But since the Hodel outburst, even industry estimates have dipped, bringing them into rough agreement with the Interior estimates. The bottom line? Counting an additional 306 trillion cubic feet of reserves, the United States would thus have a 35-year gas supply. Alternatives to conventional gas include gas trapped in the seams of coal deposits and in impermeable rock.

A number of factors contributed to these less optimistic estimates, according to Mast and his colleagues. Much of the change came from the oil and gas industry itself. Spurred by high prices, it launched a frenzied drilling effort in the early 1980s that would test the optimism of the 1981 estimates. In almost all areas, that confidence was misplaced. In the frontiers of oil and gas exploration of Alaska, the offshore Atlantic, and the thrust belts of the West, disappointing drilling results forced downward reassessments of the resources left to be discovered. In better known areas, the continued decline in the size of newly discovered fields confirmed that regions that have been producing new discoveries for decades are drying up as fast as feared.

The modest amount of oil and gas that was discovered between the two reports not only reduced the general optimism, it inevitably shrank the new estimates. The transfers of the new oil and gas from the undiscovered category to reserves accounted for 15% to 20% of the decreases.

There were also less precisely determined contributions to the drops in undiscovered resources. One was the shifting economics of oil and gas extraction. The lower the price for the product, as set by worldwide market forces, the less likely that small, hard to drill, out of the way deposits in the United States will be drawn on. When the 1981 estimates were being prepared, the world price of oil was rapidly approaching $30 per barrel. It is now about $18 per barrel and not expected to soar as high as thought earlier. That would mean that the United States would "run out of oil" with oil left in the ground that, under other economic conditions, would be in the undiscovered category. In addition to economics, more detailed and objective techniques for sizing up as yet unseen deposits, always a tricky business, left less room for the ingrained optimism of oil explorationists.

"There isn't an unlimited amount of oil," notes Mast, "particularly at today's prices." Those prices might not rise that fast before 1993, when the next Department of Interior estimates are due. The burst of exploratory drilling that reined in earlier optimism has faded away under low prices. That can only hinder the next evaluation of undiscovered oil and gas. ■ RICHARD A. KERR

Japan: Superconductor Hopes Drop

Japanese researchers and industry leaders are less optimistic now than they were a year ago about how quickly high-temperature superconductors can be moved into the marketplace, according to an article in the Japanese journal *Nikkei High Tech Report*.

Published by the Nikkei Research Institute of Industry and Markets, the article estimates that it will be at least 10 years before the first simple devices made with high-temperature superconductors are available commercially, and more like 20 years for the ambitious applications, such as superconducting supercomputers, magnetically levitated trains, electric generators, motors, magnetic resonance imaging units, and power transmission cables.

"I think in the beginning [the Japanese attitude] was unreasonably optimistic," says Mildred Dresselhaus, a Massachusetts Institute of Technology physicist who concurs with the conclusions of the report. Dresselhaus recently chaired a panel organized by the Japanese Technology Evaluation Center to compare the Japanese superconductivity effort with the one in the United States (see *Science*, 11 August, p. 594). Especially among Japanese businessmen, she says, "people got very excited," but "there is less euphoria now because the easy things have been done."

Part of the reason for the early enthusiasm in Japan, Dresselhaus suggests, was that Japanese researchers were at the forefront of the basic research into high-temperature superconductivity. "Japan was more of a focus than usual in a scientific discovery, which led to a great deal of national pride and excitement," she explains.

The MIT physicist says that, judging from her own trips to Japan, the experience of the past year has made the Japanese more aware of the problems involved with commercializing high-temperature superconductivity and brought them down to earth. Still, she adds, they remain more optimistic than people in the United States, partly because the long-term outlook of the Japanese makes their business and government leaders more cheerful about the possibility of a lengthy development period. "Ten years is nothing to them," she says.

The article in *Nikkei High Tech Report* recounts a number of the well-known difficulties facing the development of high-temperature superconductors. "The most pressing and expensive problem will be how to form superconducting wires," it says. "Wires hundreds of meters long will have to be manufactured, without losing the superconducting properties" in order to make magnets and motors. And superconducting magnets and motors will need other parallel developments, including new refrigeration systems and analytical methods for early detection of deterioration or failures.

"Thin films pose even more complications," the report says. Thin films will be needed for such applications as magnetic shielding, superconducting electronics and interconnections, and superconducting quantum interference devices, or SQUIDs. "Any bumps or indentations in the surface must be no larger than 0.1 nanometer. The smoothest surfaces possible at present still have irregularities 100 times the target uniformity, so some kind of breakthrough will be required."

Refrigeration of superconducting devices down to liquid nitrogen temperatures or colder will also pose various technical problems, depending on the particular application under consideration. "Magnetic shielding calls for techniques capable of cooling large surface areas, while power transmission cables have to be cooled over long distances—up to tens of kilometers," the report says. "No clear solution is on the horizon as yet."

The article goes on to list several other practices that must be mastered before high-temperature superconductors can be used in applications, including processing tiny superconductor electronic circuits, putting silicon and superconductors on the same chip, and improving the reliability and durability of superconductors. "Still, even with so many difficulties remaining to be addressed," the article says, "many researchers remain optimistic—particularly in Japan. Overall, they see the matter mainly as a question of setting priorities on R&D to find practical solutions to the problems, one by one."

One question that remains to be answered is whether the optimistic attitude of the Japanese or the more cautious attitude of the Americans will prove to be the better one in the long-term competition for the coming high-temperature superconductor market. ■ ROBERT POOL