CLEAN ENERGY TRENDS 2010

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CLEAN EDGE
THE CLEAN-TECH MARKET AUTHORITY

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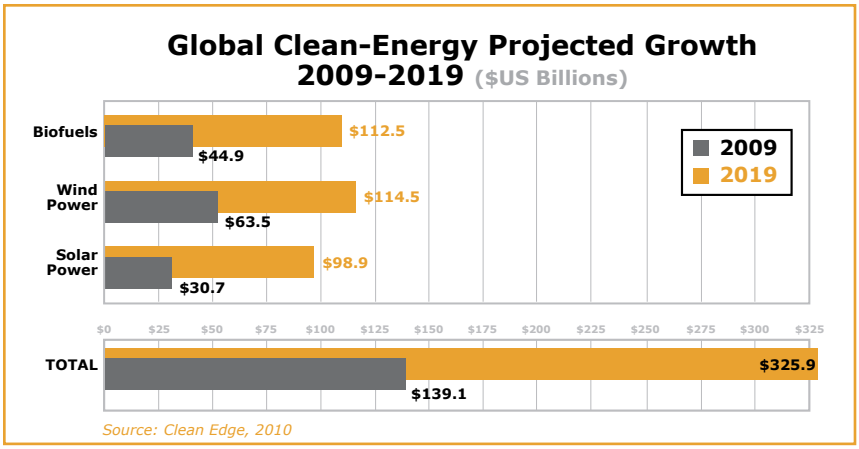
CLEAN ENERGY TRENDS 2010

Clean energy has become a driving force for economic recovery

2009 will go down as one of the worst years in economic history. Overall venture capital spending fell to its lowest level in more than a decade. Initial public offerings (IPOs) in the U.S. continued at historic lows, with just 13 venture-backed IPOs in 2009 (up only slightly from a meager six venture-backed IPOs in 2008), according to Thomson Reuters and the National Venture Capital Association. Once stalwart financial and market leaders crumbled under new harsh economic realities, with many shuttering their operations or surviving as a mere shell of their former selves. Governments around the world, working to stave off a global depression, announced unprecedented commitments to stimulus programs to keep the global economy on life support.

But signs of hope have begun to emerge for the clean-tech sector. From Beijing to Seoul, and Washington, D.C. to Brussels, clean energy has become a driving force for economic recovery. Approximately $100 billion of the $787 billion stimulus package in the U.S. will go to clean-tech investments and activities; South Korea's "Green New Deal" is estimated to commit $84 billion to clean-tech investments by 2013; and China, by some estimates, could end up spending $440 billion to $660 billion toward its clean-energy build out over the next ten years. And while total venture activity was down, clean energy's percent of the total continued to increase, to 12.5 percent of total venture activity in 2009 in the U.S. alone.



Source: Clean Edge, 2010

Against this backdrop, combined global revenue in 2009 for solar photovoltaics (PV), wind power, and biofuels expanded by 11.4 percent over the prior year, reaching $139.1 billion. All three sectors saw an increase in total deployment, with increased revenue for both biofuels and wind power. Solar, however, saw its first decrease in total revenue over the prior year since Clean Edge began tracking global revenues in 2000. This was a direct result of the rapid decline in solar PV pricing (see "Steep PV Price Drops Redefine the Solar Industry" on page 10).

According to our research:

- Biofuels (global production and wholesale pricing of ethanol and biodiesel) reached $44.9 billion in 2009 and are projected to grow to $112.5 billion by 2019. In 2009 the biofuels market consisted of more than 23.6 billion gallons of ethanol and biodiesel production worldwide.
- Wind power (new installation capital costs) is projected to expand from $63.5 billion in 2009 to $114.5 billion in 2019. Last year's global wind power installations reached a record 37,500 MW. China, the global leader in new installations for the first time, accounted for more than a third of new installations, or 13,000 MW.

- Solar photovoltaics (including modules, system components, and installation) will grow from a $30.7 billion industry in 2009 to $98.9 billion by 2019. New installations reached just less than 6 GW worldwide in 2009, a nearly sixfold increase from five years earlier, when the solar PV market reached the gigawatt milestone for the first time. But because of rapidly declining solar PV prices, industry revenue between 2008 and 2009 was down about 20 percent – from a revised $38.5 billion in 2008 – as solar prices dropped from an average $7 peak watt installed in 2008 to $5.12 peak watt installed last year.

Clean-Energy Venture Capital Investments in U.S.- Based Companies as Percent of Total 2001-2009

Year	Total Venture Investments (US$ Billions)	Energy Technology Investments (US$ Millions)	Energy Technology Percentage of Venture Total
2001	$40.6	$351	.09%
2002	$22.0	$271	1.2%
2003	$19.7	$424	2.2%
2004	$22.5	$650	2.9%
2005	$23.0	$797	3.5%
2006	$26.5	$1,308	4.9%
2007	$29.4	$2,867	9.8%
2008	$28.3	$3,213	11.4%
2009	$17.7	$2,216	12.5%

Source: Bloomberg New Energy Finance with supporting data from Clean Edge and Nth Power, 2010. NOTE: New Energy Finance's energy-tech VC numbers include investment in renewable energy, biofuels, low-carbon technologies, and the carbon markets. VC figures are for development and initial commercialization of technologies, products, and services, and do not include private investments in public equity (PIPE) or expansion capital deals.

Together, we project these three benchmark technologies, which totaled $124.8 billion in 2008 and grew 11 percent to $139.1 billion in 2009, to grow to $325.9 billion within a decade.

U.S. Venture and Global Clean-Energy Investments

In 2009, U.S.-based venture capital investments in energy technologies declined from $3.2 billion in 2008 to $2.2 billion in 2009, according to Bloomberg New Energy Finance. However, as a percent of total VC investments, energy tech grew from 11.4 percent in 2008 to 12.5 percent in 2009. This represented the largest share in the history of the clean-energy asset class.

The global growth rate in clean-energy investments, across a wide range of investment categories, declined as well, impacted by the overall economic climate. However, government investments helped soften the blow. According to preliminary Bloomberg New Energy Finance analysis, new global investment in clean energy declined from $155.4 billion in 2008 to $145.3 billion in 2009. This figure includes investments made by VC and private equity investors; public market activity (IPOs, etc.); project financing; asset financing; government research & development; and corporate research, development, & deployment.

But clean-energy investments still remain at historical levels, with total investments in new clean-energy generation capacity now outpacing those for conventional fossil fuels for the past two years in a row. In the U.S., wind power roughly matched natural gas as the leading source of new electricity generation for the third consecutive year.

IPO Watch List

Will 2010 and 2011 represent the return of the initial public offering? Crystal-ball gazing these days, when it comes to financial markets, is often an exercise in futility. But it's worth noting the recent announcements and filings that demonstrate a potential shift in things to come. Here's a list of recent filings and potential IPOs.

The following companies have filed for IPOs on U.S. exchanges as of March 1, 2010

Company	Sector
Codexis - *www.codexis.com*	Biofuels and Biomaterials, Advanced Enzymes
Fallbrook Technologies - *www.fallbrooktech.com*	High-efficiency transmission
Solyndra - *www.solyndra.com*	Solar PV, CIGS
Tesla Motors - *www.teslamotors.com*	Electric Vehicles, Automobiles

The following companies are Clean Edge top picks for potential IPOs in 2010/2011

Company	Sector
Amyris Biotechnologies - *www.amyrisbiotech.com*	Synthetic biology for jet fuel, industrial chemicals, and biodiesel
BrightSource Energy - *www.brightsourceenergy.com*	Concentrated Solar Power
Miasolé - *www.miasole.com*	Solar PV, CIGS
Silver Spring Networks - *www.silverspringnet.com*	Smart Grid, Networking

Source: Clean Edge, Inc., 2010

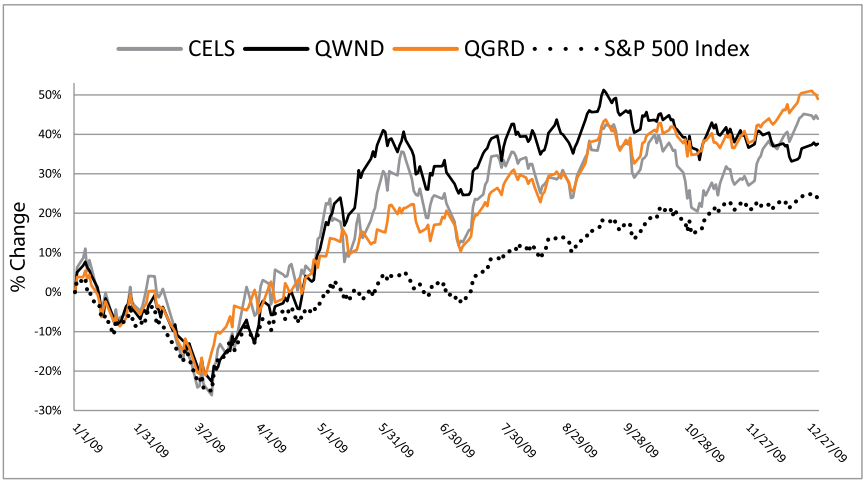
NASDAQ® Clean Edge® Stock Index Performance

Another view on the markets comes from tracking the performance of publicly traded clean-energy stocks. Clean Edge, along with NASDAQ, currently produces three indexes which act as transparent and liquid benchmarks for the sector: CELS – which tracks U.S. listed clean-energy companies; QWND, which tracks global wind power companies; and QGRD, which looks at smart grid and grid infrastructure companies. These three Clean Edge indexes* were up a meteoric rise of 75, 67, and 34 percent respectively in 2007, came back down by 64, 54, and 43 percent respectively in 2008, and outperformed most market indicators once again in 2009, rising 44, 38, and 49 percent respectively. We expect clean-energy indexes to continue to demonstrate volatility, outperforming the general market during stock market upswings, and trending downwards further during market corrections.

The Decade of Ubiquitous and Cheap

Clean-energy technologies are becoming cheaper and ever more ubiquitous. At Clean Edge, we believe that the commoditization of solar PV, smart meters, energy storage devices, wind turbines, and other clean technologies will be one of the top stories of the decade. These technologies are becoming ubiquitous in everyday products and services: think roof tiles from Dow Chemical integrated with solar PV, or washing machines from GE embedded with smart devices that can "communicate" with grid operators. As the market matures in the coming decade, we believe that we'll see considerable consolidation, with multinationals and the strongest pure plays gobbling up smaller competitors to compete in a commoditized environment.

NASDAQ® Clean Edge® Stock Index Performance* (2009)



** Index data is provided by FactSet Research Systems and NASDAQ OMX. Index values for QGRD prior to inception (9/22/09) and for QWND prior to inception (6/26/08) are hypothetical and NASDAQ OMX and Clean Edge make no guarantee of their accuracy.*

The scaling up of clean tech is resulting in cost and price declines

As we've reported for nearly a decade, the scaling up of clean tech is resulting in cost and price declines. As a result, these lower prices are enabling the build out of clean-energy deployment. Within a decade, for example, we project that the installed price for solar PV will drop nearly 60 percent, from an average of $5.12 per peak watt in 2009 (down from $7.00 in 2008) to $2.11 per peak watt in 2019. Installed wind turbine pricing, which declined 11.1 percent from $1.9 million per MW installed in 2008 to $1.69 million per MW installed in 2009, is now cost-competitive, with limited or no subsidies, in an increasingly large percentage of the world. We see wind turbine pricing coming down to around $1.5 million per MW installed within the next decade. Pricing for biofuels is much harder to predict, because of uncertain commodity costs. However, as non-food feedstocks, waste streams, and algae become harvestable for next-gen biofuels, we believe prices will likely come down or stabilize.

U.S. Top 10 Disclosed Energy-Tech Venture Deals (2009)

Company	Primary Sector	Total Invested (U.S. $ Millions)
Solyndra	Solar	$286.0
Fisker Automotive	Efficiency: Transportation	$85.0
Tesla Motors	Efficiency: Transportation	$82.5
SolFocus	Solar	$77.6
Suniva (formerly Solarity)	Solar	$75.0
Serious Materials	Efficiency: Built Environment	$65.0
Calisolar	Solar	$60.0
Boston-Power	Power Storage	$55.0
Sierra Solar Power	Solar	$40.0
Tesla Motors	Efficiency: Transportation	$40.0

Source: Bloomberg New Energy Finance, 2010

The China Card

China, once a minor player in clean energy, now leads in the race for clean-tech dominance. While the U.S. currently holds the title for the most cumulative wind installations, in 2009 China became the largest installer of new wind farms, adding a total 13,000 MW of new wind, or more than a third of total new global installations. China also leads the world in solar hot water heater manufacturing and installations, and now manufactures more solar PV than any other country in the world. In terms of intellectual capital, China is catching up as well – big time. According to recent Thomson Reuters' research, China has demonstrated the strongest scientific research growth over the past three decades of any country in the world – and is now second only to the U.S. in terms of the production of scientific knowledge.

It's too early to declare China the de facto winner

But will cheap labor, an artificially low exchange rate, manufacturing knowhow and infrastructure, and government investments and aggressive policies guarantee China clean-energy dominance? It's possible, but it's too early to declare China the de facto winner.

First, as we've pointed out in past reports and research, no one country or region will lead in all clean-energy sectors. Instead, dozens of nodes are blooming around the world within various sectors such as solar PV, energy storage, green buildings, smart grid networking, and wind power. Second, China still faces significant environmental compliance and pollution issues that could stand in the way of true clean-energy leadership. Building clean tech off the backs of polluted water, air, and consumer products just isn't environmentally or economically sustainable. Third, while the Chinese government is investing billions and is committed to its clean-energy build out, it still constricts the free flow of information. While China is improving its educational infrastructure and science development capabilities, will it have the same level of innovation as places like the U.S. with more open and democratic forms of information exchange? China will likely address all, or many, of these issues, but it still faces significant obstacles to global domination. In the meantime, other nations interested in leading the clean-tech race, like Germany, Japan, and the U.S., will need to compete aggressively in the face of a rising China.

Global Clean-Energy Jobs (Direct and Indirect): Solar and Wind

	2009 (Current)	2019 (Projected)
Solar Photovoltaics	267,562	2,178,919
Wind Power	563,577	1,122,815
TOTAL SOLAR AND WIND JOBS (Global)	831,139	3,301,734

Source: Clean Edge, Inc., 2010

Clean Energy Jobs Expansion

Our analysis shows that the solar photovoltaics and wind power industries currently account for more than 267,562 and 563,577 direct and indirect jobs worldwide, respectively, a total of more than 830,000 jobs. By 2019, we project the number of jobs at 2,178,919 for solar and 1,122,815 for wind, for a total of more than 3.3 million jobs. These numbers are based on our projections for global industry growth through 2019.

The End of Climate

2009 ended with the failure of developed and developing nations to reach binding agreements in Copenhagen. In many ways, this represented the end of climate as the key driver behind the growth

of clean tech. The likelihood of U.S. federal cap-and-trade legislation diminished significantly with the failure to reach a global climate accord. While this is a significant disappointment and setback for climate regulation advocates, it may not be as dire as it seems. Yes, climate will not be the big driver that some had hoped for – but in many ways the climate debate had become a distraction. Americans, for example, tend to support the build out of clean energy but are less certain about cap and trade.

In many ways, the climate debate had become a distraction

Moving forward, the conversation will need to focus on energy and national security, job creation, environmental protection, and global economic competitiveness. Yes, we'll still need a price on carbon to signal markets – but that can now come by viewing carbon for what it is – a source of pollution (which is backed up in the U.S. by a Supreme Court ruling). By changing the frame, and focusing on different drivers and outcomes, the growth of clean tech may be better served than focusing solely on something as nebulous and divisive as climate.

The Road Ahead

As we highlight above, clean energy is now one of the leading forces behind a global economic recovery. China, the U.S., Japan, Europe, and other parts of Asia are all competing to dominate in a range of clean-energy sectors – making the future for clean energy look promising as the global economy begins to recover.

One great place to look for lessons is the history of the mobile and telecom industry in the U.S. Between 1997 and 2007, the mobile and telecom industries spent $850 billion to go digital – creating 1.7 million jobs in the process. According to former FCC chairman Reed Hundt, the investment to upgrade the U.S. grid and embed intelligence in it (i.e. the creation of the smart grid) will require a similar amount of money and could result in a similar number of jobs.

But the funding of clean-energy projects – whether in the U.S., China, Japan, Europe, or elsewhere – won't be easy. Like all the energy sectors that preceded it – from coal and oil to natural gas and nuclear – it will take a concerted public and private commitment, along with the necessary policy and regulatory schemes, equity and project financing, and technology innovation.

On the following pages we look at five of the key trends we believe will shape clean-energy markets in 2010 and beyond.

FIVE TRENDS TO WATCH

1. CARBON AS A FEEDSTOCK: WIN-WIN OR PIPE DREAM?

With global carbon constraints inching closer to reality, technologies and businesses are emerging to not only capture and sequester CO2, but to use it in a wide range of products including cement, asphalt, chemicals, plastics, and algae for biofuels. This trend has excited entrepreneurs, investors, and environmentalists, but many challenges still loom.

Portland cement is one of the world's most carbon-intensive materials

Portland cement, by far the most common cement used in concrete for buildings and roads, is one of the world's most carbon-intensive materials; cement production accounts for approximately five percent of global CO2 emissions. Concrete is also the world's second most-transported commodity, behind only water.

For several years, firms including CalStar Products and Hycrete have been cutting carbon intensity by using fly ash, a waste product of coal-fired power plants, to partially replace Portland cement in concrete and bricks.

But now companies such as Calera in Los Gatos, Calif., are going a step further, using captured CO2 from fossil-fuel plants to create the calcium and magnesium carbonate compounds needed for cement. This creates a double 'bang for the buck' in carbon reduction – capturing otherwise waste CO2 on the front end while displacing the equivalent amount of carbon-intensive Portland cement on the production side. "Forget the thinking that [carbon] has to be a penalty or tax," says Calera CEO Brett Constantz. "It's a raw material that we need in the cement industry."

Captured-carbon cement production is still mainly in the pilot phase, most notably at Calera's test facility using carbon from a 2,500-MW Dynegy natural gas-fired power plant in Moss Landing, Calif. But the technology has attracted attention – and funding – from some blue-chip investors. Most of Calera's reported $17 million in funding to date comes from Vinod Khosla. The U.K.'s Novacem, which is commercializing a cement-from-captured-CO2 process developed at London's Imperial College, announced a round of more than £1 million ($1.55 million) in August 2009. Skyonic in Austin, Texas, uses a cement plant itself as the carbon source to make baking soda for industrial applications; it received a $3 million federal stimulus grant in February 2010. OVP Venture Partners led a $14 million funding round in August 2009 for Novomer in

Profile: Calera

Location

Los Gatos, California
www.calera.com

Founded

2007

Employees

125

Technology

In simple terms, Calera's process mimics the natural formation of sea coral, combining carbon with water to create calcium carbonate, the key component of Portland cement. The company claims each ton of its cement can capture up to half a ton of CO2 emissions.

The Buzz

Calera has not lacked for buzz or hype, due largely to its high-profile lead investor, Vinod Khosla of Khosla Ventures. Khosla says the captured-carbon cement market could be "as big as GE's power-plant business" if viewed as a key piece of global carbon sequestration. Calera is the basis of a 2009 Harvard Business School case study on bringing clean-tech lab innovations to commercial scale.

Brain Trust

Founder and CEO Brett Constantz has created and commercialized innovations in cement for nearly three decades, mostly in the medical industry. Before Calera, he founded and ran three medical-device companies. The holder of more than 60 patents and a Ph.D, Constantz is also a consulting professor at Stanford University.

Bankrollers

Khosla Ventures has funded five rounds in Calera. Although the company has been mum about dollar amounts, press reports have placed Calera's total VC backing to date at around $17 million.

Our Take

When targeting a trillion-dollar global industry (cement), a very small market percentage can pay off well. Calera's big challenge is proving that its process works, cost-effectively, at large commercial scale. But with deep-pocketed investors and a working pilot plant well underway, Calera seems to have as good a chance as anyone in this emerging sector.

Waltham, Mass., which uses captured carbon to make plastics, polymers, and resins – some of them at a former Eastman Kodak chemicals plant in Rochester, New York.

CO2 is also a critical component in the production of algae, and several algae startups, creating so-called "oilgae" to replace petroleum fuels, are testing the carbon-capture waters. Solix Biofuels is working with Colorado State University on a Fort Collins, Colo. plant that uses CO2 from the nearby New Belgium Brewery; Scottish Bioenergy is producing algae using CO2 from Scotland's oldest distillery, Glenturret, maker of Famous Grouse Scotch whisky. Sapphire Energy, the well-funded algae player whose backers include Bill Gates's Cascade Investment, is seeking CO2-supplying partners. But the sector also suffered a setback in May 2009 when GreenFuel Technologies, which had test projects underway with power plants in Arizona and Louisiana, hit a financial crunch and went out of business.

Although GreenFuel's fate involved many different factors, it points up the challenges still faced by this nascent sector: technology cost, the need to co-locate factories near CO2 feedstock sources, uncertainty about how carbon credits would be calculated and awarded, and longer-term concerns about the availability of those sources as the world moves to a cleaner energy mix.

"It is concerning to invest in things tied to carbon-heavy legacy solutions that will hopefully be obsolete in 10 to 15 years," says Claire Tomkins, research director at the Carbon War Room, a non-profit founded by Sir Richard Branson and others to seek market solutions to climate change. "I see [captured-carbon products] as a transitional step, not the end game." Yet with the world heavily dependent on fossil fuel power and emissions-intensive industrial processes, we're confident in carbon's future as a feedstock – if the technology and financial challenges can be met.

Recent Headlines

Calera and Novacem Use Concrete to Capture CO2

Novomer Brings in $14 Million for Bioplastics

Will CO2 Become the Next Hot Commodity?

APS Gets $70.5M to Feed Captured Carbon to Algae

Algae Demonstrator Project Goes Live at Glenturret

Skyonic Gets $3M Stimulus Funding to Turn CO2 into Baking Soda

Select Companies to Watch

Calera
www.calera.com

Carbon Capture Corp.
www.carbcc.com

Novacem
www.novacem.com

Novomer
www.novomer.com

Solix Biofuels
www.solixbiofuels.com

2. STEEP PV PRICE DROPS REDEFINE THE SOLAR INDUSTRY

Relative to the long list of innovations in clean tech, solar photovoltaic (PV) technology is old news. Invented more than 50 years ago, it is now a proven, commercialized product manufactured and installed at multi-megawatt scale. In 2009 alone, nearly six gigawatts of solar were installed globally. It would be foolish, though, to assume that any of this leads to industry stability. Advancements in technology, inventive financing strategies, and most importantly, price declines, are rapidly altering the solar landscape. This rate of change will only accelerate in the coming years.

PV's installed cost fell dramatically from $7 per peak watt in 2008 to just more than $5 per peak watt in 2009

In 2010, the story is all about price.

Traditionally, a doubling of global PV manufacturing capacity has resulted in roughly a 20 percent price decline. But about five years ago, this pattern was interrupted as shortages in production of polysilicon – the key ingredient of most solar panels – sent prices of the material skyrocketing from around $30 per kilogram in 2004 to more than $400 per kilogram in 2008. This drove demand for alternative products like thin-film and CIGS PV, which can produce electricity with little or no processed silicon, although usually at lower levels of efficiency. Led by companies like First Solar, thin-film cells soon became the cheapest form of solar and can now be made for as little as $1 per peak watt.

Elevated polysilicon prices, while a boon for thin-film PV, slowed solar's overall journey down the price curve. The silicon shortage finally eased in late 2008/early 2009 and spot prices fell from their highs, holding today at around $50 per kilogram. Cheaper silicon – along with increased production capacity, declining demand growth, and price competition – led to a 30 to 50 percent drop in crystalline silicon module prices during 2009. Another major factor was the emergence of China as a leading PV cell manufacturer, bringing a vast amount of low-cost production online.

As a result of cheaper modules, PV's installed cost also fell dramatically from $7 per peak watt in 2008 to slightly more than $5 per peak watt in 2009 and as low as $3 per watt installed for some utility-scale projects.

Profile: Trina Solar

Location

Changzhou, China

www.trinasolar.com

Founded

1997

Employees

Approximately 8,000

Technology

The China-based manufacturer shifted from R&D efforts to commercial production in 2004 when it launched its PV module business. Trina's activities now span the entire solar PV value chain – from silicon-ingot and wafer production to development of mono and multi-crystalline silicon solar cells and modules.

The Buzz

Trina is aiming to grow annual module output capacity to 950 MW by the end of 2010, quite a leap from an annual output capacity of 450 MW in Q3 2009. Averaging $1.24 per watt in Q4 2009, the company also boasts some of the industry's lowest module manufacturing costs.

Brain Trust

The company was established by chairman and CEO Jifan Gao and a small group of scientists. Gao was inspired by the Clinton administration's 'Million Solar Roofs' initiative and originally intended to create a solar PV system installation company for China's domestic market. Working on several projects with the Chinese government gave Trina some industry traction and enabled its eventual transformation into a vertically integrated manufacturer.

Bankrollers

Trina Solar completed its initial public offering in December 2006 and trades on the NYSE under the ticker symbol TSL. The company's 2009 revenue totaled $845.1 million.

Our Take

Trina Solar has ambitious growth targets. If the company is able to stay on track, it may well be able to continue to cut manufacturing costs — now the name of the game in silicon PV and especially key once Germany's impending feed-in tariff reduction intensifies the need for cheap solar. Further pushing down costs could also allow Trina to compete with thin-film developers for lucrative contracts.

The price drop, along with other internal financial and policy drivers, is causing some countries to reduce national incentive programs. Germany plans to reduce feed-in tariffs at the beginning of July 2010 by 11 to 16 percent, depending on the application – a move that will further intensify the demand for less expensive PV in the world's largest solar market.

Although solar's price decline is likely to slow in the coming years, it's clear that a new age of cheap solar is upon us – and PV product makers have to adapt. "The industry is operating at very low profitability all the way from the manufacturer to the installer," says Ron Kenedi, solar industry veteran and vice president of Sharp's Solar Energy Solutions Group. This may present a short-term headache, but affordable solar is key to the technology's long-term success. "Our job in the industry is to move day-by-day towards grid parity," Kenedi says.

With these challenging market conditions and price declines, solar industry acquisitions are on the rise. One of the more interesting transactions of 2009 was MEMC Electronic Materials' $200 million buyout of SunEdison, taking MEMC beyond wafer manufacturing to the installation and ownership of solar projects. Other notable moves included SunPower's $277 million acquisition of European developer SunRay, and Spain-based Fotowatio's $19.7 million purchase of U.S. developer MMA Renewable Ventures.

As the industry matures and solar's price decline marches on, we can expect to see more consolidation across the value chain and the increased commoditization of solar technology. The new age of affordable solar will spawn innovative ownership models, unlock new markets around the world, and solidify manufacturing leadership for a select group of large industry players.

Recent Headlines

Homeowners Shopping for Solar Panels Find Prices Have Dropped

German Solar Companies Face Incentive Cuts, Foreign Sales Key

PV Market Continues to Suffer From Glut

China Invites Bid for Biggest Solar PV Power Plant

Falling Silicon Prices Pressure Thin-Film Solar

Economy Forces Consolidation in Solar Industry

Select Companies to Watch

First Solar
www.firstsolar.com

MEMC Electronic Materials
www.memc.com

Sharp
www.sharpusa.com

SunPower
www.sunpowercorp.com

Trina Solar
www.trinasolar.com

3. BIOMASS FIRES UP UTILITIES AND DISTRICT HEATING

From forest trimmings and manufacturing residues to municipal and organic waste streams, woody biomass is gaining prominence as a reliable source of electricity, heat, and combined heat and power (CHP). Utilities that operate in states or countries with aggressive renewable portfolio standard (RPS) targets, or regions that have put restrictions on carbon emissions, increasingly see biomass as an attractive renewable baseload power source that creates jobs and displaces fossil fuels.

Many utilities have recently converted or are planning to fully or partially convert their coal and natural gas boilers to biomass

On one end of the scale is Denmark, a country that started banning new coal facilities in 1996, and which is home to 670 CHP-equipped power plants that generate approximately 60 percent of all the country's heat and half of its electricity. Approximately 10 percent of all power in Denmark is generated from biomass and organic waste in CHP plants, according to the Danish Energy Agency. Companies like Denmark's DONG Energy, Germany's Viessman, and Sweden's Vattenfall have all but perfected boiler systems rated between 80-95 percent efficient at residential and municipal scales. These systems can use biomass to displace a percentage of natural gas or coal in a process known as co-firing, or can operate using solely biomass -- with feedstocks such as wood pellets, wood waste, straw, and agricultural waste.

In the U.S., biomass currently provides approximately three percent of energy production (not including transportation fuels), primarily via small power plants and niche industrial applications, according to the U.S. Energy Information Administration. But the scale of operation has been changing. FirstEnergy, Southern Co., Xcel Energy, and many other utilities have recently converted or are planning to fully or partially convert their coal and natural gas boilers to biomass (known as "repowering"). As more utilities start using biomass for heat and power at a larger scale, however, the more this energy source bumps up against a host of complex economic, land-use, and logistical issues. Biomass power emits particulates and other pollutants, and opponents question whether it really reduces CO2 emissions. Supporters counter that emissions are far less than those from coal plants – when taking into account the full biomass life cycle and new cleaner-burning boilers.

Profile: District Energy St. Paul

Location

St. Paul, Minnesota

www.districtenergy.com

Founded

1979 (as District Heating Development Company)

Employees

Approximately 75

Technology

District Energy St. Paul operates the largest wood-fired CHP plant serving a district energy system in the nation. The company produces about 65 megawatts of thermal energy for District Energy and 25 megawatts of electricity for Xcel Energy.

The Buzz

The success of District Energy St. Paul has motivated many other U.S. district energy proponents to champion the benefits of district energy in their hometowns – including Las Vegas, Nevada; Taos Pueblo, New Mexico; and Portland, Oregon.

Brain Trust

District Energy St. Paul started out as a vision of former St. Paul Mayor George Latimer in response to the 1970's energy crisis. Two Swedish colleagues, Hans Nyder and the current president Anders Rydaker, have led the company since 1983, bringing their experience from a similar district heating system in Uppsala, Sweden.

Bankrollers

District Energy is a longstanding public-private partnership between the City of St. Paul, State of Minnesota, U.S. DOE, and the St. Paul business community.

Our Take

The infrastructure costs and community support required to implement district energy systems in the U.S. are major obstacles. St. Paul District Energy serves as a unique example of how creative financing, partnerships, and organized political leadership can overcome these challenges. As more cities begin to take notice of the St. Paul example, we expect more local champions of district energy to come out of the woodwork nationwide.

The U.S. Departments of Energy and Agriculture, for example, estimate that U.S. biopower (both heat and electricity) can sustainably reach five percent of the nation's industrial and electric generator energy demand by 2020 by utilizing existing waste streams and increased output from forest and agricultural land – without displacing food production or impacting environmentally sensitive areas. Some industry analysts have projected that the number could be far greater, with the potential for biomass to sustainably provide up to 20 percent of total U.S. electricity generation.

It all comes down to cost. "If a utility can broker a sustainable biomass fuel at a competitive cost, while minimizing plant retrofit costs, then biomass co-firing is an easy first option when faced with an RPS or carbon regulations," says biomass expert Chris Zygarlicke, deputy associate director for research at the Energy and Environmental Research Center at the University of North Dakota.

Regions like British Columbia and the American Southeast that have forestry infrastructure and knowhow are eyeing woody biomass use as a way to revive economic activity. A growing supply of readily available feedstock will make it easier for district energy systems, like the one operated by Minnesota's District Energy St. Paul, to expand – and for large-scale systems, like those proposed by Adage (a Duke Energy/Areva joint venture), to come online.

Despite its many challenges, woody biomass's unique versatility and distinct advantage as a baseload power source make it an increasingly important piece of the energy puzzle. That said, investors and entrepreneurs should heed the lessons of the ethanol fallout with respect to the importance of sustainable land use that underpins the biomass industry.

Recent Headlines

World's Largest Wood-Pellet Factory to be Built in Georgia

Belgian Firms to Convert Coal-Fired Power Station into Biomass Plant

Southern Company to Build 100 MW Biomass Plant in Texas

Abengoa, Kansas Utility Sign 20-Year Biomass Energy Supply Deal

Another One Bites the Dust: Michigan Coal Plant Converts to Biomass

Biomass Plants in Europe Increase by 40% in Last Five Years

UN OKs Biomass Co-Firing to Meet CO2 Targets Under CDM

Select Organizations to Watch

Adage
www.adagebiopower.com

District Energy St. Paul
www.districtenergy.com

First Energy
www.firstenergycorp.com

Viessman
www.viessmann.us

Xcel Energy
www.xcelenergy.com

4. CLEAN-TECH MEGAPROJECTS SEE BIG ADVANCES - AND BIG CHALLENGES

Belying the long-held conventional wisdom that clean tech can't operate at massive scale, projects of unprecedented size in wind, solar, smart grid, and urban design are underway around the world. These projects are creating a vision of a clean-tech future way beyond traditional thinking. But many have seen their original drawing-board plans delayed, scaled back, or scrapped altogether – pointing up the challenge of transforming a fossil fuels-based economy into a cleaner one.

Several new deployments bring single-location wind and solar projects into the gigawatt range

Any clean-tech megaproject is rife with financial and logistical risks, and 2009 saw many projects derailed, often (but not always) due to the global economic recession. T. Boone Pickens pulled the plug indefinitely on his well-bankrolled plan to build 1,000 MW of wind power (with talk of 4,000 MW by 2014) in the Texas Panhandle. The highest-profile plans to build from-the-ground-up cities powered by clean energy had a rough year too. Masdar City in Abu Dhabi (see Profile) has delayed its construction targets and China appears to have completely abandoned plans for Dongtan, a new eco-city near Shanghai that had targeted a population of 20,000.

These types of utopian-vision cities have always faced major challenges -- and at a time of slashed government budgets and tight credit, higher priority has gone to investing in energy-efficient retrofits of existing buildings, and smart new construction in existing cities. But that doesn't mean that clean-energy providers aren't continuing to think big.

Several new deployments bring single-location wind and solar projects into the gigawatt range. And many of them are in the country that's fast becoming synonymous with "mega" in clean energy: China.

Pasadena, California-based eSolar is providing the technology and expertise for a series of concentrating solar power (CSP) towers in China, slated to total 2,000 MW, with construction on the first 92 MW tower beginning this summer. (The current global size leader in CSP is the venerable Kramer Junction Solar Energy Generating Station in California's Mojave Desert, dating back to 1984, with nine installations totaling a capacity of 354 MW). The world's largest PV farm is Fotowatio's 60

Profile: Masdar City

Location

Abu Dhabi, United Arab Emirates

www.masdarcity.ae

Founded

2006

Employees

500

Technology

The Masdar Initiative's showpiece $22 billion megaproject is Masdar City, planned to be the world's largest carbon-neutral, zero-waste community. Designed by British architects Foster + Partners and managed by CH2MHill, Masdar City envisions 50,000 residents by 2020.

The Buzz

Masdar officials confirmed in early 2010 that Masdar City's completion target has been pushed back from 2016 to 2020. Officials say Phase 1 is still on track for completion in 2013. Masdar has tweaked some of its original clean-energy plans, scaling back on CSP (dust on the lenses hurt efficiency) and drilling for geothermal power instead. In 2009, a 10 MW, grid-connected solar PV plant came online.

Brain Trust

Masdar's top executive is 36-year-old Dr. Sultan Ahmed Al Jaber, CEO and managing director. Arabian Business magazine ranked Al Jaber 14th in its 2009 Power 100 list of the world's most influential Arabs, and No. 1 in energy. But the resignations of two other top executives in early 2010 raise potential concerns about leadership going forward.

Bankrollers

Abu Dhabi's government has committed about $4 billion to fund the construction of Masdar City, with the balance of the $22 billion budget coming from equity partners and debt finance.

Our Take

Despite some setbacks, Masdar City remains the world's leading showcase for the grand vision of an eco-city (U.S. Energy Secretary Steven Chu visited in February). The megaproject has survived both the global and local Dubai economic crises; we're confident that Masdar City will continue to be both a valuable eco-city pioneer and a clean-energy test bed for the foreseeable future.

MW Olmedilla Photovoltaic Park in Spain, but later this year First Solar will start building a 2,000 MW PV farm in Inner Mongolia, slated for completion in 2019.

Even if these projects don't end up delivering 100 percent of their target size, they still prove that clean energy can deliver huge chunks of utility-scale power – a notion that many doubted just a few years ago. "These are on the order of scale of traditional [fossil fuel] energy projects, and we should start thinking of that as normal," says Silicon Valley entrepreneur Sunil Paul, founder of Gigaton Throwdown, an initiative mapping out pathways for a massive scaleup in nine different clean-tech sectors by 2020. "Anything utility-scale requires megaprojects."

In wind power, German utility E.On completed the world's largest wind installation, the 780 MW Roscoe Wind Farm in West Texas, in October 2009. Its primacy, however, may not last long. Indian wind giant Suzlon has begun work on a 1,000-MW farm in Dhule, India, although the project has been stalled by disputes with local landowners. And in what could be a sign of future offshore wind megaprojects, Norwegian energy incubator Enova said in February that it is funding development of a 10-MW offshore wind turbine – the world's largest ever.

Massive clean-energy scale ups, particularly in the solar PV and smart-grid sectors, can also come from big growth in small distributed systems. In one of the largest smart-grid deployments underway, Southern California Edison (SCE) in 2009 began its rollout of five million smart meters – covering most of its customer base. And SCE also won regulatory approval to install up to 500 MW of distributed solar PV across its service territory – one commercial rooftop at a time. There's more than one way to create a megaproject.

Recent Headlines

$50M Solar Plant Comes Online to Power Masdar City Construction

Pickens Shelves Texas Wind Project

World's Largest Solar Project Planned for Saharan Desert

E.ON Opens 780 MW Wind Farm in Texas

First Solar to Build Mammoth PV Plant in Mongolia

Southern California Edison Installs First of 5 Million Smart Meters

Select Organizations to Watch

eSolar
www.esolar.com

Gigaton Throwdown
www.gigatonthrowdown.org

Masdar City
www.masdarcity.ae

Southern California Edison
www.sce.com/PowerandEnvironment/smartconnect/

Suzlon
www.suzlon.com

5. HIGH SPEED RAIL SURGES AHEAD – BUT AT WHAT COST?

High speed rail (HSR) – defined today as trains traveling at 180 mph or faster – has existed for decades in Europe and Japan. But governments around the world, most notably the United States and China, are now investing billions in new HSR ventures in the hopes of gaining a competitive edge, reducing carbon emissions, and helping pull their countries out of economic doldrums. With the perfect storm of job creation, government and private funding, and technological innovation, HSR today may be better poised for the long haul than at any time in the past.

The 800-mile Beijing-to-Shanghai line will cost an estimated $32 billion – in the same cost ballpark as the gargantuan Three Gorges Dam

As in so many areas of clean tech, China is leading the surge. China's Ministry of Railways reportedly spent $88 billion on HSR projects in 2009 – part of an existing $300 billion plan to expand and connect all of the country's major cities with a projected 10,000 miles of dedicated HSR lines by 2020. There will be more high-speed rail added in China over the next five years than the rest of the world combined, says Keith Dierkx, director of IBM's Global Rail Innovation Center in Beijing.

Global HSR manufacturers like Kawasaki Heavy Industries, Alstom, GE Transportation, Siemens, and others have formed joint ventures or partnerships in China. A Canadian-Chinese joint venture, Bombardier Sifang, recently won $4 billion from the Chinese government to manufacture up to 80 high-speed trains. These same companies are now eyeing or already capturing similar, albeit smaller, opportunities in other emerging countries like Brazil, Russia and South Korea.

HSR's main development challenge is its high price tag. The 800-mile Beijing-to-Shanghai line will cost an estimated $32 billion – in the same cost ballpark (at least officially) as the gargantuan Three Gorges Dam hydroelectric project. In the U.S., where HSR has been slow to leave the station, a proposed 750-mile HSR network connecting San Diego, San Francisco, and Sacramento could cost more than $40 billion.

The Obama Administration recently committed $8 billion in stimulus funding spread across a dozen potential HSR corridors (in some of these areas 'high speed' is considered 120 mph). U.S. Secretary of Transportation Ray LaHood says he is courting many domestic and foreign rail investors to supply

Profile: Central Japan Railway Co.

Location

Nagoya, Japan
http://english.jr-central.co.jp

Founded

1987 (Successor to Japan National Railways)

Employees

Approximately 16,000

Technology

Central Japan Railway Company (JR Central) is a leading HSR manufacturer and rail operator that holds the world speed record for manned railway vehicles at 581 km/h (361 mph) achieved by its test-bed, superconducting magnetic levitation (maglev) high-speed train system.

The Buzz

JR Central has set its sights on leading U.S. rail corridors to initiate its first international foray and has created two new U.S. based companies – U.S.-Japan High-Speed Rail specializing in bullet trains, and U.S.-Japan Maglev specializing in superconducting maglev technology.

Brain Trust

JR Central chairman Yoshiyuki Kansai is described as a larger-than-life figure in Japan who doesn't mince words. The 69-year-old, 48-year rail veteran has led the charge to enter the U.S. market but is uniquely cautious in his company's approach to China. "It's not possible to export our trains to China. They would steal our technology and they would not respect it," he has said.

Bankrollers

As the successor to Japan National Railways and operator of one of the busiest Japanese rail lines, JR Central has deep pockets that afford the company a long-term approach to creating rail systems that are up to 50 percent faster than today's high-speed trains.

Our Take

The company's focus on improving safety and speed of trains has made it an industry leader for more than two decades. Based on its history in Japan, and its new foray into the U.S., we would not be surprised to see JR Central playing a central role in building out HSR in the U.S. and elsewhere.

the hundreds of billions in private capital required to build out a national infrastructure. Siemens, for one, recently purchased 20 acres of land next to its current light-rail manufacturing plant in Sacramento, in anticipation of future HSR projects.

Innovation in overhead electrification and propulsion systems, regenerative breaking, and dynamic scheduling now enables HSR to travel more than 220 mph. The fastest trains in the world, known as maglevs (magnetic levitation systems), are propelled and lifted by high-powered electromagnets. Many point to this technology as the next major HSR breakthrough, but the world's only commercially operating high-speed maglev train system is the German-engineered Transrapid that has connected Shanghai with the Pudong Airport since 2004. However, its price tag turned out to be approximately $1.1 billion ($57 million per mile), well over the original price projection. Cost risk has not deterred the Central Japan Railway Company from setting up two maglev joint ventures in the U.S., or the public-private California-Nevada Super Speed Train Commission from planning a maglev system connecting Las Vegas and Orange County.

Since HSR is electrically powered, its proponents point out that emissions will continue to decrease as more green electrons – from large-scale wind, solar, and other sources – come online. But many have questioned how much HSR really reduces carbon emissions; HSR projects in Tampa, Hong Kong, and London, for example, have endured fierce debates on this issue. A UC-Berkeley life-cycle assessment of the proposed California HSR network says HSR has the potential to be the lowest energy user and greenhouse-gas emitter compared to automobiles, heavy rail, and aircraft – but only if appropriate planning ensures high ridership levels. Moving forward, HSR backers will face continued challenges in proving that high speed is truly worth its high cost.

Recent Headlines

Foreign Suitors Lining Up for U.S. High-Speed Rail Payday

Bombardier Wins $2B Contract for High-Speed Trains in China

GE Fires Up Rail Deals In China, Eyes U.S. High-Speed Rail Projects

Spain's High-Speed Trains Win Over Fed-Up Flyers

Siemens Fills Russia's Need for a High-Speed Train

Korea Eyes $20 Billion Brazil Rail Project

Select Companies to Watch

Alstom
www.transport.alstom.com

Central Japan Railway Company (JR Central)
http://english.jr-central.co.jp

CSR Qishuyan Locomotive Co.
www.qscn.com/english/index.asp

GE Transportation
www.getransportation.com

Siemens
www.mobility.siemens.com

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AUTHORS

Ron Pernick, co-founder and managing director of Clean Edge, is an accomplished market research, publishing, and business development entrepreneur with more than two decades of high-tech experience. He is also the co-author of the highly acclaimed business book *The Clean Tech Revolution* (Collins). Ron has co-authored more than a dozen reports at Clean Edge and oversees the company's many projects and initiatives. He speaks regularly at industry conferences and is widely quoted in the media.

Clint Wilder, senior editor for Clean Edge, is an award-winning technology and business journalist. His book *The Clean Tech Revolution* (with co-author Ron Pernick), has been called "the best clean tech book" by ClimateProgress.org and has been translated into seven languages, most recently Chinese. Wilder is a frequent speaker at industry events and business schools, and writes a blog on clean tech for the Green section of The Huffington Post.

Dexter Gauntlett, senior research and marketing associate, has worked in the clean-energy sector for both private and non-profit organizations in the U.S. and developing countries.

Trevor Winnie, research and marketing associate, is involved in a range of activities at Clean Edge including working on the firm's stock index products and supporting Clean Edge staff in the preparation of reports and consulting projects.

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MAJOR SPONSORS

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Bloomberg New Energy Finance *(www.newenergyfinance.com)* is the world's leading independent provider of news, data, research, and analysis to decision-makers in renewable energy, the carbon markets, energy smart technologies, carbon capture and storage, and nuclear power. The group has staff of more than 130, based in Europe, the Americas, Africa, and Asia. New Energy Finance Limited was acquired by Bloomberg L.P. in December 2009, and became Bloomberg New Energy Finance.

Blue Practice *(www.blue practice.com)* Clean technology companies deserve clear, informed communications from industry professionals who speak their language. Solely dedicated to the sustainability and clean-tech sectors, Blue Practice is as a collection of creative, strategic communications specialists who use their marketing and public relations expertise toward supporting tomorrow's transformative technologies and products. We're a voice for innovation and conservation, and we're making an impact on awareness and behavior with marketing and PR campaigns for a cleaner future.

Environmental Entrepreneurs (E2) *(www.e2.org)* is the *independent* business voice for the environment. E2 is a national community of individual business professionals who work towards developing economically beneficial solutions to top priority environmental issues. Founded in 2000, E2 has grown to 850 members across the country. Our diverse membership provides the business voice needed to advance sound environmental policy – addressing environmental issues from climate change to energy to oceans – based on its economic merits.

Mintz Levin *(www.mintz.com)* works with start-up, emerging, and established companies in all sectors: renewables, smart grid, water, waste treatment, biofuels, electric vehicles, and green building, among others. Our Energy and Clean Technology attorneys help clients optimize IP, raise capital, manage operations, interact with government, build and expand facilities, and enter into joint ventures. We have closed more than 120 clean-tech transactions and supported the successful development and financing of more than 8300 MWs ($9 billion) of energy generating facilities.

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