Superconductivity
A Briefing Paper for The Economic Policy Council
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Recently, major scientific breakthroughs have occurred in the field of superconductors, affecting the basic science underlying electric power and electronic technology. These breakthroughs could eventually have more impact than development of the transistor. This could provide a tremendous opportunity for furthering the President's goal of assuring American competitive preeminence into the 21st Century.

Superconductivity is the ability of a substance to transmit electricity with no resistance, which means no loss of power in the transmission process.

- Until recently, superconductivity was observed in certain metals only at ultra cold temperatures approaching absolute zero (-459°F). The cost of the refrigeration needed to reach such temperatures, involving the use of liquid helium, is uneconomical for most applications.

- Ceramics have been discovered recently which exhibit superconductivity at much higher temperatures--temperatures which can be achieved at 5% of the cost required previously for conventional superconductors, at which semiconductors used in computer chips can operate, and which are naturally available in space.

- If superconductivity becomes practical, economic applications could include:

  -- "superchips" and super fast computers with both commercial and defense applications (including the Strategic Defense Initiative);

  -- less costly power generation and transmission;

  -- improved prospects for electric vehicles; and,

  -- greatly improved medical imaging machines.

Potential Benefits

The pace of recent discoveries has been breathtaking, but it may be years before the full potential of these discoveries is realized. Then, however, the economic benefits will be enormous.

As an example, superconductivity could produce large savings in the energy area:

- Present electricity needs could be met using less fuel, saving several billion dollars per year.

  -- Electricity could be transmitted over vast distances without power loss through superconducting wires.

  -- Power plants could become more efficient by using generators made with superconducting magnets.

  -- Power could be stored cheaply for peak load periods.

If we allow for changes in the pattern of energy production and use, the benefits could be even greater. The country's energy needs could be met through greater reliance on electricity generated from cheaper, cleaner, safer and more secure energy sources and production methods than at present.

- Greater use of coal.

  -- Power plants could be located where the coal is mined, rather than shipping the coal at great expense to power plants near end users. Western coal would become more economical.

  -- Use of low sulfur western coal could reduce the cost of controlling acid rain and other forms of pollution, as would locating power plants farther from urban areas.

- Greater use of nuclear power.

  -- The ability to locate plants farther from urban areas might also improve prospects for nuclear power from a safety standpoint.

  -- Super-magnets might be possible to create "magnetic bottles" able to contain nuclear fusion reactions, producing virtually unlimited electric power without the safety and hazardous waste problems of fission plants.

- Less dependence on foreign oil.

  -- Coal and nuclear power are domestic energy resources that could reduce our dependence on oil imports from insecure foreign sources in the production of electric power.

  -- Efficient electric powered cars could partially replace vehicles that require gasoline; electric heating could reduce the demand for heating oil.

  -- These developments could be especially important as domestic production of oil declines in the years ahead.

Few Drawbacks

There may be concern over the prospect of economic dislocation in certain industries -- e.g., reduced demand for gasoline or for cars powered by internal combustion engines -- which could injure firms which are heavily invested in these industries. However, this will probably not be a significant problem in practice, for several reasons.

- First, there will be no sudden shocks to industry. Major commercial applications will come gradually.
  - -- The new superconducting materials are brittle ceramics. It will take time to find a way to produce the new materials in the forms needed -- wire, rods, tubes, films and ribbons -- for practical applications.
  - -- A critical problem is that the amount of electrical current that can be pushed through the new superconductors is too small for practical uses. Scientists at IBM recently made major progress in solving this current-density problem, boosting the amount of current 100-fold as compared with the other new superconducting materials. Another 10- to 100-fold increase would be needed for some applications.
- Second, in most cases, the new technologies and products will be developed and produced by companies currently in the field. E.g., companies now producing gasoline-powered cars will have significant expertise and capital advantages in the production of electric-powered cars.
- Third, many firms will experience a smooth transition, gradually introducing the new technology in the normal course of replacing old plant and equipment.
- Fourth, oil and gas will always be in demand.
  - -- They will remain essential feedstocks for petrochemicals.
  - -- It is unlikely that electric vehicles will dominate the market for long distance transportation.
  - -- Most importantly, U.S. oil production is falling as old fields become depleted. Fuel-saving and fuel-switching technologies based on superconduction will coincide roughly with the natural decline in U.S. oil output, with no disadvantage to the petroleum industry.
  - -- In fact, energy firms may diversify, and shift exploration funds to help finance the new technologies.

Reasons for Excitement

- Ordinary superconductors have been researched for years. Many applications have already been thought out. This is in contrast to the transistor; when it was first discovered, no one knew what to do with it.

  -- One obvious use is to combine the new superconductors with the semiconductors in computer chips for faster, more powerful computers. Ordinary superconductors operate at temperatures far too cold for semiconductors to function.

- Some applications are just short of the point where they would be economical. This breakthrough may bring some applications on stream quickly.

  -- Superconducting cables must be buried, but much of the cost is in the digging. Where cables are going to be underground anyway, ordinary superconduction is close to being practical now.

  -- Japan has an experimental magnetic cushion train with a test track already built using expensive ordinary superconductors. It is close to being economical.

In brief, superconductivity is likely to be of major benefit to the nation, regarding the balance of payments, energy security, and national defense. Negative impacts should be minor. This landmark scientific advance should be viewed as expanding our economic horizons, pushing back limits on our standard of living and creating greater opportunities for growth and employment.

Federal Involvement

- Members of the scientific community and others are urging the Federal Government to boost research and development in the superconductivity area, to coordinate with private sector researchers, and to facilitate the transfer and commercialization of Government-funded discoveries.

- There is fear that other countries, such as Japan, will move faster than we to organize their research into a program with strong commercial goals, one of Japan's great strengths.

- At the same time, it must be recognized that centralized direction of research can stifle creativity and miss promising opportunities.

  -- One of this country's great strengths is the diversity of its research community, and the presence of many firms with large research budgets and visions of various commercial applications.

-- Over-bureaucratization of the research effort and quarrels over turf would be counterproductive.

° Patent and intellectual property right issues appear manageable.

-- While patents for composition of materials may be filed, there are many different ceramics with high temperature superconducting properties; therefore, the key patents will probably be based on future solutions to the current-density and pliability problems.

-- There appear to be no institutional or procedural problems with the patent process, but more personnel with specific training in superconductivity might shorten the time required.

-- Cross-licensing should permit the rapid spread of the technology regardless of who holds the patents.

-- Some applications have been patented, based on ordinary superconducting materials. Some of these may be close to expiration, throwing the field open to all comers.

Federal research on superconductivity provides a timely opportunity for demonstrating the effectiveness of Executive Order 12591. President Reagan issued the order on April 10 as part of his competitiveness initiative. The Order directs Federal agencies:

-- to encourage their scientists to facilitate the commercialization of their research;

-- to speed technology transfers and commercial spin-offs from Federal R&D; and,

-- to speed dissemination of information on foreign research and technology developments to the private sector.

The following summarizes Federal efforts in superconductivity.

<u>Department of Energy</u>

° The Department of Energy (DOE) has had the largest Federal program in superconductivity, including: a) research into the properties of materials and the phenomenon of superconductivity through programs at DOE laboratories and universities; b) application of superconductivity in fusion, accelerator physics, and electricity transmission, generation and storage; and c) working with industry in the manufacture of superconducting materials and the design of devices.

- -- DOE labs have redirected $10 million of existing funds to produce and test new superconducting materials.
- -- DOE also spends another $15 million on research and development associated with more conventional superconductors. This research is directed at metallic superconducting alloys and at developing techniques for fabricating these alloys into practical conductors.
- -- The Department is publishing a newsletter to publicize the results of DOE-supported research.

Department of Defense

- DOD has recently doubled its research effort to around $10 million. Efforts involve DOD labs, universities, and non-DOD Federal Research Centers, and participation in symposiums with other agencies, industry and universities.
- DOD research objectives are to achieve higher transition temperatures, greater current carrying capacity and improved flexibility of material.

National Science Foundation

- The NSF recently allotted an additional $1 million for research on superconducting materials at three of the Materials Research Laboratories it supports.
- The NSF has begun a program of rapid turnaround grants for researchers with promising ideas for processing brittle superconducting materials into useful forms. This program will provide $600,000 primarily for research in engineering.
- These programs bring NSF's total research effort on superconducting materials to more than $6.5 million in FY 1987.
- NSF has commissioned the National Academy of Sciences to review progress in superconductivity research and recommend actions. The report is due by mid-summer.

NASA

- NASA, along with NSF and DOE, helped fund the major breakthrough by University of Houston/University of Alabama scientists in February 1987. NASA plans include: redirecting research at several NASA Centers; collaborating with private firms; and increasing university and industrial involvement in exploring potential space applications.

Commerce

- National Bureau of Standards scientists are working on two major scientific problems related to superconductivity:

  1) how to make superconductive materials in pliable form;

  2) solving the current-density problem.

Other Countries

- Present superconducting technology is available throughout the industrial world (U.S., Japan, Western Europe, U.S.S.R., China); all are working on new superconductors.

- The high temperature superconductivity discovery in Houston meshes well with technology Japan has worked on for years.

  -- Japan has developed an experimental train using conventional superconductors; it travels at more than 250 mph while hovering five inches above a track on a magnetic cushion created by superconducting coils.

  -- Japan's shipbuilders have spent $23 million to develop a fast ship propelled by superconducting magnets.

  -- NEC and others have produced prototypes of superconducting computer chips.

  -- Japan supplies the U.S. with superconducting wire.

  -- MITI hopes for a model superconducting power plant by 1992.

- It is reported that eleven days after the February announcement in Houston of the high temperature superconducting breakthrough, Japan's Science and Technology Agency had in place a research consortium of companies, universities and government labs.

- The Soviet Union has worked on superconducting for years, seeking to create low loss transmission lines.

Additional Federal Initiatives

Commercialization of emerging superconducting technology depends not only on significant additional scientific developments, but also on the speed at which processes are subsequently developed by the U.S. private sector to mass produce products using the technology.

- Bipartisan legislation, H.R. 2069, introduced April 9, would establish a four-month national commission on commercialization of superconductivity technology. The Congressional Office of Technology Assessment is planning a study as well.

- The White House Office of Science and Technology Policy and DOE are planning a government-industry conference this summer on the commercial application of superconductors. In addition the Federal Coordinating Council for Science, Engineering and Technology (FCCSET) will coordinate interagency technical activities involving superconducting materials and their applications. FCCSET is chaired by the President's Science Advisor; members include the heads of eleven Federal Departments and agencies responsible for science and research and development: USDA, DOC, DOD, DOE, HHS, DOI, State, DOT, EPA, NASA and NSF.

Areas for further study by the Working Group on R&D include:

- Development of a plan to use this issue to demonstrate and publicize the Executive Order;
- A national initiative to highlight U.S. progress in superconductivity and encourage U.S. commercialization and collaboration efforts;
- Clarification of intellectual property rights protection both in the U.S. and abroad for superconducting discoveries, and development of options for reform, if necessary. Potential initiatives:
  - -- Priority by the Patent and Trademark Office for handling applications and disputes involving superconductivity;
  - -- Increase efforts to enact H.R. 1155, the Administration's legislation to remove disincentives for patent licensing, such as "blocking" or closely related patents;
  - -- Explore ways to strengthen the National Cooperative Research Act of 1984 that modified the antitrust treatment of joint R&D ventures. Potential reforms could provide additional protection covering certain advanced development and manufacturing activities.