

Sustainability and Nanotechnology

The Worldwatch Institute recently released its 2013 report on the *State of the World*, titled *Is Sustainability Still Possible?* The last chapter of the book (*Is It Too Late?*) is written by a science fiction writer, Kim Stanley Robinson. Mr. Robinson sets out a cautiously optimistic view in answer to his question. He discusses the idea of just how much damage the world can sustain and how much will we save given the current constraints of path dependencies. These path dependencies occur in all three areas of sustainability—the environment, society, and economy. At this time, we need to re-examine the ideas that led to those paths and become nimble enough to change the future by looking ahead. Here is where a disruptive technology such as nanotechnology can step in to take a long view and set us on a more sustainable pathway.

In 2011, a multidisciplinary group of researchers, students, and government staff came together to look ahead and see how science and engineering can set us on a new pathway that leads to a sustainable future. In a narrow sense, this group practices nanotechnology or studies nanotechnology as it relates to the tripartite aspects of sustainability—the environment, society, and economy. From the discussions of this group at the 2011 Gordon Research Conference on Environmental Nanotechnology, the Sustainable Nanotechnology Organization (SNO) was born.

SNO's mission includes the following:

1. Support the development of sustainable nanotechnology for the improvement of society, the environment, and human health.
2. Promote the advancement and application of scientific research related to nanotechnology, implementation of sustainable nanotechnology for the environment, health, and safety, and the use of nanotechnology in policy and decision making.
3. Provide a forum where scientists, engineers, and other professionals exchange information and ideas for the development and use of nanotechnology leading to overall sustainability.

A small group organized the first conference on Sustainable Nanotechnology in November 2012. The 200 attendees at the meeting became a core membership that will continue the dialogue about sustainable nanotechnology and incorporate sustainability principles into their research goals. Research papers presented at the SNO conference form the bulk of this special issue, dedicated to sustainable nanotechnology.

Three of the papers (Huang and Keller, Rayner et al., and Wang et al.) address applications of nanotechnology to improve the environment. In addition to cleaning up legacy environmental problems, these applications can address broader issues in public health.

Another five papers (Baruwati et al., Dai et al., Quigg et al., and Ma et al.) address the implications of nanotechnology to health and the environment. Understanding possible adverse effects from nanotechnology allows for forward thinking to protect the public and ecosystems from harm before it occurs.

Energy is a critical sustainability issue. The papers of Ramsurn and Gupta and Sun et al. describe two approaches to this important problem.

The largest group of papers (Hebbalalu et al., Nasir Baig and Varma, Kou et al., Cumberland and Lead, Mohammed et al., Dominguez-Medina et al., and Gass et al.) addresses the issue of environmentally benign synthesis of nanomaterials. The opportunity for lowering energy use, removing toxics and critical materials, and making products sustainable occurs at the synthesis stage. These papers describe methods that make nanomaterials in a greener fashion.

Also included is a review of nanostructured sensors to detect heavy metals (Li et al.) and a discussion of governance systems for sustainable nanomaterials (Bergeson). Monitoring and measuring are essential to maintaining a sustainable environment, and nano-enabled sensors are improving our ability in these areas. Building good governance systems is also essential to promote the benefits of nanotechnology to sustainability while protecting against any adverse effects.

The papers in this issue set the stage for ongoing and future work where nanotechnology can be used to promote sustainability and set changes in place so we are not too late. Readers are invited to peruse these articles to get a glimpse of the future directions of sustainable nanotechnology and join the SNO forum (www.susnano.org) to continue the discussion of sustainable nanotechnology.

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