Testimony before: The Subcommittee on Energy of the Committee on Science, at a hearing on *Renewable energy technologies - research directions, investment opportunities, and challenges to deployment in the developing world"* Wednesday, August 2, 2006, by Arno Penzias

Thank you for allowing me to contribute to this important hearing. I have framed my prepared testimony to respond to the four questions posed in the Charter for this hearing.

1. What is the current state of adoption of renewable energy sources in the United States? What factors are limiting the rate of adoption of renewable energy technologies?

Right now, I think it's fair to say that relatively high cost and current supply constraints associated with currently-available renewable energy technologies are limiting adoption.

2. What is the outlook for potential improvement in market penetration of renewable energy technologies? What are the main research efforts that could improve that outlook?

Based upon what is currently happening in this technology area, I see the outlook for dramatic improvements in market penetration as being very positive. As an active venture investor and advisor for the past ten years, I can recall few investment areas which have engendered a degree of investment interest comparable to what we now see in the renewable energy arena. Speaking personally, I very much share this point of view, so much so, that I now devote the major portion of my efforts to investments in this area.

I have been concerned about energy issues for some thirty years, and have worked to seek and perfect alternatives to our country's dependence upon fossil fuels, but felt frustrated by the lack of viable alternative approaches to this vexing problem. It wasn't a question of resources or interest. Even given the best intentions, talent and resources, program after program yielded little in the way of concrete results. In the last few years, however, this situation has taken a dramatic turn for the better, thanks to a growing array of novel ways is which advances in a wide variety of seemingly-unrelated technology areas - as well as in several areas of applied science - are being employed to overcome my earlier concerns about conventional approaches to green energy.

Silicon solar cells, for example, work well but cost too much to produce and install. Despite some incremental progress in silicon device costs, I see other photovoltaic technologies poised to grow far more rapidly—notably large-area PV modules based upon thin crystalline films and organic materials, as well as novel approaches to even higher efficiencies through a combination of emerging advances in sunlight concentration, with small but extremely efficient multi-junction devices.

I can illustrate this last point in detail, by citing three key elements of a solar concentrator recently completed by SolFocus - our firm's most recent energy investment. These innovations should give you the flavor of what went into their design. First: the use of an innovative imaging geometry called *non-imaging optics* (created and perfected by Professor Roland Winston of the University of California, Merced) allows each module to capture more solar energy per square inch of area than the most perfect conventional magnifier one can buy. Second: the precision optics necessary to implement this minor miracle can be formed and assembled out of a total of only eight parts per module, including the detector, at a manufacturing cost comparable to that achieved by the makers of today's sealed automotive headlights (the enabling technology in this instance). Third: The concentrated light is converted into electricity with unsurpassed efficiency by a unique triple-junction solar cell invented at the National Renewable Energy Laboratory (far more expensive per unit area than other types of solar cells, a tiny device serves a surface area some five hundred times larger).

3. What should the Federal Government be doing (or not doing) to encourage the commercialization of, and demand for, new renewable energy technologies? How well aligned are the Department of Energy's activities with what the investment community is doing?

First and most important, in my judgment, the Federal Government can encourage the commercialization of new renewable technologies through continued support for our country's universities, the source of America's innovation edge, a tradition of support that traces back to the land grant colleges of the 19th century and the GI Bill that fueled our country's emergence as the world's unquestioned leader in science and technology. There is hardly a place on the face of this Earth that doesn't hope to have its own "Silicon Valley," rooted in the presence of a great university. With the demise of vertical integration as the economic base for corporately supported long-term applied research, the task of fueling continued innovation has fallen upon our university system.

The wide variety of mandates, subsidies and other incentives for the creation and use of alternative energy, enacted at the Federal and state level, serve to spur demand for new technologies of various kinds, thereby spurring innovation, investment, market testing and further innovation, in virtuous circles. The great virtue of what some might see as needless duplication encourages exactly the kind of exploration and opportunistic advances that has made our country's venture capital system the unmatched model for progress in the global economy. One-size-fits-all buzzwords, such as "hydrogen economy" can help focus attention, as long as they don't constrain behavior.

The vast and diverse needs of Federal agencies and suppliers frequently offer ideal early test beds for new solutions to under-solved problems. Given the necessarily complex nature of Federal procurement regulations, I'm pleased that Federally-funded sales of innovative products have often proven to be an early means of showcasing new alternative-energy ideas and products.

At Bell Labs, I encouraged active partnerships between efforts in my research organization with those business-oriented organizations, by making sure that both sides had skin in each game. In the same way, I now see successful examples of alignment between DOE Labs and the investment community, in the increasing use of CRADA's, particularly at NREL.

4. What opportunities and challenges exist for the sale and use of renewable energy generation in developing countries? How do these opportunities and challenges differ from those in developed countries?

Opportunities include inter-company partnering, particularly in the case of local manufacture, distribution and support, for energy technology developed in the U.S.. These opportunities should grow dramatically as unit costs drop to more attractive levels. Challenges include difficulty in applying common business practices and the protection of intellectual property.

Given the lower levels of infrastructure in the developing world, the centralized manufacture and distribution models favored in our country may not apply as universally. On the other hand, labor intensive installation costs ought to prove less of a barrier to adoption in developing economies.

In biofuels, for example, short term opportunities in the U.S. would include using existing feed stocks - such as corn for ethanol, and waste grease and edible seed oils for biodiesel, possibly followed later by cellulosic ethanol. In the developing world, we are more likely to see special plants (especially *Jatropha*) in arid areas such as northern India, and sugar cane in areas of abundant rainfall. These crops appear especially useful in the developing world, where transportation favors local processing on small scales, with the work of harvesting done by local farmers as an additional source of income.