of this duplicate capacity and/or storage is not included in the above 8.9 cent per kWh delivered cost estimate.

Geothermal energy, using subterranean hot water or steam, operates with a very high load factor, but has high capital costs. To induce development of significant new geothermal capacity will require even higher retail prices than wind.

Solar is a different animal. Solar collectors use photovoltaic devices to convert solar energy into direct current, which is then converted to alternating current by a solid state device called an inverter. The capital costs of PV have fallen sharply, but solar is still more than three times as costly as new central generation. It will be a number of years before there is enough solar capacity to make much difference in national statistics or in reducing global greenhouse emissions. For now, solar energy requires roughly 24 cents per kilowatt-hour, over 200% more than the average price of retail power (Solar PV costs would appear above the chart range and are not shown). In spite of these high costs, solar energy, with today's technology, is often the most cost effective option for off-grid power. Solar power is already the least expensive option for electricity on small islands, in remote villages, for billboards that are a long way from the nearest wire, and for emergency telephones along highways and along jogging paths. However, solar PV remains an expensive substitute for grid power, given current technology.

This leaves society with a discouraging list of conventional and renewable generation options. The conventional options burn two to three units of fossil fuel per unit of power and emit associated pollution and greenhouse gasses. Using conventional options to serve load growth will increase the average cost of delivered power by 20% to 100% over 2005 average U.S. industrial prices and drive up CO₂ emissions. The cleaner renewable energy options have even higher costs. If society continues to meet load growth

with only these options, the nation had better prepare for a major economic slowdown.

Happily, there are other options, namely local generation that recycles energy. Combined heat and power plants (CHP), burning coal or natural gas, can deliver a unit of power with incremental net consumption of roughly 1.5 units of fossil fuel, half of the current average for the U.S. These CHP units cover all of their costs while selling power for roughly the current average industrial cost of power, or 5.5 cents per kWh. This is good news for the environment and for future load growth and at worst, neutral to the economy. CHP can serve load growth at today's prices and cut fossil fuel use in half. But this is not society's best first choice.

Recycling industrial waste energy streams is the best electric generation option, up to the limit of waste energy streams. Large energy recycling plants earn a profit from selling electricity at half of the average industrial retail rate. Smaller plants might require 80% of current industrial rates. These plants improve the host's competitive position and help preserve manufacturing jobs. Amazingly, the environmental performance of recycled energy facilities is better than renewable energy. The chart shows that recycled energy from industrial waste energy streams saves a half of unit of fossil fuel for each unit of delivered electricity. This may sound like a violation of the laws of physics, but is correct, as explained below.

The typical waste energy recycling plant starts with hot exhaust, like the Cokenergy plant shown earlier, or with a low energy content gas, such as blast furnace gas, that would otherwise be flared. In other words, these industrial waste energy recycling plants consume no incremental fossil fuel. Then, the plants typically produce both electricity and process steam. High pressure steam is used to drive a turbine generator, and then some of the steam is removed at a lower pressure to provide thermal energy for space heating or other processes, which displaces boiler fuel. These industrial waste energy recycling plants displace boiler fuel by the beneficial use of waste heat, largely left over after electricity generation. Crediting these plants with the boiler fuel they displace allows one to calculate the incremental fossil fuel used to generate electricity. Since waste energy recycling plants start with zero fossil fuel, and then displace a quantity of boiler fuel, the net fossil fuel chargeable to electricity is negative.

The bottom line is profound: waste energy recycling plants reduce pollution, save fossil fuel, and cut the price of electricity. And, unlike conventional fossil generation options, most of the money paid for heat and power stays in the local area, servicing the capital and paying the operators and mechanics.

2.1.1. Energy Recycling Development Requires More Skilled People

Developing local CHP generation and industrial energy recycling requires more skilled people than developing new centralized plants. The same people skills and time needed to develop a 10 megawatt recycled energy plant could develop a 500 megawatt central plant. Each new electric generating plant development requires site acquisition, engineering design, permits, procurement, construction, commissioning, and financing. These are high-skill, high-value jobs and experienced people are in short supply. Furthermore, developing local CHP plants requires mastery of the host facilities' thermal energy needs and/or their supply of waste energy streams. Local CHP plants do not proceed to construction until the developer negotiates complete commercial terms with the host facility, a complication missing from the development of centralized generation plants.

One might think that it would take more operators and mechanics to run a system of multiple local CHP plants than to run a system of larger centralized plants. If this were so, local generation, which clearly requires more people to develop, would also require more operators and thus increase the labor costs embedded in each kilowatt-hour of electricity. But the data shows the reverse; local CHP generation has labor productivity advantages over current centralized generation. The U.S. utility industry employed 409,000 people in 2004, or 39 persons per 100 megawatts of generating capacity (EIA, online). This may exclude some outsourcing of utility functions. By contrast, analysis of Primary Energy's employment data for 13 local CHP plants shows the company employs only 25 persons per 100 megawatts of capacity, thus achieving higher labor productivity than the operators of centralized generation, transmission and distribution. Local generation does not need added transmission and distribution and the related T&D employees, whereas the centralized U.S. electric power system employment included 17 persons dedi-

cated to T&D per 100 megawatts of generation capacity.

Utilities and their regulators see the need for more human resources to develop new generation, as well as the added complexity of understanding and negotiating commercial arrangements with the thermal host/waste energy supplier as a negative feature of local CHP. From the perspective of a power industry executive, local CHP generation is fraught with complexity that would overwhelm existing staff. In fact, a move to local CHP generation could reduce the value of the central generation plant development skill sets that have taken decades to master, just as the move to personal computers devalued skills of some corporate IT managers who had cut their teeth on mainframe computers.

From the regulators' perspective, changing governance to induce the power industry to construct multiple small plants will either vastly increase regulatory complexity, or more likely, will enable the market to perform much of the regulator's job. Either outcome frightens some regulators.

But adding high-skill development jobs to reduce power costs and related emissions would be positive for society.

2.2 WORLD POWER SYSTEM CHOICES

How much capital investment will the world need to continue to embrace yesterday's centralized generation approach instead of satisfying expected load growth with new local CHP plants? A recent study by the World Alliance for Decentralized Energy extended the above analysis to determine the costs of supplying world electric load growth through 2030, and compared the two 'bookend' or extreme cases of all centralized generation or all local generation to serve the world's expected electric load growth. The International Energy Agency (IEA) base case for 2030 assumes the addition of 4.4 billion kilowatts of new electric load (4,370 gigawatts). Using current capital cost estimates for the likely mix of generation plants, WADE found that the expected increase in electricity demand would require worldwide capital outlays of \$10.8 trillion to supply the expected 2030 load growth with central generation. On the other hand, supplying the increased demand with local CHP plants would require capital outlays of only \$5.8 tril-

lion. The local CHP generation approach would thus save the world \$5.0 trillion of capital.

This analysis of power system choices suggests that the U.S. power system has not made optimal choices and that these poor choices have increased fuel use, pollution, and the cost of delivered power. Furthermore the centralized approach has strongly negative impacts on the environment, grid reliability, and economic growth versus a more optimal system. Yet, the myth that the U.S. power system is economically and environmentally optimal, given current technology lives on and informs policy decisions. To understand the perpetuation of this myth or ‘mindset’, we turn to an analysis of power industry governance.

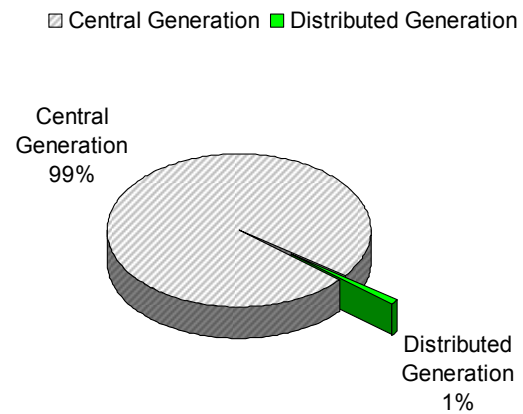
Part 2: Understanding Power Industry Governance

3. Conventional Thinking versus Free Market Economics

If the above analysis is correct, why then does nearly every country continue to build new centralized generation to serve electric load growth when local CHP plants are more efficient and less polluting, require half of the capital, and reduce system vulnerability to weather and terrorism? Is this analysis flawed, or is there a flaw in conventional thinking?

Facts suggest the latter. The power industry will not make economically optimal choices until all players face true competition. This is especially so for those entities distributing electricity. The record shows that the regulated power industry has shunned local CHP generation. Between 1970 and 2003, U.S. regulated utilities, including government owned utilities, built 435,000 megawatts of new generation. An incredible 99% of this new capacity came from centralized plants that cannot recycle waste energy streams in lieu of fossil fuel.

Chart 3: 435,000 MW New Generation Built by U.S. Electric Utilities, 1973 – 2002



U.S. independent power producers built 175,000 megawatts of new power in the same period, of which only 34% is able to recycle waste thermal energy. The independent power companies largely stopped developing local CHP plants after 1992 when the federal law was changed to allow non-utility generation that does not recycle energy. The power industry has been able to avoid the complexity of developing multiple small plants that must interface with user waste streams or user thermal requirements, because local competition is largely blocked by power industry regulations. Without more open competition and/or mandates and incentives, the power industry will continue to build central generation and discard waste energy. Few power executives in either regulated or unregulated power companies relish the complexity of building many small energy recycling plants, even though the result would be to reduce power costs and pollution.

3.1 GOVERNANCE PRESERVES WASTE

In competitive free markets, such suboptimal behavior would be an entrepreneur’s dream, promising rich opportunities for profits. Entrepreneurs would actively search for ways to capture market share by offering better value propositions. But current power industry governance blocks competition from local generation.

The most important barrier to competition, as mentioned earlier, is the universal legal prohibition against private electric wires crossing public streets. This ban is supported by a century-old ‘natural mo-

nopoly' argument. According to the original economic theory, it would be a waste of resources to build two sets of electric wires. Consumers should thus benefit from governance that gives one organization a distribution monopoly in each geographic territory. This same 'central planning' logic wrecked the soviet economy, yet seems to go unchallenged in regard to electric power system governance. The good news is that monopoly-protected wires are just about the last vestige of failed central planning. The bad news is that the ban on private wires virtually guarantees continued mediocre performance of the world's largest and most important industry.

If restricting private wires ever made sense, which is doubtful, the logic had to be based on yesterday's limited technology choices. Electric distribution might be a natural monopoly if the only way to economically produce power was in large remote central plants, in which case all electricity would then have to flow through the distribution wires. But today there are abundant, proven ways to generate electric power locally. In fact local generation uses substantially the same technology and same fuel used by central plants. Local generation needs no long-distance transmission systems to deliver power to users, and excess power produced locally could simply flow across the street. Regulations typically allow private pipes to transport excess heat across public streets to nearby users, but ban private wires from moving excess power across the same street. Local CHP power, using modern technology, could and would compete with central power if laws allowed private wires.

Consider the real life example of the McCormick Place Convention Complex in Chicago, IL, which is North America's largest convention center. In 1991, Trigen Energy Corporation won a bid to supply the heating and cooling to the three large halls and could have generated roughly 20 megawatts of electricity, or two thirds of the McCormick Place load and then used recycled waste heat from power generation to supply all of the heating and cooling needs (using heat driven absorption chillers). This would have produced electricity at a net efficiency of 80%, more than double the 33% national average. But the power plant site was separated from the convention center by local commuter rail lines that belong to the city. Illinois law, like every other state, prohibits electric wires that use (cross) the facilities of the state or any subdivision thereof. This banned Trigen from crossing the rail right of way with a private wire to supply

discounted electricity to McCormick Place. Com Ed's offer to purchase the power for 20% of the retail price was uneconomic, so the plant was built without fuel and money saving combined heat and power.

The bans on private wires are supposed to reduce societal costs by preventing the wasteful construction of duplicate wires. Ironically, the bans dramatically increase society's overall investment in wires. Remote power generation requires long transmission wires, transformers, capacitance banks, and inductance banks that local generation avoids. The universal bans on building cheap, short local wires leads to the construction of expensive, long transmission wires. Electric customers pay for these extra wires.

Another flaw in governance is the well documented and probably inevitable capture of regulatory agencies by the industry they regulate (Lowi, 1979). Regulators come to believe it is their job to protect the financial health of the monopolies they regulate, even if their decisions hurt consumers. A stunning example can be found in recent California experience. When a series of governance blunders threatened utility financial health, the state of California purchased the transmission wires, saving the utilities from bankruptcy. Their very next action was to end California's four year old experiment that allowed local CHP generators to run wires to adjacent electric power users. California chose to go back to the future.

Allowing everyone to build private wires would not result in a tangle of new wires. If a local power developer has the right to sell power via private wires to neighbors, the local distribution utility will offer competitive prices to move that power in their existing wires. This is precisely what happens in natural gas distribution, where private pipes are allowed to tap transcontinental natural gas delivery pipes. When gas users receive FERC approval to tap the interstate pipe, the local gas distribution companies knock on their door and say, "Let us reason together." Deals are made good for both parties. With the ban on private wires removed, the electric distribution utility might even decide to compete more fully by offering local CHP options to customers. Competition would work its usual magic, reducing consumer prices and wringing inefficiencies out of the system.

Experiments with deregulation have mostly focused on opening competition among central plants, not realizing that this is like 'clapping with one hand'. This approach to deregulation assumes that the only viable

competition will be from other remote, centralized plants. But a power entrepreneur cannot truly compete without the unfettered ability to deliver product to customers. The private wire prohibition blocks much potential competition from local CHP generation.

An example will illustrate this point. Primary Energy is a company originally formed in the early 1990's to develop, build, and fund projects that recycle waste energy in Northern Indiana steel plants. In 2000, the company expanded to offer similar services all over North America. Today, the firm owns and manages 13 energy recycling projects with cumulative generation capacity of 780 megawatts of electricity and 5.0 million pounds of steam. The company's Chair and CEO is one of the authors (Casten). In 2002-3, Primary Energy was developing a facility to recycle the waste gas produced by a carbon black manufacturer in Louisiana. The carbon black plant flared enough low grade fuel to generate about 30 megawatts of electric power. The new energy recycling plant would be expensive, costing over \$50 million, but with no fuel cost, the plant could sell power at a discount to retail prices and still earn a profit. Permitting was easy because the EPA recognizes that boilers burn waste gas more cleanly than flares, thus reducing pollution. The potential project was designated a pollution control device.

The carbon black facility that produced the waste gas required only 10 megawatts of electricity – one third of the recycling facility's output. The carbon black plant paid the local utility roughly \$55 per megawatt hour (5.5 cents per kilowatt hour). They agreed to purchase their power needs from the recycling facility for \$40-\$45 per megawatt hour, saving \$10 to \$15/MWh, or \$800 thousand to \$1.3 million per year. The project economics depended upon the sales price for the remaining 20 megawatts.

There was another industrial facility across the road, less than one half mile away, which also purchased power for \$55/MWh, and could have saved over \$1.6 million per year by purchasing power from the recycling facility for \$45/MWh. **However, moving the electricity from the recycling facility across the street to the second factory was and is illegal; private wires are banned in Louisiana, as well as in the other 49 U.S. States.** The only legal outlet for the excess power was sale to the local utility. The astute reader may sense the next step.

The utility initially offered to pay Primary Energy \$20/MWh (2 cents per kilowatt hour). After one year of negotiation, the utility upped its offer to a princely \$28/MWh, roughly half of the retail industrial price. Accepting such a low rate would have required the energy recycling project to charge higher rates to the carbon black factory and probably kill the deal. So the Primary Energy developers kept negotiating. The team met the Governor, pointed out the job benefits of the project, and asked him to intervene and require the utility pay fair prices. The intervention, after much delay, bore some fruit, causing the utility to raise its offer to \$38 per megawatt-hour. But two years of negotiations had, by then, taken a fatal toll. The carbon black company developed deal fatigue – lost interest in more delays – and the development was stopped. Four years later, the carbon black factory continues to flare its gas. Over one billion kilowatt hours of fuel-free electricity have been lost in those four years.

But the story is not over. The utility has since been granted approval by the regulatory commission to build new transmission lines and to build a new central generation plant to serve this area's growing load. The new investment will raise every customer's electric rates and increase local air pollution. These rate increases and wasted fuel would all have been avoided, but for governance problems.

Many other regulatory barriers that block local generation could fill another chapter. Instead of detailing each barrier, we look briefly at how governance can encourage more optimal power industry behavior. We divide the answer into two parts, beginning with a theoretical economic approach, followed by suggestions for gradual changes.

3.2 GUIDANCE FROM ECONOMIC THEORY

Economists offer clear guidance on how to stimulate innovation and drive any industry towards optimal production: *expose that industry to market forces*. To work well, markets require that:

- There is free entry and exit into the business (i.e. no barriers to entry, no subsidies to prevent failure)
- Prices send clear and accurate cost signals
- There is an absence of subsidies that distort pricing decisions

- Externality costs are passed on to customers
- Predatory practices are prohibited.

No power industry governance in any territory in the world embodies all of these conditions. Consider typical power industry governance:

3.2.1. *Entry Is Blocked*

Partial deregulation has allowed new entrants to central power generation, which has reduced some waste. But governance everywhere has continued to enforce local distribution monopolies and left incentives for local utilities to block local CHP generation. To compete, entrepreneurs must be allowed to build local power plants. Limiting competition to central generation is like allowing new competitors in a foot race but only if they have their feet tied together.

Governance rules do not typically legally ban local CHP generation. However, various rules prevent local power plants from capturing all of the value they create and create road blocks that delay development. Although some local CHP projects struggle past all of the obstacles and are built, most die before birth. A local generation plant displaces the host's purchased power at retail prices, which include costs of transmission, and thus can capture some grid displacement value. But regulators then allow excessive standby rates that take the value back. Excess power can only be sold to the grid at wholesale prices, even though all excess power automatically flows to nearest neighbors, who are then forced to pay retail prices.

Example: Sugarcane factories all over the world typically burn the cane residue, called bagasse, in old and inefficient power plants that generate only enough electricity and steam to meet the sugar mill needs. The rest of the bagasse is simply incinerated – its energy content is wasted. Local utilities, which are often government owned, either refuse to purchase power from local producers, or offer only a small fraction of retail power prices. Such prices make it uneconomic for the sugar mills or third parties to invest in power generation that exceeds the sugar mill's needs. This is a terrible waste, because a modern power plant would convert the bagasse into three times the electricity needed by the sugar mill and thus supply power to the surrounding rural area. When local utilities have been forced to offer fair prices, the sugar industry has built new plants that efficiently recycle the remaining energy potential in the bagasse. Recent

regulatory changes in India have induced 87 sugar mills to construct over 750 megawatts of new recycled energy capacity, and are expected to call forth 5,000 megawatts of recycled energy over time, which would be roughly 5% of India's present generation capacity (Natu, 2005). The resulting power is pristine, burning no incremental fuel (the bagasse would have been burned for disposal anyway) and emitting no incremental pollution.

3.2.2. *Energy Price Signals Are Misleading*

Functioning markets depend on accurate and timely price signals, but electricity is typically sold at average prices, even though marginal costs are up to ten times higher during peak hours than during off peak hours. Real-time pricing would cause consumers to shift some power use to off peak periods, reducing system peak loads and reducing the average cost of electricity. Real time pricing would signal power entrepreneurs to develop new on-peak generation and to store energy during off-peak hours for on-peak use. Prior to the explosion of computer technology, the cost of metering use in real time was expensive and limited to large industrial customers. For the past decade, the power industry could purchase and install relatively cheap meters that record real time use and receive signals over the electric wires with the instant marginal price of power. However, little has been done to modernize the method of selling power in real time.

Example: California's electric system peak is 50,000 megawatts, which strains the grid and has caused frequent brownouts. California consumers, seeing only average prices, use 1,000 megawatts of power during peak hours to wash their clothes.⁸ Accurate price signals would allow these consumers to reduce their electric bills by washing clothes during off peak hours, and might induce appliance manufacturers to add smart controls to washers and dryers, automatically shifting loads.

3.3 ENERGY PRICE SIGNALS, PART TWO

In 1978, Congress enacted the Public Utility Policy Reform Act, or PURPA, which was intended to promote more efficient generation. Third parties were

⁸ Comments from William Reed, Senior Vice President, Regulatory Affairs and Strategic Planning, San Diego Gas & Electric at the West Coast Energy Management Conference on June 28, 2005.

allowed to own and operate power plants that combined heat and power generation and met certain efficiency tests or that produced ‘bottoming cycle’ power, recycling energy streams left over from some industrial process. We refer to these ‘bottoming cycle’ plants as industrial waste energy recycling facilities. Such facilities were exempted from Federal Power Act regulations. PURPA refers to all of these facilities as ‘qualified facilities’ or QFs for short.

PURPA required states to induce construction of more efficient generation by causing utilities to purchase power from qualified facilities at the utilities ‘avoided costs’ or such other arrangement that each state felt would induce construction of more efficient plants.

Much can be learned about the power industry by studying the responses to this 1978 law. Regulated utilities objected and have generally worked ever since PURPA’s enactment to blunt or repeal the law. One group of utilities repeatedly challenged the constitutionality of PURPA, and appealed three separate cases all the way to the U.S. Supreme Court. The Court found PURPA constitutional in all three cases, with the last ruling in 1984. Fighting these cases all the way to the Supreme Court totally stopped entrepreneurs for six years.

Some states enthusiastically embraced PURPA and set arbitrary prices for ‘avoided costs’. New York initially offered QF facilities 6¢ per KWh, while Maine offered 10¢ per KWh. In other cases, commissions asked the regulated utilities to specify what plant they would build as the next electric generating unit, and then used the economics of that plant as a bogey for avoided costs. Other states did nothing. In the 28 years since PURPA enactment, we are unaware of any contract ever issued to a QF in Louisiana, South Carolina, South Dakota or Kentucky.

The utilities have worked hard and often successfully to persuade their commissions to lower the offered ‘avoided costs’ to only cover short run avoided costs. The short run avoided costs only cover fuel and incremental maintenance while ignoring longer term costs of capital amortization, T&D construction and losses, and system redundancy requirements. Commissions have been asked to believe that wholesale power market competition will drive electric wholesale prices down until they just cover short run incremental costs – fuel and marginal operating costs. Since no one can afford to build new generation for

only wholesale spot prices, no CHP is built, and society then pays higher prices for central power.

The most revealing part of the 28 year PURPA history is the way commissions have determined what costs new local generation plants would avoid. By and large, the analysis has been limited to the avoided cost of new central generation only. To be of use to customers, centrally generated power must be delivered through T&D systems and include the costs of line losses, redundancy, and T&D capital amortization. Local generation avoids most T&D, line losses, and redundant capacity costs and should receive value for avoiding these costs. But state regulatory commissions have typically approved ‘avoided costs’ that do not include savings due to avoided T&D capital or avoided T&D losses. This failure to ask the right question – what is the delivered cost of power for each option – goes far to explain the continuing reliance on suboptimal central generation.

A current example demonstrates how such governance fails to produce economically rational power industry decisions.

3.3.1. Case Study: Recycling Energy from Silicon Production

Silicon metal is used in over 2500 products from bathtub caulk to aluminum alloys to computer chips and solar collectors. Current world production of metallurgical grade silicon is about 3 million tons per year, of which only 300 tons or 10% are produced in the U.S. Silicon production is energy intensive; energy represents one third of total production costs. Quartz rocks, coal, charcoal, and wood chips are continually fed into smelters, which are then heated to 3000-5000 degrees Fahrenheit by electric furnaces. For obvious reasons, silicon factories are located in low priced electricity territories.

It is technically feasible to recycle exhaust from silicon smelters and generate nearly one megawatt-hour of fuel-free electricity for every two megawatt-hours of electricity used by the smelter. The waste energy stream of hot exhaust comes from the electric arcs as well as from burning coal, charcoal and wood chips. Typical silicon factories use 40 to 120 megawatts for smelting and could thus produce 20 to 60 megawatts of fuel-free power by recycling hot smelter exhaust.

Now, our story gets interesting. The capital costs for a new energy recycling facility are about \$1.8 million per megawatt of capacity. If the recycling facilities

sell electricity for \$35 to \$45 per MWh, the owner can cover operating costs and repay the capital investment. This compares to \$55 per MWh charged to the average U.S. industrial customer and \$96/MWh for the cheapest new central generation, so there would seem to be an economic logic to building these recycling plants. But the silicon plants are located in low-cost power areas such as West Virginia and Alabama, where they currently purchase power for \$30 to \$35 per MWh. Thus a silicon factory could lose money if it built a recycling facility only to displace its own purchased power.

Is this a good outcome for society? Is it good policy in Alabama or West Virginia? We think not, for the following reason. Electric power demand is growing in both states. The delivered cost of power from a new coal-fired plant will be roughly \$96 per MWh. Serving this load growth with any other centralized option will require even higher costs for incremental delivered power. Both states would clearly benefit from meeting load growth with energy recycling facilities that deliver electricity for \$35 to \$45/MWh.

Under current regulatory policy, this will not be the outcome. As we have seen, the recycling plant is not economic if it simply displaces \$30 retail power. This leaves no savings for the silicon factory and thus no reason for them to spend time on an energy recycling project. If the recycling plant developer seeks to sell the power, the local utility will claim it can purchase wholesale power on the spot market at even lower prices, and the regulators seldom intervene in favor of higher prices.

Current utility actions all over the U.S. illustrate the problem. Utilities are asking and receiving permission from regulatory commissions to build new coal plants that will go into rate base. For example, the Colorado Public Service Commission authorized Xcel to construct a new coal plant to meet load growth. The construction costs, including elaborate pollution control equipment, will go into the rate base. The plant will require added transmission lines, which will also go into rate base. After 2009, when the plant is expected to be completed, Xcel will ask for rates that recover all of the fuel and operating costs, all of the capital amortization, including T&D and sufficient profit to generate the allowed rate of return.

The regulators apparently examined the average cost for power from the proposed new coal-fired plant without considering T&D capital and losses or redun-

dancy needs, because the same commission allows Xcel to offer only the prior years average coal cost per megawatt-hour to CHP plants. Primary Energy's 85 MW CHP plant is located in Greeley Colorado, and all 85 megawatts would be consumed in the Greeley area, freeing transmission wires. The commission allowed Xcel to offer only \$12 per MWh to this CHP plant in 2005, but has allowed Xcel to build a new coal plant that will require an incremental \$90 to \$100 per MWh to deliver power to Greeley. Regulatory commission analyses, by ignoring power delivery costs, typically conclude that it is prudent for the utility to build a new central plant, even though local CHP provides a significantly cheaper option.

Sadly, this story has been the norm for many years. Most of the time the governance system ends up choosing suboptimal central generation to serve expected load growth. In the instant case, average rates to consumers will increase and Colorado's energy intensive factories may even close, unable to compete with foreign production. The new central generation plants will burn three units of coal or natural gas for each unit of delivered power, with associated carbon dioxide emissions. So far, political leaders have responded to pressure to limit greenhouse gas emissions by appropriating taxpayer funds to subsidize renewable energy capacity, which will further increase electric rates, but lessen pollution.

Everyone's goal should be a system of regulation/free markets that permits (better yet encourages) the maximal deployment of recycled energy plants. The outcomes would then be very different: average power costs would fall, air pollution including greenhouse gasses would fall, and manufacturing competitiveness would improve.

3.3.2. Energy Subsidies Are the Rule

Subsidies of any product distort price signals and lead to suboptimal investments. But this undisputed economic fact is honored in the breach in the global electric power industry. All over the world, politicians have responded to citizens' desires for cheaper energy by subsidizing various parts of the energy system. These subsidies, which are paid out of tax revenues, buy down electric prices to consumers and thus signal those consumers to overuse energy and to underinvest in conservation and efficiency.

Example: State and municipally owned power systems, unlike other manufacturing enterprises, pay no

income tax and are allowed to issue tax exempt and/or taxpayer-backed debt with interest rates well below those paid by competitive industries. Tax credits for wind, solar, geothermal, and biomass power generation subsidize power from these technologies. These subsidies hide the true cost of electricity, encouraging waste. Consumers collectively pay for all the subsidies, because governments must tax other activities to make up for lost revenues. But the subsidies lead to many sub-optimal decisions that increase the cost of heat and power. Although energy subsidies represent a true 'lose-lose' policy, they are nearly universal.

Second Example: The 2005 U.S. Energy Policy Act (EPACT) gave a bonanza to the oil and gas companies who leased blocks of drilling rights in U.S. territorial waters in the Gulf of Mexico. A provision in the law waived the royalty payments for oil produced on federal property in the Gulf of Mexico, even though such payments are required for oil produced on all other federal property. In other words, EPACT said to the oil companies, "You may extract the oil from these federal lands without paying anything to the federal government." The New York Times estimated this subsidy will cost taxpayers between \$7 and \$28 billion over the next five years (Andrews, 2006). The subsidy does very little to help the American consumer. The lease-free oil either increases oil company profits or finds its way into the world price of oil, and the subsidy is thus dissipated over the world's oil consumers. But the loss of revenue must all be made up by U.S. taxpayers. To the extent this subsidy of oil companies lowers oil prices, it obscures the true cost of using oil and gas, thus making investments in energy efficiency less attractive than their true economic impact.

3.3.3. Externality Costs Are Not Included in Energy Prices

Businesses and consumers typically ignore the costs of externalities unless these costs are included in the product's selling price. Fossil fuel taxes seldom cover the externality costs of burning fossil fuel, thus understating energy costs.

Example: Societies pay health costs caused by pollution from burning fossil fuel with tax-supported Medicare, health insurance, and individual medical bills. Other taxpayer funded programs pay to remediate acid rain damages. Recent legislation seeks to mitigate climate change caused by fossil fuel emissions with taxpayer funded programs. These actions,

by using tax dollars to pay for the externality costs of burning fossil fuel, hide the true cost of energy from energy users. Taxing fossil fuel to recover the estimated externality costs would increase the cost of electricity and stimulate investments in efficiency. This could be made tax neutral by lowering other taxes. Because European countries tax fossil fuels more heavily than is the case in North America, Europeans have invested heavily in energy efficiency. Typical European countries produce a dollar of gross domestic product with half of the fossil fuel that is used to produce the same dollar of GDP in the U.S.

3.3.4. Predatory Monopoly Practices Are Protected by Law

Dominant incumbent firms can often afford to engage in predatory practices, offering products at below cost until the low prices destroy competition. The dominant firm can then raise prices to new highs and extract 'monopoly rent.' To prevent such predatory actions, governments have enacted anti-trust rules. These rules apply to nearly all business activity and help promote and preserve competition. But the anti-trust rules do not apply to electric utilities, which are allowed to engage in precisely the predatory practices that are banned in all other businesses.

Example: Many regulatory commissions allow electric utilities to offer discounted rates for 'all electric' buildings that agree to use electricity for all heating, cooling and lighting. This discourages non-electric heating and cooling systems that are more fossil-efficient. A large office complex that uses CHP for some of its power does not qualify for the 'all electric' rate and thus pays a premium for the power they purchase from the grid. By contrast, when Kodak offered lower prices for copiers to those consumers who also agreed to purchase maintenance from Kodak, the Supreme Court held that this violated anti-trust statutes against product bundling. There are many other examples of predatory practices by electric utilities that are allowed by current power industry governance.

Power industry laws and regulations throughout the world thus ignore the lessons of economics. Without these minimum conditions, Adam Smith's 'invisible hand' cannot work; the power industry continues to waste energy and capital.

3.4 POLICY OPTIONS TO ENCOURAGE RECYCLED ENERGY

We now move to suggestions for regulatory changes that would induce more optimal behavior. Changing power industry governance will not be easy, given the widely believed myths and the vested interests of a century of monopoly protection. Politicians risk unemployment when they propose to tax energy or to remove energy subsidies. The citizens who receive subsidized power inevitably band together to oppose any party or politician who threatens their subsidy. These efforts typically overwhelm the much larger and more diverse group of taxpayers who fund the subsidies.

Happily, there are some politically feasible first steps. Removing barriers to innovation and mandating clean energy are less politically charged than fully opening competition; such changes could be enacted. Small policy changes will deliver appreciable benefits to the public and create a case for further unleashing market forces to wring waste out of the world's largest and most important industry. The public has experienced problems stemming from poorly designed partial deregulation, such as occurred in California, but has not recognized the full benefits. We suggest some first steps that will start society towards full power industry competition.

Policy Change: Allow local CHP generators to build private wires to a limited number of retail customers, sufficient to transmit excess capacity. Alternatively, require commissions to set variable grid charges based on the distance the power will move and the relative tightness of the existing network. The simple 'postage stamp' rates that are employed in most jurisdictions charge all generators the average cost of moving power across the state, which obscures the transmission benefits of local generation.

Policy Change: Each state regulatory commission modify the rules for utility returns on capital so the utility will not be penalized from loss of load to local CHP generation or from efficiency investments by customers that reduce electricity sold by the utility. At present, most rates are set based on a test case of presumed electricity consumption by each class of customers. If exactly that amount of consumption occurs, the utility should earn the allowed 'target' rate of return on their invested capital. But if the consumption is less, due to conservation, local generation, or depressed economic performance in the area,

the utility profits drop sharply. The inverse is also true and load growth is richly rewarding for the typical utility. The Regulatory Assistance Project (RAP) in Montpelier Vermont has crafted some innovative approaches that isolate the utility from lost profits due to conservation and local CHP generation. If enacted, such programs remove the misalignment of utility shareholder interest with societal interest.

Policy Change: Make recycled energy eligible for all Renewable Portfolio Standards (RPS). Many states and nations have recently enacted laws mandating that a growing percentage of power be obtained from a specified list of clean energy technologies. These rules usually limit eligibility to renewable energy, mistakenly assuming this is the only 'clean energy' option. We suggest the rules should also credit power recycled from industrial waste energy and credit thermal energy recycled from local CHP generation plants. Five U.S. states (North Dakota, South Dakota, Nevada, Connecticut and Pennsylvania) have included recycled energy in their clean energy portfolio standards.

The U.S. Congress considered enactment of a national Renewable Portfolio Standard in 2001, but the measure, mandating a growing percentage of power be generated by renewable energy sources (solar, small hydroelectric, wind, and certain biomass) met strong opposition for good reasons, and was not enacted. By requiring all states to obtain a growing percentage of their electric power from clean sources, but then limiting the definition of clean energy to power produced from renewable energy sources, the proposed law would have created a wealth transfer from most of the states to the 7 to 8 states with extensive wind resources. Wind, as shown above, is far cheaper than other sources of renewable energy. Wind would have been the 'clean energy' of choice, forcing most industrial states to pay subsidies for wind power in the windy states. By contrast, every state has many opportunities to recycle industrial waste energy and to deploy CHP plants that recycle heat from electric generation.

An amendment to the National RPS proposal that included recycled energy was discussed with House and Senate leaders in 2001 and was well received, until several environmental activist groups ganged up and threatened to withdraw support for a national RPS if the bill made recycled energy eligible to compete with

other clean energy.⁹ The environmental organizations who opposed adding recycled energy wanted to cause development of renewable energy technologies at any cost and were fearful that recycled energy would undercut the premiums paid for renewable energy. The question of proper national goals is at the root of this conflict. Is the goal to produce more clean energy at the lowest possible cost, or is the goal to stimulate the development of certain types of clean energy technology? We suggest the goal should be to induce more clean energy at the lowest possible cost. Enacting a national 'clean energy' portfolio standard that includes recycled energy should be politically feasible, since every state has the potential to recycle energy.

One objection to including recycled energy in portfolio standards bears further discussion. Opponents to including recycled energy in the RPS mandates point to a second political goal, namely to create new industrial clusters that will manufacture tomorrow's technology. Denmark's mandates for increased wind power created a strong local market for wind turbines, which enabled Danish firms to develop and sell world class wind technology. We suggest that energy recycling is also an important future industrial cluster, with double benefits. Laws mandating more recycled energy will help entrepreneurs develop recycling technology for export, and will encourage existing local industries to recycle energy, thus improving their competitiveness.

Policy Change: Require grid operators to interconnect in parallel with backup generators, in return for the right to purchase power from those generators during extreme system peaks and emergencies. The U.S. has standby generation installed in hospitals, prisons, critical industrial facilities and high rise buildings of roughly 90,000 megawatts of capacity, roughly equal to 12% of U.S. electric system peak. However, very little of this standby generation capacity is interconnected with the grid. In the typical arrangement demanded by the local electric distribution monopoly, the standby generators are required to be electrically isolated from the grid at all times. When the grid fails, the breakers open such that no electricity can flow to or from the grid, and then a second or two later, the breakers close between the standby gen-

eration and selected building emergency loads. When the grid returns to service, there is another power outage before reconnecting the building/facility to the grid. This clearly prevents the use of the standby generation to produce any of the power the facility needs while connected to the grid, and thus prevents the standby generation from helping to supply system peak electric loads.

When the grid is strained, very little of the 12% standby capacity can be used to avoid full system failure. In the August of 2002 transmission wires in the northeastern U.S. and Canada became overloaded and began to fail. System operators rerouted more power over the lines still in service and those lines either failed or were shut down by automatic safety devices. Over 50 million consumers lost power for 24 to 60 hours with incredible economic disruption and costs. If the utility regulators had demanded that all standby generation be interconnected with the grid, just like all of the centralized power plants, the utilities could have requested standby generation to ease the transmission overload, and the blackout would never have occurred. Using standby generation to shave extreme electric system load peaks would lighten grid loads, help avoid brownouts and blackouts, and save lives. Parallel standby generation could also, by shaving system peaks, avoid the cost of new T&D. This change has great significance to local CHP development, which is often frustrated by the utility's refusal to interconnect in parallel with the grid.

Policy Change: Require utilities to pay local generators for the full value that such plants provide to the grid, including avoided capital cost for generation and T&D, saved line losses, reduced pollution, and grid voltage support. Utilities always ask regulators to approve charges to local generators to pay for backup service provided by the grid, which is reasonable. But commissions need to invert the analysis and ask utilities to pay local generators for the services they provide to the grid.

A recent study conducted at the University of Massachusetts found that each kilowatt of new distributed generation installed in Boston would produce a net societal benefit of \$351 per year. In other words, the savings of capital investment in the grid and the value of reduced line losses, less the costs to the utility of providing backup service to the local generator netted out to a value to the grid of \$351 per year per kilowatt of new capacity. Ignoring this study, Massachusetts

⁹ One of the authors, Casten, worked with the Senate Energy Committee in 2001 to craft the proposal to include recycled energy, and discussed the proposal with then House Commerce Committee Chairman, Billy Tauzin and others, with positive reception until the environmental groups persuaded Senators on the Senate Energy Committee to oppose the change.

regulators recently approved standby charges in Boston of \$114 per year for each kilowatt of local CHP generation capacity. Regulators allowed a deal without a rate case that requires Boston CHP plants to pay an annual penalty of \$465 per kilowatt of capacity for the right to operate with grid backup (Receive nothing for the \$351 per year net benefit they provide and pay a \$114 per year penalty) (Kosanovic and Ambs, 2005). Not surprisingly, no one is building new local CHP generation in Boston.

Policy Change: Make carbon savings from recycled energy eligible for ‘green tags’ and carbon trading credits. Many electric consumers voluntarily pay a premium for clean electricity but the choices are limited to renewable energy. Including recycled energy will increase clean energy production and reduce its cost.

Although these suggested policy changes are only a start, they will create significant benefits and weaken the centralized generation mindset. The business-as-usual approach will, as always, command great allegiance from incumbent firms who benefit from present rules. But the rapidly growing energy disaster requires dramatic change, fresh ideas, and political leadership.

4. The Stakes Are Very High

We close this chapter with a warning that continuing the current power industry governance has dire consequences to the economy and the environment.

Continuing current power industry governance in the face of rising fossil fuel prices could not only stop income growth, but could even lead also to declining per capita incomes. The long term trends that have lowered the cost of energy services throughout the 20th century have stalled, threatening to severely disrupt economic progress. Average delivered electric generation efficiency has not improved significantly since 1959. Fuel prices are three to five times 1999 levels. Power quality is costing the U.S. economy nearly \$200 billion per year according to a recent Electric Power Research Institute study (EPRI, online). Transmission systems are strained, such that extreme weather regularly disrupts electricity supply. Vehicle and appliance efficiency gains have slowed.

Continuing current power industry governance will, without doubt, accelerate the emission of greenhouse gasses and thus speed the global warming trends that

are causing climate changes and disrupting the entire ecosphere. It makes no sense to block electric power innovations and cause excessive burning of fossil fuel and concomitant excessive emissions of carbon dioxide and excessive power costs.

Continuing current power industry governance will exacerbate several other major problems. The centralized generation system is vastly more vulnerable to extreme weather and terrorists than a system of local generation, and this vulnerability is being tested by the increasingly violent storms like Katrina and Rita of 2005. Those violent storms do not ‘prove’ global warming but are consistent with climate scientist’s prediction of weather changes from increasing average global temperatures. Senator Lugar of Indiana and James Wolsely estimated that the U.S. is spending \$100 billion per year defending access to foreign petroleum and natural gas supplies, and these costs are exacerbated by the 17 quads of fossil fuel that are needlessly burned to produce heat and power in the U.S. Finally, rising power prices exacerbate the loss of manufacturing jobs.

The stakes to the economy from energy efficiency may be much higher than generally realized, and a final comment is called for at this point. Though the full story is too complicated to tell here, there can be little doubt that productivity increases and economic growth in the past have been driven very largely by the use of fossil fuels to drive machines – notably steam engines and internal combustion engines (Ayres, *et.al*, 2003, 2005 and 2006). These, in turn, have performed useful work (much of it electric) and substituted energy services for human and animal labor. For over two centuries these ‘engines of growth’ have contributed to, and been driven by, declining fossil fuel prices and increasing efficiency of conversion of raw energy to ‘useful work’ – especially to electric power.

But industrial societies are now dealing with sharply higher prices for petroleum, natural gas, and coal. Ubiquitous energy subsidies and the current energy governance stoke the demand for fuel and induce further fossil fuel price rises in ways described above. Outmoded regulatory policy forces further increases in average electricity costs by demanding clean energy but restricting the supply to only renewable energy sources. The consequences, in the absence of a major structural change, could be reduced economic growth, extended recession and declining standards of

living. The stakes are high, and energy recycling with local CHP plants is the single most promising strategy for avoiding this threat.

Political leaders have failed to fix governance, but have mandated higher energy prices be paid for certain types of clean energy. We believe this strange behavior is explained by the assumption that the present energy system is economically optimal. This entire book shows the fallacy of the prevailing energy myths. The power system is neither economically nor environmentally optimal.

In a way, this is good news. To paraphrase Al Gore's new movie, our findings are 'convenient truths.' Political leaders seeking to mitigate climate change, reduce fuel imports, and preserve jobs, have attractive choices. Indeed, society can "have its cake and eat it too". Demand clean energy and remove barriers, rule sets and mindsets, and power industry entrepreneurs will deliver clean, affordable, sustainable heat and power. By contrast, the alternative of continuing with the century-old central generation paradigm will slash economic growth and could lead to declining standards of living.

As shown above, the costs to the world of continuing to service electric load growth from centralized power plants that cannot recycle energy are very high. Spending \$10.8 trillion to supply global electric load growth over the next 30 years with central generation will greatly worsen CO₂ emissions. Moreover, according to the International Energy Agency, business as usual will still leave over 1.4 billion people in a state of energy poverty (IEA, 2002). The world would be better off to deploy local generation with doubled efficiency, save \$5.0 trillion, and then use some of the savings to extend energy services to all people.

There is no reason to settle for current energy inefficiencies. *Energy recycling is economically advantageous using existing technology.* But because energy recycling requires massive human resources to develop, it will proceed slowly unless mandated, either by governments or by market forces. We believe the best way to improve energy system efficiency is for governments to heed the lessons of economics and fully expose the power industry to market forces. Failing such full deregulation, performance can be improved by eliminating regulatory biases against local CHP generation and by encouraging energy recycling. Once the public sees the benefits, support for more comprehensive changes will grow.

It should be emphasized that there is no need to eliminate existing central generation capacity. A great deal of new local generation is needed just to meet the world's expected electric load growth and cover retirement of the aging fleet of central plants. Nor is there any reason to weep for the established utilities. Nothing should prevent these organizations from participating in the inevitable (and profitable) new market for decentralized CHP plants that recycle energy.

It is time to challenge the widely held assumptions among economists and policy makers that central generation and monopoly protected electric distribution are optimal. Like Voltaire's *Candide*, these folks assume (contrary to evidence) that this is "the best of all possible worlds." Global economic and environmental health depends upon the speed at which governments stimulate economic efficiency in the world's largest industry: electric power production and distribution.

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