International Cooperation Needed to Lower Proliferation Risks as Nuclear Energy Grows

As more nations pursue nuclear power, the United States and Russia, along with other countries and the International Atomic Energy Agency (IAEA), should redouble efforts to ensure a reliable supply of nuclear fuel so that countries seeking nuclear energy have less incentive to build their own facilities to enrich uranium and reprocess spent nuclear fuel, according to a report by the U.S. National Academy of Sciences and Russian Academy of Sciences. Such facilities pose proliferation risks because they can also be used to produce the key ingredients for nuclear weapons.

Driven by growing energy demands, high prices for fossil fuels, and concern about climate change, more than two dozen nations—Egypt, Vietnam, Belarus, the Gulf States, and Turkey, among others—have announced that they are considering or planning their first nuclear power plants. The fuel for these plants is fabricated from enriched uranium, which can be purchased from outside suppliers—currently, two international consortia, Russia and the United States. However, some countries may fear that relying on others could make them vulnerable to a cutoff of supplies for political reasons. The report draws upon discussions from an international workshop convened by the academies at the IAEA, involving 10 countries that might participate in a system to assure reliable supplies of fuel.

The international community, supported by the United States and Russia, should continue to explore a broad menu of approaches to provide assurances against political disruptions of the nuclear fuel supply, an effort led by the IAEA, the report said.

Over time, Russia, the United States, and other countries should work to create a global system of a small number of international centers to handle sensitive steps of the fuel cycle, such as enrichment and management of spent fuel, possibly including reprocessing, storage, and disposal. Russia has created one such center, the International Uranium Enrichment Center at Angarsk. The centers could either be owned by groups of nations—as with two existing consortia—or overseen by an international organization. Aside from the countries that provide technology for the fuel cycle centers, participating nations should meet two major criteria: They should not have an enrichment facility or be developing one, and they should be in compliance with IAEA safeguards and nonproliferation agreements.

International institutions that manage the nuclear fuel cycle and arrangements that let many countries share in the profits of uranium enrichment provide a more equitable and sustainable long-term basis for limiting enrichment and reprocessing to a small number of countries, the report said. And nations may feel assured of a stable fuel supply if they are part-owners of the fuel centers, or if international mechanisms are in place to provide back-up supplies.

The chief disadvantage of international centers is the potential for sensitive technology or knowledge to leak and contribute to a nation's efforts to build nuclear weapons, the report said. The United States and Russia should work diligently with other countries to create specific, stringent plans to prevent this from happening.

Assuring fuel supplies may have only a modest impact on lessening countries' motives to build enrichment facilities, the report said. It urges the United States and Russia to provide other incentives, such as assistance in establishing the infrastructure for safe and secure use of nuclear energy.

Agreeing to take back spent fuel also could be a very powerful incentive—since nations would not need to build facilities to store their own spent fuel or waste—and would lower the number of countries that store plutonium-bearing material. However, many countries face political barriers to taking other nations' spent fuel or nuclear waste. The United States and Russia should work on cooperative approaches to lease fuel to "newcomer" nations for the lifetime of their reactors, with the spent fuel being sent back to Russia for the present—since it is further along in offering these services to other nations—or to the United States as well if that eventually becomes possible.

Many proposals are in development to reduce proliferation risks from the nuclear fuel cycle, the report said. Some proposals are based on technology—for example, facilities whose uranium or plutonium cannot be used in a nuclear weapon without substantial additional processing. Others are based on re-examining and modifying regulations and requirements concerning nuclear materials, technology, activities, and expertise. Similarly, efforts are under way to reduce the environmental impacts of the fuel cycle while increasing the amount of energy extracted from fuel material. Such options should be developed and assessed systematically, with decisions based on clear objectives and technically sound criteria, the report said. However, while these are being explored, the international community should not delay taking steps that are currently feasible, such as assuring a reliable fuel supply.

In addition, the report recommends that nations stop accumulating plutonium as soon as practicable, and reprocess spent fuel only when it is necessary to make new fuel or for safety reasons. Reprocessing when fuel is not needed in the near-term creates excess stocks of plutonium, which pose security risks.

The United States and Russia have signed an agreement on peaceful nuclear cooperation, but the agreement faces several obstacles in the U.S. Congress, and President Bush has withdrawn it from consideration there. The lack of a working agreement makes some international fuel cycle options impossible and is impeding joint efforts on nonproliferation for nuclear energy technologies. The report said that it is unlikely that the U.S. government will bring the agreement into force in an environment of worsening relations between the United States and Russia, but study co-chairs John Ahearne (Sigma Xi, The Scientific Research Society, Research Triangle Park) and Nikolay Laverov (Russian Academy of Sciences, Moscow) said, "We hope that the current disagreements that have recently emerged will not interfere with our countries working together toward our common goal of inhibiting nuclear weapons proliferation as nuclear energy use grows across the world." The year 2009 will mark the 50th anniversary of the U.S. National Academy of Sciences and the Russian Academy of Sciences' Cooperative Agreement on Science, Engineering, and Health, under the auspices of which this project took place.

The two-year study was sponsored by the John D. and Catherine T. MacArthur Foundation and the Carnegie Corporation of New York, with additional support from the Russian Academy of Sciences and assistance from the IAEA in arranging the international workshop. The U.S. committee was appointed by the National Research Council, the operating arm of the National Academy of Sciences and the National Academy of Engineering. They are private, nonprofit institutions that provide science, technology, and health policy advice under a congressional charter. The Russian committee was appointed by the Russian Academy of Sciences, a self-governing, nonprofit organization chartered by the Russian government to conduct research to understand the natural world and society, and to promote technology and prosperity.

Copies of ***Internationalization of the Nuclear Fuel Cycle: Goals, Strategies,***

and Challenges are available from the National Academies Press; tel. 202-334-3313 or 1-800-624-6242 or on the Internet at www.nap.edu.

Europe Rallies Behind Nanotechnology to Wean World from Fossil Fuels

Nanotechnologies can be used to develop sustainable energy systems while reducing the harmful effects of fossil fuels as they are gradually phased out over the next century. This optimistic scenario is coming closer to reality as new technologies such as biomimetics and dye-sensitized solar cells (DSCs) emerge with great promise for capturing or storing solar energy, and the field of nanocatalysis develops efficient catalysts for energy-saving industrial processes. Europe is ready to accelerate development of these technologies, as delegates heard at a recent conference, Nanotechnology for Sustainable Energy, organized by the European Science Foundation (ESF) in partnership with Fonds zur Förderung der wissenschaftlichen Forschung in Österreich (FWF) and the Leopold-Franzens-Universität Innsbruck (LFUI).

The conference focused on solar rather than other sustainable energy sources such as wind because that is where nanotechnology is most applicable and also because solar energy conversion holds the greatest promise as a long-term replacement of fossil fuels, according to the sponsoring organizations. Solar energy can be harvested directly to generate electricity or to yield fuels such as hydrogen for use in engines. Such fuels can also in turn be used indirectly to generate electricity in conventional power stations.

"The potential of solar power is much, much larger in absolute numbers than that of wind," said Bengt Kasemo from Chalmers University of Technology, the chair of the ESF conference. However, like wind, the potential of solar-power generation varies greatly across time and geography, being confined to the daytime and less suitable for regions in higher latitudes, such as Scandinavia and Siberia. For this reason, there is growing interest in the idea of a global electricity grid according to Kasemo.

"If solar energy is harvested where it is most abundant, and distributed on a global net (easy to say—and a hard but not impossible task to do) it will be enough to replace a large fraction of today's fossil-based electricity generation," said Kasemo. "It also would solve the day/night problem and therefore reduce storage needs because the sun always shines somewhere."

In the immediate future, solid-state technologies based on silicon are likely to predominate the manufacture of solar cells, but DSC and other "runners ups" are likely to lower costs in the long term, using cheaper semiconductor materials to produce robust flexible sheets strong enough to resist buffeting from hail for example. Although less efficient than the very best silicon or thin-film cells using current technology, their better price/performance has led the European Union to predict that DSCs will be a significant contributor to renewable energy production in Europe by 2020.

The DSC was invented by Michael Grätzel, one of the speakers and vice chair of the ESF conference. The key point to emerge from the ESF conference, though, is that there will be growing choice and competition between emerging nanotechnology-based solar conversion technologies. "I think the important fact is that there is strong competition and that installed solar power is growing very rapidly, albeit from a small base," said Kasemo. "This will push prices down and make solar electricity more and more competitive."

According to the conference proceedings, some of the most exciting of these alternatives lie in the field of biomimetics, which involves mimicking processes that have been perfected in biological organisms. Plants and a class of bacteria, cyanobacteria, have evolved photosynthesis, involving the harvesting of light and the splitting of water into electrons and protons to provide a stream of energy that in turn produces the key molecules of life. Photosynthesis can potentially be harnessed either in genetically-engineered organisms, or completely artificial human-made systems that mimic the processes, to produce carbon-free fuels such as hydrogen. Alternatively, photosynthesis could be tweaked to produce fuels such as alcohol or even hydrocarbons that do contain carbon molecules but recycle them from the atmosphere and therefore make no net contribution to carbon dioxide levels above ground.

Biomimetics could also solve the long-standing problem of how to store large amounts of electricity efficiently. This could finally open the floodgates for electrically powered vehicles by enabling them at last to match the performance and range of their petrol or diesel-based counterparts, according to the conference proceedings. One highlight of the ESF conference was a presentation by Angela Belcher, who played a major role in pioneering nanowires made from viruses at the Massachusetts Institute of Technology. There is a type of virus that infects *E. coli* bacteria (a bacteriophage) capable of coating itself in electrically conducting materials such as gold. This can be used to build compact high-capacity batteries, with the added advantage that it can potentially assemble itself, exploiting the natural replicating ability of the virus. The key to the high capacity in small space lies in the microscopic size of the nanowires constructed by the viruses—this means that a greater surface area of charge-carrying capacity can be packed into a given volume.

However, commercial realization of biomimetic and other emerging technologies lies far in the future. In the meantime, as delegates heard from several speakers at the ESF conference, nanotechnology has an important contribution to make, improving the efficiency of existing energy-generating systems during the transition from fossil fuels. For example, Robert Schlögl outlined how nanoscale catalysts can be used to improve the efficiency of engines or systems consuming fossil fuels.

The ESF-FWF conference in Partnership with LFUI on Nanotechnology for Sustainable Energy was held at the Universitätszentrum Obergurgl, near Innsbruck in Austria during June 2008. More information can be accessed at Web site www.esf.org. □