SPECIAL REPORT

Solar power: California's latest gold rush

Green-energy companies are enjoying a boom in investment. But will they live up to expectation, asks **Declan Butler**.

Silicon Valley is greening. Investors are flocking to low-carbon (clean) energy technologies, fuelling a boom in the sector, with investments set to overtake those in Internet start-ups. But does this venture-capital explosion herald another dotcom bubble?

Last week, Google announced its entrance into the green-energy field — hundreds of millions of dollars for a technology push to make renewable energies cheaper than coal. And in the same month, Nobel prizewinner Al Gore and his London-based firm Generation Investment Management joined forces with one of Silicon Valley's foremost green-energy investors, Kleiner Perkins Caufield & Byers in Menlo Park, California — the company that nurtured the likes of Amazon, Google and Genentech — to create an alliance to fund global climate solutions.

For the fast-moving entrepreneurs of the valley, who have successfully invested in disruptive technologies such as the Internet to change the face of entire industries, the next frontier is the roughly US\$6-trillion energy market, where the dinosaurs of power-generation utilities have traditionally invested a pittance in research and development. "Venture capital is exactly what we need to try new things outside the bounds of what the traditional energy companies think is worth doing," says Vinod Khosla, a veteran entrepreneur who co-founded Sun Microsystems and now heads Khosla Ventures in Menlo Park, one of the most prominent clean-energy venture-capital firms. "There is almost no technology risk-taking in any of the energy companies." Khosla predicts that within five years there will be a green form of electricity that is cheaper than coal, and cleaner fuels that are cheaper than oil.

The US venture-capital industry has spent \$2.6 billion on clean-energy technologies in the first three-quarters of this year — up from \$1.8 billion last year, and \$533 million in 2005 — according to new figures released on

28 November by Thomson Financial and the US National Venture Capital Association (NVCA), which represents almost 500 venture-capital funds. Venture capital is a thermometer of a new sector, dealing as it does with investment in new technologies, products and services. And for every dollar invested here, many more are spent in operations, building such things as solar generators, wind farms and bio-fuel plants. Total worldwide investment in clean tech, including such investments, jumped from \$28.3 billion in 2004 to \$75.4 billion last year. This year, that figure has already climbed to \$94.5 billion, says Philip Verey at the London-based consultancy firm New Energy Finance.

"Don't make the mistake of looking for the future in your rear-view mirror."

— Vinod Khosla

Worldwide, the star attraction for venture-capital investors is solar power. Although other forms of renewable energy can make significant contributions to current markets, only sunlight is available in the amounts required to substitute completely for the energy quantities currently derived from hydrocarbons. This year's US figures show the same trend, with solar attracting the largest share of investments, \$664.6 million, followed by biofuels and smart power systems (see *Nature* **445**, 586–588; 2007).

Although the United States is lagging far behind European countries such as Denmark and Germany in implementing renewables, its venture-capital investments in clean tech now more than double those in Europe. California scooped \$726.2 million of this year's US clean-tech venture funding, followed by

Massachusetts (\$292.6 million) and Texas (\$149.4 million). Almost \$1 billion of US investment went abroad, including a \$200-million investment in Brazil's Brazilian Renewable Energy, which produces ethanol, and a \$118-million investment in China's Yingli Green Energy Holding Company, which makes photovoltaic solar systems.

On the up

The increases significantly buck a trend — total public and private spending on energy research in the United States and elsewhere has been dropping steadily since the 1970s. In an analysis of energy-research spending published in January (G. F. Nemet and D. M. Kammen *Energy Policy* **35**, 746–755; 2007), the authors estimate that the US invests \$1 billion less in energy R&D

than it did a decade ago, and that this now represents just 2% of all federal R&D, compared with 10% in the 1980s. By contrast, spending on defence and health has been increasing by 10–15% annually during that period.

The private sector's share of the shrinking energy-research pie has also dwindled, and now makes up just a quarter of investments, compared with a half in the 1980s. The surge in new investment in energy by venture capitalists, established

Google is committing millions to solar, wind and geothermal technologies.

G. STEINMETZ/CORBIS

Californian investments in solar power, such as that produced at Dagget in the Mojave Desert, are leading the market in renewable energy worldwide.

energy firms such as General Electric and new entrants such as Google is therefore “extremely important”, says Gregory Nemet of the University of Wisconsin-Madison. “It’s difficult to envision successfully addressing concerns about energy independence and climate change without fully engaging the capabilities, resources and human ingenuity that these entities can apply,” he says.

But he cautions that the growth in green investment needs to be seen in perspective. For example, the entire US venture-capital investment in clean tech in 2006 — at \$1.8 billion — was exactly the same as that spent on R&D by the biotech company Genentech. “The magnitudes of the challenges of energy independence and climate change are so large that we are still orders of magnitude away from devoting the societal resources we need to deal with them,” Nemet says.

There is always a chance that the current wave of investment could peter out, perhaps owing to a substantial fall in oil and energy prices, or a fading of environmental concerns — but these are unlikely. The biggest risk is that the pace of basic technological improvements may fail to provide a pipeline of emerging technologies that

venture capitalists can feed off. Venture capitalists are not in the business of funding the basic research that will be needed to make the sort of breakthroughs needed to make solar energy cheaper than coal. Without a significant expansion of public spending on basic energy research, the innovation pipeline risks drying up.

The clean-tech market is “fraught with pitfalls and not for the inexperienced or the faint of heart”, according to NVCA president Mark Heesen. It is fit only for investors ready to look long-term and with a deep knowledge of the sector, he warns. “Short-term ‘tourists’ should steer clear.”

But for the moment, investor interest shows no sign of waning, and a string of new companies is preparing initial public offerings. The WilderHill New Energy Global Innovation Index (NEX), which tracks the share performance of new energy companies, is outperforming indices such as the P&P 500 and NASDAQ. Clean energy is already creating its billionaires: Shi Zhengrong, for example, who in 2001 created the company Suntech, making solar cells, is now China’s second wealthiest man.

The investments being made will allow development of many new technologies, with

rapid natural selection leaving fewer survivors. “Ninety per cent of the companies that exist today in this segment won’t be around in five years,” predicts Martin Roscheisen, chief executive of Nanosolar in San José, California, which tests new materials in solar-cell design (see *Nature* 443, 19–22; 2006). But this period of exuberance will be vital to spawning the next generation of low-carbon energy giants, he argues.

And if the bubble bursts? “Bubbles happen when over-exuberant investors who don’t understand the business get in, and I am certain one will happen in energy too,” says Khosla. “But just as in the dotcom world, good companies will continue to be built before and after the bubble.”

Venture capitalists will no doubt create stunningly successful new energy companies — the Googles and Amazons of tomorrow’s lower-carbon world — but only time will tell whether these can be sufficiently disruptive to the gargantuan energy industry on the massive scale needed to affect climate change. Solar energy and other renewables hardly make it above the x-axis on a bar chart of world-energy use, after all. But, Khosla advises, “don’t make the mistake of looking for the future in your rear-view mirror”.

Declan Butler

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