

Not All Megawatts are Created Equal

Tom Casten, (Other authors pending)

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Contrary to most regulatory treatment, all megawatts are not equal. In fact, one megawatt-hour generated near users with a distributed generation plant (DG) can displace 1.2 to 1.45 megawatt-hours from centrally generated (CG) units. We will show that installing 80 gigawatts of well-placed DG could reduce U.S. end-user electric costs by \$21.5 to \$36 billion per year, free transmission lines to carry over 100 gigawatts more renewable energy, and avoid 4.4% of U.S. greenhouse gas emissions.

Treating all megawatts as equal – paying a DG MWh the same price as a CG MWh – discourages DG deployment and attendant benefits. Emerging generation and transmission competition has not yet induced an optimal electric supply, largely because regulators do not recognize nor reward the true value of DG power.

No doubt megawatts were roughly equal in yesterday's world of integrated electric monopolies. Each utility generated electricity in remote stations for delivery to end users through its transmission and distribution (T&D) system. Allowed rates covered a return on the entire capital investment, fuel, operations, maintenance costs and line losses.

Much has changed since 1978, when the Public Utility Regulatory Policies Act (PURPA) allowed independent power producers (IPPs) to build distributed generation plants at or near users. Further law changes in 1990 granted IPP plants rights to compete with utility-owned generation. Non-utility generation rose from under 4 percent of total power in 1977 to over 42 percent of total U.S. generating capacity in 2010. Further enriching electric system options, independent generation plants employ multiple technologies and multiple energy inputs, including renewable energy, and independent firms now build and own transmission wires. Some states required utilities to divest generation, and 33 states require growing renewable/clean generation.

Many economists assured policy makers that this partial deregulation of generation and transmission (distribution remains monopoly protected everywhere) would spur innovation and reduce the cost and associated pollution of delivered power. To determine the impact of emerging electric system competition, we looked EIA data, but found little improvement in either price or efficiency of delivered power in the U.S.

Figure 1

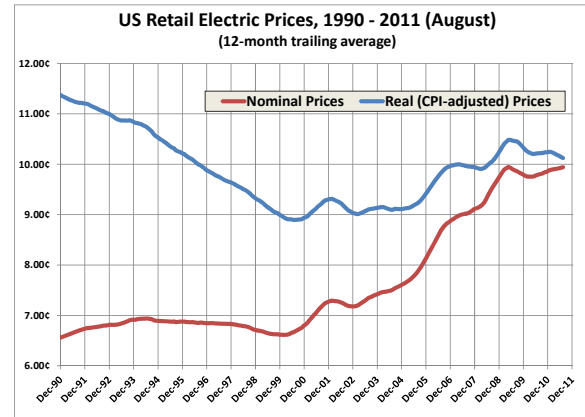


Figure 1 shows that nominal prices for U.S. retail electricity (bottom red line) rising from 6.6 cents/kWh in 1990 to nearly 10 cents/kWh in 2011. Real prices declined from 1990 through 2000, but then rose 15% in the past 11 years. If emerging competition drove the real price drop, why the recent real price increases? Could fuel price changes explain?

Figure 2 compares fuel and electricity price changes since 2000. Real coal prices rose dramatically, by 52 percent, while natural gas prices declined by 14 percent. Coal-fired generation dropped from 51.7 percent of total power in 2000 to under 44.8 percent in 2010, demonstrating that competition does impact dispatch of central generation. (EIA released data in late February showing coal-fired generation dropped below 40% in November/December of 2011, lowest since 1978.)

Figure 2

Changes in Real Prices Since 2000				
	Units	Dec-00	Aug-11	Change
Coal	MMBtu	\$ 1.58	\$ 2.40	52%
Natural Gas	MMBtu	\$ 5.72	\$ 4.92	-14%
Retail Electricity	kWh	8.9 cents	10.2 cents	15%

Prices above are 12 month trailing average

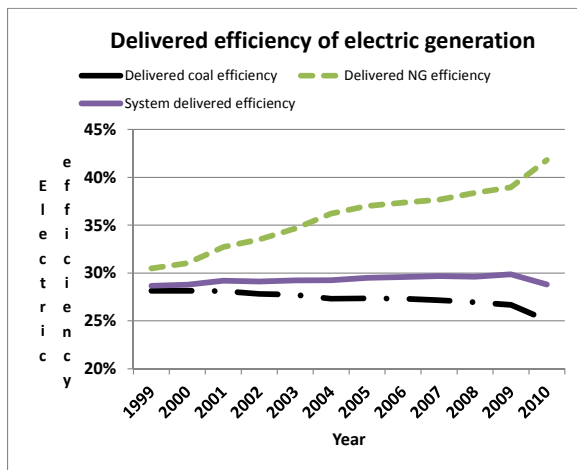
Competition in other industries spurs efficiency gains, and it would be instructive to examine U.S. delivered electric efficiency. Unfortunately, U.S. Energy Information Agency statistics do not calculate nor enable accurate calculation of overall generation efficiency, much less calculations of delivered efficiency by generation type. For example, EIA reports coal use in tons, but not in units of energy, even though Btu content per ton varies widely by type of coal.

EIA reports fuel consumed by CHP plants, but not the amount of either electricity or useful thermal energy produced by CHP plants. Consequently, claims about delivered efficiency of U.S. electric power depend on assumptions.

Given these warnings, Figure 3 presents average delivered efficiency for all U.S. fossil fuel-based generation and for coal and natural gas since 1999. The calculations assumed average coal energy contentⁱ and guessed that CHP useful thermal production equaled half of the fuel burned. With these two guesses applied evenly to each year's data, U.S. fossil delivered efficiency was essentially flat, at 28.7% in 1999 and 28.8% in 2010.

Coal's delivered efficiency declined from 30 percent to 26.6 percent, reflecting increased parasitic loads for emission controls and the Clean Air Act penalties for any major modification, including investments in efficiency.ⁱⁱ Natural gas plant efficiency has improved with gas turbine technology advances and use of combined cycle plants that boil water with exhaust heat to drive a second generator.

Figure 3



Good CHP efficiency can reach 85% with no line losses, but EIA provides no data to determine average CHP efficiency. Nonetheless, CHP should take an increasing share of total fossil fuel in a competitive market, but the data tell a different story. CHP plants burned 6.1 percent of all fossil fuel used to generate power in 1999, but only 5.2 percent of fossil fuel in 2010, reflecting the near ceasing of CHP development in the past decade and the idling of many earlier CHP plants when their original power purchase contracts expired.

In other words, the opening of generation and transmission competition has largely far failed to produce demonstrable benefits to society. We suggest that a major reason generation competition is not working is the distorted

price signals from continued treatment of all megawatts as equal. DG will not begin decreasing average fuel use and costs until financial and environmental regulators recognize and reward the incremental values of generating megawatts near users.

DG Megawatts Have More Value than CG Megawatts

DG megawatts are significantly more valuable than centrally generated megawatt for several major reasons.

First, DG megawatts usually flow directly to users, regardless of who purchased the power, thus bypassing long wires and associated line losses and capital investment.

Second, by reducing the power flowing through the wires, DG also reduces line losses on all remaining centrally generated power.

Third, DG greatly eases the need for new transmission. Federal Energy Regulatory Commission Chair Jon Wellinghoff recently noted a danger of overinvesting in transmission 'if we don't break down the non-economic barriers to putting in the distributed generation.'ⁱⁱⁱ

Fourth, DG enables use of normally wasted thermal energy to displace boiler fuel by combining heat and power generation. Central generation cannot recycle exhaust heat, because heat will not travel economically and can only be used within three to five miles of generation. In other cases, industrial processes emit waste energy as flare gas, hot exhaust and high-pressure steam or gas, all possible to recycle with local generation, but not with remote generation. Fueled CHP efficiencies rise to 85 percent after credit for displaced boiler fuel. DG using industrial process waste energy or using local renewable energy burns no fossil fuel and emits no incremental pollution. Denmark, with over half its power generated locally, achieves delivered efficiency from fossil fuel of over 50%, nearly double U.S. averages.

Finally, DG decreases grid vulnerability to extreme weather, operator error and terrorism. Large system blackouts occur every few years to CG-based systems when a tornado, an ice storm, exceptionally hot weather or operator error causes a line failure and starts a cascading set of generator safety trips. Terrorists could cause the same failures by knocking out major transformers and/or key transmission lines. Multiple DG units provide local voltage and power support that would prevent most of these blackouts.

Studies Prove DG's Added Value

Society could reap rich rewards from deploying strategically placed DG. Studies by Professor Marija Ilic and colleagues at Carnegie Mellon & MIT have shown how DG, by supplying 10 percent of total energy, could cut line losses in half. These studies show that each megawatt-hour of DG could displace 1.2 to 1.45 MWhs of CG generation,

providing a 20-45 percent benefit. Extrapolating study results suggests that installing 80 gigawatts of well-placed DG could reduce U.S. end-user electric costs by \$21.5 to \$38 billion per year, free transmission lines to carry over 100 gigawatts more renewable energy, and avoid 4.4% of U.S. greenhouse gas emissions. Here are the details:

Line losses on the U.S. T&D system averaged 236 million megawatt-hours per year (2001-2010), equivalent to the annual consumption of California (239 million MWh in 2010).^{iv} At 2010 retail power costs of 9.8 cents per kWh, the U.S. line losses cost \$23.2 billion. Deploying DG to eliminate half of the losses would save about \$12 billion per year, plus avoid \$9.5 to \$26 billion of net capital investment each year to provide for 1 percent annual system growth.

Deploying 80 GW of DG would:

- Cut peak U.S. generation and transmission requirements by 100 to 120 gigawatts, and avoid the need for another 10 gigawatts reserve capacity to cover the avoided line losses.
- Reduce U.S. CO₂ emissions by roughly 290 million tons, 4.4% of U.S. CO₂ equivalent emissions in 2009.^v
- Avoid \$95 to \$260 billion of capital investment over ten years. The 80 gigawatts of DG would provide for 10% load growth with \$160 to \$240 million of capital investment instead of spending \$335 to \$420 billion on 96 to 120 gigawatts of new CG and T&D capacity. (Assumes T&D costs \$1.5 million per MW and peaking generation costs \$1.0 million per MW). Spread over ten years, DG would save \$9.5 to \$26 billion per year in capital investment.

Technical Explanation of the Added Value of DG Generation

Centrally generated power line losses average 6.2% but can reach 25% during peak loads.^{vi} DG megawatts, by flowing directly to users, have no line losses. In addition, DG allows additional savings by reducing the flow of remaining power through T&D wires. Because line losses are roughly proportional to the square of the flow of power, a wire carrying 100% of its design capacity loses 1² times a constant factor. Cut power flow in half and line losses drop to 0.5² times the same constant factor, or only 25% of the peak line losses.

To determine the average line loss reduction over a year, Professor Ilic and others modeled two Portuguese islands operating at distribution voltages and a complex continental system with transmission and distribution, as well as several U.S. area grids. The studies showed that each DG MWh displaced 1.2 to 1.45 MWhs of CG. Roughly 80% of the line loss savings resulted from supplying active power while the remaining 20% resulted from using DG to supply balancing reactive power – electric or magnetic fields.

Transmission lines and loads create varying amounts of reactive power. The conversion of active power into reactive power would reduce delivered power but for a magic relationship – each VAR (variable ampere reactive) of capacitance cancels one VAR of inductance. The inductance and capacitance on each line are unfortunately nearly always out of balance and change with shifting loads. For example, turning on florescent lights creates capacitance while partly loading electric motors creates inductance. To balance these fluctuating loads, grid managers use gross tools, such as large capacitance or inductance banks that are either on or off. As a result, reactive power is usually unbalanced and contributes to line losses.

Adding relatively simple controls to DG would enable production of balancing reactive power from each DG plant. Grid managers do purchase VARs from CG plants, but this has limited value VARs do not travel down wire and thus cannot balance the reactive power reaching users. DG VARs, generated at the business end of the wires, provide balancing reactive power to reduce losses. Further, DG-generated reactive power does not degrade as system voltage decreases, making DG VARs higher quality reactive power than from capacitors or inductance banks. Despite such clear benefits, virtually no grid manager currently sources (or pays for) balancing reactive power from DG.

A DG Case Study

To illustrate the cost to society of treating all megawatts equally, we modeled recycling waste energy from a facility that produces lime for steel production and sulfur scrubbers. The proposed DG plant would use the lime kilns' hot exhaust to make steam for a steam turbine and produce 8.75 MW. The lime production facility operates 24/7, enabling the proposed DG plant to produce about 70,000 MWh per year of fuel-free electricity.

The project would require \$20 million capital investment versus \$31 million to supply the same load with new CG generation and new T&D, assuming each DG megawatt-hour displaces 1.3 CG megawatt-hours. About half of the power would flow to the lime plant with the other half into the grid, regardless of contract terms.

Developer/funders require a risk-adjusted rate of return of 15% to 20%, due to the inherent mill risk, since revenue from electric generation depends on continued lime production over the life of the project. (The waste energy recycling project's input energy is the lime facilities output exhaust.) The project economics require a power sales contract paying \$80 to \$90 per MWh.

We calculated the cost of power from a new combined cycle gas turbine central plant and new T&D to be \$77 to \$80 per MWh at \$5.00 natural gas, slightly less than the

cost of power from the waste energy recycling local generation. However, replacing one MWh of DG will require 1.3 MWh of CG, and this translates into over \$100/MWh of equivalent cost for each DG MWh. (For CG, assume 7 MMBtus of natural gas per MWh and \$5.00 operation and maintenance cost, plus amortization of \$1.2 million per MW of generating capacity and \$1.5 million per MW of T&D.)

Although this DG plant could save society \$10 to \$20 per MWh, it will not be built under today's regulatory approach.

- First, regulators seldom credit the avoidance of T&D capital, assuming that the system has sufficient capacity before the addition of a single DG plant. In other words, DG gets little to no credit for avoiding future T&D.
- Second, regulators continue to assume that all megawatts are equal, offering only one for one avoided costs.
- The typical power purchase agreement would offer maximum of 8.0 MMBtu's of avoided fuel per MWh, and avoided capital cost of one for one displacement of the gas turbine central plant, with no credit for T&D.

Actual offers ranged from \$50 to \$57 per MWh of DG power and the plant will not be built at these prices. In fact, we are only aware of one lime plant in North America with any waste energy recycling, out of roughly 100 North American lime plants.

Table 1 summarizes the economics that are implied for each MWh from a typical lime plant waste energy recycling plant:

	Cost/MWh	% of CG cost
Societal cost, equivalent CG	\$100.50	100%
Typical DG offer	\$57.00	56.7%
Theoretical societal savings from DG	\$43.50	43.3%
Actual societal savings	0	0
Give DG 80% of value it creates	\$80.40	80%
Actual Societal Savings/DG MWh	\$20.10	20%%

Three observations:

1. DG economics do not work unless DG plants are given some of the value they create for the grid.
2. DG becomes attractive at 80% of the cost of equivalent CG, leaving \$20/MWh to share between end users and distribution utilities
3. These DG economics do not include any value for avoiding fossil fuel, avoiding carbon dioxide emissions, or enhancing grid stability.

Policy Issues and Opportunities

Treating all megawatts as equal sends distorted price signals to the power industry, needlessly increasing both cost and pollution. **The typical power purchase offer to DG understates the avoided costs by over 40%.**

Furthermore, power-purchasing utilities assume each MW of new DG capacity will displace only one MW of the least cost CG capacity, despite the reality of each DG MW displacing 1.2 to 1.45 MW of the highest cost CG.

When rate commissions approve an individual power purchase agreement, they typically accept utilities' arguments that the DG plant will sooner or later be out of service at the system peak hour, and thus will not reduce the need for central generation or T&D capacity. But this argument is deeply flawed for a system of multiple DG plants. One hundred DG plants, with a capacity of 10 MW each and 2% random unplanned outages will have a statistical availability of 980 MW during peak capacity, greatly reducing society's T&D needs.

These practices, by under paying for DG's financial advantages retard DG deployment.

Current environmental rules also penalize DG. First, the rules require each new generating plant, whether DG or CG, to control emissions to 'Best Available Control Technology' or BACT levels. Since each MWh from DG avoids 1.2 to 1.45 MWh of central generation, DG is forced to emit less pollution per delivered MWh than new central plants.

Environmental rules also grant existing generation plants grandfathered rights to historic emissions. To appreciate the magnitude of this problem, consider that current BACT standards for NOx emissions are 99% lower than permitted emissions from a plant built in 1980. To obtain an air permit, a new DG plant must control NOx emissions to 1% of the emissions allowed from existing 30-year-old existing plants, and then compete directly with the old dirty plant. Switching air regulation to energy output-based allowances that applied to all generation would level the environmental impact on generation choices.

A final hurdle to DG deployment is the near universal utility opposition to all local power, which is a direct result of the obsolete regulatory paradigm. The century-old ap-

proach of setting rates to reward utility capital investment and passing all efficiency gains to electric consumers causes distributed generation to reduce utility profits in three ways:

- First, utilities receive no financial reward for reducing line losses or fuel costs.
- Second, the DG plants, by cutting the need for new T&D and new generation, reduce the need for future rate-base investments by the monopoly utility and thus decrease its future profits.
- Third, DG power that is sold directly to a consumer cuts utility revenues and lowers profits until the next rate case.

Not surprisingly, utility managers go out of their way to discourage all DG.^{vii} This historic approach to utility rate making theoretically provides electric consumers with 100% of the savings from all efficiency gains and from avoidance of new capital investment. Because utilities have no opportunity to share DG's value to offset their own decreased rate-based returns, they oppose DG and erect every possible hurdle to deployment. DG deployment and associated efficiency gains are blocked by refusals to pay DG developers for much of the value they create.

The unintended consequence is five decades of stagnant U.S. electric efficiency. The power industry delivered 33% of its input energy content to end users in 1960, when Eisenhower was still in the White House. In 2010, fifty years and ten presidents later, the delivered efficiency appears to have dropped below 29 percent despite incredible technical progress and the partial introduction of competition in generation markets.

Conclusions

DG is a key component of a sustainable energy system. Besides avoiding line losses and enhancing grid stability, DG lowers fossil fuel use and greenhouse-gas emissions. DG also improves the economy by lowering the cost of power, making local manufacturing more competitive and thus preserving jobs. Finally, a system with many small DG plants is less vulnerable to extreme weather and terrorism than the current system of a few large remote stations.

Deploying DG would significantly improve U.S. delivered electricity efficiency were it not for our outdated regulatory paradigm. Until these perversities are fixed, utility actions will continue to retard penetration of DG, despite its massive potential rewards to society.

We ask policymakers to recognize the differential economic and environmental value of megawatts and megawatt-hours from strategically placed distributed generation, and to then share those benefits among DG developers, electric utilities and end users, enabling emerging competitive markets to work their magic. The resulting surge in effi-

cient DG will benefit all stakeholders while reducing emissions of criteria pollutants and greenhouse gases.^{viii}

ⁱ Coal was assumed to contain 22.4 MMBtu's per short ton, on average, for all coal burned over the 1999 through 2011 period.

ⁱⁱ The Clean Air Act grants grandfathered rights to emit pollutants at historic levels or the levels permitted at the time of the plant construction, but if the plant owners make a 'major modification', this triggers a 'New Source Review', essentially a requirement to re-permit emissions at levels then achievable with 'Best Available Control Technology' or BACT. Several later actions have required emission controls on old coal plants, but within limits of achievable limits. Reaching BACT level emissions with an old coal plant is problematic without a complete rebuild, so owners have assiduously avoided 'major modifications', including all efficiency investments.

ⁱⁱⁱ 'Reshaping Federal Transmission Policy', energy biz, Volume 9, issue 2 March/April 2012 page 20

^{iv} See U.S. Energy Information Agency, Electric Power Annual Report 2010, revised January 2012

^v Generating 236 million MWh of line losses with today's CG fleet emits 137 million metric tons of CO₂, (0.58 metric tons of CO₂ per MWh in 2010).^v 80 gigawatts of DG would eliminate half, or 68 million tons associated with line losses, and then displace 526 million CG MWhs with cleaner, more efficient DG, avoiding another 220 million tons, resulting in a total annual reduction of 288 million metric tons of CO₂. (DG emits 0 to .25 tons/MWh, so we assume .2 tons CO₂/DG MWh on average, versus .62 tons/MWh for average CG.

^{vi} U.S. Energy Information Agency, Electric Power Annual Report, 2010

^{vii} Many utilities seem to have embraced roof-top solar, which would contradict the statement. This may be explained by three factors: 1) Solar energy has very broad public support and utility managers do not like to be seen as opposing public interest, and 2) In spite of the massive press coverage, the total generation from solar remains miniscule, and thus not much of a threat, and 3) Some utilities, like Duke, see ways to invest directly in roof top solar and put the generation in rate base, thus increasing profits. So far, no one has enacted regulatory changes to give utilities comparable reasons to support other DG, which does have the potential to displace as much as 40% of central generation.

^{viii} Interested readers may send an email to areick@recycled-energy.com to request the Department of Energy's EIA files with calculations added to determine fuel and carbon dioxide savings from extrapolating Professor Ilic and colleagues' findings to the overall U.S. power system.