The winds of change
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The new generation of alternative power sources are providing attractive prospects for industrial mineral applications. Despite the recession, and against expectations, the photovoltaic and wind power sectors grew significantly in 2009, a trend that is expected to continue through 2014

Keywords: Power sources, photovoltaic, wind

The ethos of survival for industrial mineral producers has always been one of market diversification, ie. don’t have all your mineral eggs in one market basket. Therefore, new markets such as the continuing development of alternative sources of power generation are attracting much interest.

This fledgling market sector has thrown up an array of exciting new opportunities for industrial mineral applications. The trick of course, is securing, and then processing, the right raw material to make the correct grade for a particular application.

*Offshore wind farm Lillgrund being built in the Oresund between Malmo and Copenhagen
Siemens press picture*
Most applications for minerals in this growth market are low volume but high value, and demand tight raw material specifications.

Some of the new energy technologies are more advanced than others, and have already sparked widespread interest among mineral developers and investors in their anticipation of future market demand growth for what have already become “strategic” alternative energy minerals.

Clearly, lithium and rare earth minerals are the buzz words of an excited, and at times over excited, mineral investor market. But there are other key minerals required, such as graphite, boron minerals, zirconia, quartz, fused silica, fluorspar, filler minerals, and fibreglass minerals (see accompanying table).

**IM new power applications**

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The evolution of electrically powered vehicles has perhaps grabbed the most headlines, and with it the potential for increased use of lithium ion batteries (see Lithium Supplement starting p.51).

Fuel cell technology also remains an important and potential new energy source, offering applications for borates, graphite, phosphate, rare earths, and zirconia.

However, it is wind and solar (photovoltaic (PV)) power technology which are perhaps the more tangible growth markets for minerals since their development is already relatively well established and their benefits, albeit in their infancy, are being realised and are expected to make a bigger impact soon.

**Figure 1: Transforming the global energy mix: the exemplary path until 2050/2100**

*Source: WBGU*
New energy, new growth

In its 2003 report World in Transition: Towards Sustainable Energy Systems, the German Advisory Council on Global Change (WBGU) urged that “It is essential to turn energy systems towards sustainability worldwide. Nothing less than a fundamental transformation of energy systems will be needed to return development trajectories to sustainable corridors.”

To this end the WBGU forecasts a significant change in the “global energy mix”, projecting a steady decline in fossil fuel usage from 2030, and an increase in new renewable energy sources, including solar and wind from about 2020, with solar power expanding markedly from 2030 (see Figure 1).

However, the onset of the recession in 2008 and through 2009 impacted investment in renewable power developments, which had enjoyed a heady previous five years of growth. Initially, the once promising prospects for the sector appeared to face a barrier at the start of their real development.

One chink of light was that development costs were also plummeting Bloomberg New Energy Finance estimated that costs fell by an average of 10% across most sectors, including mature onshore wind, but especially PV (around 50%), where there was a significant oversupply in the market.

Unfortunately, this positive trend was offset by higher financing costs, and competition with falling prices for oil and gas as another outcome of the crisis.
But by the end of 2009, the sector bounced back. Bloomberg New Energy Finance reported $145bn. in total investment in clean energy, only a 6.5% drop from the record year of 2008.

The world’s wind industry defied the economic downturn and saw its annual market grow by 41.5% over 2008, and total global wind power capacity increased by 31.7% to 158 GW in 2009. More grid-connected PV capacity was added worldwide than in the boom year 2008.

Crucial to the future of new power generation are government supported and regionally organised schemes, as well as the all-influential impact of politics. Regarding the latter, although some technologies maybe proven, there is no certainty in their timescales of coming to fruition.

That said, the raft of government funded stimulus packages unveiled in 2009 for recovering their respective economies also contained green energy components, which was no bad thing for the sector.

Regarding green stimulus to clean energy exclusively (ie. energy efficiency, renewable, electricity grids, low-carbon cars), the USA is in first place with $66bn., followed by China ($47bn.), the EU ($31.1bn.), and South Korea ($16bn.). HSBC Holdings Plc predicts that global green stimulus spending on renewable energy and energy efficiency may triple in 2010.

**Figure 3: World and European PV markets in 2009 in MW**

Source: EPIA
Figure 4: Regional PV distribution in the World (Policy-Driven scenario)

Source: EPIA

Europe gets SET

Europe appears well ahead in exploring alternative power sources, and it is perhaps no surprise to see it leading the global solar market. Key among its energy policies is the Strategic Energy Technology Plan (SET-Plan), published by the European Commission in November 2007. SET aims to increase, coordinate, and focus EU support on key low-carbon energy technologies, such as wind and solar power.

There are two main deadlines for SET. By 2020, a framework in place to accelerate the development and deployment of cost-effective low carbon technologies, to help meet the 2020 targets to reduce greenhouse gas emissions by 20%, and ensure that 20% of Europe’s energy comes from renewable energy sources.

By 2050, to limit climate change to a global temperature rise of no more than 2°C, to reduce EU greenhouse gas emissions by 80-95%.

Photovoltaic cells

The PV market is already well entrenched in our everyday lives through hand-held devices, and domestic, municipal, and industrial applications. However, PV use is expected to grow significantly over the next few years and in a variety of new applications.

Of symbolic importance, early July 2010 saw the Solar Impulse HB-SIA, a prototype solar powered aircraft, make an extended day and night flight over Switzerland.

The aircraft is powered by 12,000 solar panels built into its 63.4 metre wingspan, which feed its 400kg of batteries (which are lithium-polymer batteries).
Minerals in PV cells

There are two main types of PV technology: crystalline silicon technology and thin film technology. The majority of world PV capacity comprises crystalline silica PV cell modules (78% in 2009) against thin film PV cells (22%).

This ratio is expected to change little over the next few years with thin film PV increasing its share to perhaps 25% by 2014.

Crystalline silicon cells are made from thin slices of a single crystal (monocrystalline), or slices from a block of crystals (polycrystalline or multicrystalline).

Thin film PV cells are produced by deposition of very thin layers of photosensitive materials on to a low cost backing such as glass, stainless steel, or aluminium.

Figure 2. shows the main stages in the production process of a crystalline silicon PV cell and shows the input of industrial minerals: metallurgical grade quartz; fused silica; silicon carbide; filler and glass minerals; and fluoropolymers (for details of their application see IM March 2010, p.83: Solar cell future for minerals; IM May 2010, p.26: The cut and thrust of SiC).

Producers and developers of all these minerals are already focusing on how they can maximise the potential of this market. For example, silicon carbide producers Washington Mills Electro Minerals Corp. and Saint-Gobain SA have already developed special micro grit grades for wire sawing silicon wafers; Vesuvius and Ceradyne Inc. have invested in fused silica crucible manufacturing facilities in China; DuPont, a major consumer of fluorspar, has made considerable investments in PV fluoropolymer technology in the USA.

Figure 5: Production capacity vs. market outlook until 2014

Source: EPIA
PV growth forecast

In 2009, the world PV market increased its installed capacity by 7.2 GW (of which Europe accounted for 5.6 GW), reaching a total capacity of over 22.8 GW worldwide. According to the European Photovoltaic Industry Association (EPIA), this marked the most important annual capacity increase ever, being particularly impressive in light of the recent recession.

In 2000, world PV capacity was about 1.4 GW, which increased cumulatively to 15.6 GW in 2008, with a marked annual increase in growth starting from 2004.

During 2009, Germany remained the largest PV market, with Italy ranking second, followed by Japan and the USA. Germany is expected to remain the largest market in 2010, while new markets in particular from southern Europe, Asia and the USA are anticipated to grow significantly (see Figure 3.). Canada and Australia are now starting to develop in PV.

There is clearly a ramping up of PV applications, as the EPIA forecasts for 2010 that the global PV market could reach between 10.1 GW and 15.5 GW of new installations in 2010 under the moderate scenario (business as usual) and the policy-driven scenario (positive impact of support mechanisms and political will), respectively.

Strong PV growth in Germany and Italy in the first months of 2010 forced the EPIA to revise its forecasts made earlier in 2010. In Germany, the market has benefited from a combination of a proven incentive schemes, good financing opportunities, a large availability of skilled PV companies, and good public awareness of PV technology.

In the policy-driven scenario, the global annual PV market could reach up to 30 GW in 2014 based on favourable conditions established by policy makers, regulators and the energy sector at large (see Figure 4). As can be seen, the key market regions will be the EU, USA, China, and Japan.

Figure 5. shows the two forecast PV market scenarios against projected PV cell announced capacity. Crystalline silicon cell production capacity as well as module
(combined c-Si and Thin Film) production capacity is expected to grow with a CAGR of around 22% over the next five years.

**Figure 7: A typical wind turbine upper assembly showing main mineral applications**

![Wind Turbine Assembly Diagram](image)

_Smc/Fibreglass wind turbine blade -
Fibreglass minerals, e.g. kaolin
borates, alumina, lime, silica,
Soda ash, graphite

_Smc/Fibreglass nacelle -
Fibreglass minerals

_Smc/Fibreglass tower -
Fibreglass minerals

Motor, permanent
magnets using
Nd, Pr, Dy, Th -
rare earths, boron

Source: adapted from Siemens press picture

**Emerging markets**

The ideal combination for a PV growth market is a developing country with a large population located in the so-called “Sunbelt”, i.e. located between 30 degrees North and 30 degrees South of the equator. This is certainly where China and India score.

China was until recently almost absent from the world PV market, but with more than 12 GW of large PV projects in the pipeline, it could rapidly become a major market in Asia and in the world.

According to the national energy plan of 2009, cumulative installed PV power in China is forecast to reach at least 20 GW by 2020, and there is presently a surge in electricity demand. So the potential for PV in China is immense, although how much comes to fruition lies with the government’s decision-making.

Similarly in India, PV potential is described as “huge” by the EPIA. Recent targets defined by the government include 20 GW of PV capacity in 2022. The country started from a low 30 MW installed in 2009, but could grow to 1.5 GW in 2014 in the Policy-Driven scenario and “probably well beyond afterwards”.

**Wind turbines**

Like PV cells, wind power, through wind turbines, is now a mainstream source of energy. However, Figure 6. shows how it has taken until as recently as the mid-2000s for this sector to really take off in wind power capacity installation.
Minerals in wind turbines

Figure 7. illustrates the business end of a typical wind turbine and the main industrial mineral applications.

There are essentially two main areas for industrial mineral applications in wind turbines: manufacture of the primary body and blades, of fibreglass or carbon fibre; and manufacture of components within the motor driving the turbine, mainly in the permanent magnets.

Research conducted by fibreglass manufacturer Owens Corning Composite Materials LLC in 2009, estimated that in 2020, there would be installed capacity of 120,000 MW, which would equate to 1m. tonnes of reinforcement fibre required, at a rate of 7 tonnes reinforcement/MW.

This marks a tremendous market outlet for minerals used in fibreglass manufacture, such as lime, silica, soda ash, borates, fluorspar, and kaolin.

The turbine blades, which may be up to 40-50 metres in diameter, and 80-100 metres in length, are usually composed of a polymer composite material made not only from fibre glass, but also using an epoxy resin, which may contain mineral fillers, such as wollastonite, ground calcium carbonate, and talc.

However, fibreglass has to compete with carbon fibre-reinforced blades. Carbon fibre-reinforced blades have been identified as a cost-effective means for reducing weight and increasing stiffness. The use of carbon fibres in 60 metre turbine blades is estimated to result in a 38% reduction in total blade mass and a 14% decrease in cost as compared to a 100% fibreglass design.

Wind turbine motors utilise new generation permanent magnets, which provide high performance while at the same time being lightweight. Rare earth elements (REE) and boron are the principal industrial minerals used in such high performance permanent magnets.

Primary REE used in magnets include neodymium and samarium, while secondary REE include dysprosium. The workhorse permanent magnet remains the neodymium-iron-boron magnet, although the samarium-cobalt magnet can be used where very high temperatures are expected (see IM June 2010, p.42: Minerals for the digital age).

Capacity increases

In 2009, the world’s wind power sector grew by 41.5% over 2008, and total global wind power capacity increased 38 GW, or by 31.7%, to 158.5 GW. The 2009 market for turbine installations was worth about €45bn.

Asia and Europe remain strong markets for wind power, while the USA maintained its global leadership in installed capacity, increasing the country’s installed capacity by 39% (adding nearly 10 GW) and bringing the total installed grid-connected capacity to 35 GW in 2009.
New wind energy projects completed in 2009 accounted for about 40% of the new power generation capacity added in the USA during the year, and wind power now covers 2% of the country’s total electricity demand.

For the next few years, the GWEC expects the USA to be hampered by lack of financing, and its performance somewhat flat. In contrast, China’s market is forecast to soar and drive the Asian wind power market.

The GWEC predicts that in 2014, global wind capacity will stand at 409 GW, up from 158 GW at the end of 2008. During 2014, 62.5 GW of new capacity will be added to the global total, compared to 38.3 GW in 2009.

Annual growth rates during this period will average 20.9% in terms of total installed capacity, and 10.3% for annual market growth

**Strong growth in Asia**

Incredibly, one third of the 2009 installations were made in China, which added 13.8 GW of capacity, more than doubling its capacity from 12.1 GW in 2008 to nearly 25.8 GW, and making it the world’s top wind power market.

The Chinese wind power sector is well established with turbine and component producers satisfying domestic demand and now looking to supply overseas markets. The leading two Chinese companies, Sinovel and Goldwind, are now among the world’s top five wind turbine manufacturers.

China’s Wind Base programme, aiming to build 127.5 GW of wind capacity in six provinces, is well underway. It is expected that even the unofficial Chinese target of 150 GW will be met well ahead of 2020.

India also continued growing its wind market with 1.3 GW of new installed capacity, bringing its total up to 10.9 GW in 2009. The leading wind power state remains Tamil Nadu with 4.3 GW installed, followed by Maharashtra and Karnataka.

India’s Generation Based Incentive, initiated at the end of 2009, is expected to give renewable energy a substantial push, and the industry forecasts additions of at least 2.2 GW for 2010.

Other Asian countries with new capacity additions in 2009 included Japan (178 MW, taking the total to 2.1 GW), South Korea (112 MW for a total of 348 MW) and Taiwan (78 MW for a total of 436 MW).

**Europe targets 2030**

The European Wind Energy Association (EWEA) expects 10 GW of new wind power capacity to be installed in the EU during 2010, taking total installed capacity by the end of 2010 to almost 85 GW representing an increase of 13%.

Last year saw a record 10.163 GW of new wind power capacity installed, constituting 39% of all new power capacity installed in the EU that year. Total installed wind power capacity by the end of 2009 was 74.767 GW.
Although offshore installations remain in the minority (<10% of world wind turbine capacity; 2.8% of EU capacity), 2010 is expected to see more installations in offshore wind power, with up to 1 GW of new capacity expected to be installed during the year, compared to 577 MW installed in 2009.

As in the PV market, Germany is expected to be the largest market in wind power this year, closely followed by the UK.

In 2020, EWEA’s targets are for 230 GW installed wind capacity in Europe (190 GW onshore and 40 GW offshore) which would produce 14-17% of the EU’s electricity.

By 2030, EWEA is looking to have 400 GW installed wind capacity in Europe (250 GW onshore and 150 GW offshore), producing 26-35% of the EU’s electricity.