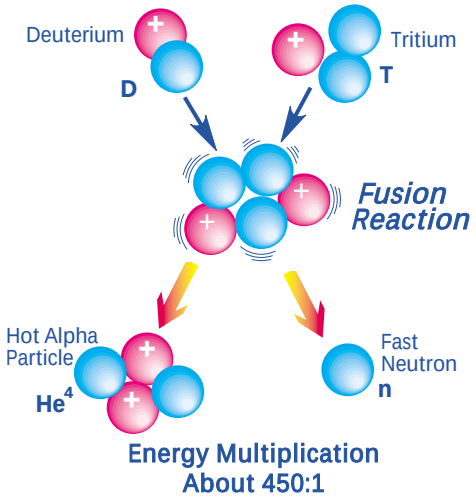
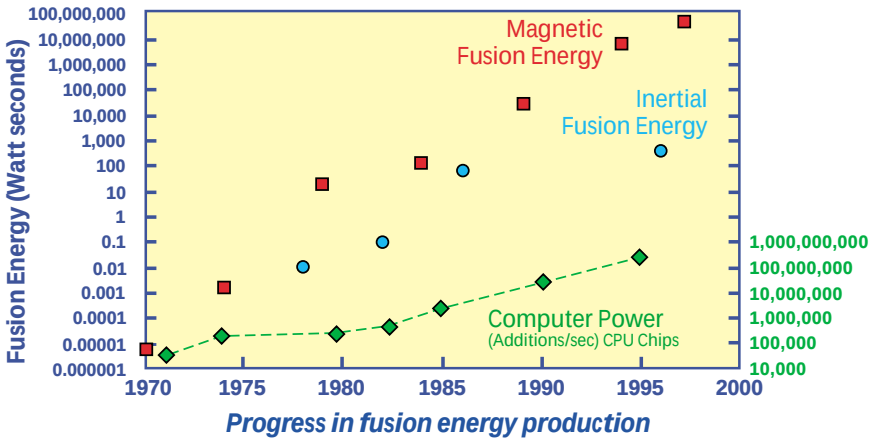
FUSION ENERGY SCIENCES PROGRAM

One of the missions of the U.S. Department of Energy's Office of Science is to make America a world leader in providing the scientific basis for new, clean and abundant energy sources. Fusion energy and other alternative energy sources are vital for a strong and secure nation in the future. The Office of Science's Fusion Energy Sciences Program leads the nation's effort in the study of plasma, the fourth state of matter, which constitutes most of the visible universe, and is at the core of a fusion power system.



Fusion is the power source of the sun and other stars. It occurs when forms of the lightest atom, hydrogen, combine to make helium in a very hot (100 million degree centigrade) ionized gas, or plasma. A small amount of matter involved in the reaction is converted to a large amount of energy. When developed, fusion will provide a virtually inexhaustible, safe, environmentally benign, and affordable energy source. Its fundamental fuel, from seawater, is readily available to all nations.

The fusion energy produced in an individual magnetic confinement fusion experiment has risen by a factor of more than one trillion during the time period when computer speed has risen by a factor of one-hundred thousand (see graph). Along with this progress in fusion energy has come much deeper understanding of the underlying plasma science. The dramatic advances in the scientific understanding of fusion plasmas led the National Academy of Sciences, National Research Council to state in October 2000 in a draft report, ... *"the quality of the science funded by the U.S. fusion research program in pursuit of a practical power source (the fusion energy goal) is easily on a par with other areas of contemporary physical science."* In addition, the Secretary of Energy's Advisory Board (SEAB) stated in its August 9, 1999 report: *"The scientific progress on fusion has been remarkable. As a result, it is the Task Force's view that the threshold scientific question — namely, whether a fusion system capable of producing sufficient net energy gain to be attractive as a commercial power source can be sustained and controlled — can and will be solved... In light of fusion's potential and the risks arising from increasing worldwide energy demand and from eventually declining fossil energy supply, it is our view that we should pursue fusion energy aggressively."*



Progress in fusion energy production

The major challenge today is to make fusion energy practical by further advancing our scientific understanding of high-temperature plasmas. This science-based ap-

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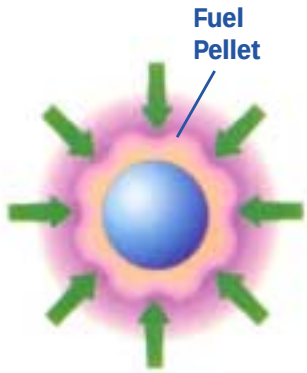

Inertial fusion energy concept

proach offers the most expeditious path to the fusion energy objective and is advancing our knowledge of plasma physics and associated technologies, yielding near-term benefits in a broad range of disciplines. Examples include plasma processing of semiconductor chips for computers and other electronic devices, advanced video displays, innovative materials coatings, the efficient destruction of chemical and radioactive wastes, and more efficient space propulsion.

There are two distinct approaches to producing fusion energy. In magnetic fusion energy (MFE), the plasma is confined by a magnetic field and held at the required density and temperature. To achieve inertial fusion energy (IFE), powerful lasers or particle beams are focused on a small pellet of fuel for a few billionths of a second. To date, MFE has been the primary subject of research worldwide for fusion energy applications. Consequently, the U.S. fusion program is highly leveraged against more than $1 billion in magnetic fusion research performed by other nations. Magnetic fusion research is an international effort in which experimental results are openly shared and in which collaboration on experiments is extensive.

IFE research has been pursued primarily as a key component of the Department of Energy's Stockpile Stewardship Program. Leveraging off this large investment is an excellent opportunity, for IFE may also present a promising path to practical fusion power. The MFE and IFE scientific communities are working together closely and have created a research plan with key assessment points in 5, 10, and 15 years. If adequately funded and implemented, the plan will deliver essential progress in key scientific and technological areas, positioning the fusion program to make critical choices about the next phase of the U.S. fusion research program.

The MFE/IFE research plan was developed by the Fusion Energy Sciences Advisory Committee (FESAC). As detailed in the FESAC report, increased effort is needed in a balanced set of areas. These include:

- Strengthening basic plasma science and computational programs;
- Placing greater emphasis on innovative experiments to broaden the science base and make fusion more practical;
- Increasing upgrades and operation time on the oversubscribed major experiments;
- Expanding research on how inertial fusion leads to practical energy;
- Revitalizing the fusion technology program.

Magnetic fusion energy concept

Additionally, the National Academy of Sciences/National Research Council Report recommended:

- Make scientific understanding of fusion plasmas a central program goal;
- Strengthening connections with other scientific disciplines; and
- Partnering more strongly with the National Science Foundation, in both basic plasma science and high temperature plasma physics.

The full implementation of the FESAC and NAS/NRC recommendations will result in a robust and productive fusion energy sciences program.