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Abstract:

As worldwide demand for energy surges at an ever-increasing rate, there is a new urgency to improve the efficiency and sustainability of power generation technologies. One of the keys to addressing this challenge is innovation, and some of the most promising solutions are occurring at the smallest scale - the nanoscale.

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The 'Power' of Nanotechnology

As worldwide demand for energy surges at an ever-increasing rate, there is a new urgency to improve the efficiency and sustainability of power generation technologies. One of the keys to addressing this challenge is innovation, and some of the most promising solutions are occurring at the smallest scale - the nanoscale.

This phenomenon is increasingly evident in conventional power generation plants, as nanotechnology-based innovation is being credited with improvements in efficiencies and life-spans of existing technologies, as well as the introduction of new and disruptive power-generating components.

Take, for instance, modern fossil-fuel power plants, including coal-fired systems, which require components that are able to withstand higher temperatures and pressures to improve efficiency, lower maintenance costs and decrease emissions levels. Many of the damage mechanisms that affect power plant performance, such as abrasion, corrosion and oxidation - which are responsible for millions of dollars in operating costs for a typical fossil-fuel plant each year - act on the surface of the plant's components.

Coal-fired power systems that are now being built with higher efficiency and lower emissions are incorporating a new generation of ceramic nanocoatings to protect metallic components from corrosion, extending the life, increasing the output and reducing the energy consumption of these systems. The integration of such nanotechnology advances into large-scale power generation has led to significant improvements in the durability and performance of the material infrastructure in these plants.

Components of a power plant that directly benefit from nanotechnology-related innovations include raw water and pretreatment systems, cooling water, service water and fire protection systems, condensers, cooling towers, auxiliary heat exchangers, low-pressure feedwater heaters

and piping, de-aerators, steam turbines, electric generators, air heaters and ducts, flue gas desulfurization systems, and flue gas ducts and stacks.

Nanotech 'fuels' alternate energy technology

Meanwhile, the field of alternative energy provides a platform for some of nanotechnology's most exciting contributions. Today, the renewables industry represents the fastest-growing energy market in the world: global wind generation has grown threefold over the past five years and the production of photovoltaic solar cells is more than six times greater than in 2000 - and nanoscale science and engineering are playing an increasingly critical role.

Silicon-based photovoltaic solar cells, for example, currently account for about 95 percent of commercial solar panels available on the market. Silicon-based cells already utilize nanoscale processes, materials and devices utilized in semiconductor manufacturing. Moreover, discoveries in nanotechnology have led to what many consider the next generation of solar technology: ultra-thin amorphous silicon, organic and inorganic solar cells derived from nanocrystals that convert sunlight into electricity at a fraction of the cost of silicon-based solar cells. They are also more flexible, less brittle, and can even be painted onto structures, allowing more possibilities for building integrated architectural design, and helping to ensure that more of our future electricity generation will be derived from the clean energy of the sun. Greater research investment in these technologies is yielding continually higher sunlight-to-electricity conversion efficiencies, bringing them closer to full-scale commercialization.

Fuel cells also benefit from nanotechnology. While the ability to store adequate quantities of hydrogen molecules has remained a serious dilemma in developing the technology for large-scale use, nanotechnology has the potential to put hydrogen storage in the fuel cell directly using nanostructures of carbon, zeolites, or stacked clays. Nanoengineered electrodes in the form of cathodes and anodes are currently being manufactured and incorporated in solid oxide and polymer electrode-based fuel cells that provide higher efficiency and performance. Nanotechnology applied to fuel cells enables more efficient and reduced use of precious metals - such as using platinum nanoparticles for high surface area and low volume - along with improved membrane function and durability.

Perhaps the most mainstream acceptance of renewable technology has come in the form of wind energy, which is approaching complete cost competitiveness with traditional energy sources. Countries such as Germany, Spain and Denmark are already beginning to utilize substantial amounts of wind energy to meet their growing electricity needs, but there remains enormous potential for worldwide expansion in the wind industry. Nanotechnology helps to realize the wind's enormous potential through various improvements in the efficiency of wind turbines.

New lubricants that contain nanoparticles that act like mini ball-bearings help reduce the friction generated from the rotation of the turbines, decreasing wear-and-tear on the machine throughout its life cycle. Advancements in nanocoatings, such as de-icing and self-cleaning technologies, also help improve efficiencies, rendering ice and dirt buildup on the turbines virtually nonexistent. The most promising contributions of nanotechnology come from the integration of advanced materials technology in wind blades in the form of nanocomposites, which provide

lighter and substantially stronger blades. Nanotechnology impacts the wind industry in general, by improving turbine performance and reliability to allow for longer lifetime, less fatigue failure, and lower costs of generation.

Clearly, the pursuit of cleaner and more efficient ways of generating power is of critical importance to our future. Through innovation, we can improve the efficiencies of the technologies we have and discover new ways by which we can prosper. Nanotechnology provides us with the opportunity to attain sustainable development - and to overcome one of the greatest challenges of our time - by using some of the simplest and smallest means at our disposal.

Dr. Pradeep Haldar is professor of nanoengineering and director of E2TAC, the Energy and Environmental Technology Applications Center (E2TAC) at the University at Albany's College of Nanoscale Science and Engineering (CNSE), which was created to provide a critical platform for CNSE to leverage its intellectual power base and state-of-the-art infrastructure to provide an applications-targeted resource supporting technology development, leading to the integration of nanotechnology in advanced energy and environmental applications. For more information, visit E2TAC's Web site at <http://www.e2tac.org> .

He is also chair of the Clean Energy Alliance, which was originally created by the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) in Golden, CO and is the leading national resource for clean energy businesses, utilizing member technology innovations, resources and networks to develop the clean energy marketplace and foster economic development for its partners.