

# Time for a game-changing nuclear technology

David Kramer raises issues vital to world energy policy in his report "As its renaissance recedes, US nuclear industry looks abroad" (PHYSICS TODAY, November 2012, page 24). If the world continues with its current rate of development and population growth, global energy consumption is projected to expand by 350% by 2100. Few credible options are available to meet that need, so we'd better find some sustainable solutions.

The relatively new abundance of shale gas is creating price competition in US energy markets, but the low price of natural gas is not the only factor driving the competition. Natural-gas power plants have achieved remarkable efficiencies of more than 60%, and their low capital cost and relatively short build time make them attractive investments in energy generation. Those characteristics create significant challenges for the nuclear industry.

The principal barriers preventing nuclear power from competing in today's mix of energy technologies are relatively low efficiency and large scale. Current light water reactor technology tops out at about 34% efficiency, and typical advanced LWR plants cost on the order of \$10 billion, which means that few utility companies in the US can afford them. And even small modular LWRs (SMLWRs) are not that small. For one such design, the reactor with its steam generator is more than 25 meters tall, not including the relatively large building for the turbine required to turn steam into electric power. The complexity of such a large structure makes its build time relatively long and its cost potentially high.

Going back to basic principles can provide opportunities to overcome those barriers. Thermodynamic efficiency can be dramatically improved—to more than 50%—by running reactors

at higher temperatures and by better harnessing the reaction energy through a high-heat-capacity medium and state-of-the-art turbine generators. Reactor temperatures around 950 °C, more than three times that of current advanced LWRs, have been demonstrated over sustained periods in Japan. However, higher temperature alone cannot dramatically change the economics of nuclear power. Reducing reactor size while maintaining high thermal output is the key to better economics.

Fortunately, high-efficiency reactor designs are now being pursued. One of these, the Energy Multiplier Module, is being developed by General Atomics. The EM<sup>2</sup> is a compact fast reactor about 12 meters high, with 265 megawatts electric (MWe) output. The immediate challenge for the reactor is proving out the fuel element, which consists of novel ceramic cladding and fuel that enable the reactor to operate at high temperatures and high power densities. The company is also developing and testing a compact high-speed turbine generator that can achieve efficiencies of more than 50%.

The Washington-based TerraPower, backed by Bill Gates, also is pursuing a fast reactor based on sodium as a coolant, with an innovative fuel-handling system and core design that can output 500 MWe. The conceptual design of its traveling wave reactor has been completed with the objective of finishing construction and startup by 2020.

The new designs could also

- ▶ Produce reactor cores that have 30-year lifespans.
- ▶ Burn various forms of nuclear fuel while creating dramatically less waste.
- ▶ Reduce proliferation risk.
- ▶ Provide cost-competitive electricity through new, lower-cost fabrication and construction of nuclear power plants.

The typical arguments against more advanced designs are that they will take too long and that the technical risks of fuel and power conversion are high. But what does "too long" mean? Photoelectric materials were discovered in the 1800s, yet we are still working on them. Windmills go back much further in history. Yet neither of those technologies is currently game changing. There are countless other examples. Moreover, due to market conditions, it is unlikely that many LWRs or SMLWRs will be built in the next 10–20 years. So this would be a great time to come up with truly game-changing approaches.

Risk must be considered in the context of assessing the ultimate reward. If the energy content from known uranium reserves could be efficiently extracted, it would be 60 times that of known world oil reserves, 50 times the known gas reserves, 20 times the known coal reserves, 260 times the energy from using only LWR technology, or the equivalent of about 90 trillion barrels of oil—400 times the oil reserves of Saudi Arabia. Assuming an oil equivalent of \$80 per barrel, the value of known uranium reserves would be \$7.3 quadrillion. That's a pretty attractive reward.

Truly new approaches to nuclear energy have not been developed because the nuclear industry has good reasons to be extremely risk averse, and government policies discourage the innovation and science-based discovery that could advance nuclear power.

It may be time for physicists, the professionals who led the creation of nuclear reactors, to take a hard look at the science of new materials and research on new processes to help continue the development of radically new technologies like those indicated above to provide energy for many centuries. The nuclear industry needs a major paradigm shift toward better economics, improved safety, proliferation reduction, and reduction of nuclear waste. At the very least, we need to inspire our youth to explore the possibilities. Engaging those who only know one approach to nuclear power will not change anything. Basic logic and Albert Einstein's famous quote dictate that you cannot solve a problem with the same reasoning that was used to create it in the first place. However, changing the constraints can change the solution.

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## Identifying Herschel misidentification

We read and appreciated the brief note about the opening of the Herschel archives (PHYSICS TODAY, April 2012, page 30), but noticed that the credit for the illustration was misidentified. We write to correct the identification. From our past study of the Herschel drawings by William, Caroline, and John and from research for our book,<sup>1</sup> we learned that the white-on-black comet drawings such as the panel

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