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Banking on the future of power

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Power Currents

Monthly Coverage of the Energy Technology Industry

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IT Hardware Growth—Still Waiting for

On the cover of our last issue we discussed the threat of war in Iraq and suggested that certain energy technologies might benefit should a military conflict lead to a third oil crisis.

Having looked at possible energy tech industry beneficiaries of the consequences of war, here we turn to those segments that appear to have been hurt—power semiconductors and power electronics.

Starting with a broad look at the US economy, it would be inaccurate to claim that 2003 would have been a strong year if it were not for the Iraqi conflict. The best that could be said is that 2003 was off to a wobbly start, but there were enough signs of firming to indicate that the economy could exit the year at a fairly healthy clip. However, recent data points, such as manufacturing activity and unemployment claims, suggest sluggishness and caution. Further, the Federal Reserve has signaled that its concern is now deflation as much as it is inflation, reinforcing the argument that growth has stalled. Although the war is over, businesses remain reluctant to invest.

Within energy tech, power semiconductor and power electronics sales are probably the most economically sensitive, and signs of weakness have appeared (the Nasdaq rally notwithstanding). EPS estimates continue to decline, April chip sales were poor and the president of the Semiconductor Industry Association was one of a number of commentators to observe that the PC upgrade cycle is still nowhere in sight. When IT spending does recover, growth of 10% would be impressive—the days of 30% - 50% annual gains are over.

However, not all power semiconductor and power electronics companies are created equal. Those that sell into the defense industry, such as MicroSemi and Vicor, may see relatively strong results as global military budgets grow.

In This Month's Issue

The most significant energy tech industry news flow in the last few months has concerned solar, wind and other renewable energy sources. Budget allocations, legislative proposals, acquisitions and restructurings in renewable energy are covered in this month's *GridWatch* and *The (De-) Construction Site*.

The recent release of 2002 data showing continued robust demand for solar and wind power systems has prompted us to look closely at these industries in this month's *Inductance &Reactance*. Both solar and wind have made impressive strides in cost and performance, both have experienced remarkable growth over the last decade, and both offer at least part of the solution to the political and environmental problems caused by dependence on oil.

This issue also includes a fair amount of commentary on the future of the automobile. In the aftermath of the war in Iraq and the midst of a war on terror, we believe renewable energy and next-generation vehicles merit much discussion and substantial support.

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Please see p. 55 for important disclosures and notices.

GridWatch

Energy and Power Industry Announcements and Developments

Overview. Probably the single most important industry-level development in the last several months was a proposal made in the US Senate to increase the production tax credit for renewable energy and establish it as a permanent incentive rather than one requiring regular approval. At the state level, New Jersey regulators introduced a generous subsidy for the purchase of solar power systems. But progress is not inevitable. The British government and state legislators in New Mexico threw up obstacles to efforts underway to put supports in place for a variety of renewable energy sources.

April 24. The Department of Energy has announced $123 million of funding for two new projects to be headed by **FuelCell Energy** and **Acumentrics Corp.** as part of the government's Solid State Energy Conversion Alliance (SECA) program. SECA's goal is to develop a solid-state fuel cell so economical and versatile that it might one day provide auxiliary power for large trucks, supply the military with a battlefield power source, or generate clean electricity in high-efficiency power plants. To make this possible, the DOE wants to develop breakthroughs in fuel cell design and manufacturing that can cut costs to one-tenth of today's commercial fuel cells. The department's goal is to develop a ceramic fuel cell with factory costs as low as $400 per kilowatt. FuelCell Energy and Acumentrics will join four other industry development teams selected by the DOE back in August 2001.

April 23. The FCC voted to solicit public comment on broadband Internet service delivered over ordinary electric power lines, a step that could create widespread competition for cable modem and DSL services. Because of the comprehensive network of power lines already in place, broadband over power lines (BPL) could bring broadband services to rural areas that may not have such access otherwise. Companies such as **Amperion** and **Current Technologies** are already planning to roll out limited BPL services by later this year, and they are allowed to do so as long as they stay within current FCC rules on unlicensed radio frequency emissions. Phil Hunt, chairman and CEO of Amperion, has told the FCC's Technological Advisory Council that BPL could deliver data at speeds up to 20M bit/sec, similar to current versions of cable and DSL.

April 16. Three of the biggest power grid operators in the eastern half of the United States announced their intent to integrate their power markets. The **Midwest Independent Transmission System Operator** (MISO), **PJM Interconnection** (PJM) and the **Tennessee Valley Authority** (TVA) said this was the first step in a process that will create a wholesale power market covering much of the US east of the Rockies. Importantly, the announcement furthers the Federal Energy Regulatory Commission's (FERC) goal of creating a national Standard Market Design (SMD) based, in part, on the PJM market model.

The PJM system is the world's largest wholesale electricity market serving 25 million people in all or parts of seven states and the District of Columbia. In addition, **Commonwealth Edison's** transmission network will become a part of the PJM on June 1. MISO operates the transmission system serving 24 million people in all or parts of 15 states and parts of Canada. TVA is a federal corporation that is the sole power wholesaler to more than eight million residents in all or parts of Kentucky, Tennessee, Virginia, North Carolina, Georgia, Alabama and Mississippi. These three entities together include 295,000MW of generating capacity, 150,000 miles of transmission lines and more than 57 million customers.

March 26. The Federal Energy Regulatory Commission (FERC) found "epidemic" energy and power price manipulation by Avista Energy, Enron, Pacific Gas & Electric, Williams Energy Services and 33 other suppliers during California's 2000-01 power crisis, whose effects included numerous blackouts and massive state bailouts. FERC staff have formally recommended that the agency consider forcing such companies to refund unjust profits. FERC is expected to rule on this proposal shortly. FERC has already awarded the State of California refunds on overpayments totaling around $3.3 billion, and California officials are about to file a complaint demanding another $4.3 billion.

Comment. Although the process is far from finished, the recent FERC finding is an important step toward cleaning up the mess in the California power markets. Final resolution there should remove significant questions surrounding the health and the liabilities of numerous large power suppliers, and enable all parties to focus on the road ahead instead of the rear-view mirror. If nothing else, the California experience has provided numerous lessons about how not to deregulate power markets, and subsequent state deregulation programs, such as that of Texas, seem to be going more smoothly.

March 17. The four Senate committee leaders with jurisdiction over energy taxes and energy policy introduced a comprehensive bill including a series of alternative energy production tax incentives. The bill is very similar to the tax package that the Senate passed last year. Solar tax provisions in the bill include a 15% residential solar tax credit for PV and solar water heating, with a cap of $2,000. The bill also expands the wind PTC (Production Tax Credit) to include solar, and extends the wind PTC through 2007. In addition, the bill provides or extends tax credits and subsidies for biomass, biodiesel, small-scale ethanol production, energy-efficient appliance manufacturing, and fuel production from unconventional sources such as coal-bed methane and heavy oil, and provides incentives to increase traditional oil and gas production.

Comment. The passage of this bill would be an important milestone for the renewable energy industry. Until now the federal government has approved these credits for a specific period of time, and as the expiration date of the authorization loomed near, it was never clear if they would be extended. The on-again, off-again nature of the PTC and other federal support programs for renewables has increased the risk involved in renewable energy project ownership and led to mini boom-and-bust cycles in the renewables industry as supports have been granted, terminated for a time, granted again and so forth. Making the PTC permanent would create a stable and predictable set of incentives for renewable energy. And of course, a 20% increase in the PTC is a plus as well.

March 17. **GTCR Golder Rauner LLC**, a Chicago-based private equity firm, announced it has completed an equity investment in **Invenergy LLC**, a developer and operator of power facilities in North America. Under terms of the agreement, GTCR will be Invenergy's preferred provider of equity capital that will be used to acquire and develop power generation and transmission assets. Invenergy and GTCR aim to build a portfolio in the power sector of approximately $1 billion in asset value by accelerating existing development and acquisition activities in the Americas and Europe. By leveraging both GTCR's strategic capital resources and Invenergy's management team, the firms believe their portfolio target can be achieved in two to three years.

Comment. The entrance of another sophisticated private equity fund with billions of dollars under management into the energy and power industry is a positive development. On the power generation side it should help to rationalize capacity, and more importantly, on the transmission side it could mark the beginning of a sustained investment cycle to upgrade the aging utility network.

March 7. **Goldman Sachs** has bought the European gas and electricity trading books of U.S. firms **Dynegy** and **El Paso**, becoming a major regional power trader in the process. El Paso reportedly said last month it had sold its European gas trading portfolio for $80 million but did not name the buyer. Goldman is following in the wake of European banks that have already expanded into regional power markets, stepping into the opening created by the departure of numerous US energy and power traders. Barclays Capital last month extended its trading presence into continental Europe after its recent entry into Britain's electricity and gas markets. Deutsche Bank has begun trading operations, and French bank BNP Paribas is setting up a European power trading desk in London. At least three more banks are reportedly preparing to enter the market.

Comment. We have suggested in previous commentary that banks and finance companies are better suited to trading and providing liquidity in energy markets than the merchant energy companies that have historically dominated trading. With asset bases in the tens or hundreds of billions of dollars, large banks can support trading books much larger than those carried by the likes of Constellation, Dynegy and Sempra. The credit crisis in the energy and power industry has forced merchant energy trading desks to scale way back, reducing the liquidity of wholesale energy and power markets. The entry of commercial and investment banks into these markets should bring much-needed liquidity.

March 3. **ISO New England Inc.**, the region's whole power systems operator, announced the launching of its Standard Market Design (SMD), a new set of rules for buying and selling wholesale power in the in New England. Under the previous framework, wholesale power was priced uniformly across New England, a system that did not accurately price the cost of transmission congestion. As of March 1, the region has been divided into eight pricing zones, and cost of transmission congestion will be priced at a market rate based on the location where it occurs. The New England ISO believes these rules should improve transmission planning, alleviate transmission congestion, encourage optimal siting of power generators, and improve power price competition. Daily trading patterns thus far suggest that the market is pricing power and transmission congestion rationally.

February 28. **DTE Energy** announced it had completed the sale of its transmission business subsidiary, **International Transmission Co. (ITC)**, to an investor group including **Kohlberg Kravis Roberts & Co. (KKR)** and **Trimaran Capital Partners L.L.C.** for approximately $610 million cash. The previous week, the Federal Energy Regulatory Commission (FERC) approved a substantial increase in the rate of return on the federally regulated power lines transferred to KKR to 13.9%.

Comment. The rate of return secured by KKR and Trimaran on their newly-purchased transmission assets is roughly 2%-3% higher than customary rates. Considering that the investor group can earn nearly 14% annual returns on an asset that may have been acquired on a leveraged basis, the return to equity looks attractive. For those of us who do not have capital under management by KKR or Trimaran and will not enjoy those returns, the transaction is nonetheless significant because of what it could lead to more broadly. As transmission assets pass into the hands of profit-motivated owners, the long-deferred and badly-needed upgrade of the transmission network may finally begin in earnest, improving the reliability of the nation's power supply. Further, there are a number of energy technology companies with products to enhance the utility grid that would stand to benefit.

February 27. Demonstrating that progress is almost never linear, New Mexico's State Senate passed a Joint Memorial calling on the New Mexico Public Regulation Commission to suspend the renewable-energy rule the Commission enacted in December. The rule would have required local utilities to turn to renewable energy sources for a sizable share of total electricity sales. The State Senate pushed this measure through despite strong public support for renewable energy.

February 26. The Australia Greenhouse Office (AGO) recently decided to cap grants for new solar power systems. Due to overwhelming demand, the subsidy for the purchase of residential solar power systems has been capped at A$100,000 per month to enable the program to continue until the end of the financial year. Only 14 household systems now can be supported each month Australia-wide. The limitations placed on the number of systems receiving support do not even cover the applications already submitted, and effectively remove a key engine of growth for Australia's nascent solar power industry. The program commenced on January 1, 2000 and provides households that install a PV system a rebate of A$5/watt, up to a maximum of A$7500 per household.

Comment. The strength of demand for affordable solar power is a real positive; on the other hand, the inability of the government to provide sufficient resources to accommodate that demand is unfortunate for Australia's solar power industry, which had benefited from the program. Nonetheless, for those involved in the renewable energy industry, a solar power subsidy program with too much demand and insufficient funds is clearly preferable to a program with plenty of funds but no takers—for products in any market, lack of demand is the kiss of death.

February 17. **PSA Peugeot Citroen** (France) announced that it was abandoning its fuel cell plans and concentrating its research on hybrid electric vehicles. CEO Jean-Martin Folz said the technical barriers to fuel cell development meant hydrogen-powered cars would not be a commercial reality for at least 15 years. Peugeot will instead be launching hybrid cars with both Peugeot and Citroen-branded models coming to market next year. Folz was quoted as saying "we have decided not to embark on large expenses for development of this technology. The many obstacles that fuel cell cars are meeting justifies our decision."

Comment. Recent Bush administration projections about the timing of fuel-cell vehicle (FCV) commercialization reached similar conclusions – FCVs will probably not be viable until 2015-20. Assuming this is so, we see two major implications. First, any serious program to reduce dependence on oil imports within this decade should focus on hybrid electric vehicles (HEVs). Funding the development of FCVs has merit as well, but the return on investment will be a long time coming. And second, given the very long lead time and enormous expense involved in not just developing FCVs but also the infrastructure to support them, as well as the

potential public benefits eventually created, there is a legitimate role for government to play in subsidizing FCV programs for some years to come. (*See pg. xx—xx for additional news and commentary on next-generation automobiles*)

February 16. Tony Blair has blocked plans to produce 20% of Britain's electricity from renewable sources, in apparent contradiction to his earlier pronouncements about making the U.K. a leader in the green industrial revolution. Reports linked Blair's backpedaling on renewable energy support to a rejection of his proposal to build six new nuclear power plants. Britain has more renewable energy potential than any other country in Europe – 40% of the continent's wind power resources are in Britain, and the country has significant wave power potential – but does little to support its use.

February 12. As part of the state's Clean Energy Program, the New Jersey Board of Public Utilities has announced an aggressive subsidy program for residential and commercial buyers of solar power systems. Purchases of systems under 10kW are entitled to a rebate of up to 70% of the system's cost; systems from 10kW – 1MW are eligible for rebates up to 60%; and solar installations larger than 1MW can obtain rebates for the first megawatt of capacity. Refunds are paid through a state-established trust and funded by customers through their utility providers. The management of the overall renewables Clean Energy Fund, authorized to reach at least $800 million, has recently been transferred to the Board of Public Utilities.

February 10. The **Electricity Innovation Institute** (E2I), an affiliate of the **Electric Power Research Institute** (EPRI), announced that **Cisco Systems** is the first technology leader to become a member of a public/private consortium that is taking the lead in upgrading the aging US electric system. The Consortium's immediate goal is to create a networked architecture for a "smart grid" that will utilize advanced communications and computing technologies to deliver highly reliable power over a secure system and create opportunities for new energy service offerings. The system architecture will include a networked communications infrastructure that links energy users to markets and enables real-time pricing, customer energy management and other innovative services.

Comment. The nation's electric utility network, from generation to transmission & distribution to end user, is a multi-trillion dollar asset base managed with dated technology by hundreds if not thousands of actors under a bewildering array of rules and regulations tasked with delivering over $200 billion of power per year. Bringing next-generation communications and computing systems to make the grid more "intelligent," from the standpoint of both suppliers and users of electricity, would seem to present enormous opportunities for value creation. The formation of a consortium such as the one above could be an important part of this process.

The perennial issue facing any effort to make changes in the utility grid is the regulatory question: whether all the relevant state utility commissions, federal agencies and other regulatory bodies will approve the change, and will they create an economic incentive for the change to be made.

February 7. The **Intercontinental Exchange** (ICE), a privately-held online energy exchange and clearinghouse, announced a 72% increase in revenues from over-the-counter trades last year, and saw over 780 firms using its trading platform, up 50% from the year prior.

Comment. As noted in *UtiliPoint*, the FERC recently issued a report praising clearinghouses as a way to minimize counterparty exposure in bilateral trades and restore greater liquidity to energy and power wholesale markets. Exchanges providing clearinghouse functions investigate the creditworthiness of their members, require that members post collateral and hold reserves against their open positions, and carry insurance coverage in case of default. In this way, clearinghouses stand between two parties to a trade, minimize counterparty risk on both sides, and help create the confidence necessary to support liquid and transparent markets. A recent report from the merchant generation industry found that energy and power companies could reduce the collateral required to back their trades by as much as 75-90% if they traded through clearinghouses rather than bilaterally. Given the enormous debt burden the industry must refinance (rough estimates are $100+ billion), any move that frees up capital could provide significant relief.

Energy Techline

Company News Releases

April 28. **International Transmission Company** has begun operating as an independently owned, for-profit business, moving electricity from power generating facilities in parts of Michigan and other Midwestern states to customers in southeastern Michigan. The majority shareholder in the new company is **ITC Holdings LP**, a Michigan partnership. Company management and employees own a minority interest. International Transmission currently employs 50 people and expects to double that number within the next 12 months. International Transmission's service territory covers 7,500 square miles in southeastern Michigan. This includes all or parts of 12 counties and metropolitan Detroit, an area with more than 4.5 million people. Its system comprises more than 2,500 pole-miles of overhead and underground high-voltage transmission lines, transmission structures (poles, towers), 39 transmission sub-stations, rights-of-way and easements, and the power coordination center in Ann Arbor.

April 15. **Systems Design & Technology**, an energy and engineering holding firm, announced the launch of **SolarOne Products and Consulting**, a product and business development firm that will provide consulting services to companies seeking to develop clean energy-based products. SolarOne will also continue to pursue certain of the business activities of **Solar Dynamics**, a Connecticut-based manufacturer of portable solar power systems dissolved in March 2003 whose assets System Design and Technology acquired.

April 10. **International Automated Systems Inc.** (IAS) announced that it has been awarded a patent on its propulsion turbine, which is intended to be a revolutionary solution to low-cost, solar hydrogen, fuel production and electrical power generation. The company claims its turbine should deliver "remarkable advantages" in cost, maintenance, size, efficiency and versatility. IAS expects to launch a commercial version this year, and will offer units sized for the residential and small business power consumer.

The Many Roads to the Future of the Automobile

A. The Superhighway

April 17. **Toyota Motor Corp.** unveiled a more powerful version of its hybrid electric vehicle (HEV), the Prius sedan. Toyota raised the voltage of the electrical system and improved the battery to give the new Prius the power of a 2.0 liter engine, although it only has a 1.5 liter engine. As for fuel economy, this version of the Prius is projected to get about 55 miles a gallon under U.S. driving conditions, up from 52 miles a gallon for the current model. The price is still being decided, but will likely be close to that of the current Prius, which starts at around $20,000 in the United States. Toyota has sold 131,000 hybrids since introducing the first model in 1997, over three times the number sold by **Honda**, the next leading HEV producer. Within the next few years Toyota expects to offer 10 different HEV models and sell 300,000 hybrids per year.

B. The Dead Ends

April 18. In 2002, **Ford Motor Co.** announced its intention of improving the fuel economy of its sport-utility vehicles by 25% no later than 2005. A year later the company announced that it will not meet that goal. Ford's failure could increase pressure on the federal government to mandate higher vehicle fuel efficiencies. Some technologies that Ford has been working on have not yet proved out, and raising average SUV fleet efficiency has faced the additional challenge of a market that has demanded bigger, not smaller vehicles.

April 17. **General Motors Corp.** is reported to be taking back the remaining 375 of its 1,000 EV1s as their leases expire because it cannot supply parts to repair them. GM plans to have five fuel cell models, which have twice the range of its best EV1s in the Los Angeles city fleet by June.

C. The Scenic Route?

April 17. Not to be outdone by the Bush Administration, a US Senate committee endorsed a five-year, nearly $3 billion research program to develop hydrogen fuel cells and a hydrogen infrastructure, and make hydrogen-powered fuel cell cars a commercial reality by 2020. This allocation is almost twice the size of the hydrogen initiative proposed by President Bush earlier this year. In addition, the legislation would require the government to purchase, if possible, a certain number of hydrogen-powered vehicles and electricity from hydrogen sources once they become available.

Comment. These articles illustrate a number of key points about the technological future of the automotive industry. On the one hand, there is the hybrid-electric vehicle (HEV), a car that combines a traditional gasoline-powered internal combustion engine with an electric motor and an array of batteries. HEVs run on the same gasoline found at the corner gas station, so there is no need to replace the existing fuel infrastructure, and the batteries do not need to be plugged in to recharge – like the standard 12-volt battery in every car today, the batteries in an HEV charge up when the engine drives the vehicle. The additional, and crucial, advantages of HEVs such as the Prius is that they deliver twice the fuel efficiency and a 90% reduction in emissions compared to traditional automobiles at only a modest premium in price. In short, HEVs are here now, they run on good old-fashioned gasoline, they accomplish two vital goals – improved fuel efficiency and drastically reduced emissions – and all at a pretty reasonable price.

On the other hand, the articles about Ford, GM and the Senate's proposal point to automotive technology initiatives that either have not worked or may work but not for another two decades. Ford tried to increase the fuel efficiency of its SUV fleet and failed, and General Motors has abandoned its electric vehicles. Meanwhile, the federal government intends to invest in the development of a hydrogen infrastructure and hydrogen-powered fuel-cell vehicles. However, the Bush administration itself has stated that there is no guarantee that these fuel cell vehicles will ever become commercially viable, and indeed, the Secretary of Energy expects that we will have to wait until 2020 to have an answer.

The argument for pressing ahead with a hydrogen infrastructure despite the extremely long timeline is that although HEVs are a good interim solution, they do not free us from the grip of petroleum, a polluting energy source that we will eventually exhaust. We agree fully, and therefore continue to support a well-funded public-sector fuel cell and hydrogen infrastructure development program. Nonetheless, much more should be done to accelerate the growth of the HEV market. Even if HEVs are ultimately "interim" solutions, they should reach cost parity with traditional automobiles soon. They are priced at only $2,000 - $3,000 more than the gasoline engine equivalent now, and as annual production volumes climb out of the thousands and into the millions, much of the cost premium should evaporate. Add to this the 50% improvement in fuel efficiency and 90% reduction in emissions, we reach two conclusions:

1. HEVs are worthy of substantial public-sector support, in the form of research and development programs, tax breaks and the like—in other words, HEVs should enjoy a bit more of the same kinds of supports that tax payers are being called on to provide to the hydrogen infrastructure.
2. Even as an interim solution that bridges the way to hydrogen-power fuel-cell vehicles, for the HEV, "interim" may end up meaning 15-25 years, possibly more.

The Powerful Attraction of Power Electronics—The Solar Inverter Market Heats Up

April 1. The international solar wholesaler **AET**, owned by **Conergy AG**, has signed a Memorandum of Understanding with **Xantrex** for rights to distribute Xantrex's inverters for off-grid solar applications in Europe. Xantrex will benefit from the market access of the international solar wholesaler. With local offices in Madrid, Zurich, Berlin, Munich and Marseille, AET has a substantial presence in Europe. The company's sales exceeded 16MW last year, which was up 65% from 2001. Canada-based Xantrex Technology Inc. is a world leader in the market for both grid-connected and off-grid solar power inverters.

April 4. **Sharp Corporation** and **Daihen Corporation** are jointly developing a 100kW solar inverter for large-scale solar power systems for commercial users and electric utilities. Daihen will manufacture the inverters, and Sharp will distribute them as part of a turnkey solution that will include solar power modules (produced, we suspect, by Sharp) and ancillary equipment. This solar inverter is the first high-power standard-spec unit offered in the Japanese market. Until now, high-power inverters have generally been manufactured on an "order-booked" basis, entailing significant lead-times before delivery. By creating a standard specification for large-scale inverters, Sharp and Daihen should be able to reduce time from order to delivery and gain cost advantages. Testing begins this May, with product launch in Japan scheduled for July 2003, in the US in December 2003 and Europe in January 2004.

Comment. These announcements are just the most recent in a long string of news items about business activity in the inverter market, not just for solar power applications but also for fuel cells, wind turbines and other emerging power generation technologies. Several examples come to mind. Magnetek, a long-time supplier of high-power inverters for United Technologies' 200kW phosphoric acid fuel cells, is developing inverters for wind and other renewable energy sources. GE is receiving support from the Department of Energy to develop a 5kW solar power inverter. And SMA, the dominant provider of solar power inverters in Europe, has begun selling in the North American market, and has quickly built a presence here.

There is a simple reason why inverters are attracting significant attention: the inverter is a key enabling technology embedded in virtually every distributed generation device. Selling inverters is a way to benefit from the growth of the solar power market (or the distributed generation market more broadly) without having to rely for success on a particular manufacturing process or technology. In contrast, producers of solar systems, fuel cells and the like must depend on one or at best a few technical approaches, and are typically not able to address as much of the market as an inverter supplier.

The inverter market is still relatively immature. As global unit sales continue to grow, we believe the winning suppliers will be those with the technology, the volume or the distribution.

March 7. After successful pilot programs, **SoftSwitching Technologies Corp.** debuted its I-Grid web-based power monitoring system, which is a web-based, real-time distributed power quality and reliability monitoring and notification system that uses the company's low-cost I-Sense monitors. SoftSwitching Technologies is able to offer a power monitor at less than 10% of the cost of existing monitors without sacrificing significant capability.

Comment. The implications of the I-Grid product for power quality equipment markets could be profound. There is a large disconnect between the economic losses caused by power quality problems and the annual purchase of power quality solutions. The **Electric Power Research Institute** has estimated that the US economy loses upwards of $100 billion per year due to disruptions in production, loss of work-in-process, workforce downtime and maintenance and repair of equipment damage caused by unstable or interrupted power supplies. On the other hand, annual spending on power quality and reliability solutions such as surge suppressors, voltage sag correctors, uninterruptible power systems and backup generators is roughly $15 billion, a small fraction of annual power quality-related losses.

One obstacle to larger power quality solutions budgets has been lack of awareness. Commercial and industrial company managers have generally accepted the losses due to power quality problems as simply part of the cost of doing business. Broad-based installation of power flow monitors like SoftSwitching's I-Grid should enable utilities, energy service providers and power quality equipment producers to accumulate valuable databases of power quality and reliability incidents, and develop targeted sales and marketing efforts to companies affected by power quality issues. One result could be a sizable increase in sales of power quality management hardware, and one of the power quality equipment producers that could benefit is Softswitching Technologies (and as well they should).

March 2. **Duke Solar Energy** is well on its way to approval for what is likely to be the largest solar project under development in the US – a 50-megawatt solar power project in the Eldorado Valley near Boulder City, Nevada. Duke Solar plans to provide the solar energy to **Nevada Power Co.** and **Sierra Pacific Power Co.** at a price of 16 to 17 cents per kilowatt-hour (kWh). State laws mandating the purchase of power from solar and other renewable energy sources help guarantee demand for the output of Duke Solar's plant.

Comment. The announcement of this project creates an opportunity to compare solar power in terms of price and scale versus power from fossil fuels as well as from renewable energy sources. To begin, the 16 to 17 cents per kilowatt-hour Duke Solar Energy is proposing would be roughly four times the amount the Nevada utilities currently pay for electricity generated by traditional coal- and natural gas-fired power generation plants. It is also roughly four times the price of other renewables in Nevada. The Nevada utilities have asked the state Public Utilities Commission (PUC) to approve contracts to buy geothermal power from hot underground water for 4.3 to 5.2 cents per kWh, and wind power for 3 to 4 cents per kWh.

In fairness, the Duke Solar Energy plant, like solar in general, is most efficient at generating power on hot summer afternoons when the addition of significant air conditioning to the typical daily load drives demand to peak annual levels, and the real economic value of electricity is highest. In other words, solar systems reach maximum output exactly when power is needed most. Meanwhile, there is no guarantee that a wind turbine will be delivering power to serve critical summer peaks.

The other noteworthy point of contrast is scale. The largest solar power plant in the US will weigh in at 50 megawatts. Geothermal power projects regularly run between 50MW – 100MW, while onshore wind farms of several hundred megawatts are not uncommon, and off-shore wind farms have the potential to achieve even greater output. Fossil fuel-fired power generators with several hundred megawatts of capacity are typical, and plants can range above 1,000MW.

The conclusion is not that solar power has no future – we believe the truth is very much to the contrary. It does mean that both renewable and non-renewable energy sources have their strengths and weaknesses, and no single energy source is best in all applications. Although solar does not scale up as well as the others, it is particularly well suited for scaling down. Solar modules, the most basic unit of solar power generation, are usually sized at around 100 watts (one ten-thousandth of one megawatt). Unlike any of the other energy sources, solar holds the potential of becoming a building material – solar cells are already used as roofing tiles, transparent solar cells can act as windows, and solar cells can be tinted various colors and designed into a building's façade. Solar is also unique among energy sources in that it can be made flexible for folding or rolling to provide portable power, and could even become a clothing fabric.

TapeTalk

Energy Tech Company Share Price and Earnings Performance

Overall energy tech stock returns for the last three months have been solid, tracking ahead of both the Nasdaq and S&P 500 indexes. Shares of energy IT companies Intergraph (+18%) and Itron (+20%) posted solid gains last month, and energy storage stocks traded exceptionally well (up an average of 40%). Meanwhile, Astro-Power shares continued to drag on average returns of the distributed generation segment. The stock has been delisted from the Nasdaq National Market and the company still struggles with accounting-related issues.

Company	Price 16-May-03	Mkt Cap ($MM)	Share Price % Change 2003 YTD	Last Mo.	Last Yr.	Price/Earnings FY 02	FY 03	Price/ Book	Price/ Cash	Price/ LTM Sales
Distributed Generation										
AstroPower	3.99	87	-50.1%	-29.2%	-70.4%	20.0	12.9	0.6	2.6	1.0
Ballard Power	13.17	1,525	19.0%	9.6%	-62.6%	n/a	n/a	1.9	4.0	16.8
Capstone Turbine	1.27	104	41.1%	11.1%	-83.4%	n/a	n/a	0.6	0.7	5.3
Energy Conversion Devices	10.07	221	2.8%	12.2%	-48.3%	n/a	n/a	1.7	1.6	2.9
Evergreen Solar	1.50	17	16.3%	-3.7%	-62.1%	n/a	n/a	0.6	2.0	2.6
FuelCell Energy	8.09	318	23.5%	22.0%	-63.9%	n/a	n/a	1.2	1.6	7.1
H Power	4.14	45	8.1%	n/a	22.8%	n/a	n/a	0.8	1.0	14.9
Millennium Cell	1.79	53	-25.1%	2.8%	-54.2%	n/a	n/a	7.2	6.5	75.9
Plug Power	5.39	322	20.0%	0.2%	-48.6%	n/a	n/a	3.0	4.9	27.3
Proton Energy Systems	2.96	99	-1.3%	7.7%	-63.6%	n/a	n/a	0.6	0.7	21.1
Average			**5.4%**	**3.6%**	**-53.4%**			**1.8**	**2.5**	**17.5**
Clean Fuel & Combustion Technology										
Catalytica Energy Systems	2.62	46	-5.1%	17.6%	-39.6%	n/a	n/a	0.7	0.7	9.6
Fuel-Tech N.V.	4.39	86	4.8%	10.3%	-30.7%	36.6	14.6	5.1	7.9	2.7
Headwaters	17.46	483	12.6%	17.3%	35.3%	13.3	11.1	4.1	45.1	2.5
Methanex Corporation	10.10	1,278	20.5%	2.4%	51.3%	n/a	n/a	1.3	2.7	1.3
Quantum Fuel Systems Tech	2.07	47	-11.9%	-13.7%	-59.5%	n/a	n/a	0.8	3.4	2.0
Syntroleum Corporation	1.96	66	13.3%	-7.8%	-75.6%	n/a	n/a	(16.3)	4.5	5.7
Average			**5.7%**	**4.4%**	**-19.8%**			**(0.7)**	**10.7**	**4.0**
Energy Information Technology										
Caminus Corporation	8.90	152	280.3%	n/a	-89.8%	n/a	n/a	1.2	3.9	1.7
Intergraph	21.56	997	21.4%	17.6%	29.3%	58.3	47.9	1.6	2.0	2.0
Itron	21.41	433	11.7%	19.8%	-36.7%	17.5	14.6	2.6	33.6	1.5
Average			**104.5%**	**18.7%**	**-32.4%**			**1.8**	**13.2**	**1.7**
Energy Storage										
Active Power	1.66	70	-6.7%	23.4%	-73.8%	n/a	n/a	0.7	0.8	5.1
Beacon Power	0.27	12	28.6%	35.3%	-83.8%	n/a	n/a	0.6	0.6	n/a
C&D Technologies	13.70	351	-22.5%	11.0%	-22.7%	19.3	13.8	1.4	27.0	1.0
Electric Fuel Corporation	0.98	34	53.1%	86.3%	-61.4%	n/a	n/a	3.8	22.9	5.4
Medis Technologies	7.48	175	49.6%	52.7%	-32.0%	n/a	n/a	2.4	29.2	n/a
Ultralife Batteries	6.40	82	73.0%	22.4%	-17.6%	18.3	9.8	3.7	28.4	2.5
Valence Technology	3.96	272	204.6%	45.1%	-61.4%	n/a	n/a	(14.1)	85.1	151.2
Average			**54.2%**	**39.5%**	**-50.4%**			**-0.2**	**27.7**	**33.1**
ENERGY TECHNOLOGY INDUSTRY										
Mean			**22.6%**	**13.9%**	**-46.2%**			**1.2**	**9.1**	**8.8**
Median			**14.8%**	**11.1%**	**-53.8%**			**1.4**	**3.5**	**2.4**
NASDAQ			**15.2%**	**9.2%**	**-31.5%**					
S&P 500			**7.3%**	**8.1%**	**-24.0%**					

Note: Sources for data presented in *TapeTalk* and *Capital Markets Monitor* are I/B/E/S, Market Guide and Vortex Energy LLC estimates

TapeTalk (cont'd)

Energy Tech Company Share Price and Earnings Performance

The broad market rally of the past month or so also lifted shares of power semiconductor, power electronics and power quality companies. The battered power electronics segment outperformed in April as investors gained confidence that a recovery is on the way and returned to riskier names. Of the three energy tech segments involved in power conversion (power semiconductors, power electronics and power quality), the power semis continue to show particular strength, reflecting their generally positive earnings performance.

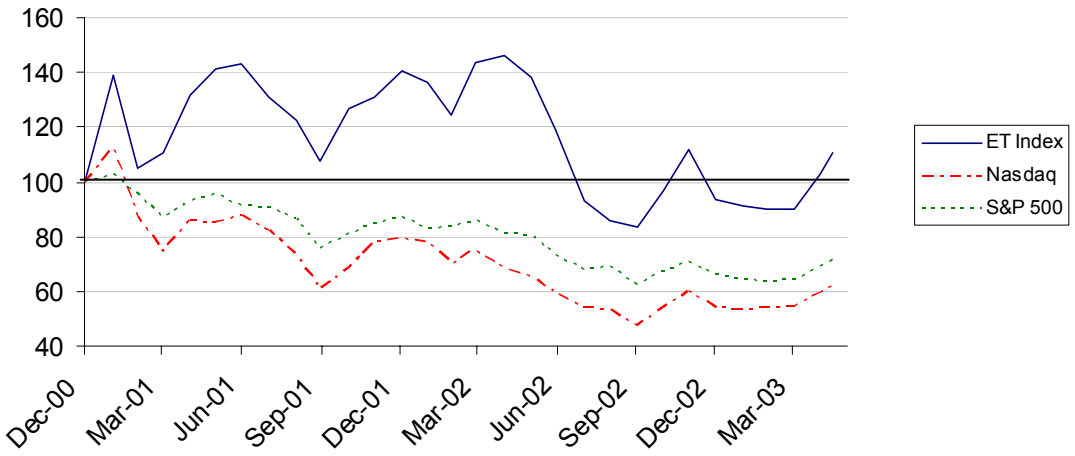
Company	Price 16-May-03	Mkt Cap ($MM)	Share Price % Change 2003 YTD	Last Mo.	Last Yr.	Price/Earnings FY 02	FY 03	Price/ Book	Price/ Cash	Price/ LTM Sales
Power Semiconductors										
Advanced Power Technology	4.31	45	33.0%	28.3%	-72.1%	n/a	39.2	0.6	2.3	1.0
AVX Corporation	11.40	1,983	16.3%	18.1%	-58.5%	n/a	45.6	1.4	2.8	1.7
Fairchild Semiconductor	13.05	1,530	21.8%	13.5%	-62.0%	50.2	22.1	1.3	2.3	1.1
International Rectifier	23.06	1,480	24.9%	15.0%	-47.1%	30.7	18.2	1.5	2.2	1.8
IXYS	7.69	246	8.9%	34.2%	-12.7%	n/a	29.6	1.7	6.6	2.1
Kemet	9.70	836	11.0%	-29.0%	-50.8%	n/a	48.5	1.1	3.2	1.8
Maxwell Technologies	6.30	87	4.1%	-5.4%	-38.3%	126.0	n/a	1.7	7.9	1.5
Microsemi	11.72	339	92.4%	7.3%	-79.5%	83.7	36.6	1.9	12.5	1.7
O2Micro International	13.08	498	34.3%	9.1%	-59.5%	46.7	26.2	3.7	4.3	7.4
ON Semiconductor	2.28	402	66.4%	7.1%	-33.8%	n/a	17.5	(0.6)	1.4	0.4
Power Integrations	24.65	713	45.0%	6.8%	-25.6%	43.2	32.4	4.7	6.3	6.6
Semtech	16.76	1,228	53.2%	5.0%	-69.3%	32.9	23.0	3.6	2.5	6.4
Siliconix	29.25	874	25.0%	18.7%	-14.7%	17.3	13.1	2.2	5.4	2.3
Average			**33.6%**	**9.9%**	**-48.0%**			**1.9**	**4.6**	**2.8**
Power Electronics										
Artesyn Technologies	3.92	152	2.1%	35.2%	-58.8%	n/a	39.2	1.3	2.9	0.4
Magnetek	2.25	53	-49.3%	-10.0%	-50.7%	n/a	n/a	0.4	17.6	0.3
PECO II	0.63	13	-1.6%	48.9%	-89.3%	n/a	n/a	0.2	0.5	0.2
Power-One	6.98	575	23.1%	32.9%	-45.5%	n/a	n/a	2.0	5.6	2.5
Powerwave Technologies	5.04	333	-6.7%	17.4%	-68.8%	n/a	n/a	1.1	2.0	0.9
SatCon Technology	0.63	11	-55.0%	6.9%	-73.1%	n/a	n/a	0.4	6.3	0.3
UQM Technologies	2.35	44	-7.1%	-3.7%	-53.4%	n/a	n/a	4.9	20.1	2.6
Vicor	7.94	335	-3.8%	17.9%	-49.1%	n/a	n/a	1.4	3.4	2.2
Average			**-12.3%**	**18.2%**	**-61.1%**			**1.5**	**7.3**	**1.2**
Power Quality										
American Power Conversion	15.90	3,126	5.0%	9.4%	4.8%	20.7	17.5	2.3	4.6	2.4
American Superconductor	3.66	78	21.6%	1.4%	-75.4%	n/a	n/a	0.5	3.3	5.8
Intermagnetics General	16.89	278	-14.0%	8.9%	-24.2%	18.0	15.9	1.8	3.6	1.9
Average			**4.2%**	**6.6%**	**-31.6%**			**1.6**	**3.8**	**3.4**
ENERGY TECHNOLOGY INDUSTRY										
Mean			**22.6%**	**13.9%**	**-46.2%**			**1.2**	**9.1**	**8.8**
Median			**14.8%**	**11.1%**	**-53.8%**			**1.4**	**3.5**	**2.4**
NASDAQ			**15.2%**	**9.2%**	**-31.5%**					
S&P 500			**7.3%**	**8.1%**	**-24.0%**					

TapeTalk (cont'd)

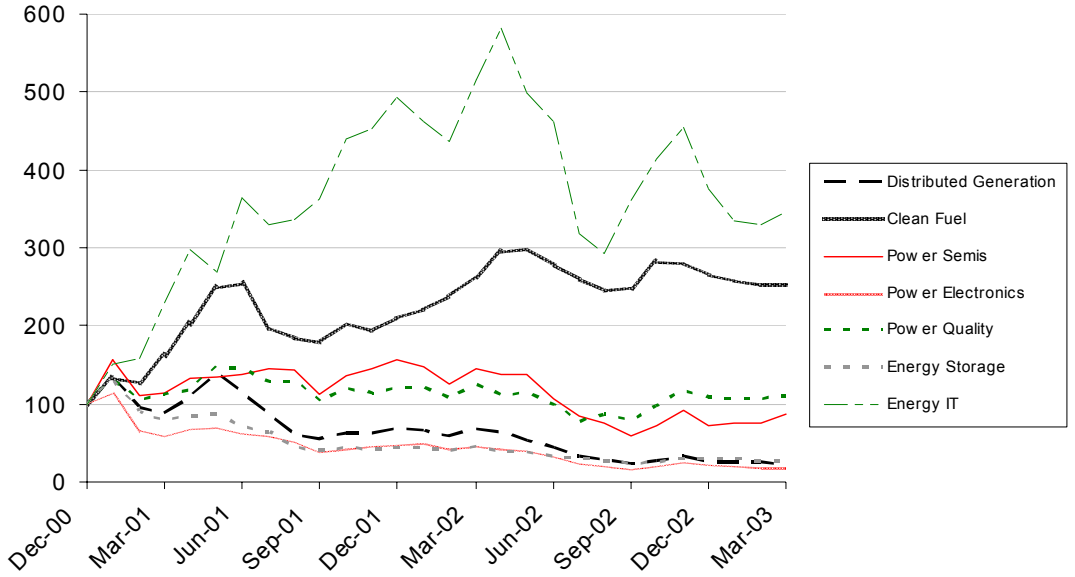
Energy Tech Company Share Price and Earnings Performance

The first graph below, plotting the stock price performance of the overall energy tech industry versus the major indexes, , shows that energy tech shares held up reasonably well over the course of two difficult years (2001-02), and returned to positive territory in 2003. The second graph below shows energy tech share price performance by segment, and underscores the importance of stock selection. Energy IT (topmost green dashed line) and clean fuel & combustion technology shares have outperformed the others by a wide margin.

VORTEX ENERGY TECH INDUSTRY INDEX



VORTEX ENERGY TECH SEGMENT INDEXES



TapeTalk (cont'd)

Energy Tech Company Share Price and Earnings Performance

Taken as a whole, technical stock indicators have improved over the last few months. First, insider buying has remained well ahead of selling, but is still concentrated at a few companies. Second, short interest has remained flattish since February. And last, both 4-week and 13-week relative strength versus the S&P 500 has moved into positive territory, driven primarily by energy storage and power electronics stocks.

Company	Insider Trading		Short Interest - Apr		Short Interest - Mar		Average Volume		Beta	Relative Strength	
	Buys	Sells	Shares	% of Float	Shares	% of Float	Daily	Monthly		4-week	13-week
Distributed Generation											
AstroPower	-	-	5,362	28.7%	5,138	27.5%	349	7,717	1.9	35	-42
Ballard Power	-	-	11,140	9.8%	10,899	9.6%	912	11,819	1.8	28	14
Capstone Turbine	13	-	1,099	2.2%	1,156	2.4%	1,442	10,291	3.8	54	40
Energy Conversion Devices	1	15	622	3.4%	616	3.3%	49	764	1.1	6	-5
Evergreen Solar	-	-	118	1.4%	127	1.6%	32	792	2.4	-21	2
FuelCell Energy	-	-	4,072	12.2%	3,782	11.3%	744	8,823	1.6	42	33
H Power	-	174	162	2.0%	125	1.6%	24	659	2.3	-5	6
Millennium Cell	-	155	392	1.7%	388	1.7%	143	1,955	1.2	-8	-15
Plug Power	-	760	3,132	12.2%	3,424	13.3%	499	4,807	1.8	4	-7
Proton Energy Systems	-	-	301	2.6%	308	2.7%	113	1,180	3.1	12	-8
Clean Fuel & Combustion Technology											
Catalytica Energy Systems	-	-	86	0.5%	88	0.5%	9	313	-0.4	-1	-17
Fuel-Tech N.V.	2	49	46	0.3%	233	1.5%	32	627	0.0	30	-6
Headwaters	1	-	1,650	6.3%	1,548	5.9%	341	5,249	0.7	22	7
Methanex Corporation	-	-	334	0.3%	309	0.3%	146	3,644	0.2	-4	1
Quantum Fuel Systems Tech	-	-	1,392	6.4%	1,157	5.4%	106	1,909	0.0	-5	-36
Syntroleum Corporation	405	-	90	0.4%	127	0.6%	63	925	0.2	-27	-17
Power Semiconductors											
Advanced Power Technology	4	-	180	3.1%	134	2.3%	31	672	2.8	27	-8
AVX Corporation	-	-	1,959	3.7%	1,403	2.6%	309	4,739	1.7	13	9
Fairchild Semiconductor	-	2,847	4,283	5.3%	4,226	5.2%	1,250	25,608	2.1	4	5
International Rectifier	-	8	5,365	8.8%	4,875	8.0%	847	21,817	2.7	10	0
IXYS	-	-	318	1.7%	330	1.8%	39	866	2.3	7	3
Kemet	-	445	3,223	3.8%	2,829	3.3%	521	6,875	1.5	9	7
Maxwell Technologies	-	15	739	5.9%	764	6.1%	30	420	1.2	-2	-11
Microsemi	-	-	2,116	7.7%	1,791	6.5%	359	10,388	2.0	-6	35
O2Micro International	-	-	3,774	16.6%	3,280	14.4%	204	4,615	3.3	-4	27
ON Semiconductor	195	10	79	0.1%	91	0.1%	546	10,703	3.0	73	71
Power Integrations	-	215	3,414	12.0%	3,453	12.2%	615	14,431	1.8	6	2
Semtech	-	-	3,879	5.5%	4,754	6.8%	960	26,642	1.5	-3	20
Siliconix	-	-	87	1.5%	57	1.0%	35	746	1.7	-10	14
Power Electronics											
Artesyn Technologies	-	10	104	0.3%	117	0.4%	178	3,118	2.6	5	8
Magnetek	2	-	211	0.9%	153	0.7%	125	1,992	1.1	9	-38
PECO II	-	-	20	0.1%	30	0.2%	35	393	1.5	24	39
Power-One	374	2	913	1.4%	837	1.3%	572	10,959	3.5	23	33
Powerwave Technologies	-	-	889	1.4%	1,054	1.6%	869	14,544	2.7	21	19
SatCon Technology	50	-	493	4.2%	353	3.0%	185	1,278	1.3	-28	-34
UQM Technologies	4	20	6	0.0%	6	0.0%	46	401	0.9	-19	-24
Vicor	-	10	146	0.7%	153	0.8%	90	1,849	1.8	24	8
Power Quality											
American Power Conversion	-	478	5,091	3.0%	2,788	1.7%	1,092	29,502	1.8	-2	-7
American Superconductor	-	-	1,783	8.6%	1,765	8.5%	88	2,612	1.8	1	-7
Intermagnetics General	-	8	391	2.4%	406	2.5%	81	1,027	1.0	-16	-10
Energy Storage											
Active Power	127	-	2,118	6.0%	1,992	5.6%	198	2,700	3.3	20	-2
Beacon Power	4,411	4,411	7	0.0%	13	0.0%	273	1,688	2.4	42	26
C&D Technologies	-	-	498	2.0%	379	1.5%	220	3,143	1.7	-1	-28
Electric Fuel Corporation	-	125	524	1.9%	525	1.9%	529	6,221	1.8	27	77
Medis Technologies	-	-	868	9.0%	827	8.5%	36	768	2.2	15	69
Ultralife Batteries	60	51	218	2.2%	218	2.2%	138	719	0.6	40	43
Valence Technology	21,147	1	3,522	8.2%	3,291	7.7%	351	5,777	2.6	34	79
Energy Information Technology											
Caminus Corporation	-	-	962	7.8%	318	2.6%	261	6,788	1.6	-1	231
Intergraph	-	42	655	1.6%	753	1.8%	271	6,314	0.8	-1	3
Itron	9	49	1,401	7.0%	866	4.3%	122	4,602	0.4	20	13
Total	26,796	9,851	78,833	4.5%	73,390	4.3%	16,388	291,789			
Average							348	6,169	1.8	9.5	4.2

All share data in thousands
Insider trading data covers the last 6 months of activity
Daily trading volume based on 10-day average; monthly volume based on 3-month average
Relative strength indicates how well a stock has performed versus the S&P 500 over a specified time

TapeTalk (cont'd)

Energy Tech Company Share Price and Earnings Performance

EPS remain largely negative. Revenues at many companies are trending higher both sequentially and year over year. Median revenues in power semiconductors and power electronics, by far the largest sectors by revenue, are flat to down -15% sequentially, in part due to seasonality. Year/year sales are generally higher, with sizable and broad-based growth evident in distributed generation, clean fuels, energy IT and power semis.

	Revenues				Last Q Revs - % Chg		Diluted Continuing EPS				Last Q EPS - % Chg	
Company	Last Q	2001	2000	LTM	Q/Q	Y/Y	Last Q	FY2001	FY2000	LTM	Q/Q	Y/Y
Distributed Generation												
AstroPower	23.0	69.5	49.8	84.8	12.7%	25.0%	0.04	0.16	0.18	0.23	100.0%	-33.3%
Ballard Power	33.1	90.9	36.2	90.9	13.0%	173.6%	(0.33)	(1.05)	90.90	(1.39)	n/a	n/a
Capstone Turbine	3.6	19.5	36.0	19.5	-7.7%	-64.4%	(0.26)	(0.61)	(12.82)	(0.95)	n/a	n/a
Energy Conversion Devices	18.5	91.7	71.4	76.9	16.4%	-30.7%	(0.26)	(0.96)	(0.27)	(1.15)	n/a	n/a
Evergreen Solar	2.2	6.7	2.5	6.7	4.8%	144.4%	(0.31)	(1.16)	(1.10)	(1.16)	n/a	n/a
FuelCell Energy	10.3	41.2	26.2	44.6	-24.8%	47.1%	(0.41)	(1.25)	(0.45)	(1.51)	n/a	n/a
H Power	0.7	2.6	3.6	3.0	-22.2%	-12.5%	(0.87)	(2.59)	(2.20)	(2.82)	n/a	n/a
Millennium Cell	0.2	0.7	-	0.7	100.0%	n/a	(0.12)	(0.58)	(0.72)	(0.58)	n/a	n/a
Plug Power	3.4	11.8	5.7	11.8	13.3%	36.0%	(0.25)	(0.93)	(1.56)	(0.93)	n/a	n/a
Proton Energy Systems	0.9	4.7	3.0	4.7	-43.8%	-50.0%	(0.11)	(0.15)	(5.92)	(0.41)	n/a	n/a
Clean Fuel & Combustion Technology												
Catalytica Energy Systems	1.5	4.8	5.5	4.8	0.0%	114.3%	(0.20)	(1.33)	(1.25)	(1.02)	n/a	n/a
Fuel-Tech N.V.	11.4	32.6	17.7	32.6	42.5%	103.6%	0.06	(0.09)	0.02	0.14	200.0%	n/a
Headwaters	86.1	119.3	45.5	189.7	-2.9%	240.3%	0.24	0.94	0.87	1.04	-17.2%	14.3%
Methanex Corporation	336.7	1,041.8	1,195.5	1,008.8	9.7%	85.3%	0.58	0.21	0.46	0.21	n/a	n/a
Quantum Fuel Systems Tech	6.0	23.4	23.4	23.3	7.1%	71.4%	(0.23)	(2.46)	(1.71)	(1.27)	n/a	n/a
Syntroleum Corporation	2.4	11.6	6.7	11.6	-38.5%	50.0%	(0.34)	(1.98)	(0.91)	(1.98)	n/a	n/a
Power Semiconductors												
Advanced Power Technology	11.4	43.4	36.9	43.4	-13.0%	115.1%	(0.06)	(0.36)	0.19	(0.36)	n/a	n/a
AVX Corporation	261.2	1,134.1	1,250.0	1,148.0	-7.6%	-5.1%	(0.08)	(0.04)	3.22	0.01	n/a	n/a
Fairchild Semiconductor	351.1	1,411.9	1,407.7	1,411.9	-0.8%	4.2%	(0.15)	(0.02)	(0.42)	(0.02)	n/a	n/a
International Rectifier	214.4	720.2	978.6	801.3	2.3%	20.0%	0.12	0.75	1.35	(1.29)	n/a	-36.8%
IXYS	35.5	82.8	111.4	118.6	0.6%	120.5%	(0.03)	0.07	0.49	(0.18)	n/a	n/a
Kemet	106.5	447.3	508.6	458.7	2.7%	-9.7%	(0.19)	(0.32)	4.00	(0.63)	n/a	n/a
Maxwell Technologies	15.5	58.0	77.9	58.0	-6.6%	0.6%	(0.01)	(0.82)	(1.66)	(2.86)	n/a	n/a
Microsemi	45.9	212.6	243.4	201.6	-6.7%	-19.5%	(0.06)	(0.16)	0.59	(0.37)	n/a	n/a
O2Micro International	19.3	70.2	45.8	67.2	4.9%	19.9%	0.04	0.16	0.21	0.30	-33.3%	-50.0%
ON Semiconductor	265.7	1,084.5	1,214.6	1,084.5	-2.3%	-0.4%	(0.24)	(0.82)	(4.21)	(0.83)	n/a	n/a
Power Integrations	29.1	108.2	94.1	108.2	-0.3%	22.8%	0.13	0.33	0.23	0.32	8.3%	160.0%
Semtech	44.5	193.0	191.2	193.0	-5.7%	-4.1%	-	0.54	0.34	0.55	n/a	n/a
Siliconix	97.8	372.9	305.6	372.9	-0.5%	17.0%	0.34	1.55	0.51	1.56	-24.4%	21.4%
Power Electronics												
Artesyn Technologies	81.9	350.8	494.0	350.8	-1.8%	-9.5%	(0.93)	(2.84)	(0.83)	(2.83)	n/a	n/a
Magnetek	51.3	188.2	298.3	182.7	19.9%	8.9%	(1.71)	0.06	0.39	(1.05)	n/a	n/a
PECO II	10.7	62.1	106.7	62.1	-40.2%	-53.5%	(0.47)	(1.85)	(0.31)	(1.87)	n/a	n/a
Power-One	56.3	230.7	363.7	230.6	-14.7%	16.3%	(0.04)	(2.64)	(2.36)	(2.63)	n/a	n/a
Powerwave Technologies	52.2	384.9	300.3	384.9	-31.4%	-49.9%	(0.16)	0.06	(0.33)	0.07	n/a	n/a
SatCon Technology	6.9	41.6	41.7	40.2	-38.4%	-16.9%	(0.31)	(1.25)	(1.51)	(1.23)	n/a	n/a
UQM Technologies	3.7	21.4	25.3	17.1	-9.8%	-28.8%	(0.07)	(0.36)	(0.12)	(0.41)	n/a	n/a
Vicor	37.7	152.6	195.9	152.5	-9.4%	9.0%	(0.16)	(0.38)	(0.01)	(0.37)	n/a	n/a
Power Quality												
American Power Conversion	309.0	1,300.0	1,404.8	1,300.0	-13.7%	4.1%	0.15	0.59	0.58	0.58	7.1%	66.7%
American Superconductor	2.8	11.7	16.8	13.4	-37.8%	-20.0%	(0.60)	(2.79)	(1.08)	(3.00)	n/a	n/a
Intermagnetics General	37.8	153.3	138.2	146.7	3.0%	1.6%	0.25	1.19	0.67	0.82	56.3%	38.9%
Energy Storage												
Active Power	1.6	13.5	22.6	13.5	-48.4%	-61.0%	(0.15)	(0.67)	(0.70)	(0.67)	n/a	n/a
Beacon Power	-	-	-	-	n/a	n/a	(0.05)	(0.62)	(10.77)	(0.58)	n/a	n/a
C&D Technologies	79.8	335.7	471.6	335.7	-8.9%	-9.6%	0.20	1.35	2.05	0.75	0.0%	25.0%
Electric Fuel Corporation	2.1	6.4	2.1	6.4	-36.4%	250.0%	(0.06)	(0.71)	(0.62)	(0.28)	n/a	n/a
Medis Technologies	-	0.2	-	-	n/a	n/a	(0.13)	(0.60)	(1.79)	(0.60)	n/a	n/a
Ultralife Batteries	8.8	15.6	32.5	33.1	29.4%	17.3%	(0.10)	(2.03)	(1.55)	(1.68)	n/a	n/a
Valence Technology	0.6	4.9	8.7	1.8	100.0%	-45.5%	(0.14)	(1.53)	(1.14)	(0.70)	n/a	n/a
Energy Information Technology												
Caminus Corporation	19.7	74.7	51.7	89.2	4.8%	29.6%	(0.29)	(0.39)	(1.04)	(0.66)	n/a	n/a
Intergraph	120.6	501.2	532.1	501.2	-1.1%	-2.0%	0.17	7.48	0.39	7.37	-90.8%	112.5%
Itron	74.6	284.8	225.6	284.9	-3.5%	20.1%	0.14	0.41	0.75	0.35	n/a	n/a

All revenue data in millions

For companies with non-calendar fiscal years, revenue and EPS data is for FY2002 and FY2001

Diluted continuing EPS as reported in SEC filings; excludes extraordinary items but includes "above the line" gains and charges

TapeTalk (cont'd)

Energy Tech Company Share Price and Earnings Performance

The latest EPS results continue to surpass consensus. We have said since January that 2H03 probably need to come down, and this is indeed what is happening. Cuts are mostly in power semi and power electronics estimates.

Latest Quarter Earnings Surprises	
Upside	26
Downside	13

Total Estimate Revisions ↑ / ↓		
Current Q	Next Q	Current Year
7 ↑	6 ↑	12 ↑
12 ↓	12 ↓	15 ↓

	Earnings Surprises - Latest Q			EPS Estimate			EPS Est. % Chg		
Company	Actual	Estimated	Variance	Current Q	Next Q	Current Year	Current Q	Next Q	Current Year
Distributed Generation									
AstroPower	0.04	0.07	(0.03)	0.06	-	0.20	20.0%	0.0%	5.3%
Ballard Power	(0.33)	(0.34)	0.01	(0.28)	(0.26)	(0.98)	0.0%	0.0%	0.0%
Capstone Turbine	(0.09)	(0.14)	0.05	(0.13)	(0.13)	(0.50)	7.1%	7.1%	10.7%
Energy Conversion Devices	(0.26)	-	-	-	-	(0.62)	0.0%	0.0%	0.0%
Evergreen Solar	(0.31)	(0.30)	(0.01)	-	-	-	0.0%	0.0%	0.0%
FuelCell Energy	(0.41)	(0.44)	0.03	(0.42)	(0.39)	(1.55)	0.0%	0.0%	0.6%
Millennium Cell	(0.13)	(0.08)	(0.05)	(0.13)	(0.13)	(0.52)	-62.5%	-62.5%	-62.5%
Plug Power	(0.27)	(0.24)	(0.03)	(0.20)	(0.19)	(0.86)	4.8%	9.5%	6.5%
Proton Energy Systems	(0.14)	(0.09)	(0.05)	(0.13)	(0.12)	(0.48)	-44.4%	-33.3%	-33.3%
Clean Fuel & Combustion Technology									
Catalytica Energy Systems	(0.20)	n/a	n/a	-	-	-	0.0%	0.0%	0.0%
Fuel-Tech N.V.	(0.02)	-	-	0.02	0.04	0.12	0.0%	0.0%	-65.7%
Headwaters	0.24	0.22	0.02	0.35	0.44	1.31	-2.8%	0.0%	0.0%
Methanex Corporation	0.35	(0.09)	0.44	-	-	1.15	0.0%	0.0%	-5.7%
Quantum Fuel Systems Tech	(0.22)	(0.30)	0.08	(0.22)	(0.19)	(1.05)	0.0%	0.0%	0.0%
Syntroleum Corporation	(0.34)	-	-	-	-	(0.25)	0.0%	0.0%	0.0%
Power Semiconductors									
Advanced Power Technology	(0.06)	(0.06)	-	(0.03)	-	(0.07)	25.0%	0.0%	0.0%
AVX Corporation	(0.06)	(0.03)	(0.03)	(0.02)	-	0.01	-100.0%	-100.0%	-87.5%
Fairchild Semiconductor	0.04	0.03	0.01	0.03	0.07	0.26	-57.1%	-41.7%	-33.3%
International Rectifier	0.19	0.18	0.01	0.23	0.27	0.75	0.0%	8.0%	1.4%
IXYS	(0.03)	(0.05)	0.02	-	0.03	(0.16)	0.0%	0.0%	0.0%
Kemet	(0.04)	(0.03)	(0.01)	(0.03)	(0.02)	(0.04)	-200.0%	0.0%	-233.3%
Maxwell Technologies	(0.01)	-	-	(0.07)	(0.02)	0.05	0.0%	0.0%	-75.0%
Microsemi	0.03	0.02	0.01	0.04	0.06	0.14	0.0%	20.0%	16.7%
O2Micro International	0.04	0.03	0.01	0.06	0.08	0.28	0.0%	-11.1%	-6.7%
ON Semiconductor	(0.17)	(0.19)	0.02	(0.13)	(0.08)	(0.40)	7.1%	0.0%	0.0%
Power Integrations	0.13	0.11	0.02	0.12	0.15	0.57	0.0%	-6.3%	0.0%
Semtech	0.11	0.10	0.01	0.11	0.12	0.51	0.0%	0.0%	0.0%
Siliconix	0.33	0.44	(0.11)	0.41	0.45	1.69	-12.8%	-10.0%	-13.8%
Power Electronics									
Artesyn Technologies	(0.13)	(0.14)	0.01	(0.10)	(0.06)	(0.31)	-11.1%	0.0%	-3.3%
Magnetek	(0.05)	(0.05)	-	(0.05)	(0.03)	(0.20)	0.0%	0.0%	0.0%
PECO II	-	(0.18)	(0.20)	(0.20)	(0.18)	(0.70)	0.0%	0.0%	0.0%
Power-One	(0.04)	(0.05)	0.01	(0.07)	(0.05)	(0.19)	-133.3%	-150.0%	-58.3%
Powerwave Technologies	(0.11)	(0.09)	(0.02)	(0.09)	(0.06)	(0.31)	0.0%	0.0%	0.0%
SatCon Technology	(0.32)	(0.09)	(0.23)	-	(0.23)	(0.89)	0.0%	0.0%	0.0%
UQM Technologies	(0.07)	-	-	-	-	-	0.0%	0.0%	0.0%
Vicor	(0.16)	(0.06)	(0.10)	(0.13)	(0.10)	(0.47)	-160.0%	-233.3%	-235.7%
Power Quality									
American Power Conversion	0.15	0.14	0.01	0.17	0.22	0.77	0.0%	0.0%	1.3%
American Superconductor	(0.41)	(0.52)	0.11	-	-	(1.53)	0.0%	0.0%	-2.0%
Intermagnetics General	0.25	0.25	-	0.26	0.24	0.94	0.0%	-4.0%	0.0%
Energy Storage									
Active Power	(0.15)	(0.16)	0.01	(0.15)	(0.14)	(0.57)	0.0%	6.7%	5.0%
Beacon Power	(0.21)	-	-	(0.07)	(0.07)	(0.69)	0.0%	0.0%	0.0%
C&D Technologies	0.21	0.19	0.02	0.14	0.16	0.71	-12.5%	-5.9%	-6.6%
Electric Fuel Corporation	(0.06)	n/a	n/a	-	-	-	0.0%	0.0%	0.0%
Medis Technologies	(0.13)	-	-	-	-	-	0.0%	0.0%	0.0%
Ultralife Batteries	0.02	0.02	-	0.14	0.09	0.35	250.0%	200.0%	191.7%
Valence Technology	(0.14)	(0.16)	0.02	(0.14)	-	(0.64)	0.0%	0.0%	0.0%
Energy Information Technology									
Intergraph	0.08	0.07	0.01	0.08	0.10	0.37	0.0%	0.0%	8.8%
Itron	0.29	0.24	0.05	0.27	0.31	1.22	-3.6%	-3.1%	1.7%

Capital Markets Monitor

Overview. February was a quiet month, which is not surprising given the high degree of uncertainty about market direction and the looming war. Those transactions that did close were relatively small and were completed as private placements rather than a broadly marketed offering. Activity picked up in March, with companies representing a range of industry segments accessing the capital markets.

April 9. **Comverge**, a provider of intelligent energy management systems, announced the completion of its previously announced $13 million private equity financing. The financing round was led by **Nth Power** and includes **E.ON Venture Partners GmbH**, **EnerTech Capital**, **Shell Internet Ventures,** and **Easton Hunt Capital Partners, L.P.** in the syndicate as new shareholders. **Data Systems & Software**, Comverge's parent company, also participated in the round and remains its largest shareholder. In addition, Comverge announced that it finalized terms for new credit arrangements totaling $6.5 million. Proceeds will be used to fund Comverge's product development and growth.

March 28. **Ultralife Batteries Inc.** announced that its primary lending bank, Congress Financial Corp., has agreed to amend its $15 million credit facility that was first established in June 2000, and extend the new facility through June 2004. The amendment also revises certain borrowing base formulas that are less restrictive given recent order activity with the US military.

March 24. **Evergreen Solar, Inc.,** a developer, marketer, and manufacturer of photovoltaic products, announced that it has executed a definitive Purchase Agreement for a private placement equity financing of $29.475 million of Series A Convertible Preferred Stock and a warrant. The purchase price will fall somewhere between $0.68 and $1.12 per share, depending on the average price of Evergreen's common stock over a certain time period. Between 26.2 million and 43.2 million new shares will be issued, to be determined by the final purchase price. Investors include the company's previous venture backers, a number of new funds, and **Beacon Power Corp.**, a developer of flywheel energy storage systems. Net proceeds of approximately $28.3 million will be used to expand manufacturing capacity, strengthen sales initiatives, and fund R&D activities.

Comment. There is no shortage of public and private energy tech companies in need of funds. The fact that Evergreen was able to raise substantial capital in the current environment is a positive statement about both the company and the solar power industry. Evergreen has made significant strides in lowering the cost and improving the productivity of its next-generation solar systems production process. Actually, Evergreen is just one among a number of companies developing promising technologies for bringing down the cost of solar power systems (details in *Inductance & Reactance*, pages *xx-xx*). The combination of technical progress in manufacturing with continued strong industry growth (megawatts shipped were up 26% in 2002) has meant that solar is one of the few areas of energy tech still able to attract funding.

Capital Markets Monitor (cont'd)

March 14. **Medis Technologies Ltd.** reported that its recently completed rights offering was over-subscribed. Medis reported stockholders purchased 2,325,600 shares of common stock at a fixed subscription price of $2.15 per share. Net proceeds from the offering will be used for working capital, including for the continued development of Medis' direct liquid fuel cells and attendant refueling cartridges for portable power applications. In addition to its fuel cell technology, Medis' product pipeline, in varying stages of development, includes highly conductive polymers, the toroidal engine and compressor, Stirling cycle system and Rankin cycle linear compressor. Medis has also developed the CellScan with many potential applications relating to disease diagnostics and chemo sensitivity.

March 13. **Clean Air Partners**, a provider of alternative fuel systems to reduce emissions from mobile and stationary engines, said it closed a second round of funding with $8.6 million. Previous investors **CIBC Capital Partners**, **Emerson Electric**, **EnerTech Capital**, **Exelon Capital Partners**, **Nth Power**, and **RBC Capital Partners** participated in the round. As a result of the funding RBC Capital Partners transferred from an observer on the board to a full board member. The company will use the funds for product and market expansion for low emission vehicles, electric distributed generation, and oil and gas application products. The company has signed on approximately 250 customers, including United Parcel Service, Sysco Foods, and the city of Los Angeles. The company raised $26 million in first round funding in July 2001.

Comment. We believe the market for clean fuel technologies holds much promise, and that Clean Air Partners is pursuing what should become a sizable opportunity. As a general rule we view products bought because of regulatory requirements as less attractive than products freely bought because of real consumer demand. The risk is that regulations can be changed, suspended, tightened or removed for political rather than economic reasons. One exception to our general rule – products bought to meet environmental regulations. For several decades now, the secular trend in environmental regulation has been toward increasing stringency. Although there are steps back as well as forward, limits on pollution by and large have continued to tighten, and we are confident that in five years' time they will be tighter still.

March 13. **Prenova**, a provider of energy management services, said it has received $15.5 million in funding in a recapitalized Series A round. With this funding the company, founded in 1997 as facility management outsourcing provider **Service Resources**, is re-naming itself Prenova. **Frontenac**, the company's principal investor since 2001, led the round, with existing investor **Austin Ventures** and new investor **River Cities Capital Funds** also participating. The company began to refocus exclusively on the energy management services sector last July. Prenova expects to reach profitability this year and has no plans to raise further funding.

Customers include **The Home Depot**, **Gap**, **AT&T**, and **Owens Corning**. The company's only other financing was a $32.5-million round of funding in May 2001.

March 5. **iWatt, Inc.**, a power management IC company developing and marketing digital controllers for power supplies, announced that it closed a $14.5 million Series B financing, led by new investor **VantagePoint Venture Partners**. Existing investors **Horizon Ventures**, **PTI Alliance of Taiwan**, and **Sigma Partners**, as well as several private investors, also participated in the round. The funding will be used for product development and market launch of its power management chips to computer and consumer electronics manufacturers worldwide.

Comment. Power has increasingly become the limiting factor in the design and functionality of a wide range of electronic products, including cell phones, PDAs, laptops, servers, routers and so on. As microprocessors become faster they require more power, but delivering increasing amounts of power efficiently in a small space without producing so much waste heat that the device incurs damage is a growing challenge – or in the case of iWatt, an opportunity.

March 6. **ON Semiconductor Corp.** raised $200 million through the issuance of senior secured notes priced at 95.467% of the principal amount, with a coupon of 12%. The notes will mature on March 15, 2010, and are non-callable for four years. The company has used the net proceeds from the offering to prepay a portion of the term loan under its senior bank facilities and to pay down debt drawn from its revolving credit facility.

February 18. **SatCon Technology Corporation** reported that it had finalized a $4 million financing transaction to provide working capital and satisfy lender expectations. The transaction includes approximately $3.2 million of equity financing and $800,000 of secured convertible subordinated debentures.

February 18. **Fuel Cell Technologies** (FCT) completed a private placement of 9,933,870 units issued at $0.46 per unit, for total gross proceeds of $4,569,580. The net proceeds will support the development of the company's combined heat and power 5kW solid-oxide fuel cell system. Fuel Cell Technologies designs and produces aluminum/oxygen power systems for underwater vehicles, and is developing a solid oxide fuel cell.

Capital Markets Monitor (cont'd)

In the table below we introduce a new feature to the *Capital Markets Monitor* -- a tool for tracking the aftermarket performance of new energy technology stocks issued within the last several years. Next month's issue of *Power Currents* will include data on follow-on offerings as well. Looking at both average and median returns, it is clear that public equity investors have shaken off their earlier enthusiasm for energy IPOs and generally sold with a vengeance.

IPO Aftermarket Performance

Company	Ticker	Market Cap	Price / Cash	Price 16-May-03	Offering Price	% Change	Date of Pricing
Beacon Power	BCON	11.6	0.6	0.27	6	-96%	16-Nov-00
Evergreen Solar	ESLR	17.1	2.0	1.5	14	-89%	1-Nov-00
Hydrogenics	HYGS	241.8	4.4	4.58	12	-62%	26-Oct-00
Proton Energy Systems	PRTN	103.5	0.7	2.96	17	-83%	28-Sep-00
02Micro International	OIIM	497.8	4.3	13.07	9	45%	22-Aug-00
Peco II	PIII	13.3	0.5	0.63	15	-96%	17-Aug-00
H Power	HPOW	44.6	1.0	4.14	16	-74%	8-Aug-00
Millennium Cell	MCEL	51.6	6.3	1.79	10	-82%	8-Aug-00
Active Power	ACPW	69.3	0.8	1.66	17	-90%	7-Aug-00
Advanced Power Technology	APTI	44.8	2.3	4.31	15	-71%	7-Aug-00
Capstone Turbine	CPST	101.8	0.7	1.27	16	-92%	28-Jun-00
Caminus	CAMZ	160.8	3.4	9.00	16	-44%	27-Jan-00
Plug Power	PLUG	274.4	4.2	5.39	15	-64%	28-Oct-99
Avg. IPO Performance			**2.4**			**-69%**	
Median IPO Performance			**2.0**			**-82%**	

The (De-)Construction Site

Strategic Deals, M&A, Restructurings, Bankruptcies and the Birth & Death of Companies

Overall Comment. Consolidation continued apace in the energy IT segment, with Indus acquiring the utility industry customer care business of Systems & Computing Technology, Lodestar buying an Australian energy software and sales organization, and Power Measurement acquiring the distributed generation and power monitoring product lines of D.L. Steiner. The power electronics segment also a number of deals, driven primarily by difficult end market conditions that are pushing small companies into the arms of larger players. The repositioning in the solar power industry that began a few months back is not over yet, as witnessed by Konarka's acquisition of Quantum Solar Energy Linz and the reports that Bekaert may walk away from its thin-film solar power investment altogether. And lastly, another fuel cell company acquisition was announced in which the principal motivation appears to be access to cash.

STRATEGIC DEALS

April 23. **SunWize Technologies** and **Global Solar Energy** have reached an exclusive agreement to sell flexible folding photovoltaic modules to the United States government. The agreement also gives SunWize the non-exclusive right to sell products built from Global Solar's technology in other domestic markets. Global Solar asserts that this technology offers distinct advantages over traditional solar power material, including the ability to mold to an irregular surface or even fold or roll up into a compact bundle that can be easily transported, deployed and stored. SunWize Technologies specializes in the design, manufacture, siting and installation of integrated solar power systems. Global Solar Energy manufactures thin-film solar power arrays for aerospace, military and commercial applications. The company also designs, installs, commissions and services complete turnkey solar power stations using standard crystalline silicon solar modules. **UniSource Energy Corporation** of Tucson is the majority owner of Global Solar Energy.

April 7. **Electric City** announced that it has entered into an agreement with **Commonwealth Edison** (ComEd) to develop a 50MW demand curtailment system using its EnergySaver /GlobalCommander solution. Electric City's technology will allow ComEd to remotely control commercial, industrial and government lighting systems over a secure IP network, lowering peak power demand while providing measurement and verification of load reduction. The system will cost approximately $25 million, will incorporate roughly 1500 EnergySaver systems, and should take about 18-24 months to fully deploy. Third-party lenders in long-term agreements with ComEd will pay for the system, while Electric City will guarantee the delivery of peak power reduction. In exchange for hosting the system and allowing remote control over their lighting systems, customers will receive the technology for free and will receive free steady-state energy savings.

April 7. **DTE Energy Technologies** and **Menag Holding AG** announced the signing of a joint distribution agreement under DTE's energy|now brand, which will give each company access to the products, services and distribution channels of the other. The agreement should advance DTE's efforts to penetrate the European energy service and equipment market, and Menag's efforts to enter the North American market. DTE Energy Technologies' portfolio of onsite energy products and systems includes power generation and combined heat and power using a variety of advanced solutions, in sizes ranging from 75kW to over 1MW. It also offers a remote monitoring and control system to ensure continuous reliability and efficiency.

April 2. **Astris Energi** announced that its joint venture partner, Montreal-based **CareAction**, acquired **H-Power's** fuel cell laboratory and production facility in Montreal. The facility was offered up for sale by **Plug Power** after acquiring H-Power. The Astris-CareAction joint venture, **Astris Transportation Systems**, will operate the facility together. It should become the first volume manufacturer of alkaline fuel cells in the world. Initial output of the plant will be concentrated on alkaline fuel cell power plants for small vehjcles, the first of which will be the ZENN (Zero Emission, No Noise) mini-car scheduled to roll out before the end of this year. The Astris-CareAction joint venture combines Astris's advanced alkaline fuel cell technology with the financial and management resources of CareAction.

March 17. **MesoFuel Inc.** and **Jadoo Power Systems LLC** jointly announced a strategic partnership arrangement to integrate MesoFuel's hydrogen generator products with Jadoo's fuel cell products. MesoFuel, a company that develops on-site, on-demand hydrogen generators, will jointly develop fuel cell products with Jadoo, a company currently marketing portable proton-exchange membrane fuel cells.

February 19. **Toshiba** and **Plug Power** announced a marketing agreement to explore the use of fuel cells for industrial premium power markets. The agreement will define a product that combines Plug Power's fuel cell technology with Toshiba's uninterruptible power systems. The companies expect the joint marketing agreement to lead to subsequent product development and commercialization agreements.

February 12. **BluePoint Energy** announced that it has entered into a strategic alliance with **URS Corporation**, a leading engineering firm, to provide engineering and installation services utilizing the BluePoint Lean-One Cogeneration System.

M&A ACTIVITY

April 16. A subsidiary of **Crane Co.** is making a cash tender offer to acquire all of the outstanding shares of **Signal Technology Corp.** at a price of $13.25 per share, for a total consideration of $153MM (about $135MM net cash). The purchase price of $13.25 per common share represents a 17.6% premium over the closing price on April 15, 2003 and a 29.4% premium over the average close since the beginning of the year. Signal Technology, headquartered in Danvers, Massachusetts, manufactures highly engineered power management products and radio frequency and microwave frequency components and subsystems for the defense, space and military communications markets. Signal Technology 2002 annual sales were approximately $87 million, implying an acquisition consideration of about 1.6x last year's sales. The company's operations will be integrated with Crane's Aerospace Electronics business.

April 9. **Quantum Fuel Systems Technologies Worldwide** said it would acquire **Global Thermoelectric** in a stock swap valued at about $75 million. Quantum, which makes fuel systems and fuel tanks for alternative-fuel vehicles and fuel cell applications, said it will issue Global Thermoelectric shareholders between 0.835 and 1.020 shares of Quantum stock for each share of Global common stock outstanding. The deal, expected to close in the third quarter, is subject to approval by shareholders of both companies.

Comment. "Cash is King" — nowhere in energy tech is it more true than among fuel cell and hydrogen-related companies. For most in this segment, time to significant commercial sales, much less positive cash flow and profits, is some years away. But in the current funding environment, finding the cash to finance operations in the meantime is extremely challenging. We find the strategic logic of Quantum's proposed takeover of Global Thermoelectric less than compelling. However, Global Thermo has one crucial feature — it has been trading below cash. As with Plug Power's recent acquisition of H-Power, the Quantum-Global Thermoelectric transaction appears to be driven primarily by Quantum's need for cash.

March 26. **Midtronics, Inc.** recently announced the acquisition of the assets of **Intra Technologies**, a producer of power management solutions used to improve the reliability, efficiency, and cost of DC power systems. Intra Technologies' product set is based on its patented MOSFET semiconductor switch, which can manage extremely high electrical current while generating very small amounts of heat in cost- and size- efficient packaging. Its products target the transportation, UPS, marine/off-highway, and military/aerospace industries. Midtronics focuses on the development and marketing of battery management technologies tailored to a variety of applications, including transportation (automotive, heavy-duty trucking, off-road), stationary and motive power, and military use.

Comment. The new frontier for power electronics is the transportation industry. Developments underway such as the increasing use of "drive-by-wire" technology, the use of electrical devices like GPS and personal entertainment systems, the transition to 42-volt power from the current 14-volt system and growing commercial acceptance of hybrid electric vehicles all create demand for new power electronics solutions. With this acquisition, Midtronics appears to be better positioning itself to take advantage of a large emerging opportunity.

March 24. **LODESTAR Corp.**, a provider of software solutions for the energy industry, announced that it has signed a definitive agreement to acquire **Office Management Services (Qld) Pty Ltd t/a Advanced Utility Solutions of Australia**, an energy software sales and support organization. Terms of the transaction were not disclosed. In November 2001, the company entered a Preferred Partner relationship with LODESTAR that led to the introduction of LODESTAR's software in the Australian and New Zealand energy markets.

Comment. Over the last six months, energy software & IT companies have been acquired. This is one of the first cross-national deals, and it appears to make good sense. LODESTAR gains access to two new markets, plus a platform from which to expand further into Asia. The timing is also good – utility software spending in the US has been depressed by difficult industry conditions, so stepping into overseas markets should offer a new source of growth.

March 13. Danish wind turbine maker **Vestas** is reportedly close to a deal to buy the wind turbine unit of Spain's top power utility **Endesa** for 150 million euros ($165.3 million). The report came a day after Vestas said it planned to buy an unnamed Spanish wind turbine maker in the first half of 2003. Endesa is in the process of selling **Made Tecnologias Renovables**, one of many assets up for sale in a campaign to reduce debt. A company spokesman said Endesa has received several offers for Made, and that an agreement could be reached soon, but would not comment further. Vestas, the world's largest producer of wind turbines for electric power generation, previously had an alliance with Spanish wind power firm Gamesa.

Comment. The Spanish wind turbine market is one of the largest in the world, and has experienced rapid growth for the past several years, in part due to the introduction of a rich subsidy program provided by the central government. Vestas may be re-positioning itself to better take advantage of the strong Spanish wind turbine market

March 10. **American Electric Power** has completed the sale of **Mutual Energy Service Company, LLC**, the customer care operation created to manage retail customer accounts in Texas, to **Alliance Data Systems**, a provider of transaction, marketing and credit services. In the transaction, which has a cash value of $30 million, ADS purchased the customer relationship and bill management operations that AEP established in 2001 to serve retail customers in Texas as well as the remainder of AEP's contract to provide Centrica back-office customer service for 810,000 retail customer accounts. AEP will realize a gain of approximately $9 million from the sale.

Comment. This deal follows on Indus Software's acquisition of SCT's utility industry customer care division last month (*see pg. 31 for details*). Energy software and services continues to be the most active area of M&A activity in the energy tech industry. While most of the buyers have been other energy IT companies, Alliance Data Systems and Indus are both broadline software and service companies looking to penetrate or expand into the energy and power industry. The fact that strategic buyers from outside the energy industry like ADS are seeking to get involved is a vote of confidence in an eventual recovery in utility company technology budgets as well as in the attractiveness of the energy IT market.

March 3. **TDK USA Corp.**, a subsidiary of TDK Corp., announced that it has agreed to acquire 100% ownership of **Innoveta Technologies Inc.**, a developer of high-performance, high-density board-mounted DC/DC power converters for computing and communications equipment, by means of a merger of TDK USA's wholly owned subsidiary with Innoveta. TDK USA will pay an aggregate amount of up to $18.5 million in cash to the holders of Innoveta's stock and options, of which $2.5 million is contingent upon attainment of specified revenue thresholds over the three years following the closing.

Comment. The Innoveta transaction is similar to that consummated between Power-One and di/dt in February (*see pg. 30 for details*). In both cases, the larger, acquiring company (Power-One and TDK) had a pre-existing relationship with the smaller, acquired company (di/dt and Innoveta). Both Innoveta and di/dt have been developing cutting-edge power converters, and their acquisition gives the acquiring companies complete access to their technology. It may have been the case that the long depression in computing and communications spending has weakened small companies with limited financial resources like Innoveta and di/dt to the point that a sale becomes their best means of assuring survival.

February 24. **Power Measurement**, an enterprise energy management systems provider, has acquired the distributed generation and power-monitoring division of **D.L. Steiner**, **Inc.**, an Ohio-based engineering service business. Power Measurement offers an array of products that enable energy users to improve their power quality, monitor electrical system status in real time and reduce energy costs. The company expects the acquisition of D.L. Steiner to round out existing product capabilities. Details on the acquisition consideration were not provided.

February 19. **Ballard Power Systems** and **Coleman Powermate**, a unit of **American Household**, have entered into a Memorandum of Understanding in which Ballard will purchase Coleman Powermate's AirGen portable fuel cell system assets, and will develop its own sales, marketing and distribution strategy for the portable fuel cell. The two companies had been working together on the 1-kilowatt AirGen for several years, and it was launched for commercial sale in December 2002.

Comment. Given that the AirGen became available for purchase only two months prior, it was a little surprising that Coleman Powermate pulled out so quickly. The decision came on the heels of **American Household**'s consolidation of Coleman Powermate with the First Alert business unit, which apparently gave management an opportunity for a strategic review. Since Coleman Powermate has a long history of producing and selling small and portable generators, the issue is not portable generators *per se* but portable fuel cell generators. Implicit in the decision, then, may have been a belief on the part of American Household that portable fuel cell generators might not be a profitable product line for some time.

February 14. In an all-stock transaction, **Power-One Inc.** announced that it had acquired **di/dt Inc.**, a supplier of high-density board-mounted DC/DC converters, or "bricks," used mainly in communications systems and networking environments. Power-One paid approximately 1.4 million shares of its common stock, and may pay out up to 1 million more shares through 2005 based on certain operational criteria. The transaction is anticipated to have a positive EBITDA impact and is expected to be neutral to slightly accretive to Power-One's earnings per share by the end of 2003. Power-One is a leading designer and manufacturer of standard DC/DC converters, power supplies, and power plant systems. Power-One was previously a di/dt stockholder and exclusive licensee of di/dt's high-performance power conversion technology.

February 14. **Amsterdam Power Exchange** acquired 100% of the shares in **Automated Power Exchange UK Ltd.**, formerly owned by **Automated Power Exchange Inc. of California, USA**. The two companies have also agreed that Amsterdam Power Exchange will have the rights to the brand name "APX" in all 51 countries in Europe.

February 13. **Indus International**, an enterprise asset management (EAM) software provider, announced it has entered into a definitive agreement to acquire the **Global Energy and Utility Solutions** (GEUS) software business unit of **Systems & Computer Technology Corporation** for $39 million. Indus provides asset management software for industries with complex asset bases, such as utility, oil and gas, defense, pulp and paper, metals and mining, and process manufacturing, while GEUS has tailored its customer information system (CIS) specifically for the energy and utility industries. Indus will use the acquisition to expand its customer base and functional footprint in the utility industry.

Comment. The GEUS deal marks the fourth energy IT acquisition in about as many months. The valuation of this most recent transaction seems more than reasonable, with the GEUS assets trading hands for roughly 0.6x - 0.7x LTM sales. What is notable about this transaction is that it represents one of the first in the software industry in which an enterprise management software company has acquired a customer care software company.

February 11. **Konarka Technologies**, a developer of flexible, polymer and nanoparticle-based photovoltaic (PV) technology, has acquired **Quantum Solar Energy Linz**, based in Linz, Austria, from Linz AG, the regional utility company. Konarka considers Quantum's organic solar cell technology to be complementary to its dye-based solar cell nanotechnology. Although details of the acquisition price were not disclosed, the consideration was at least partly stock-based, as Linz AG is now a Konarka shareholder.

RESTRUCTURINGS

March 14. **Stuart Energy Systems Corp.** (Toronto, Canada) announced that it is cutting about 70 jobs and closing down two offices following its acquisition of **Vandenborre Technologies** (Belgium), a maker of pressurized hydrogen generation systems. Stuart Energy announced plans to immediately close offices in Montreal and Trois-Rivieres, Quebec, and reduce operations at its Shawinigan, Quebec, plant. The company also announced plans to move all assembly and manufacturing to its headquarters in Ontario. The job cuts will hit all segments, including administration, operations and engineering. Besides cutting one-quarter of its work force, the company has consolidated its product and technology development programs. Company officials said it will make its organization more efficient by combining its power, transportation and industrial market groups in a regional sales structure, as it pushes its hydrogen energy station products in North America, Europe and Asia.

Comment. Stuart's announcement is one example of the on-going restructuring of the fuel cell and hydrogen technology industries now underway. While we believe the markets for fuel cells and the hydrogen products supporting them will be significant, at present there are way too many companies chasing much too little revenue.

BANKRUPTCIES

*March 26***.** The assets of **Advanced Energy Systems Inc**. (AES) were liquidated in a two-step auction process that closed on March 26. AES, which designed, manufactured and installed solar power inverters, ran out of funding in fall of 2002 and filed for bankruptcy. AES was owned by **Advanced Energy Systems** of Australia, also a solar power inverter producer, which had established a US subsidiary corporation to pursue the North American market. The Australian parent company continues to operate.

March 7. **Texas Commercial Energy**, a Plano-based electricity retailer with 1,500 commercial customers across the state, filed for Chapter 11 bankruptcy protection after failing to close a round of financing. The company claimed that Texas wholesale electricity market volatility, due in part to sharp spikes in natural gas prices, jeopardized its ability to meet upcoming credit requirements. A bankruptcy filing shields the company's customers from possibly needing to procure power on the spot market, where volatility is high and peak prices can be exorbitant.

February 24. **Flabeg Solar International** of Germany has requested that the court begin insolvency proceedings, citing falling prices and overcapacity in the German solar power market. Flabeg Solar has two main business lines - the production of large area glass-glass laminates for building-integrated solar applications, and the development of large-scale solar thermal projects. The **Flabeg-Group**, its parent company, produces technical glass, mirrors and glass for architectural applications, and is not affected by the insolvency announcement.

Comment. Flabeg Solar is not alone in its distress. The extraordinary growth in demand for solar power systems, particularly in the German market, had a predictable consequence – suppliers rushed to add capacity, and as that new capacity came online they cut prices as necessary to keep the production lines running. The most notable example would be **Sharp Solar**, which increased 2002 production to almost 125MW, 64% over the prior year and nearly 25% of production worldwide. Sharp entered the German market last year with modules priced at less than $3 per watt, representing a discount of roughly 15% to prevailing prices.

As a result, German solar industry revenue actually declined about 5%, from 500 million euros to 475 million euros, despite an 80% increase in solar cell production and capacity installed. In turn, the increasingly competitive market appears to be affecting some of the local German participants. Flabeg Solar's request for insolvency may soon be followed by others.

Not that there is anything ominous about restructurings and bankruptcies in the solar industry. Taking a broader view, solar power's experience of rapid demand growth followed by overzealous capacity expansion, pricing pressure and possible restructuring is common to many industries. The key question for solar is whether and when it can generate electricity from the

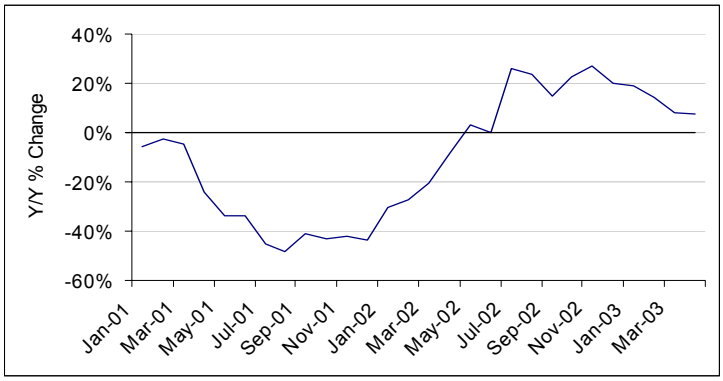
sun at an affordable price. Grid-connected solar power systems continue to rely on public support programs to offer a meaningful payback, and the subsidies will not last forever. Between technology advances on the one hand and at least a few more years of public funding on the other, we believe solar power will achieve its promise. Of course, there is no guarantee. The race is on.

Semiconductor Shipments

(Semiconductor Industry Association unadjusted monthly data)

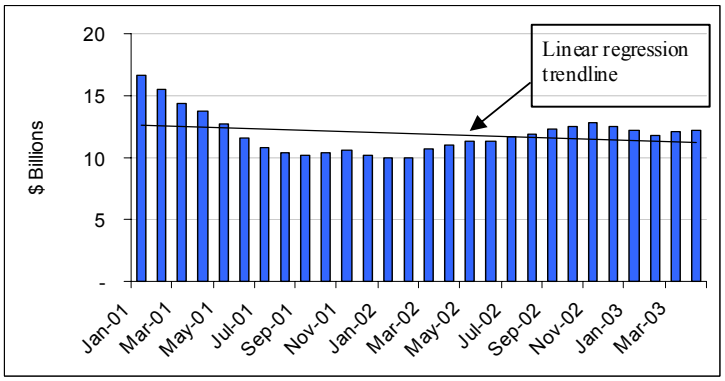
A broad measure of technology industry health. Given that virtually every information processor—logic chip, DRAM, DSP, integrated circuit (IC), etc.—requires a power conversion device—a power semiconductor, embedded power supply, rectifier, and so on, and possibly power quality protection as well—semiconductor shipments also reflect demand for a range of power technologies.

Monthly Shipments—Y/Y % Change, Jan 2001 - Apr 2003



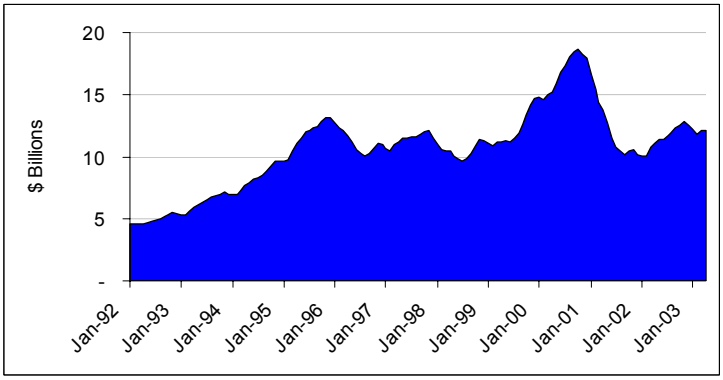
The recovery in year-over-year semiconductor shipment growth began last July. However, the rate of growth is already slowing, and the comparisons become yet more difficult soon. Recent semi shipment trends could be read as a signal that the rebound in sales of semiconductor-based finished products is not sustainable.

Shipments—3-month moving average, Jan 2001 - Apr 2003



The semi industry often looks at data on monthly shipment values by using a 3-month moving average to smooth out the characteristic spike in shipments in the third month of the quarter. The data shown here, fitted with a linear regression line to establish a rough trend, also suggests a modest but flattening recovery from the lows of 2H01-1H02.

Monthly Shipments, Jan 1992 - Apr 2003



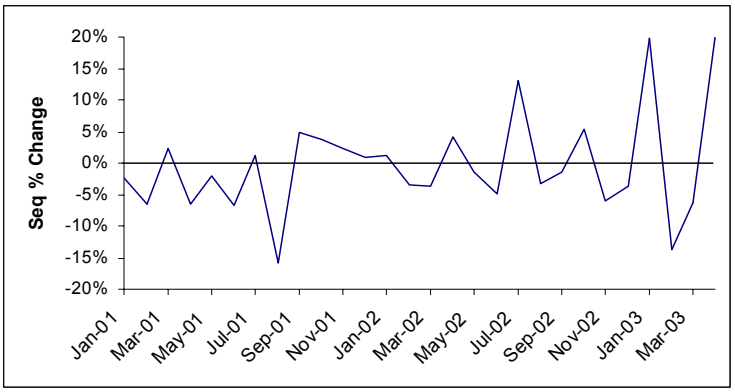
The 10-year data series shows the surge and subsequent collapse of demand from 1999-2001. Again, this is a graph that reflects an industry regaining a modicum of health. The long-term graphs of computer and especially communications equipment shipments shown on the next two pages do not look as favorable.

Computers, Storage Devices & Peripherals

(US Census Bureau, seasonally adjusted monthly data)

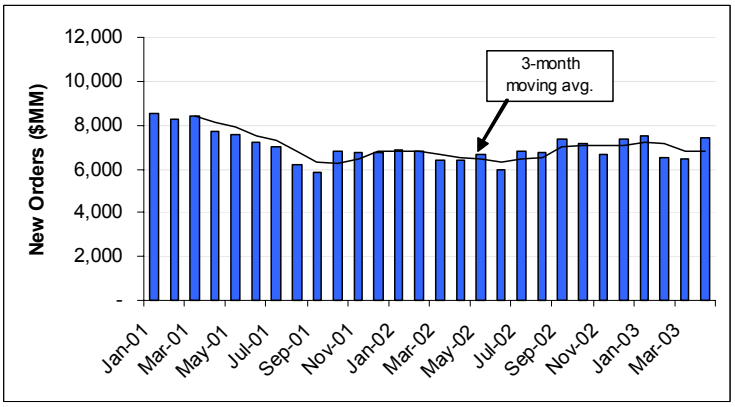
Computer, server, storage device and peripherals sales create pull-through demand for certain types of power conversion systems, such as ac/dc power supplies, voltage regulation modules, point-of-load converters and uninterruptible power supplies.

Monthly Shipments—Sequential % Change, Jan 2001 - Apr 2003



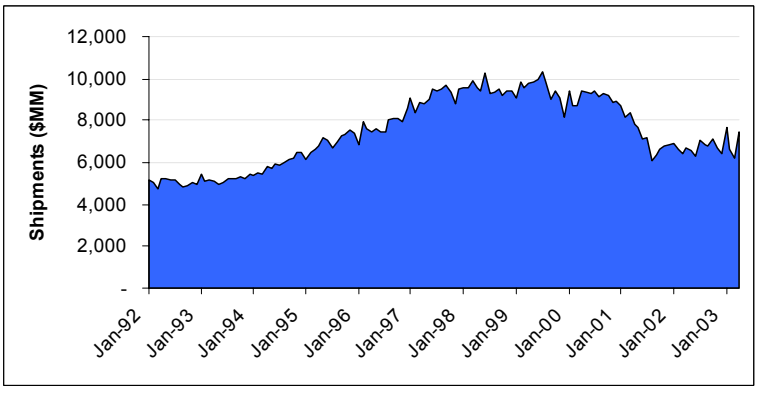
This first graph, showing the sequential change in shipments of computers and related devices, shows a large spike in shipments in April. Given that April orders also increased nicely, it looks like business should remain healthy for the next month or so. However, semiconductor shipment data could signal slower growth to come.

Monthly New Orders, Jan 2001 - Apr 2003



After several months of weak order activity, activity in April picked up nicely. A real breakout has yet to occur. Seasonally-adjusted April orders fell shy of the recent high-water mark set in January, and monthly orders still have not climbed past levels seen in the first half of 2001.

Monthly Shipments, Jan 1992 - Apr 2003



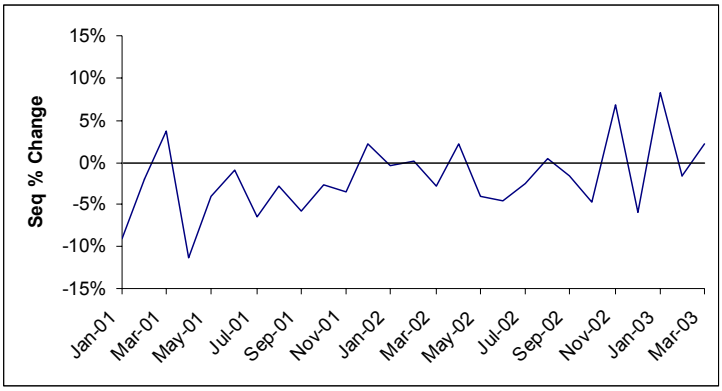
The 10-year data series shows that monthly shipments of computers, storage devices and peripherals are back to1995 levels, but are still struggling to break out from their 2-year plateau and move definitely higher.

Communications Equipment (non-defense)

(US Census Bureau, seasonally adjusted monthly data)

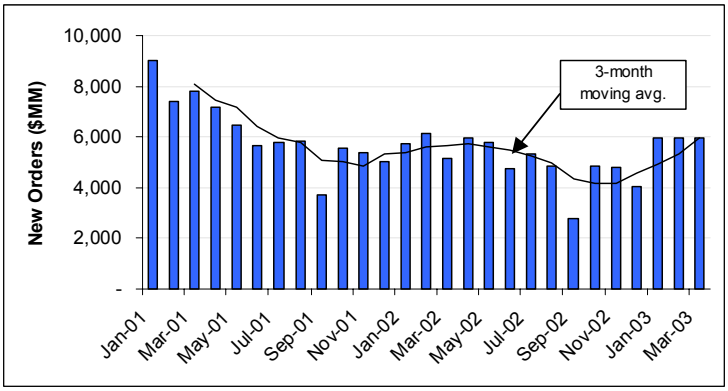
Sales of communications hardware such as switches, routers, wireless base stations and repeaters, generate demand power conversion systems such as power semiconductors, ac/dc front ends, board-mounted dc/dc bricks, and dc power plants.

Monthly Shipments—Sequential % Change, Jan 2001 - Mar 2003



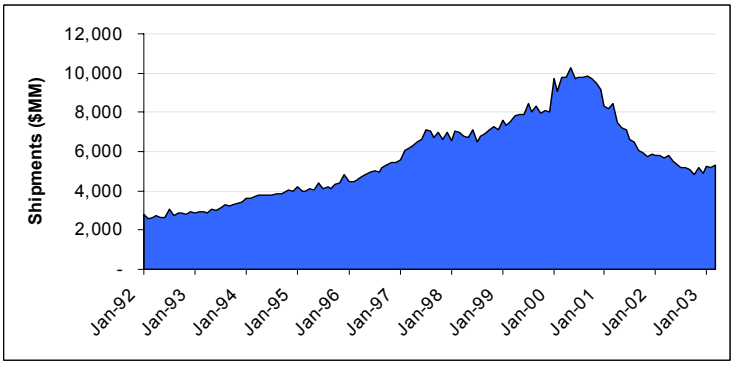
After nearly two years in which sequential changes in communications equipment shipments were overwhelmingly negative, early signs of life appeared in November 2002. However, the change in shipment growth has been uneven, and the industry has not yet established clear positive momentum.

Monthly New Orders, Jan 2001 - Mar 2003



New order activity bounced off its lows in the fall of 2002, but has leveled off and become virtually flat over the last three months. Growth in this industry remains elusive.

Monthly Shipments, Jan 1992 - Mar 2003



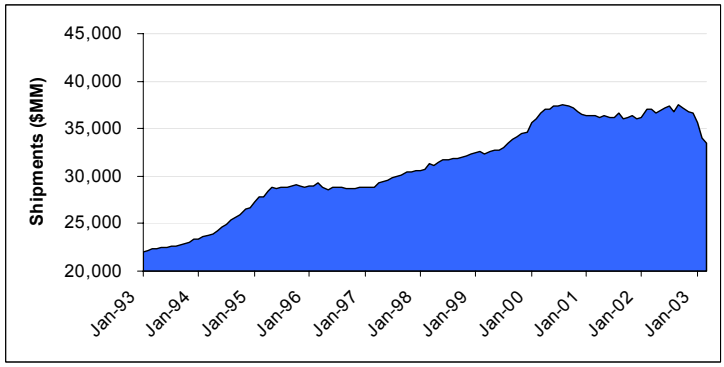
The 10-year data series highlights both the run-up in shipments in 1999-2000 and the steep drop thereafter. Importantly, recent monthly shipment trends suggest a possible leveling off rather than further declines.

Turbines, Generators & Other Power Transmission Equipment

(US Census Bureau: seasonally adjusted monthly data)

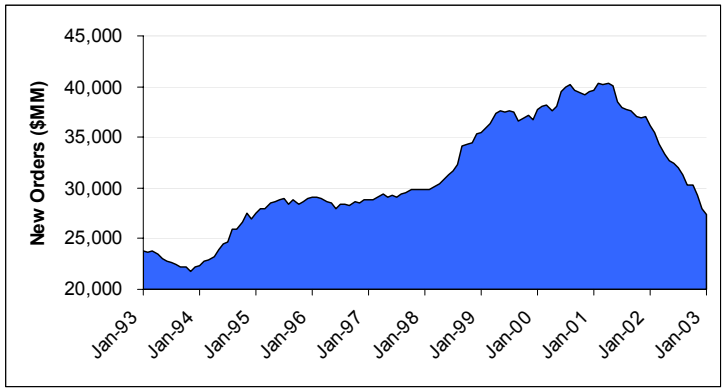
A measure of utility industry investment in large capital equipment. Reflects the spending required to maintain the installed power infrastructure and build the new capacity needed to meet demand for electricity.

Rolling 12-Month Shipments, Jan 1993 - Mar 2003



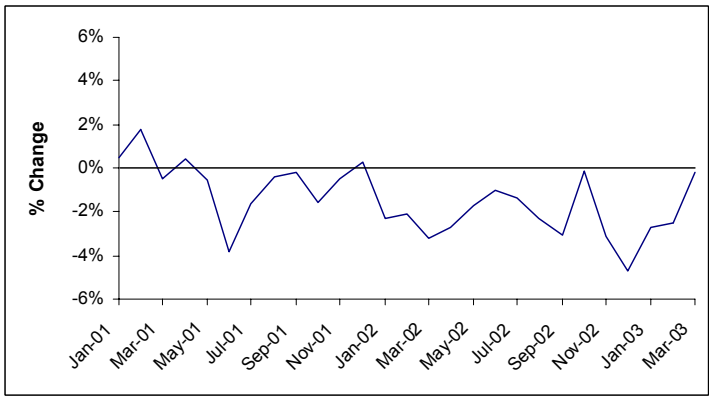
The long-term look at power equipment shipments points to a sharp fall-off in shipments after a strong multi-year run.

Rolling 12-Month New Orders, Jan 1993 - Mar 2003



The long-term data on new order activity shows even more substantial declines. Since orders for power equipment are placed as long as 2-3 years before shipment is expected, new orders data is a key leading indicator of future shipment value.

Sequential Change, Rolling 12-Month New Orders, Jan 2001 - Mar 2003



Zooming in on new order activity within the last 2 years, we see that the trend has been clearly negative. The recent spike in orders is intriguing, but must be confirmed by additional data.

Inductance & Reactance

Occasional Comments and Random Observations

Harness the Wind, Capture the Sun

In this space last issue we looked at the use of hydrogen as an energy source. We asked when hydrogen might displace fossil fuels at the base of the global economy (answer – possibly in the second half of the century), and questioned the commonly-held belief that hydrogen-powered fuel cells for automobiles and stationary power generation are green (answer – not necessarily). The reality is that while hydrogen holds tremendous promise, the commercialization of hydrogen-based devices and the creation of a hydrogen-based infrastructure are years away.

This time around we will focus on two forms of alternative energy with impeccable green credentials and rapidly growing commercial markets—wind and solar power. The recent release of production and shipment data for 2002 creates an opportunity to step into the world of wind and solar and take a look at the state of the industry. We will offer some detail on market growth, system economics and technology, and touch on the role that renewable energy sources like wind and solar can play in reducing dependence on imported energy. In particular, there are four misconceptions, both negative and positive, about wind and solar power that need to be cleared up. Each is listed below, along with a summary version of our response.

Misconception 1: Wind power systems are "Condor Cuisinarts" – their turbines pose a deadly hazard to passing birds.

Response: Numerous studies of avian deaths attributable to wind power installations suggest that the number of birds killed per year from collision with a wind turbine is extremely low, and would remain so even if the number of turbine structures grew by nearly two orders of magnitude.

Misconception 2: Solar power is for the sandal-wearing crowd, and will never be more than a niche application.

Response: Sale of solar power systems to environmentally conscious do-it-yourself types had very little to do with the growth of the industry until fairly recently. Early demand came from commercial applications, and involved the use of solar panels in remote areas to supply power to communications stations, portable road signs, highway call boxes, water pumps and other equipment. Solar is becoming more common in residential markets, and may in fact become more ubiquitous than almost anyone imagined as technology improvements make it possible to use solar cells as building materials, clothing fabric, portable power systems and elsewhere.

Misconception 3: Wind and solar power cannot generate electricity at competitive prices.

Response: Dramatic improvements in the cost and performance of wind power systems have made them cost-effective versus the utility grid in a number of locations. Although the installed cost of solar must fall by 50-75% from current levels to compete against utility-provided electricity, in remote areas where the grid is unavailable, solar has long been the most economic and reliable method of supplying power.

Misconception 4: Wind and solar power can eventually replace much of the fossil fuel-based power generation infrastructure.

Response: Wind is an intermittent resource, and without massive energy storage systems, there are upper limits to the total share of power wind can reliably provide before it destabilizes the utility network. Solar is best suited for smaller onsite installations, such as on the roofs of residential and commercial buildings. It is not yet a viable source of large-scale generation. We will probably rely on some mix of fossil fuel and renewable energy sources for decades to come, although the share contributed by renewables will grow.

Wind Power

The use of turbines to harness the wind is not a new idea—consider the windmills that have dotted the northern European landscape for centuries. What is novel is the technology that has made it possible to generate electricity from wind at cost levels competitive against the utility grid. From the mid-1980s to the mid-1990s, the cost of wind power systems fell dramatically, and while the rate of decline has slowed, cost reductions continue. Meanwhile, wind turbine shipments have grown at an exceptional pace, averaging 39% over the last 10 years, and global installed capacity has reached over 30 gigawatts (1 gigawatt, or 1,000 megawatts, can power several hundred thousand households, so 30GW is sufficient for roughly 10 million families).

Market Size and Growth

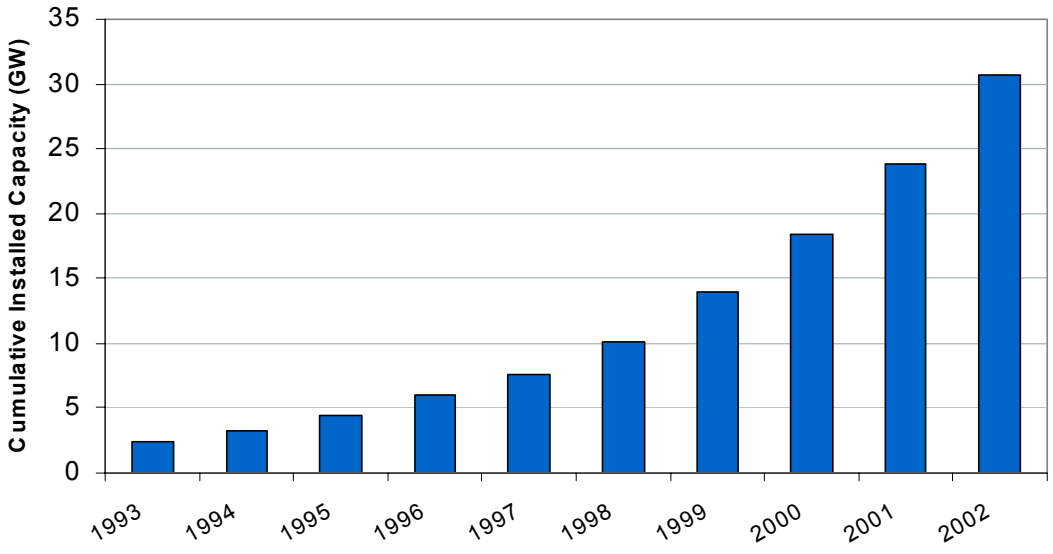
Despite a challenging environment in the key European and US economies, the wind power industry in 2002 logged another year of extraordinary growth. The European Wind Energy Association reports that a record 6.9GW of new capacity worth over $7 billion was installed last year, representing growth of 28% from 2001. With over 12GW of capacity, Germany has by far the largest installed base of wind power in the world, comprising more than one-third of the global total and more than twice the size of the next two countries down, Spain

and the US, with about 4.8GW each. About 90% of worldwide capacity is found in Europe and the US.

For the last ten years, wind has been the world's fastest-growing source of energy, and in the last five years alone the global installed base of wind power capacity has increased four times over—from 7.6GW in 1997 to 31GW in 2002. Two key drivers of this growth are the remarkable gains in the cost/performance ratio and the subsidy programs offered in US and certain European countries. From the mid-1980s to the mid-1990s the cost of a kilowatt of wind power generation capacity plummeted by about 80%, and costs have continued to decline. Importantly, in the right location a wind turbine can produce electricity for as low as $0.03-0.04 per kilowatt-hour—clearly economic versus the grid.

At the same time, generous subsidies, particularly in Germany but elsewhere as well, have made it attractive to install and operate wind power systems. By boosting demand and therefore output, these incentive programs have helped to move wind power down the cost curve through the realization of economies of scale.

Cumulative Installed Base of Wind Power Capacity, 1993-2002 (GW)



Source: European Wind Energy Association.

System Economics

The first big push for wind power occurred in the US in the 1980s. Federal subsidies and tax breaks drove initial market growth, but the underlying economics of wind power systems were unfavorable—in 1985, wind power cost $0.15 to $0.20 per kilowatt-hour (kWh). However, a number of technical breakthroughs in materials, blade design, power electronics and other subsystems over the next 10-15 years or so brought the cost of electricity from wind down by 80% or more, to levels as low as $0.03 per kWh in the right location. By the mid-late 1990s, wind power had become competitive against the utility grid with no subsidies or other support.

Because wind turbines do not need an ongoing supply of fuel, the life-cycle cost of a wind power system is largely determined by the initial cost. According to Cambridge Energy Research Associates, wind turbines cost $600 to $900 per kW (including the tower), while installation, including tower foundations, turbine placement, grid interconnection, access roads, and freight costs, generally adds another $150 to $200 per kW, bringing the total up-front cost to a figure usually below $1,000 per kW. As turbine size increases to 600kW, cost per kilowatt declines rapidly, then begins to decrease more slowly thereafter. Operating and maintenance costs are fairly low, and like the turbines, benefit from some economies of scale. In addition, vast improvements in system reliability have brought availability up to about 98%, and useful life is 20 years and more.

Also crucial to life-cycle cost is the speed and quality of the wind resource. Wind turbine output is related to the cube of the wind speed, so a small change in speed has a large impact on power generation. As shown in the table on page 43, an increase of about 15% in wind speed can mean a 30% decrease in cost per kWh and a 40% increase in capacity utilization. The level and variability of the wind is also important, since optimal output is achieved when wind speed is high but not too much so, because turbines will shift position in very strong winds to limit output and avoid equipment damage (the cut-out speed). Wind power systems also have a cut-in speed, a wind speed below which the turbine does not spin. Therefore, two sites with average annual wind speeds can yield differences of roughly 20% in power output if one is characterized by heavy gusts alternating with relative calm, and the other by lower maximum speeds that remain within a narrower range.

Wind Speed and Cost of Electricity

System Parameter	Wind Speed Scenario: Lower Wind Speed	Higher Wind Speed
Average Wind Speed	6.4 meters per second	7.5 meters per second
Capacity Factor	24 percent	34 percent
Turbine Size	600 kilowatts	600 kilowatts
Project Lifetime	20 years	20 years
Cost of Capital	7 percent	7 percent
Cost of Electricity	**$0.05 / kWh**	**$0.035 / kWh**

Source: Cambridge Energy Research Associates.

Having covered the basics on wind power economics, we can dispense with part of **Misconception 3**, that wind and solar cannot generate electricity on competitive terms. With the right wind resources, a wind power system can compete head-to-head against the utility grid.

As for **Misconception 4**, that wind and solar power can eventually supplant much of the fossil fuel-based power generation infrastructure, we have already touched on a key reason why this is probably not true for wind power—its variability. Due to the intermittent nature of wind, output at a given site can vary by 10%-20% around the mean. At some share of total capacity, variance in wind power output creates problems in maintaining utility network stability. The case of Denmark, where wind represents about 15% of generation capacity and on certain winter nights provides up to 50% of the nation's electricity, suggests that wind's contribution to the total power supply can be meaningful. The European Wind Energy Association recently published a report concluding that wind power could provide 12% of the world's electricity by 2020, and 20% by 2050.

Technology

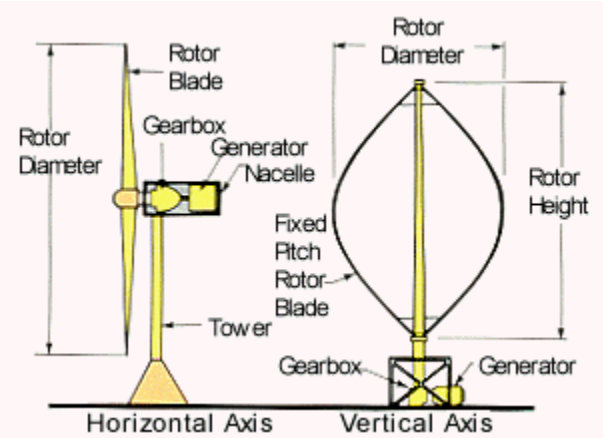
Any discussion about wind power technology must begin with the turbine. The first distinction to make is between vertical-axis and horizontal-axis turbine configurations, the two basic types of turbine.

- **Vertical-axis wind turbines**, in which the axis of rotation is vertical relative to the ground and perpendicular to the wind stream (think of a pinwheel or floor fan); and

- **Horizontal-axis turbines**, in which the axis of rotation is horizontal relative to the ground and parallel to the wind stream (think of a merry-go-round).

(Source: www.howstuffworks.com)

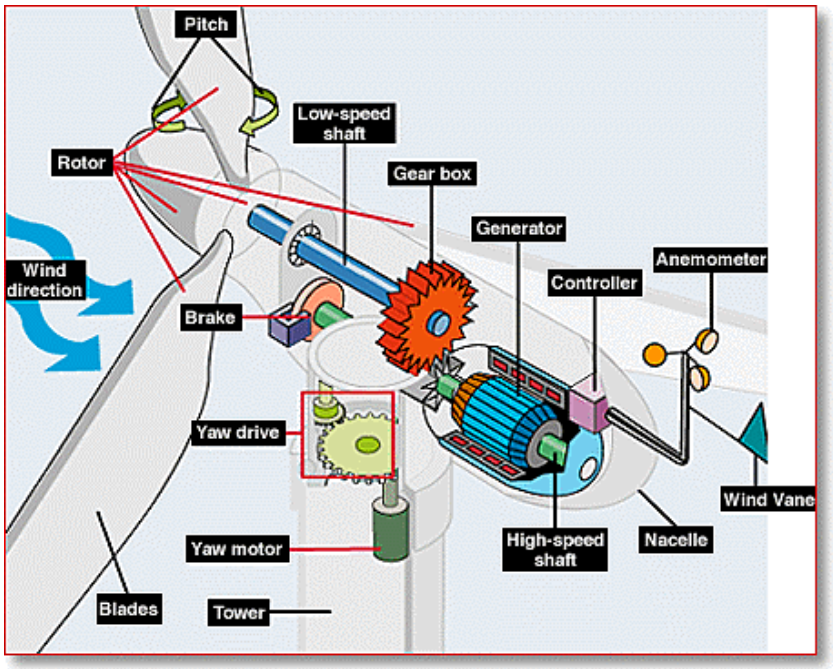
Basic Turbine Configurations



(Source: www.howstuffworks.com)

Within vertical-axis configurations there is another distinction to make: three-bladed systems, whose turbine blades face upwind; and two-bladed systems, whose turbine blades face downwind. In most configurations the balance of system that supports the turbine includes a drive shaft, brakes, gear box, generator, power electronics controls, tower and interconnection equipment, as shown below.

Wind Turbine System



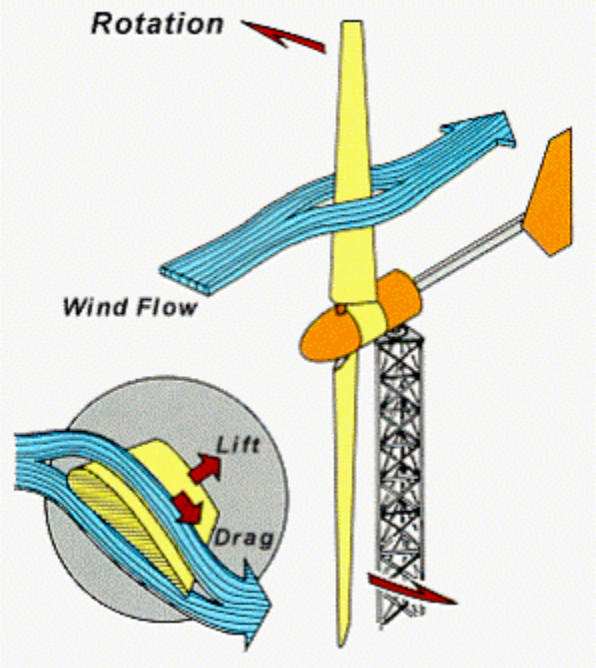
Source: Department of Energy.

Inductance & Reactance (cont'd)

Occasional Comments and Random Observations

Having looked at the rudiments of wind power system architecture, the next question is what makes a turbine spin. The American Wind Energy Association has provided a good basic description of the aerodynamic principles behind a vertical turbine. As shown in the diagram below, the wind passes over both surfaces of the blade, but moves more quickly past the longer upper side of the blade, creating a lower-pressure area above the blade. The resulting pressure differential generates aerodynamic lift. Since the turbine blades are attached to a hub and can only move in a plane centered around that hub, the lift causes the blades to rotate.

Wind Turbine Aerodynamic Lift



Source: American Wind Energy Association

With the basics of wind turbines and the balance of system that supports them sketched out, we arrive at the final question—how do wind turbines make electricity. In simplified terms, generators are devices that convert mechanical energy into electrical energy. As the wind turbine spins, it rotates a wire-wrapped shaft. This rotation is a useful form of mechanical energy. To turn the mechanical energy into electricity, the rotating shaft is housed within a fixed magnet. As the wire-wrapped shaft rotates, it cuts the magnet flux field created by the fixed magnet, which in turn induces voltage (electricity) in the wire.

Since the voltage and frequency of this electricity is directly correlated with the shaft's rotational speed, and the changing speed of the wind affects the rotational rate of the shaft, a wind turbine's electric output varies constantly. Maintaining stable electrical output requires well-designed gearboxes and power electronics control systems.

Wind turbine size has been trending higher for some time now. During the first wind power boom in the 1980s, turbines were rated at only a few hundred kilowatts. In recent years the average turbine size has climbed to roughly 1MW, and turbines are getting as large as 3MW – 5MW. A megawatt-class turbine is enormous—each blade can be as long as a football field (nearly 100 meters).

In addition to becoming larger, turbines are also spinning slower. Here we get to **Misconception 1**, that wind power systems are "Condor Cuisinarts" whose turbines pose a deadly hazard to passing birds. As it turns out, numerous studies of avian deaths attributable to wind power installations suggest that the number of birds killed per year from collision with a wind turbine is extremely low. Even if the number of turbine structures increased by nearly two orders of magnitude this would likely remain so. The relatively slow rotational speed of the turbine is probably part of the explanation; site selection and tower height are also important. On a per structure basis, communications towers appear to be a greater threat to birds than wind power systems.

Solar Power

The 1950s witnessed the dawn of the solar power industry. Starting in 1958, when the US Vanguard satellite used a small solar panel to power its radio, the space race was the key driver of the solar power industry. Early successes with solar power in space led to its widespread adoption there, and in short order virtually every satellite has been equipped with solar panels. The combination of extremely high reliability and maintenance-free operation made solar power an attractive source of power in space, and those same features are responsible for its use in earth-bound applications where the utility network is unavailable or cost is not a major issue. With the energy crisis of the 1970s, a concerted effort was made to commercialize solar power for terrestrial grid-connected markets, but costs were much too high and solar remained a niche business.

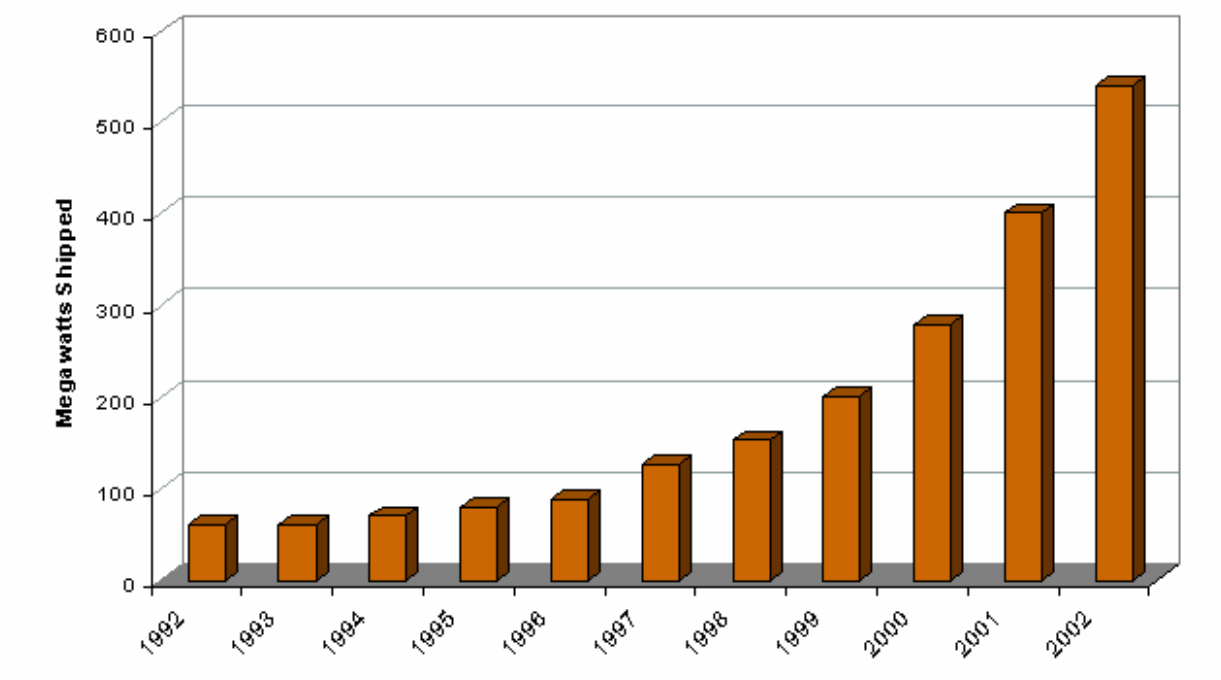
In more recent years, however, solar power has been shedding its marginal status. From the mid-1970s to the mid-1980s solar power technology moved rapidly down the cost curve—over that period the cost per watt of solar fell by roughly an order of magnitude. These cost declines helped to make solar power economic in a range of off-grid applications and to drive market

growth of 20%-25% per year. The grid-connected market took longer to develop, largely because solar power was (and still is) much more expensive than electricity from the utility grid. The creation of generous subsidy programs for grid-connected solar systems over the last five years or so has led to an acceleration in the growth of the grid-connected market.

Market Size and Growth

Similar to wind power, the solar power industry boasted another year of impressive growth, with *Photon International* estimating a production increase of 35% to 540MW, up from about 400MW in 2001. The record level of output reached in 2002 represented industry sales of roughly $3-4 billion. Over the last ten years, solar power shipments increased 25% annually, and in the last five years that growth rate accelerated to 34%. The global installed base of solar power capacity reached about 2.4GW in 2002, or about 8% of the installed base of wind power. The difference in size between the two has a lot to do with the fact that solar is generally installed a few kilowatts at a time (although larger systems are becoming a little more common), while wind power usually comes in chunks of tens or even hundreds of megawatts.

Annual Solar Power Shipments, 1992-2002 (MW)



Source: *Photon International*, Strategies Unlimited.

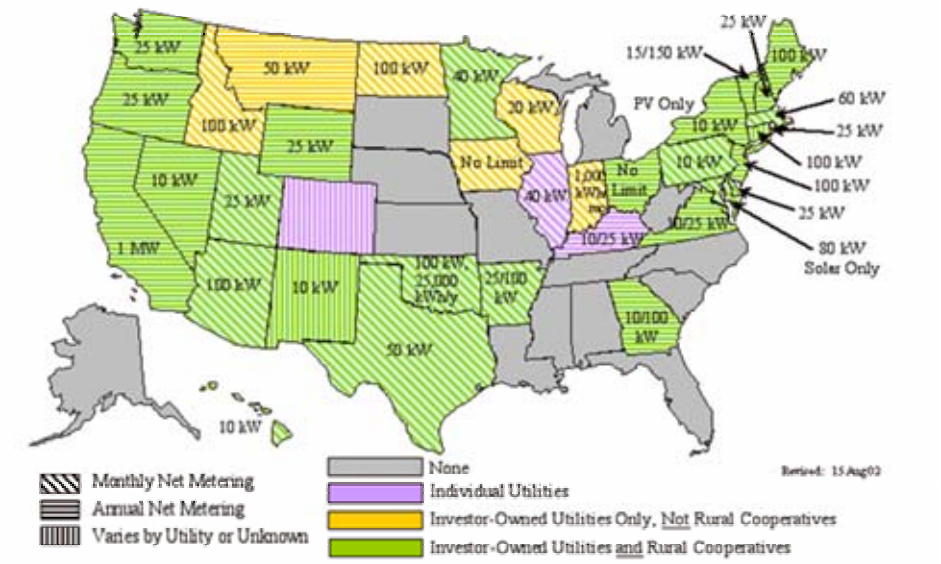
The solar power market is typically segmented into off-grid and grid-connected systems. Initial industry growth came primarily from the off-grid market. Off-grid uses for solar include bringing power to remote telecom sites, road signs, navigation aids, water pumps and villages in the developing world. Grid-connected systems are typically sold to residential and commercial building owners for rooftop or premise installation, and when configured with batteries, a grid-connected system can act as a source of uninterruptible power.

Although costs fell rapidly from the mid-1970s to the mid-1980s (in fact the cost per watt of solar declined by roughly an order of magnitude), solar systems were still too pricey for the grid-connected market. However, solar power did become economic in a range of off-grid applications. The expense entailed in constructing and maintaining a supply of power to remote locations is sufficiently high that solar has long been not only the most reliable solution, but also the most cost-effective. Even into the 1990s it was the off-grid market that drove industry growth of 20%-25% per year, and at the end of the decade off-grid systems accounted for about two-thirds of installed capacity.

In the last five years or so, the grid-connected market has begun to catch up. Purchases of grid-connected systems, primarily for residential installations, provided much of the industry's exceptional growth from 1997-2002. The implementation of substantial solar power subsidies in Germany, Japan, Spain, the State of California and elsewhere played a large role in accelerating the growth rate of the grid-connected market.

The signing of the Kyoto Accords in 1997 by most major countries was a crucial catalyst for the establishment of solar subsidies. The German and Japanese programs were particularly important. In Japan the government set aside a budget to subsidize one-third of the purchase price of residential solar power systems, while in Germany a buyer of a solar system can obtain an interest-free loan and sell any unused solar power back into the utility grid at $0.50 per kilowatt-hour (net metering). In the US the federal government has provided little support for solar systems purchase; the states have carried the cost of subsidizing grid-connected solar. Roughly 35 states currently offer net metering payments, and certain states provide other forms of support as well. As shown in the map on the following page, the terms of the net metering programs vary widely.

Net Metering Programs by State



Note: Figures in kilowatts and megawatts represent the maximum system size eligible for net metering.
Source: Energy Efficiency and Renewable Energy program, US Department of Energy

We will end our discussion of solar markets by addressing **Misconception 2**, that solar power is for the sandal-wearing crowd, and will never be more than a niche application. As it turns out, from the 1970s into the 1990s, sales of solar power systems were largely for commercial and industrial applications, not for residential installations on the homes of environmentalists concerned about coal-fired power plants creating greenhouse gases. The "solar is for the sandal-wearing crowd" belief is inaccurate—solar is for wireless telecom companies, construction companies, the shipping industry and other profit-motivated entities.

On the other hand, it is true that off-grid solar applications constitute a niche rather than a mass market. The question is whether solar can become inexpensive enough to achieve widespread market adoption. With the help of government subsidies, solar is already becoming more common in residential markets, and we believe that within 5-10 years those subsidies will be unnecessary, and at some point solar will be a building material like a roofing tile or window that is used in a sizable share of every new building constructed. Solar may also become a clothing fabric, a portable power supply and many other things as well.

System Economics

As with wind power, since there are no fuel requirements the life-cycle cost of a solar power system is based overwhelmingly on the initial cost. The installed cost of a solar system ranges somewhere between $6,000 - $10,000 per kilowatt of peak capacity. Compare this to $1,000/kW or less for wind, $400 - $800/kW for a medium-sized genset or turbine, and roughly $500/kW for a centralized power plant.

While solar has long been the most economic technology for bringing power to remote areas for applications such as telecom repeater stations, navigation aids, telemetry, water pumping and rural electrification, the installed cost of solar needs to fall by 50% - 75% to become competitive against the utility grid. This raises **Misconception 3**, that wind and solar power cannot generate electricity at competitive prices. We have already seen that wind is cost-competitive today without government support, so in the case of wind power, the response to Misconception 3 is a simple "not true." With solar, however, the response is "it depends"—it depends on whether or not the utility grid is available.

Could solar power reach competitive levels for grid-connected applications? We believe the answer is yes. To provide some context around this conclusion, we will take a brief look at the determinants of solar power system economics. Three key drivers are production process, conversion efficiency and system siting.

First, on production process, the traditional method of making solar power modules involves casting an ingot of silicon, slicing it into wafers, treating the wafers with chemicals and applying wiring and interconnects to convert them into electricity-generating cells, then laying out the cells onto a glass backing, placing protective tempered glass over the front, fitting a frame around the edges and attaching a junction box. A lot of silicon is lost along the way, and methods for packaging the cells into a module tend to be simple and labor-intensive. These and other limitations mean that new processes must be developed to produce inexpensive solar systems. A number of promising approaches have reached various levels of maturity, and will be discussed in the next section on solar technology.

The second principal cost driver is conversion efficiency. No solar cell is able to transform 100% of the sunlight it receives into electricity, but other things being equal, the higher the conversion efficiency the better. One advantage of silicon is that it is relatively efficient—standard crystalline silicon cells convert sunlight at around 13%-15% efficiency, and specialized concentrator cells, typically used on satellites, offer conversion rates of 20%-25%.

Of course, there are tradeoffs between production cost and conversion efficiency, so the game is to achieve the optimal ratio between the two rather than favor just one at the expense of the other. Substantial resources have been devoted to developing production processes using thin-film materials rather than crystalline silicon. These materials offer lower conversion efficiencies, ranging from 4%-10%, but the production processes are intended to be much cheaper than for silicon, yielding a better cost/efficiency tradeoff and reaching competitive cost levels more quickly. It remains to be seen whether or not this will come to pass.

A third determinant of lifecycle cost is system siting. Not surprisingly, there are some regions that receive more sun, and others that receive less. The daily amount of sunlight available for conversion to electricity is measurable, and is referred to as insolation. Roughly speaking, on a global basis the highest-quality sunlight generally falls onto a broad band that straddles the equator. The insolation map of the US below illustrates the variability of quality solar resources. Other things being equal, putting up a solar system in an area of high insolation rather than a low-insolation site leads to better lifecycle economics—the same system for the same price will produce more electricity.

US Insolation Map

Insolation = kWh / m^2 / day
Source: Solarex.

Solar Power Technologies

At the foundation of solar power technology is the photovoltaic effect—the transformation of photons into electricity (hence "photo–voltaic"). Photovoltaic (PV) cells are semiconductors that consist of a p-layer (positive layer) with excess bonds to accommodate electrons and an n-layer (negative layer) with excess electrons seeking out bonds. The p/n junction creates a potential electric field. When a photon (a packet of light from the sun or an artificial source) penetrates the PV cell, it excites the excess electrons in the n-layer, which migrate toward the excess bonds in the p-layer, but are instead directed out to create a usable flow of electricity.

A variety of semiconducting materials are used to produce solar photovoltaic cells. Almost 90% of cells today are made with crystalline silicon, in the form of both polycrystalline (about 50% of world output) and monocrystalline (about 35% of world output). The basic difference between the two is that polycrystalline silicon yields cells that are lower in efficiency but also in cost, while monocrystalline silicon cells have higher efficiencies but tend to cost more.

As described above, the standard method of a making a usable solar power module begins with casting an ingot of silicon. Solar-grade silicon is significantly more pure than metallurgical silicon, but not as pure as semiconductor-grade silicon. Because of this the solar industry has been living off the scraps of the semiconductor industry—literally. The discarded ends of silicon ingots cast for microprocessors (the "tops and tails") have provided the great majority of the silicon used to make solar cells.

The next step is to slice the ingot into wafers 300 microns thick. About half the silicon is lost as unrecoverable waste in this process. To turn a silicon wafer into a cell, a phosphorus diffusion layer is applied, an anti-reflective coating is deposited and wire interconnects are printed to electrically link one cell to the next and conduct away their electrical output.

Each cell can generate a few watts of power. A solar power module consists of a number of cells (24, 36, etc. depending on the desired output) that have been interconnected, covered with a layer of protective tempered glass and encapsulated in a frame. In rough terms, typical output of a single module ranges between 50 – 150 watts, with the bulk of sales probably falling between 80-120 watts. Constructing a kilowatt-size system entails interconnecting numerous modules. Regardless of size, an installed system generally also needs an inverter to convert the DC power the cells generate into AC power, along with structures to mount the system and direct it toward the sun.

There are several ways to reduce the cost of crystalline silicon solar power systems. Silicon is a major cost item, so reducing the amount of silicon required can make a significant impact on system cost. Developing lower-cost sources of silicon, reducing the losses incurred during ingot slicing, slimming down wafer thickness and improving conversion efficiency are critical, and there are a number of companies working on one or more of these measures. As examples, Solar Silicon LLC is working on new silicon production methods, and Evergreen Solar and RWE are scaling up a manufacturing technology based on pulling a ribbon of silicon out of a molten bath, which reduces slicing loss since slicing a ribbon creates much less waste than slicing an ingot. Efforts are also underway to cut wafer thickness down from 300 microns to as thin as 100 microns or so, and numerous companies are taking steps to improve conversion efficiency.

Most of the opportunities for lowering the cost of crystalline silicon solar systems are at the level of silicon raw material and wafer production. Cost reduction further along the chain—turning wafers into cells, and packaging cells into modules—are also available, and can be realized by process improvement or simply higher-volume production.

The alternative is to use a material other than crystalline silicon. Here is where thin films come in. In principle, thin-film methods offer several advantages. Because the semiconducting layer is only 5-10 microns thick, materials costs should be significantly lower, and production could occur as a continuous process rather than in batches. Ideally, a production line could be set up in which raw materials and a glass substrate are fed in one end and a solar module comes out the other. Efforts to commercialize thin-film solar began in the mid-1980s, and the lion's share of the industry's research budget has been directed toward development of thin-film technology. Two decades and hundreds of millions of dollars later, manufacturing and performance issues remain unsolved. At present, a number of companies are pursuing approaches to thin film that appear promising.

Materials used in thin-film solar include amorphous silicon, cadmium-telluride (CdTe), copper-indium-diselenide (CIS), copper-indium-gallium-diselenide (CIGS) and titanium dioxide (TiO_2). Amorphous silicon has been used for solar for many years, and the small photovoltaic cells on devices like calculators are almost always made with amorphous silicon. The share of amorphous silicon in total global output fell from 12% in 1999 to 6% in 2002 (this and other materials market share data is from *Photon International*). Poor manufacturing yields, scale-up challenges and low conversion efficiency contributed to the decline, and it may be the case that amorphous silicon as a stand-alone material faces fundamental issues large enough to limit its real commercial potential. While it is far too early to declare success, efforts to develop solar cells using layers of both amorphous and crystalline silicon are beginning to bear fruit, so amorphous silicon may eventually find its rightful place in the sun after all.

The other thin-film materials are produced in tiny volumes (no more than a few megawatts annually), and represent just over 1% of world output. Scale-up is really only beginning, and some of the same problems that plagued amorphous silicon must be solved for the other thin films before they can be cost-competitive. It will probably take several years before any pronouncements about the scalability and viability of CdTe, CIS/CIGS and TiO_2 can be made.

We are now able to return to **Misconception 4**, that wind and solar can replace much of the installed base of fossil-fuel power generation. Conversion efficiencies of commercial solar cells are generally in the 12%-15% range. Experimental work suggests that concentrator cell efficiencies could reach as high as 30%-35%, and thin films could achieve a 20% conversion rate, but it will likely take many years before these high-efficiency approaches become commercial. Even then, the footprint of a megawatt-class solar power system will be large, both relative to other forms of power generation and in absolute terms. Meanwhile, it would take up to several hundred thousand small solar systems to equal even a single 400MW natural gas-powered combined-cycle turbine. Thus, the nature of solar makes it much better suited for installations rated in the kilowatts rather than megawatts.

Lastly, to revisit **Misconception 2**, that solar will always remain a niche application, an attractive feature of the thin film technologies is that they can produce flexible modules that could be rolled up and carried to provide portable power, woven into clothing, and used in other novel ways. Ultimately, it may turn out that solar becomes more widely used than almost any of us would have ever believed.

Conclusion

Having laid to rest some common misperceptions, our conclusion is simple — wind and solar power are real. Wind turbines represent as much as 15% of total generation capacity in certain countries, and provide over 30GW of power across the globe. With no subsidies of any kind, energy from the wind can produce electricity in numerous locations at costs competitive against the utility grid. This was not the case ten years ago. Government incentives to encourage demand for wind generation equipment, in conjunction with a host of technical advances, drove the breakthrough in cost that made wind power a worthy alternative to fossil-fuel generators.

Although solar power is not yet economically viable where the utility grid is available, it has long proven its merits in off-grid applications, particularly where extremely high reliability is required. The recent history of the wind industry suggests that there is hope for solar as a future source of cost-competitive grid-connected power. In the case of wind, costs came down primarily because of two reasons:

1. Public subsidies created incremental demand, which boosted annual production, which led to economies of scale;
2. Meanwhile, technology improvements meant increasing performance out for the same dollar in.

The solar power industry is benefiting from identical processes. The number of state and national governments offering solar power subsidies has grown rapidly over the last several years. Technical progress has already brought the cost of solar power systems down by over an order of magnitude, and corporations, universities and governments are pursuing a slew of new technical approaches that could yield further dramatic reductions in cost. Stay tuned — the next five years hold much promise.

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