

**Distributed Renewable Energy & The Environment:
Developed Nation Drivers and Barriers
(Revised With Energy Security Drivers)**

**Columbia University's Sustainable Development Initiative
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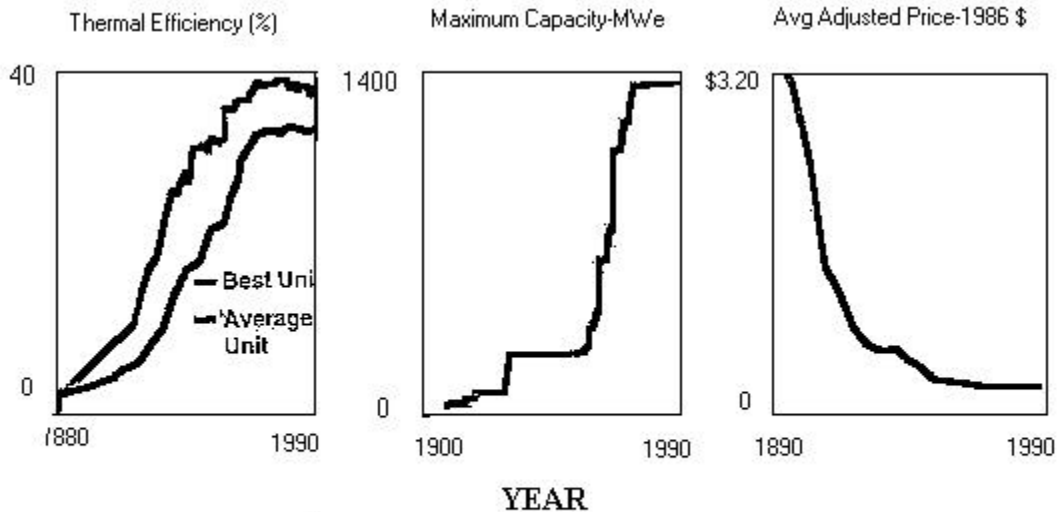
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Abstract

More than anything it has been technology which has driven deregulation of the electric industry since it became possible to capture high thermal efficiency, once only afforded to large steam plants, in relatively small gas turbines which could be economically located for on-site use. Due to the environmental excellence of combined cycle gas turbines and even a new generation of simple cycle turbines which will proliferate under utility restructuring, many of the traditional environmental drivers such as toxic air emissions will no longer stand as the most powerful arguments for renewable energy. Other short-term arguments which are economic-based such as reliability, power quality and energy security will be in the forefront before longer term environmental drivers once again become preeminent.

Background

To understand where technology is going in the realm of distributed resources, it is necessary to know how we have arrived at our present condition. This is best explained by examining the historic S-curve associated with the steam turbine¹.

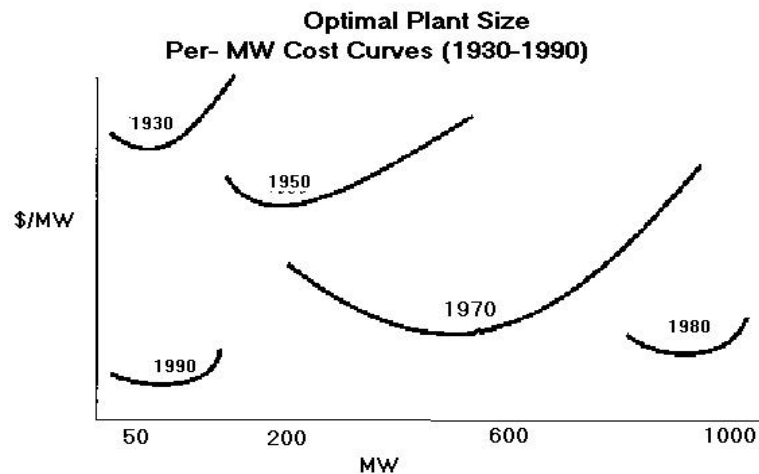


¹ Richard F. Hirsch, Technology and Transformation in the American Electric utility Industry (Cambridge University Press, 1989)

Looking at the beginning of the technology it is apparent that the thermal efficiencies were extremely low in the small sized units which were first available which resulted in extremely high cost per kilowatt-hour of electricity. Over time, the efficiency of the units grew drastically but in order to obtain this, the size of units had to grow commensurately to extremely large proportions. The size of these units might not have been achievable unless, at that time, there had been a monopoly system in place since it would be quite unlikely that competing firms could have attracted the capital to build such large units. They could have been risky unless they were guaranteed a customer base to pay for their construction before its full utilization. At the same time as the growth in size and efficiency, we can also see a dramatic drop in the cost of electricity which increased demand. These trends continued for many years until they met a series of diminishing returns both in technology gains and cost.

Another interesting way of looking at these trends is in the chart below which depicts the plant size versus cost per megawatt by decade.²

Its depiction is similar to the preceding chart except that in the 1980's we begin to see a trend back to smaller plants and that the price of those plants per megawatt is decreasing. This marks a dramatic change from what distributed generation guru Carl Weinberg calls constructed energy to manufactured energy. In the former the power plant is constructed on-site as opposed to the latter which is manufactured by and large inside a factory. The basic characteristics of each can be summarized as:



Trend is away from “constructed” generation-(on site)

- Each plant is custom built
- Large size/high capital cost
- Low fuel cost environment required
- Low efficiency
- Long lead times/built “in the field” with less quality control possible

Trend is toward “manufactured” generation-(factory)

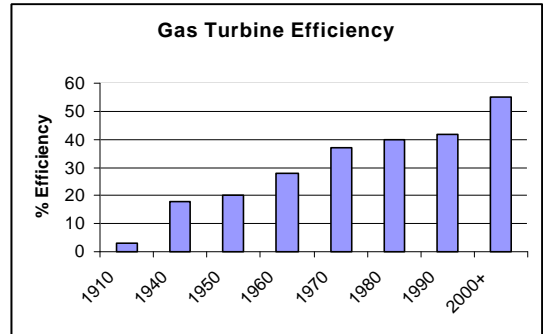
- Each plant is “cookie-cutter” uniform
- Modular
- High efficiency
- Low Capital cost
- Does well in a high fuel cost environment
- Short lead times/built “in the factory” with high quality control possible

Current Conditions

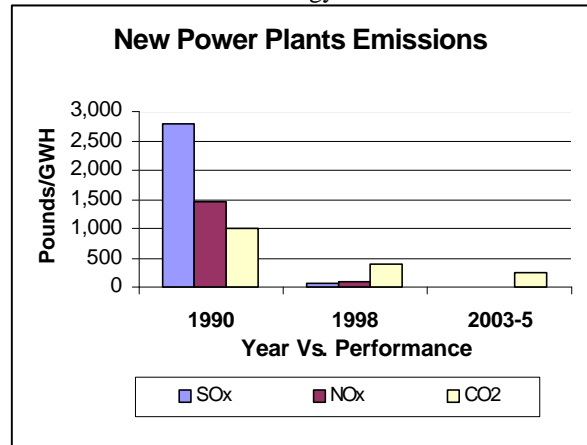
While the last years of the 1990's once again have seen a reversal not shown on the preceding charts toward large combined cycle gas turbine plants of 200 to 800 MW, this may only be a short-lived phenomenon driven by the initial stages of utility restructuring.

² Charles E. Bayless, “Less is More; Why Gas Turbines Will Transform Electric Utilities,” *Public utility Fortnightly*, 1 Dec. 1994. Pp. 21-25.

The basic technology which has driven this change is the gas turbine engine which has evolved from the jet engine used for aircraft propulsion. Once so inefficient they were only considered for short-term use as peaking generators, today, even a relatively small 42 megawatt unit can match the efficiency of the largest 1400 MW steam plant. (see chart to the right.)



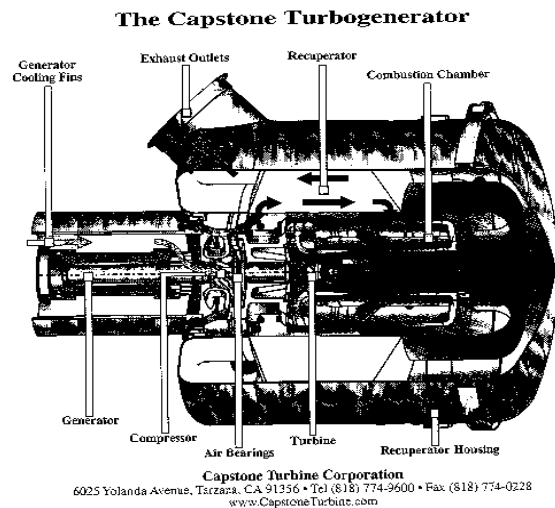
The outgrowth of this has been the evolution of the combined cycle gas turbine which uses the waste heat of simple cycle turbine to produce steam to operate a steam turbine. This has the effects of increasing capacity, efficiency and providing the cleanest emissions of any thermally based plant and doing so at the lowest cost. The advent of this technology has robbed the renewables of many of their environmental arguments. (See chart to right and below.)



Towards Tomorrow

Other environmental arguments will still provide drivers for distributed renewable energy sources since it has been noted that, “Americans’ demand for electricity is growing at almost two percent per year. But our power grid is expanding at only half that rate. In conjunction with an attitude termed by Dr. Karl Stahlkoph from the Electric Power Research Institute as BANANA (build absolutely nothing anywhere near anybody) benign renewable forms will find increasing favor.

Also finding favor will be a whole new generation of modular gas turbine and fuel cell power plants which are small enough to power retail stores, restaurants, apartment houses and in the case of some fuel cells, even individual homes. An example of one is the Capstone microturbine which is only 30 kW or small enough to entirely run a fast food restaurant. (see picture at right, below.) Increasingly, these plants will signal the trend to more distributed units which are better able to support a more resilient electrical infrastructure and provide back up for distributed renewables as well.



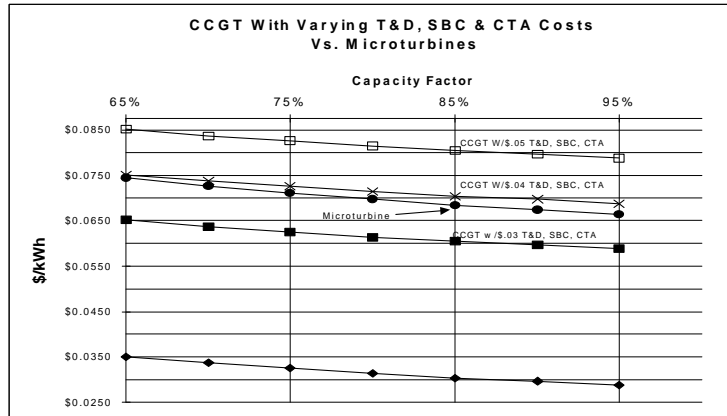
One of the more interesting outcomes of this trend toward very small on-site generation is the effect it might have on the large and efficient combined cycle gas turbines which are proliferating under restructuring. Under proper conditions, a microturbine can economically best a combined cycle gas turbines.

Most of its advantage comes from not having to pay a \$.02 /kWh to \$.04/kWh transmission and distribution charge as well as competition transition charges (CTC) and system benefits charges (SBC). However, in some states it may have to pay an exit fee which would reduce some of this advantage. Another condition which aids small scale technologies is that they are capable of maintaining a very high capacity factor.³ If it can do so, the

³ Capacity factor is the percentage of a year’s 8760 hours which a plant runs at its equivalent full capacity and can translate into the number of kWh produced in a year, an important factor in economic viability.

number of kWhs per year is increased and that lowers the cost of all kWh produced by that plant. (See chart below.) So, in the example below, when a microturbine runs with a high capacity factor, it can beat the CCGT when the T&D, CTC and SBC charges exceed \$.03/kWh. The same capacity factor for the CCGT can, however, also prove to be its weak point since if a high capacity factor is not maintained, the plant will become less economic. Where profit margins under competition may be razor thin, capacity factor will become increasingly important.

Introduction of multiple small and medium scale distributed technologies can technologically obsolete the CCGT since many small plants could erode the capacity factor of the CCGT so vital for its economic survival. In effect, their introduction will force the cost of the CCGT back up and to the left in the curve to the right. In locations where the smaller units are able to provide combined heat and power/cogeneration their advantage will grow even greater particularly where the regulatory system imposes no exit fees for self generators and the on-site generators no longer have to pay for transmission, distribution or systems benefits charges.

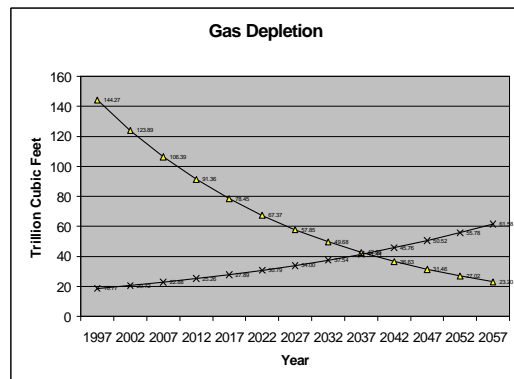


Gas Supply: An Achilles Heel?

As environmentally friendly and economical as these technologies are to operate, they do depend upon a plentiful and reliable source of relatively cheap natural gas to gain their economic and environmental advantages. While this advantage is currently available, there will still be certain considerations which must be taken into account before over-investment in gas-fueled technologies. These include:

- Additional gas supply will be required in some areas where its use for electrical generation has traditionally been low. Several pipelines in the Northeast have been either completed or planned to attempt to cope with this expansion of the supply network.
- In spite of new pipelines, there will still be supply and price pressures which must be calculated into the cash flows of projected new plants.

The chart at right depicts the theoretical interacting effects of increasing demand on decreasing the proven gas reserves over time. While this appears to confirm that there will be enough gas into the middle of the next century, it does not project what effect this increased demand will have on price. One can only assume that that price pressures will appear long before any real pressures on depletion surface.



- While supply may, for the most part, prove reliable, periodic constrictions can have enormous human and political consequences.

An example of the latter is the two-week sub zero weather which engulfed the northern tier of the nation during December 1989 and lead to full page ads asking gas customers to curtail natural gas usage. At that time only a tiny percentage of gas was used to produce electricity. Any similar situation which might arise now that gas could potentially generate 40% or more of the Northeast region’s electrical requirements could force decisions by government officials between who receives gas to heat with and who receives gas for electricity production.

There are numerous other periodic interruptions which could have more or less the same effect and a collage of some of the more recent ones appear below.

source: <http://go2.gardenofeden.com/technology/00778866.html>

The huge gas explosion that roared Melbourne last month, cutting off 1.4 million households in Victoria, has strengthened the case of Australia's renewable energy lobbyists who are questioning the country's reliance on gas and calling for the energy industry to be deregulated. Suddenly, solar is sexy and wind is wonderful, writes Amanda Foxham. *8 October 1998*

Storm affecting gas deliveries
Charleston Daily Mail
 The Gulf of Mexico's Hurricane Earl is affecting providers of natural gas to West Virginia and other states.
 "The storm is having a minor impact on Columbia Gas Transmission," said "But there is no impact on our customers."
 Columbia Gas of the Gulf to Co typically state "surrounding months, we

Natural gas line explosion leads to power shortage in Florida
 Copyright © 1998 Mando.net
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 MIAMI, (August 16, 1998 1:30 p.m. EDT <http://www.mando.net>) - Pipefitters labored Sunday to re-route fire-damaged natural gas lines that interrupted gas and electric supplies to the entire Florida peninsula, prompting calls for energy conservation to avoid rolling blackouts.
 Prisoners at the Pinellas County Jail in St. Petersburg took cold showers, while some hotel restaurants in the central Florida tourism corridor had to serve up cold cuts and salads or fire up their barbecue grills.
 Lightning ignited a fire that set off explosions at a natural gas compressor station in the north Florida town of Perry on Friday. The explosion sent a spectacular fireball 600 feet in the air, incinerated a half-dozen homes and injured five people, including several firefighters.

Arctic Cold Front Pushes Natural Gas Supplies to the Limit Responds with Stage Two Emergency
Folsom, Calif. (BUSINESS WIRE) - With natural gas in short supply and icy cold temperatures continuing in the Western United States, the California Independent System Operator (Cal-ISO) called for a Stage Two Emergency at 7:20 a.m. today, Monday, December 21, 1998, triggering the "rotation of power demand on the state's transmission system."
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Likely Non-Environmental Drivers for Distributed Resources

With environmental drivers temporarily taking a back seat in driving distributive resources, there will still be many other factors at work to insure that they are adopted. These include but are not limited to:

- Deregulation legislation has, in many states, mandated a system benefits charge which are funds charged per kilowatt-hour which are designated for use in furthering renewable energy and demand side management technologies and practices. Even many of the demand side management funds could be used for distributed resources on the customer side of the meter.

Many states have also provided for renewable portfolio standards which require providers of electricity to supply a certain percentage of their power from renewable sources, some of which could be distributed resources.

- Increased reliability due to multiplicity of generators and fuel sources⁴
- Enhanced power quality for sensitive information and manufacturing operations
- Lower cost than traditional transmission and distribution (T&D) upgrades such as substations or new high voltage lines which have become increasingly difficult to site.
- Less line losses with generation closer to points of use
- Modularity which does not overbuild/overspend
- Shorter lead times meaning less financial uncertainties
- Less risk to place large amounts of capital in larger, soon-to-be obsolete technologies
- Less financial risk for smaller scale projects in general
- Less risk of regulatory changes than for longer term projects
- Flexibility to easily move hardware if loads do not develop or decrease over time
- Some renewables not subject to fluctuating fuel prices
- Some renewables have low operations and maintenance (O&M) costs
- Risk reduction by diversifying the fuel mix

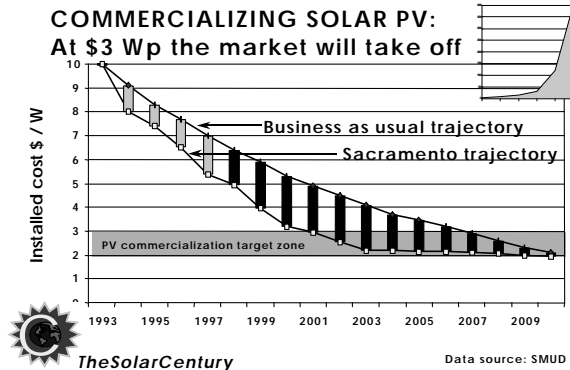
Likely Renewable Technology Winners

As additional distributed resources are deployed, there is a high probability that an increasing number of them will be renewably powered due to many of the preceding points as well as reductions in cost as they attain more favorable economies of scale. Many will also fit nicely into certain niche markets where, even in developed nations, they are already cost effective. The renewable technologies which are most conducive to distributive use are:

⁴ These points are partially derived from: Howard Brown (ed.) w/Tom Strumolo, Decentralizing Energy Production, (Yale University Press, New Haven, 1978). Fred Gordon, Joe Chaisson and Dave Andrus, *Helping Distributed Resources Happen*, The Energy Foundation, Dec. 1998. Amory Lovins and Andre' Lehman, *Small is Profitable*, pending publication in 1999.

Fuel cells, which may use fossil fuel or renewable fuel, are already commercially available in 200 kW models may soon be proliferating in units as small as 1 kW which will open up enormous markets for them. Many observers expect that work being done by Ballard with several large auto companies may provide the production economies of scale to make them not only competitive in the transportation sector but also in the stationary power sector as well. Companies such as Plug Power which have significant financial backing (GE) may be able to introduce commercially available models in the 7 kW range within two years. Fuel cells enjoy additional advantages of being multi-fuel, low emissions, low noise and having an extremely high capacity factor.

Photovoltaics are the direct conversion of sunlight into electricity and are, perhaps, the most modular of all the renewable energy distributed resources. This allows them to be tailored to many uses in remote areas or in areas where it would be inappropriate to operate other forms of generators. The primary barrier to PV is their currently high cost due to lack of economies of scale in production. The chart to the right demonstrates where the technology currently is and where it needs to be to become fully competitive. Groups such as Solar Century in UK are spurring efforts to promote greater investment into the production of PV manufacturing plants while simultaneously increasing demand. Niche markets⁵ potentially include PV powered outdoor lighting, residential rooftop PV systems with integrated UPS systems, PV augmented UPS for computer networks and PV power supplies for wireless communications systems and emergency management systems.



In addition to cost barriers, solar PV will still have to struggle with dispatchability limitations as well as unfamiliarity by most utility personnel and lack of a solid commercialization infrastructure. In spite of this, they do possess certain traits which deserve greater recognition. In particular, their modularity, reliability, zero fuel needs, and power quality will be able to generate value as the restructured electric market begins to develop.

Biomass-fired gas turbines are beginning to emerge which have the potential to supply small capacity units with efficiencies previously only seen in extremely large plants. This translates into being able to locate units closer to actual supplies of biomass without having to transport the waste large distances to a large central plant. Combined with high capacity factor, this technology could be situation for high growth since it could also be used internationally in many village settings to produce electricity.

Wind energy conversion systems, while for the most part sited in more remote areas than other distributed resources, may still become a preferred source due to its relatively low capital cost (\$1100-\$1300 per kW) compared to most other renewables. It does require minimum annual winds speeds in the 14 mph range to be viable. Capacity factors run in the 20% to 30% range.

Differentiating Price From Value

While price appears to be the overriding driver at this time, a business which suffers an interruption or whose power quality deteriorates to the point that computer-related operations are compromised, will very quickly take steps to upgrade their energy infrastructure to insure continued operations. Since a number of businesses are covered by business interruption insurance, the reliability aspects of the technology should be a prime selling point to the insurance industry as well as the customer. The following table provides

⁵ Lucid, Inc. *Commercialization Strategies for Photovoltaics in Southeastern New England*, Apr. 1998 for the Rhode Island Renewable Energy Collaborative.

some context of the value lost for operations of various businesses when electricity reliability or quality is compromised.⁶

Industry	Average Cost of Downtime	Source
Cellular Communications	\$41,000 per hour	Teleconnect Magazine
Telephone Ticket Sales	\$72,000 per hour	Contingency Planning Research-1996
Airline Reservations	\$90,000 per hour	Contingency Planning Research-1996
Credit Card Operations	\$2,580,000 per hour	Contingency Planning Operations-1996
Brokerage Operations	\$6,480,000 per hour	Contingency Planning Operations-1996
Average Small Business	\$7,500 per day	Impulse Research of Los Angeles-1998

Whether the insurance industry might be willing to reduce the premium to the business equipped with such back-up systems becomes the question of transferring that value to actual cost-sharing with the customer. This may take a number of field installations before it is verified to the satisfaction of the conservative insurance industry.

The same installation should have value afforded to it by the local transmission and distribution utility which otherwise might have to expend far greater resources to upgrade a distribution trunk to assure equal reliability and/or quality. Such was the case in the Southern California Edison distribution area when they placed PV on a nearby school to alleviate power constraints in older underground lines driven by increased usage of air conditioning.⁷ In this case, the ripping up of pavement to upgrade the line was the more expensive and disruptive option. Under such upgrades, if the utility and the customer contract for a cost-sharing arrangement, it may be possible to realize a win-win situation where each pays less [or loses less as the case may be] and reduces overall technological and financial risk.

These are some of the forms of arrangements which must be investigated and pursued as programs in distributed resources begin to function. While the primary drivers may eventually be related to cyberwar/cyberterrorism, the reasons for allocating cost must be shared by as many players as possible, each who sees their own value in their portion of the investment.

Power Reliability, A “Powerful” Driver

There has been great attention paid to the Y2K bug in recent months and most accounts of the problem mention prominently that loss electric power might be one of the outcomes. This has led to numerous reports that people are going out in great numbers to procure electric generators and back up systems.

Jack Reynolds, Sales Manager for Buckeye Power Sales in Ohio, commenting on the sales of portable generators observed, “People are scared to death. Sales are quite brisk, more so from Y2K than the weather.”

While most of this is in the form of gasoline-powered generation, a certain amount is also being reported as PV powered systems. It is becoming generally acknowledged that, in developed nations, Y2K may lead to only sporadic and short term outages and, it will be mostly a one-time event although there are several

⁶ The first five business losses were attributed to Kim Barnes, “Deregulation: Differentiate Your Energy Services Business by Providing Customers with Computer Grade Power and Reliability,” Energy.com, 7 April 1999. The last line for average small businesses came “AlliedSignal: Power outages cost small business big bucks,” PMA OnLine Breaking News, 1 February 1999. The article specifically stated, “The importance of reliable electric power can not be over emphasized for the nearly 90% of small businesses in the United States who reported experiencing at least one power outage during 1998. According to a survey of 500 small business owners sponsored by AlliedSignal Power Systems Inc., these same small businesses reported an average of three power outages last year, costing each business an approximate average of \$7,500 per day.”

⁷ Edan Prabhu, “SCE’s Innovative Solar Neighborhood Program,” *Solar Today*, July/August 1995, pp. 22-26.

other dates which may hold some perils. Still, a number of people are looking into home generation for reasons beyond Y2K concerns:

One survey found that "25% of US homeowners are actively considering purchase of back-up generating systems." The report also went on to say that affluent consumers, concerned about their computer systems, security, hobby and home entertainment equipment, would be willing to pay a premium of 10% to their energy supplier to provide back-up for their home generators. Those with home businesses had a high level of interest in on site technologies which would also ensure power quality and protect them during emergencies.⁸

Regardless of Y2K, but more probable and immediate because of it, a point which might bear further investigation was brought up by Michael Totten of World Resources Institute.⁹ While Y2K is the result of what some would call incompetence and lack of planning, the same results could be had through purposeful manipulations taken by any number of nations, groups or individuals to disrupt the infrastructure including most prominently the electric grid. This has taken on the names "cyberwar" and "cyberterrorism" to connote that it would be induced by purposeful manipulation of the computer networks controlling vital functions. While it has been a concern for a number of years now, that concern has mostly been confined to the military and some large corporations whose vulnerability has already been exposed by computer hackers. Unfortunately, it has taken and will take more time until it penetrates the psyche of most corporate and government officials and the American public that this form of "damage" is as real and destructive as if inflicted by an explosive device. President Clinton has been at the forefront of increasing awareness on this issue:

Last May, at the Naval Academy commencement, I said terrorist and outlaw states are extending the world's fields of battle, from physical space to cyberspace, from our earth's vast bodies of water to the complex workings of our own human bodies. The enemies of peace realize they cannot defeat us with traditional military means. So they are working on two new forms of assault, which you've heard about today: cyber attacks on our critical computer systems, and attacks with weapons of mass destruction -- chemical, biological, potentially even nuclear weapons. We must be ready -- ready if our adversaries try to use computers to disable power grids, banking, communications and transportation networks, police, fire and health services -- or military assets.

The potential for harm is clear. Earlier this month, an ice storm in this area crippled power systems, plunging whole communities into darkness and disrupting daily lives. We have to be ready for adversaries to launch attacks that could paralyze utilities and services across entire regions.¹⁰

While no known successful or unsuccessful attacks against an electric grid have been made known as yet, there appears to be one recent alleged episode of an attack against a computer network of a major corporation:

The computer network of a Fortune 100 company was obliterated last week by a new virus that one official called "the first legitimate incident of cyber-terrorism" he had ever seen.

Executives at Network Associates Inc. (NETA) were working the phones this morning to warn users about this new "smart virus," which attacks Windows NT-based networks and propagates over the network, said Gene Hodges, a general manager at Network Associates in Santa Clara, Calif.

Although Hodges declined to name the attacked company, he said 10 sites and several thousand servers and workstations had been infected..."These guys were very smart," Hodges said. "They had a good enough idea of where to put it in order to make it spread very quickly."¹¹

It must be noted that no further news of this "attack" was recorded in the media and so its credibility may be drawn into question but any firm so compromised would undoubtedly do its utmost to suppress widespread knowledge of such vulnerability. That, alone, might produce large losses not only in its stock value but in the market at large.

⁸ "America Unplugged? Landmark Customer Survey Points to Promising New Markets for Distributed Power Generation," Business Wire, 30 September 1998

⁹ Conversation of 12/10/98.

¹⁰ Office of the Press Secretary, The White House. Speech at the National Academy of Science, 1/22/99.

¹¹ Personal correspondence via Nancy Pitblado on 12/23/98 from Network Associates.

Still, even the potential of such attacks against computer or other critical infrastructure indicates an underlying vulnerability which will eventually become more publicly acknowledged. It will only be a matter of time until a well-documented and publicized attack does take place. With this forewarning, there are certain marketing strategies which should be prepared in advance so as to be ready to offer solutions and capitalize on the markets which will result from this situation.

What has been suggested by some is that distributed generation be employed in conjunction with microgrids to add resiliency to the system in the event of a cyberattack on a nation's electric infrastructure. In this way, portions of the larger grid could isolate themselves from attacks yet still have power resources within close proximity to operate their homes and businesses.

Distributed Resources: Adding Resiliency to the System

In the long run, the optimal defense against the future threat of cyberwar/cyberterrorism will be to move away from the current large, centralized generation system. This system, which has gone hand-in-hand with utility monopolies, has been the norm for the past 80 years. The future appears to favor multiple, small and diverse generation sources with demand side management as a means to limit loads. Together these constitute distributed resources or DR. As Michael Totten of World Resources Institute has put it:

Since large, centralized energy systems are repeatedly singled out in these reports as one of the most vulnerable parts of society's critical infrastructures, the implication is clear: transition to more resilient distributed power systems which, if they fail, do so gracefully, not catastrophically. Indeed, one of the key recommendations in the work done for the U.S. Department of Defense by the Rand Corporation, *The Advent of Netwar*, is:

"Those who want to defend against netwar will have to adopt weapons, strategies, and organizational designs like those of their adversaries [i.e., from centralized hierarchies to distributed networks]...These principles depend to some extent upon technological breakthroughs, but mainly on a willingness to innovate organizationally."¹²

Fred Gordon of Pacific Energy Associates takes a pragmatic view of the ability of cyberwar/cyberterrorism to become a driver for a distributed system:

Cyberterrorism is a great reason to think about distributed grid automation. Distributed grid automation may go forward on its own, based on intrinsic reliability and cost benefits.... (assuming these are major...), and based on avoiding cyberterrorism, without anybody thinking about DR. DR may be more feasible as a result.¹³

Even reports from the fringe right-wing have recognized modularity inherent in distributed systems as a defense. This is evidenced by an alleged report from a National Guard officer supposedly blowing the whistle on a national mobilization of guardsmen for potential disturbances connected with Y2K.

"The latest plan I've heard," said another, "is to break the power grid into several hundred little grids. Right now it's one major grid broken into four subgrids. If they don't break it into several hundred little grids, in conjunction with the phone system not working properly, they won't get their feedback mechanism right and they'll burn up the lines."¹⁴

While there is a good deal of doubt whether anything of that magnitude [breaking into several hundred little grids] could take place before the Y2K event or even after, there may be a slow evolution toward micro-grids¹⁵ with distributed resources not only for cyber security purposes but for many of the numerous other more mundane reasons already cited as well.

¹² Correspondence from Michael Totten of 1/26/99. P. 12.

¹³ Op. cit.

¹⁴ David M. Bresnahan, Panic in the Year Zero: Bad News on Power Grid National Guard, FEMA Plan for Major Y2K Breakdowns. Worldnet. 1/11/99.

¹⁵ Michael Totten brought this up in his discussion of 12/10/98.

The Ultimate Driver

Even the cyberwar/cyberterrorism driver will be dwarfed compared to what some expect from subsequent findings of the Intergovernmental Panel on Climate Change in their future reports on the need to further reduce carbon dioxide emissions. As better information becomes available, it appears inevitable that even the modest proposals of the Kyoto Protocols will be considered too little too late to cope with the increasing risks which climate change may present. If that driver materializes as some expect, calls for emission reductions in the 60% to 80% from 1990 levels would not be unexpected and could gain momentum. This would present the ultimate driver for renewably powered distributive resource since both the developed and developing nations will need to make drastic reductions in these emissions.