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Energy R&D in Japan

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ASTRACT: In 1997, the public and private sectors in Japan invested $90.3 billion in R&D. Japan is the second largest supporter of R&D after the United States. A very large percentage (79.4%) of all R&D in Japan is supported by the private sector. The prolonged economic recession that has plagued the Japanese economy for most of the 1990s has significantly reduced the scale of the Japanese R&D effort compared to what it would have been had the economy been more robust. The Japanese government has recently attempted to bring the economy out of this recession through the use of economic stimulus packages. These stimulus packages have contained significant new funding for R&D, although it is apparent that much of the funding is going to R&D programs and R&D construction projects with very near tem payoff and not to the support of longer term R&D.

In 1998, the Japanese government devoted 13.7% of all public R&D funds to the support of energy R&D. The priority accorded to energy R&D in Japan is significantly higher than in any other industrialized nation. The Japanese energy R&D program, which was funded at $2.5 billion in 1997, is overwhelmingly focused on nuclear energy R&D. Nuclear energy R&D (fission and fusion) accounts for 75% of the total national energy R&D budget. The fission energy R&D effort has decreased nearly 24% since 1996 as the government attempts to refocus this program in the face of growing public opposition to the Japanese government's efforts to expand the nuclear power program. Energy efficiency R&D (8% of the total national energy R&D budget) and renewable energy R&D (3%) receive relatively modest support from the Japanese government.

KEY WORDS: Energy R&D, Japan, climate change

Japan

Population: 125,732,794 (July 1997 est.)[1]
GDP 1996: $2.853 trillion (499.8 trillion ¥)[2]

National R&D Effort 1997:

- $90.3 billion (15,741.5 billion ¥)[3]
  - 20.4% supported by the public sector
  - 79.4% supported by the private sector
- R&D as a percent of GDP: 3.12%[4]
- Total Public[1] R&D: $18 billion (3,160 billion ¥)[5]

National Energy R&D[2] Effort 1997:[6]

- $6.8 billion (1,186 billion ¥)
  - 64% supported by the public sector
  - 36% supported by the private sector

Chapter Overview:

Analytical Findings
National S&T Effort
National Energy Policy and Energy Overview
Energy R&D Programs

[1] This figure includes "national and local governments" investments in R&D; i.e., this includes some funding from prefectural governments' support for R&D, and therefore it will differ from other accounts of "public support for R&D" contained in this report.

[2] This figure actually represents the total amount spent on "energy-related R&D" in Japan. This is a broader measure than simple energy R&D. This broader measure includes R&D related to environmental protection that is not taken up elsewhere in this report. As such, the figure above likely significantly overstates the true magnitude of Japanese energy R&D investments. This broader measure in particular overstates the government's investments in energy R&D, inflating the true measure of the narrower "energy R&D" by perhaps as much as $2 billion per year.

Summary of Analytical Findings

Japanese national (public and private sector combined) investments in research and development (R&D) were $90.3 billion in 1997. The prolonged economic recession that has plagued the Japanese economy for most of the 1990s has significantly reduced the scale of the Japanese R&D effort compared to what it would have been had the economy been more robust. The recession has seriously disrupted the private sector's ability to fund a robust program of R&D activities. Private sector R&D spending was flat or in real decline throughout most of the 1990s. Because the Japanese private sector accounts for over 75% of national investments in R&D, the decrease in private sector support for R&D was responsible for the first-ever post World War II decline in the national (public + private sectors) R&D spending. The Japanese government has reacted to the impact the prolonged recession is having on private sector R&D spending by declaring its intent to "double" (from 1992 levels) public investments in science and technology (S&T) by the year 2000. The government will likely be able to fulfill this pledge one or two years after the year 2000 target date. It is important to note the increased role played by Japan's public sector in supporting the overall national R&D effort, which appears to be an anomaly among large, industrialized countries.

The Japanese government has declared that it will refocus its R&D portfolio to increase the portion of R&D funds allocated by merit review and to decrease the portion that is allocated via block grants to universities and laboratories. This is being done to further the stated policy of the government to increase Japan's ability to produce world-class basic research. The government is moving away from its previous policies of trying to adopt and improve upon foreign technologies and basic science insights. These policies had served the country well since World War II, but the Japanese government now believes that its future prosperity and wellbeing lies in a robust, domestic, basic science capability.

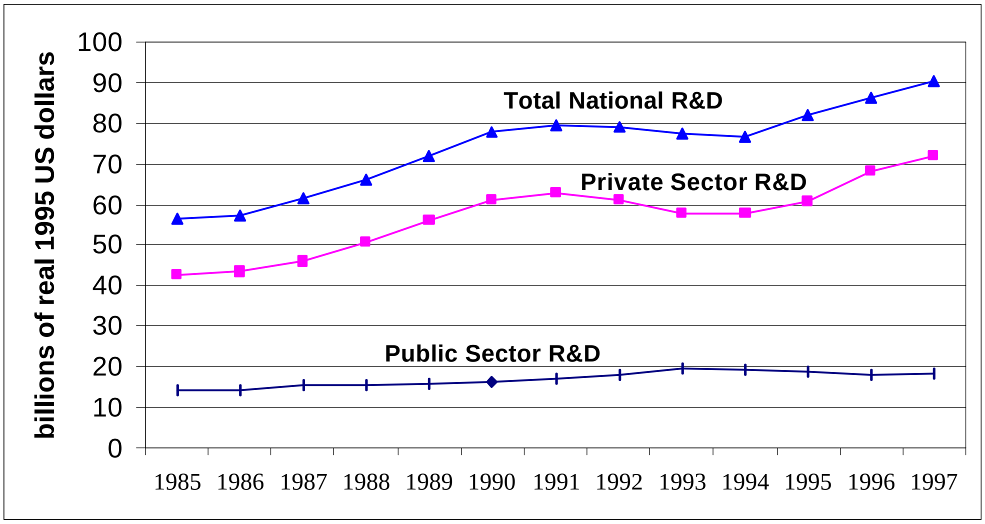
Japanese energy policy continues to focus on energy security as its top priority. Yet industrial competitiveness concerns are motivating the push for energy sector deregulation in Japan. It is also apparent that the government is struggling to find ways to reduce carbon dioxide emissions in line with its commitments under the Kyoto Protocol. The government has noted that Japan might be required to make some "painful energy choices" in the coming years to meet these emission reduction goals.

As recently as 1989, the Japanese government was devoting over 20% of all public R&D funds to energy R&D. In 1998, the government devoted only 13.7% of its R&D investments to energy R&D. Even with this decline, Japan's emphasis on energy R&D is significantly greater than that of any other industrialized nation and is a reflection of the fact that Japan remains very dependent upon imports to meet its energy needs. The Japanese energy R&D program, which was funded at $2.5 billion in 1997, is overwhelmingly focused on nuclear energy R&D. Nuclear energy R&D (fission and fusion) accounts for 75% of the total national energy R&D budget. The fission energy R&D effort has decreased nearly 24% since 1996 as the government attempts to refocus this program in the face of growing public opposition to the Japanese government's efforts to expand the nuclear power program. Energy efficiency R&D (8% of the total national energy R&D budget) and renewable energy R&D (3%) receive relatively modest support from the Japanese government.

JAPANESE NATIONAL SCIENCE AND TECHNOLOGY EFFORT

As Figure 1 shows, the Japanese government funds a rather modest share of the national R&D effort, less than 25% of the national total in any given year over the last decade. In 1997, the Japanese government spent $18.3 billion on R&D while the private sector spent $71.9 billion on R&D for a national total R&D effort of $90.3 billion.[7]

Figure 1: Japanese National S&T Effort 1985-1997[8]



The real decline in Japanese national (public and private sector) investments in R&D in the early part of the 1990s was the first-ever real decrease in the support for R&D in Japan, and in particular this represented the first real reductions in the private sector's support for R&D.[9] Clearly, the economic stagnation in Japan for most of the 1990s has impacted the private sector's ability to support R&D. In the late 1980's, the private sector's investments in R&D were growing at an annual rate close to 10% a year. Between 1991 and 1995, the private sector R&D effort was in real decline. Japanese private sector R&D has been growing since 1995.

Virtually all (98%) R&D carried out by Japanese industry is financed by the companies themselves. That is, unlike the situation in the United States, very little public R&D funding flows from the national government directly to Japanese industry for activities like cost-shared R&D projects.[10] In JFY1997, over 75% of Japanese private sector investments in R&D are accounted for by the R&D efforts of the chemicals, pharmaceuticals, electric machinery, and transport equipment (i.e., automobile) industries.[11]

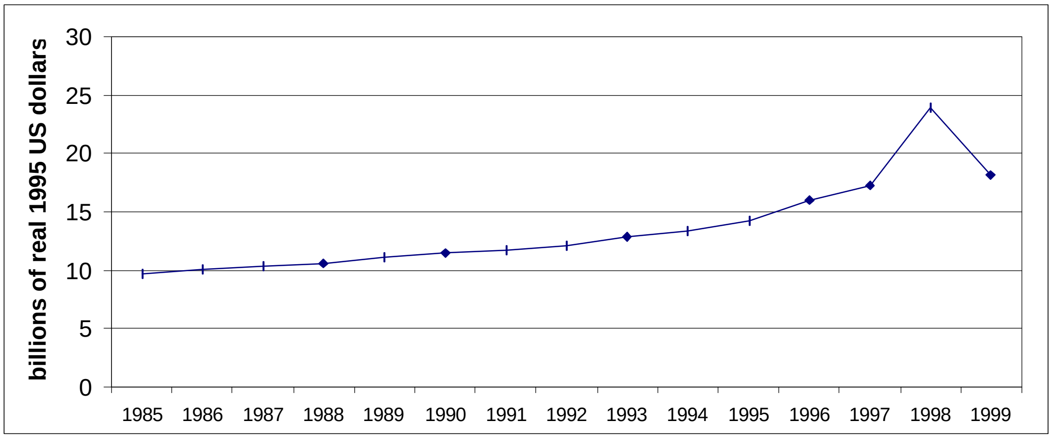
Japan's long slide into recession for most of the 1990s led to the first year-on-year (in JFY1993 and JFY1994) declines in total R&D spending since the end of World War II.[12] Some analysts have attributed the government's highly publicized decision in 1996 to double public investments in R&D to the shock resulting from this realization. That is, there was a feeling that investments in R&D were too important to the nation's future prosperity to leave these investments so exposed to the vagaries of the business cycle.[13]

The government's current emphasis on trying to develop a stronger basic science system is at least in part a recognition that industrial support for basic science is being reduced substantially and that the timeframes for private sector R&D are contracting.[14] Recent surveys of businesses indicate that private sector investments in basic research are indeed in decline.[15] Once again the government realized that perhaps the public sector should increase its investments in these long-term (presumably high-risk and hopefully high-payoff) R&D programs rather than letting national investments in basic research be so directly tied to fluctuations in the business cycle.[16]

Trends within Public Sector Support for Science and Technology

In 1996, the Japanese government publicly committed itself to doubling "R&D investments by the government as soon as possible" from its 1992 level. This plan stated that it would be desirable to accomplish this doubling by the year 2000, which would require the Japanese government to invest a cumulative total of $96 billion (17 trillion ¥) in R&D over the period 1995-2000.

Figure 2: Japanese Public Sector Support for S&T: 1985-1999[17, 3]



The initial proposed JFY1998 budget called for only a 0.9% increase in funding for R&D, which made it appear quite unlikely that Japan would be able to accomplish its much publicized goal of doubling R&D development spending by the year 2000 over the level in 1992. However, because of the increasingly worrisome financial situation in Japan, the Japanese government released in mid May 1998 a comprehensive economic stimulus package that contained $3.53 billion (618.8 ¥ billion) increase in spending for S&T.[18] On December 4, 1998, the government announced another stimulus package that contained a further $2.95 billion (511.1 Billion ¥) for S&T. Taken together these S&T stimulus packages along with the regular budget allocation represent an increase of 38.7% over the previous year.[19]

Perhaps unsurprisingly, much of the money in the science portion of these stimulus packages was earmarked for projects that will have direct and rather immediate economic benefit. For example, projects included $2.9 billion for new dormitories for foreign scientists and students, construction

[3] The figures in this chart for JFY1998 fully reflect the two additional S&T stimulus appropriations that were announced by the Japanese government during 1998. As of the spring 1999, there had yet to be any stimulus packages announced by the government for JFY1999. It is important to note what an anomaly 1998 was.

of a new high-speed internet backbone to connect universities and national laboratories, construction of new laboratory space, development of a more powerful rocket booster for Japan's space program, and the start of the construction of a new $350 million ocean drilling ship.[20, 21, 22] In addition to these infrastructure projects, the extra funds in these stimulus appropriations favor research programs that appear to have significant commercial application (e.g., nanotechnology, information science, and molecular biology).[23] The additional research funds appear to have relatively little money for existing "small science" research programs. Moreover, due to budget decisions made before the stimulus was announced, funding for certain government research institutes and large scientific facilities (e.g., high energy physics facilities) will actually experience cuts of 10% or more in their operating budgets this year.[24] The increasing use of these financial stimulus packages certainly helps to increase overall Japanese investments in S&T, but it has also raised concern that these stimulus packages' preference for funding projects with immediate economic payoff is starting to shift Japan's S&T program away from the government's stated goal of increased support for basic science.[25]

Table 1: Selected Japanese Ministries' Funding of S&T
(millions of 1995 dollars)[26]

Ministry or Agency	**JFY1997**	**JFY1998** **(including supplemental appropriations)**
Ministry of Education, Science, and Culture (Monbusho)[4]	$7,390	$9,660
Science and Technology Agency	$4,210	$5,840
Ministry of International Trade and Industry	$2,710	$4,290
Defense Agency	$1,010	$830
Ministry of Agriculture, Forestry & Fisheries	$580	$740
Ministry of Health and Welfare	$520	$590
Ministry of Post and Telecommunications	$330	$1,360
Total All Ministries	$17,220	$24,000

In addition to calling for a doubling of the public sector's support for R&D, the 1996 "Science and Technology Basic Plan" (which lays out Japan's current national science policy and goals) called for a fundamental overhaul of the Japanese S&T system. The hoped-for result of these changes would be to create a national science system that fostered a more "creative research atmosphere." It is hoped that this new research atmosphere would be capable of producing a science system in Japan that produced world class basic science and world class scientists. Moreover, in its final report issued in December 1997, the Administrative Reform Council specifically advocated that government programs that have funded applied research programs that benefited a specific industry be scaled back or terminated. The report instead advocates funding for basic research and technology programs that are "one or two stages away" from commercial product development.[27] This new framework for Japan's national S&T goals stands in rather sharp contrast to the S&T goals pursued since the end of World War II, which centered on targeted industrial research (in the vernacular, "picking winners and losers") and adopting technologies from abroad to help Japanese industry "catch-up" with the West.[28, 29] Some of the major S&T reforms underway include:[30, 31]

[4] The Japanese parliament approved a plan to merge Monbusho and STA in 2001. The combined mega-science agency would control more than 50% of Japan's public sector research funds. (Normile, Dennis. "Japan: Imura Gets Job on Top-level Council. "*Science.* 280: 5371. June 19, 1998. pp 1828-1829.)

- Establishing new peer-reviewed research programs along with concerted efforts to decrease the portion of research funding given to national universities in block/formula grants by increasing the total amount of research support that is awarded competitively.[32]
- Removing regulations and administrative procedures that hinder the private sector's ability to work with university-based researchers.[33]
- Addressing long-standing human resource issues that are hindering Japan's ability to increase the number of scientists (as opposed to engineers) -- and in particular the number of scientists with advanced degrees -- working in Japan by initiating programs to increase the number of post-doctoral researchers working, increase the mobility of scientists and engineers, and increase the number of students entering S&E studies at universities.
- Attracting significant numbers of foreign scientists to come live and work in Japan until Japan can grow an indigenous cadre of basic scientists.
- Improving and modernizing research facilities and equipment at national universities and government research laboratories.

Figure 3: Major Socioeconomic Areas of Japanese Governmental S&T Support: JFY1994[34]

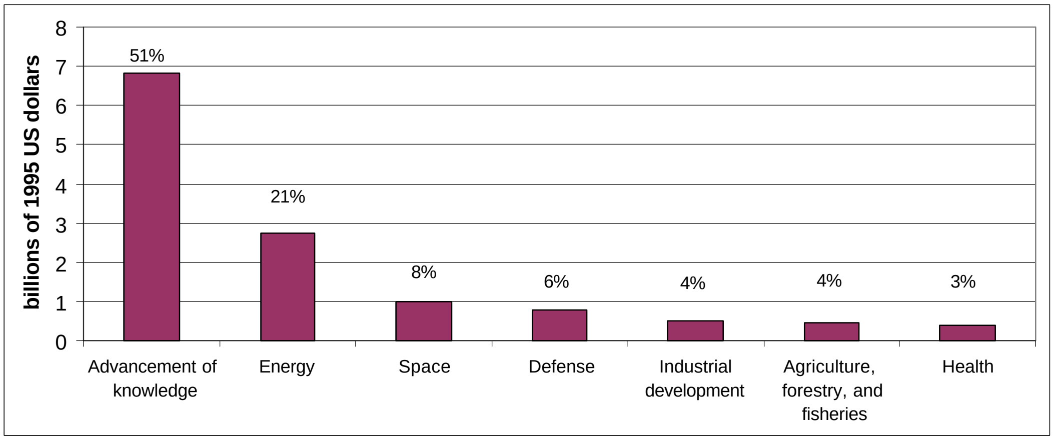


Figure 3 shows, the majority of Japan's support for research is for the "Advancement of Knowledge." These funds are essentially block grants for university-based research and for capital expenditures associated with university-based research. In other OECD nations, this "Advancement of Knowledge" category would be known as "General University Funds." The United States has no comparable system of spending significant amounts for the support of university-based research via block/formula grants. In the United States, nearly all university-based research is supported through competitive peer reviewed grants, which allow funding agencies to know what type of research is being supported (e.g., health research) and therefore make it unnecessary for the United States to use an "Advancement of Knowledge"-type blanket category.[5] It is also important to understand that this "Advancement of Knowledge" category

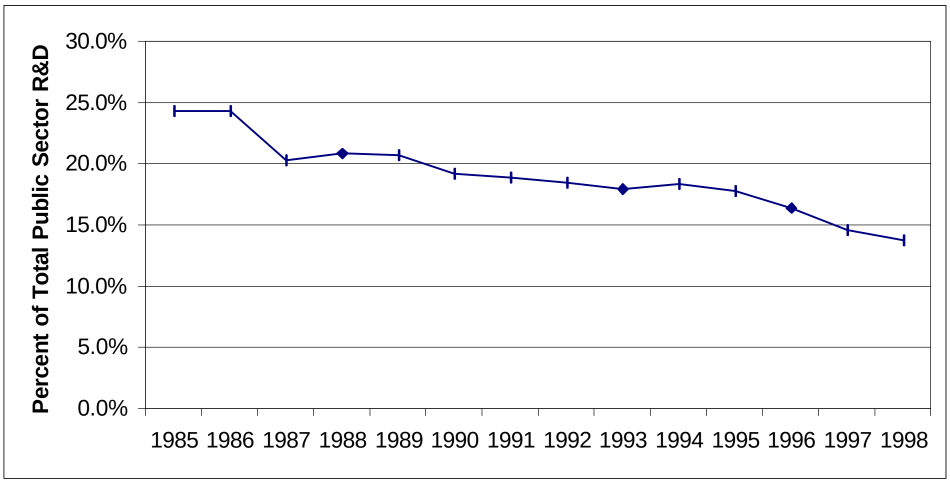
[5] It is very difficult to know with any degree of accuracy how this "Advancement of Knowledge" funding is used to support various fields of inquiry; however, it appears that health research, engineering, and social science fields of research *each* account for approximately a quarter of Japanese university-based research. See ("The Science and Technology Resources of Japan: A Comparison with the United States." Johnson, JM (Principal Author). National Science Foundation. NSF 97-324. 1997.)

does not equate to "basic research." This category covers many things other than "basic research" and indeed, as noted above, Japan believes that it continues to underinvest in basic research. For example, a recent study found that relative to the size of its economy Japan invests in basic research at a level that is only 80% that of the US level.[35]

As is apparent from Figure 3, Japan devotes relatively little public S&T support to defense R&D. In fact, when compared to the US priorities, the different priority accorded to defense spending is rather stark; in 1994, defense R&D accounted for 20% of US national (public and private sector) R&D while in Japan defense spending accounted for 1% of the national R&D effort.[36]

Although the priority accorded to energy R&D in Japan is significant, Figure 4 shows that the priority accorded to this type of research has been in decline for more than a decade. Even with these reductions, Japan still spends considerably more as percent of its public sector R&D effort on energy R&D (13.7% in JFY 1998) than any other country.

Figure 4: Japanese Public Sector Energy R&D as a Percent of Total Publicly Supported R&D



NATIONAL ENERGY POLICY AND ENERGY OVERVIEW
According to the Japanese government, the "underlying goal of Japan's energy policy is to attain the 3Es, energy security, economic growth and environmental protection simultaneously." Japan's most recent comprehensive national energy policy goes on to say,

> Japan stands at a major crossroads in terms of energy. The hurdles we must surmount are by no means low, and, unless we change our lifestyles and the socio-economic system, we will not be able to overcome them. Japan may be required to make some painful energy choices in the future.[37]

An assessment of the underlying policy measures that bolster these intertwined "3E"energy goals is therefore warranted. Figure 5 and Table 2 provide a quantitative overview of the Japanese energy situation in 1996.

Figure 5: Total Primary Energy Use by Fuel Type 1996[38]

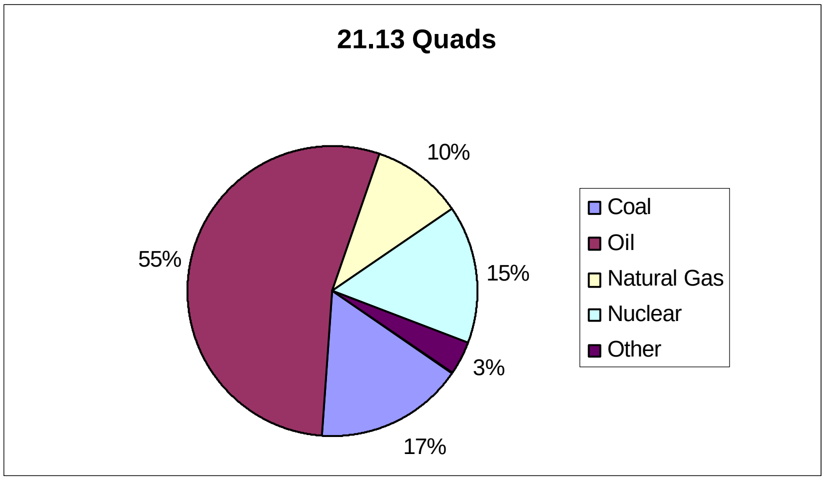


Table 2: 1996 Energy Snapshot[39]

Dependence on Energy Imports: 81%	Energy Related Carbon Emissions: 290.7 million metric tons (4.8% of world carbon emissions)
Energy Consumption per Capita: 169.9 million Btu	Carbon Emissions per $1000 of GDP: 0.09 metric tons
Energy Consumption per $1000 of GDP: 6800 Btu	Carbon Emissions per Capita: 2.3 metric tons
"Kyoto Commitment": 6% reduction below the 1990 level in GHG emissions by 2008-2012	

Energy Security: Since Japan is dependent upon imports for more than 80% of its primary energy supply and 99.7% of its petroleum, energy security is the preeminent energy policy goal for Japan. Measures taken to enhance Japan's energy security will include:

- Diversifying sources of petroleum away from heavy reliance on Middle East oil (in 1995 78.6% of Japan's crude oil came from the Middle East)
- Expanding the use of nuclear power and other "oil alternative" energy supply sources (i.e., coal, natural gas, renewables) to reduce oil imports. As a result of the policy goal of shifting Japan's energy mix away from imported oil, Japan's nuclear power output nearly doubled between 1985 and 1996, and the portion of Japan's total energy supply accounted for by oil has fallen from over 80% after the first "oil crisis" to 55% today.[40] Several accidents at nuclear facilities in Japan since late 1995 have sparked considerable public debate and in certain locales successful grassroots campaigns have been able to block the siting of new nuclear facilities.[41] Given that the government's energy security and climate change policies are so heavily dependent upon continued expansion of Japan's nuclear energy system, the government has restated its commitment to expanding nuclear power and has initiated a program to help the public better understand the role nuclear power must play in Japan's future.[42, 43] The government has also started to offer "grants" (subsidies) to local communities that are willing to host nuclear facilities (e.g., the new nuclear power plants and the numerous "interim" spent fuel storage facilities need because storage pools at many reactors will be full in the next 2-4 years.)[44]
- Implementing strict new energy efficiency measures for the industrial, buildings and transportation sectors (see Environmental Protection section below).

Economic Growth: Japan has some of the highest energy costs of any industrialized nation, i.e., it has the highest electricity prices and the second highest gasoline prices in the OECD.[45] These high energy costs were easier to bear during previous periods of high economic growth. With concern mounting over the current economic malaise, the Japanese government seems intent on deregulating major aspects of its energy economy as a way to increase economic efficiency, lower energy prices, stimulate economic growth, and improve the competitiveness of energy-intensive export industries.[46] Over the past three years, Japan has taken steps to deregulate all aspects of its energy sector:

- Deregulation of the Petroleum Sector – Japan has enacted a series of laws and administrative measures within the past few years designed to spur competition and lower prices in the petroleum and gasoline markets. In March of 1996, the Japanese government repealed laws that virtually prohibited the importation of refined petroleum products. The Japanese government also relaxed restrictions on the establishment of new gasoline retail businesses and has even approved the introduction of the first-ever Japanese "self serve" gasoline stations. These actions are designed to spur competition in the retailing of gasoline.[47]
- Deregulation of the Natural Gas Sector – In March 1995, the revised Gas Utility Industry Law went into effect. This law is designed to spur competition in the natural gas sector. The principal change has been to allow natural gas distribution companies to supply large industrial customers outside of their service areas. The government has also relaxed other restrictions, enabling industrial firms to purchase natural gas from firms other than designated natural gas distributors.[48]
- Deregulation of the Electric Utility Sector – Japan has the highest electricity costs of any OECD nation.[49] The Government of Japan and in particular the Ministry of Industry and International Trade has decided that the only way to reduce electricity prices in Japan is to deregulate the industry and expose the nation's 11 regional integrated utility monopolies to more competition. To implement this decision, the Japanese government amended the Electricity Utilities Law in April 1995. These amendments created the stimulus for the wholesale wheeling market that is now starting in Japan, removed some restrictions on the entrance of Independent Power Producers into the generation market and laid the foundation for the eventual emergence of a competitive retail market in Japan.[50] The Japanese

government believes that a more competitive electricity market has the potential to reduce Japanese electricity rates by 20%, thereby bringing these rates more in line with the average for the OECD.[51] A government-chartered advisory body, the Electric Utility Council, has suggested that the market for large customers should be partially liberalized by the end of 2000. The government's efforts to liberalize the utility sector are somewhat at odds with its concerns over energy security and carbon dioxide emissions reductions, both of which have the building of new nuclear power plants as a significant factor. This contradiction between these policy goals is believed to be playing a significant role in the government's inability to forcefully communicate its position and timetable for utility restructuring and deregulation.[52]

Environmental Protection: Japan's principal environmental concern deriving from energy use is climate change and carbon dioxide (CO_2) emissions. As the recent host of Conference of the Parties (COP) III climate negotiations, the Japanese government believes that it must undertake serious measures designed to reduce the country's emissions of carbon dioxide. Specific measures include:

- At the Kyoto climate change conference in December 1997, Japan committed itself to a 6% reduction of greenhouse gas emissions from 1990 levels by a five-year period from 2008 to 2012. The Japanese government believes that fuel switching from coal to natural gas, increased nuclear power generation and higher end use energy efficiencies will be the key to meeting these emission reduction goals between now and 2012.[53] For example, the government believes that it will need to increase electric power generation from nuclear plants by more than 50% over 1997 levels by 2010.[54] The government is also counting on aforestation, Joint Implementation and emission trading measures to play a significant part in helping Japan meet its Kyoto Protocol obligations.[55] In the mid-term (2010-2030), the government believes that the wide scale deployment of fuel cell powered automobiles and the more effective use of waste heat (see *Waste Heat Recovery* below) will be important technologies for greenhouse gas reductions. In the longer term (post 2030), the government believes that space-based solar power systems, biomass energy, and CO_2 sequestration and utilization will be key technologies for combating climate change.[56]
- In September 1998, the Japanese electric power industry released a report which claimed higher energy consumption in Japan over the course of the next decade will make "it impossible for the government to achieve its [CO_2 emission reduction] goals." According to the Central Research Institute of the Electric Power Institute (CRIEPI), an electric utility funded research institute, Japan's CO_2 emissions will be 14% over 1990 levels by 2010 and not the 6% under 1990 levels required by the Kyoto Protocol. CRIEPI says that international emissions trading system will be needed for Japan to make progress towards its Kyoto Protocol obligations.[57] The electric power industry also believes that increasing use of nuclear power and further introduction of solar and wind power energy sources will be needed to reduce emissions. The industry believes that CO_2 capture and sequestration technologies will be keys to reducing Japan's greenhouse gas emissions over the long term.[58]
- A set of detailed and specific measures designed to reduce Japan's growth in energy usage to a real rate of 0% by the year 2000 was adopted at the April 1, 1997, Ministerial Council for Comprehensive Energy Measures. These measures spell out specific actions to be taken in the industrial, residential and commercial, and transport sectors to increase energy efficiency.
  - Industrial Sector Energy Efficiency Measures include the introduction of "quantitative targets" to reduce energy consumption at all Japanese factories. The target calls for an average annual reduction in energy intensity of more than 1%. At present, these targets are to be met through voluntary actions. Firms that are unable to meet these more stringent energy conservation standards can conceivably face punishments, including fines and having the government publicly label them as being in non-compliance (i.e.,

black-listing the firm). The government will offer “energy audits” for these factories to help them identify energy saving opportunities.[59] In 1997, the government performed energy audits in 239 factories, 79 smaller sized firms and 99 office buildings. There are some 70,000 government-certified energy auditors in Japan.[60]

- Residential and Commercial Sector. The government is advancing a broad energy codes and standards program for buildings and appliances to increase energy efficiency requirements. This program will, among other things, establish new home insulation standards, introduce “energy conservation labels” for homes and buildings, establish stricter energy conservation standards for refrigerators and other appliances, encourage the adoption of high efficiency heating and cooling equipment by subsidizing the purchase of these units.[61] The “Top Runner” methodology (see below) will also be used to establish appliance energy efficiency standards. The government is also actively discussing the introduction of daylight saving time in Japan.[62]
- Transportation Sector. Specific measures include establishing a new methodology, the so-called “Top Runner” program, to compute fuel efficiency standards for automobiles. The methodology will require all cars in the future to be at least as fuel efficient as today’s most fuel-efficient car. The government intends to tighten the standard every few years to ensure continued gains in efficiency. If implemented, the current Top Runner standard will mandate significant improvements in automobile efficiency (on average a 22.8% improvement by 2010 over 1995 levels).[63] The government will also establish and implement various traffic demand management measures in urban areas (e.g., car pools, congestion pricing for tolls).[64]

• On September 8, 1998, the Diet (the Japanese Parliament) passed a law that required the national government, prefectural governments and local governments to draw up “action plans” for reducing greenhouse gases in line with Japan’s Kyoto Protocol obligations. A significant aspect of these plans will be improvements in the efficiency of government-owned buildings and the purchase of low emission vehicles for government-owned fleets.[65, 66]

JAPANESE ENERGY R&D PROGRAMS

There is relatively little data on Japanese private sector energy R&D investments. The Central Research Institute of Electric Power Industry (CRIEPI), an R&D performing consortia comprised of Japanese electric utilities similar to the Electric Power Research Institute in the United States, reports that its energy R&D programs have declined 4.5% in real terms from 1994-1998. Currently, CRIEPI invests $123 million (21.3 billion ¥) in its various energy R&D programs.[67]

An annual survey of Japanese industrial firms R&D expenditures carried out by the government reports that Japanese firms spent $2.47 billion on "energy-related R&D" in 1997. Undoubtedly, this measure of "energy-related R&D" is much broader than energy R&D, which is the focus of this report. According to this same survey, industrial firms devote approximately 4.0% of total R&D resources towards "energy-related R&D." According to this survey, industry has devoted exactly 4.0% of total R&D expenditures to "energy-related R&D" for each of the last seven years.[68]

Energy R&D Program Overview

In 1997, Japanese government support for energy R&D stood at $2.51 billion (437 billion ¥). Three ministries provide the vast majority of funding for the Japanese government's energy R&D effort. The ministries and the areas of energy R&D they are responsible for are:

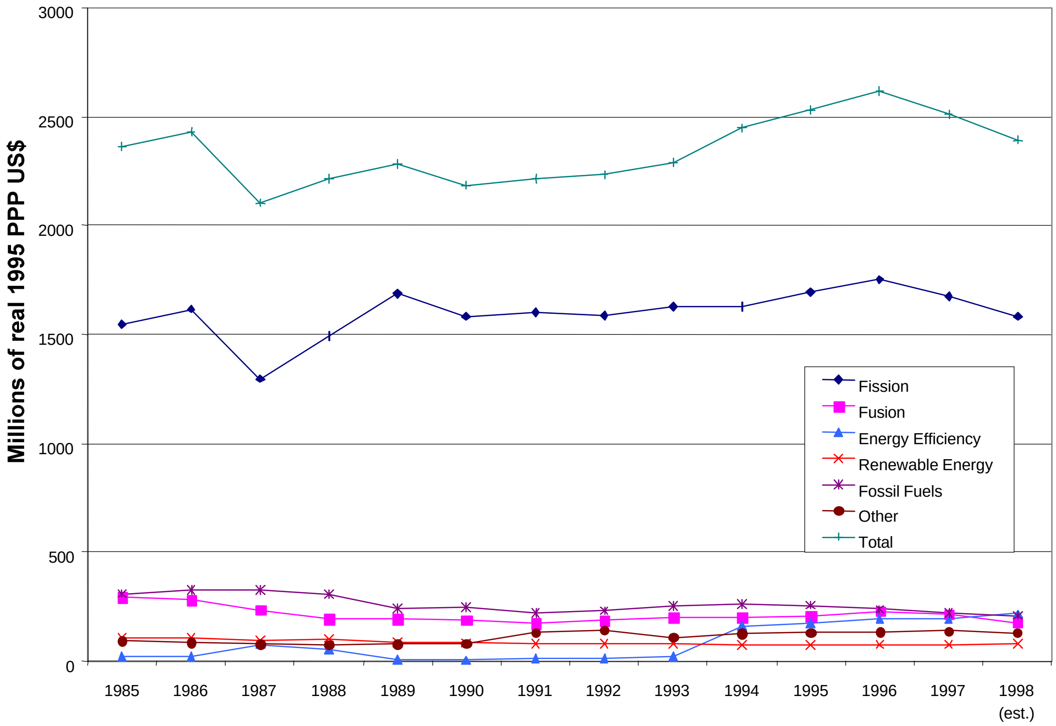
- Science and Technology Agency (STA) -- nuclear power development (principally through the Japan Atomic Energy Research Institute), basic research on climate change
- The Ministry of Education, Science, Sports, and Culture (a.k.a., "Monbusho") --university-based energy research and related university-based basic science activities
- Ministry of International Trade and Industry (MITI) -- renewable energy research, energy efficiency, and technologies relating to climate change.

The Environment Agency; the Ministry of Foreign Affairs; the Ministry of Health and Welfare; the Ministry of Agriculture, Forestry and Fisheries; the Ministry of Transport; and the Ministry of Construction all have very small "energy-related R&D programs" which cumulatively accounted for less than 2.4% of the Japanese government's JFY1998 energy R&D program.[69]

As Figure 6 shows, Japanese public sector investments in energy R&D peaked in 1996 at $2.621 billion dollars. From 1990 to 1996, Japanese public energy R&D increased more than 20% in real terms; since 1996 energy R&D budgets have fallen by approximately 9%.

Figure 7 clearly shows how heavily skewed the Japanese energy R&D portfolio is towards the support of nuclear technologies. In 1997, fission energy R&D accounted for 66% of all Japanese energy R&D. When fusion R&D is added to this, the percent of the public energy R&D budget accounted for by all nuclear energy R&D was 75%. The total fission energy R&D effort has decreased nearly 24% from 1996 to 1998 as the government attempts to refocus this program in the face of growing public opposition to the government's efforts to expand the nuclear power program. Early indications also point to a reduced funding for nuclear energy R&D for JFY1999.[70] The vast majority of the fission R&D program (perhaps as much as 80% of the budget) is directed at nuclear fuel cycle, decontamination, decommissioning and geologic disposition research and not on new reactor concepts. Even with this decrease the Japanese fission program is still in excess of $1.5 billion dollars, a figure which is larger than the combined total energy R&D programs of the European Union, Germany and the Netherlands.

Figure 6: Government Energy R&D by Major Technology Area (1985-1998)[6, 71]

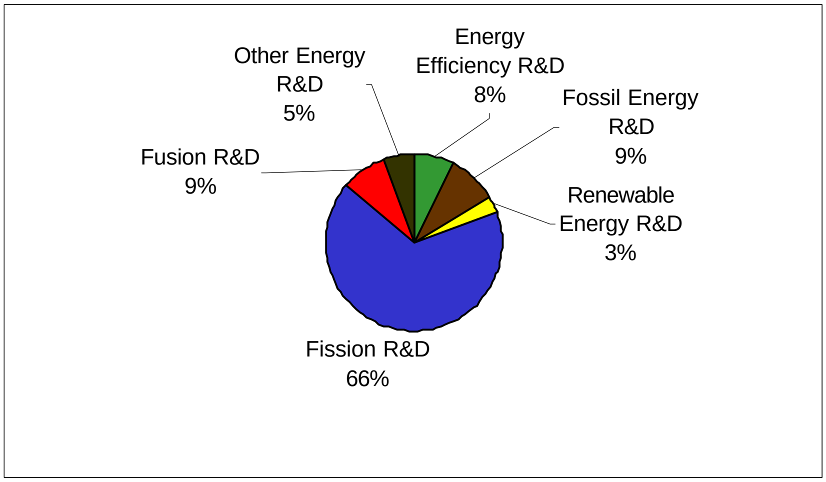


Two other technology areas thought by many nations to be the keys to a cleaner energy future -- energy efficiency R&D and renewable energy R&D -- receive relatively modest support from the Japanese government. Energy efficiency budgets received significant increases[7] in the 1990s but still account for less than 8% of the 1997 total energy R&D budget. Renewable energy budgets account for approximately 3% of the total government energy R&D effort and have decreased about 4% in real terms since the start of the 1990s. Ocean energy systems, a type of renewable energy R&D, however have seen their R&D budgets increase ten-fold since 1990.

[6] It is important to note the large decrease in Japanese funding for fission energy R&D that *appears* to have occurred in the late 1980s. Best available data suggests that part of this decline is real and part of the apparent decline is perhaps an error in the reporting of the underlying data. The Japanese government in an attempt to deal with a budget crisis, slashed overall support for S&T (presumably including funds for energy R&D) by 13.5% and 17.9% in 1986 and 1987 respectively. Compounding this is the fact that during JFY1987 and JFY1988 the Japanese government adopted a new set of accounting rules for calculating the allocation of energy R&D funds. The figure for Japanese fission energy R&D for 1988 reported here is an interpolation (simple arithmetic mean) of the amounts reported for 1987 and 1989.

[7] In 1993, the Japanese government reclassified some existing energy R&D programs as "energy efficiency R&D." This reclassification caused the reported total for energy efficiency R&D to jump more than eight-fold in one year. Given the instability in these numbers, no attempt will be made to do trend analysis for Japanese energy R&D going back to the early 1990s.

Figure 7: JFY1997 Energy R&D Budget



Fossil energy R&D programs account for 9% of the total energy R&D budget of the Japanese government. These fossil programs have shrunk about 15% in real terms since 1990 and are undergoing a profound refocusing as discussed below.

The remainder of this country report will detail Japanese government energy R&D projects and programs and provide budget levels for these programs as of JFY1997, which is the most recent year for complete data.

Nuclear Energy R&D

Fusion *JFY1997 $296.85 million (¥51,748 million)*[72]

Japan has consistently been one of the leading nations in supporting fusion research. In particular, the Japanese government has been the primary financial sponsor of the International Thermonuclear Experimental Reactor (ITER) project, and Japan expects to be the site where the first reactor is built.[73, 74] A considerable portion of Japan's fusion research program is directed towards reactor engineering technologies surrounding the preliminary design of ITER (e.g., R&D for large superconducting magnets, highly efficient plasma heating technologies, tritium fuel handling technologies, new materials to resist high energy neutron damage).[75] The Science and Technology Agency devoted $188.52 million (¥32,863 million) for its participation in ITER for JFY1997.[76] Research is also focused on experiments at the Japanese Tokamak (JT-60) fusion reactor and on methods to improve plasma performance in this reactor. The program also supports a wide-ranging basic research effort directed at various types of magnetic field containment systems for tokamak, helical, reverse magnetic pitch and mirror reactors as well as inertial containment reactor systems.[77] Monbusho's support for the National Center for Fusion Science was $108.33 (¥18,885 million) in JFY1997.[78]

Fission *JFY1997 $641.89 million (¥111,896 million)*[79]

Light Water Reactors – The Light Water Reactor (LWR) program appears to be principally focused on safety-related R&D and on research needed to extend the operating lifetimes of Japan's current fleet of LWR power plants. LWR safety research focuses on accident thermalhydraulics, fuel integrity, severe accident phenomenology and management, and deterministic and probabilistic safety analyses needed to further upgrade the safety of current LWRs.[80] Much of this safety-related research is carried out at the Japan's Nuclear Safety Research Reactor (NSRR). The program also funds research related to Advanced LWR reactor desings.

Breeder Reactors -- The Japanese have found the development of fast breeder reactors (FBRs) to be technologically and economically demanding. (The US government discontinued its fast breeder reactor program some years ago because of these challenges and a lack of a clear market for the new reactors.) By one account, the Japanese government has spent in excess of $6 billion on the development and construction of the "Monju" prototype FBR.[81] In April 1998, the Japanese government announced that it would collaborate with Russian and French programs to develop breeder reactors in order to share the costs and risks associated with the development of this class of reactors.[82] Added to these technical and economic difficulties have been a number of safety and management problems at the Monju reactor.[83, 84] All of these problems have led to a growing public unease with nuclear power, with the result that the government reduced funding for FBR R&D by more than 25% since JFY1996. However, the Japanese government remains committed to the development of FBRs and sees them as a "leading choice among future nonfossil energy sources."[85, 86] The government is currently supporting the construction of "a next stage demonstration" FBR that it hopes will pioneer new FBR construction techniques and could lower the cost of FBR construction "below that of light water reactors." This new demonstration reactor is attempting to also validate new safety measures relating to, for example, the prevention and detection of sodium leaks and fire prevention (the two problems that have plagued the Monju reactor).[87]

High Temperature Gas-Cooled Reactor -- Construction of the High-Temperature Engineering Test Reactor (HTTR) is now complete with the reactor achieving first criticality in 1997. The reactor is designed as a testbed to establish technologies for a high-temperature gas-cooled reactor (approximately 1000 degrees Celsius) and to promote advanced basic research related to high-temperature reactor engineering.[88, 89]

Nuclear-Powered Ships[8] -- Japan Atomic Energy Research Institute (JAERI) is currently carrying out research on two advanced marine nuclear reactors. The MRX (Marine Reactor X) is designed to be used in large nuclear-powered ships. The DRX (Deep-sea Reactor X) is being designed for use in a future deep-sea research submersible vessel. Both of these reactors are being designed with enhanced safety measures such as in-vessel control rod driving mechanisms, a water-filled containment vessel, and a natural circulation emergency heat removal system.[90]

Other Nuclear Research

The government also funds a wide range of other nuclear research activities. For example, research is ongoing to evaluate using the thermal energy from nuclear reactors to produce hydrogen from water for use in fuel cells and other applications. The government also supports advanced basic research for neutron science, synchrotron radiation research and research with x-ray lasers. The budget for research carried out at the Spring-8 synchroton radiation facility in JFY1997 was $110.49 million (¥19,260 million).[91] The budget for the High Energy Accelerator Research Organization (KEK), Japan's primary center for particle physics and accelerator-based research, in JFY1997 was $40.29 million (¥7,024 million).[92] The National Institute of Radiological Sciences (NIRS) is advancing nuclear medicine and has started clinical trials of

[8] Japan's civilian nuclear-powered ship reactor research appears not to be included in the government's "energy R&D" program's budget. Rather, the funds for the development of these reactors are accounted for elsewhere in the Japanese R&D budget.

cancer treatment with heavy ions from a cyclotron.[93]

Nuclear Fuel Cycle R&D *JFY1997 $778.97 million (¥135,791 million)*[94]
Because of the geologic instability of the Japanese archipelago, the Japanese government has found it difficult to close the nuclear fuel cycle through the use of a central geological repository. The government projects that many spent nuclear fuel storage facilities at commercial reactors will reach their capacities within the next 2-4 years.[95] The government believes that "Compared to other countries, Japan is10-20 years late in addressing the problem" of how to dispose of its reactor wastes.[96] Difficulties surrounding the question of a permanent solution for nuclear wastes is also one of the reasons the Japanese government is so interested in fast breeder reactors and fuel reprocessing technologies. On September 30, 1998, the government reorganized and renamed the Power Reactor and Nuclear Fuel Development Corporation. The point of this reorganization will be to refocus the new "Nuclear Fuel Cycle Development Organization" on developing technologies (principally fast breeder reactor development and high-level nuclear waste disposal technologies) and building public support needed to close the nuclear fuel cycle in Japan.[97, 98] The government has also announced its intent to start research directed at assessing the feasibility of transmuting nuclear wastes.[99] Japan is attempting to open an "underground research laboratory" to begin research on long-term geologic disposition of radioactive wastes, but these attempts to open this "laboratory" are meeting with stiff resistance from local communities in the proposed venues.[100] The government's preferred disposal method for high level wastes is to encase the wastes in glass and then isolate the waste in repositories 500-1000 meters below the surface.[101, 102]

With respect to reprocessing of nuclear fuels, Japan has initiated stepped up efforts to make use of MOX (uranium plutonium mixed oxide) fuels in 16-18 commercial light water reactors between now and 2010.[103] As a part of this program it has initiated "town meetings" to convince citizens and local officials of the need to make use of Japan's rather large stockpile of plutonium (68.9 tons as of December 1997) as an energy source.[104, 105] JAREI is funding research to develop next-generation uranium enrichment technologies, including the laser isotope separation.[106] The government is also funding research and technology development associated with the decommissioning of nuclear facilities and the handling of wastes generated by decomissoning.[107] Specific research topics include remote dismantling, decontamination, radiation measurement/data processing, and systems engineering.[108]

Cold Fusion *JFY1998 $0*
MITI's JFY1998 budget includes no funds to continue Japan's five-year old (cumulative investments of approximately $23 million) search for room temperature fusion. This most likely represents the end of the program.[109]

Fossil Fuel R&D
Coal R&D *FY1997 $62.08 million (¥10,822 million)*[110]
The Japanese government's coal R&D program is primarily funded by MITI. The program is currently being reorganized and its priorities are being reassessed. This reorganization is driven in large measure by the government's concerns relating to CO_2 emissions and other environmental considerations such as acid rain caused by coal use in other parts of Asia (e.g., China). The government has announced that the principal long-term research focus of this program is to be the liquefaction/gasification of coal to produce hydrogen and high-hydrogen content fuels for use in fuel cells and other hydrogen utilization systems. These programs will also carry out research related to reducing CO_2 emissions that are directly attributable to the liquefaction and related processes. This program and its activities are linked to the Japanese government's CO_2 capture

and sequestration programs as well as the fuel cell program to develop an "economically viable and environmentally friendly coal conversion complex" (which is quite similar in its goals to the USDOE's Office of Fossil Energy "Vision 21" program). Specific coal research areas include:

- Bituminous coal liquefaction technology. R&D is focused on liquefying coal for the manufacture of transportation fuels (e.g., light and medium oil products) that can be used in place of petroleum. In addition to this general research program, the Japanese government has supported the development of a bituminous coal liquefaction pilot production plant that has been in operation since 1996. The plant uses the NEDOL process, a single-stage liquefaction method that combines the power of a hydrogen-donor solvent and the liquefaction-promotion effect of an ultrafine iron catalyst. The plant has a 150 ton/day capacity (which is approximately equal to 600 bbl/day of liquid fuel).[111]
- Coal gasification technology. This program has two principal focuses. First, the program is continuing the development of an "entrained flow coal gasification power plant," which has been under development since 1986 and is designed to deliver higher efficiencies (more than 43%) than conventional coal thermal power plants. Second, since 1996 the program has funded research on coal hydrogasification to produce high-hydrogen content synthetic natural gas.
- Pressurized fluidized bed combustion – The Japanese government continues to support the development of pressurized fluidized bed combustion systems. The government believes this technology should be ready to be commercialized early in the 21st century.[112]
- Coal decarbonization and hydrogen production from coal. This program also supports a demonstration-scale coal "decarbonization" plant that is currently using 20 ton/day of coal to produce hydrogen, as well as another pilot test scale plant to manufacture higher hydrogen content "syngas" from coal, and advanced electricity-generating plants that would make use of these coal-based syngases.

Coal Bed Methane *FY1997 $69,000 (¥12 million)*

MITI is supporting at its National Institute for Resources and Environment (NIRE) laboratory a research program for developing technologies for mining, recovery and separation by adsorption, and catalytic conversion to fuel of coalbed methane (methane trapped in coal seams several hundred meters deep).[113]

Oil and Natural Gas R&D *FY1997 $180.16 million (¥31,406 million)*[114]

The Japanese National Oil Company (JNOC) is a government-owned corporation that is supported by MITI. JNOC carries out research relating to advanced oil discovery and production technologies including development of 3-D sedimentary basin model simulation and reservoir characterization capabilities, secondary and tertiary recovery technologies, multi-lateral and multi-branch well technologies and multi-phase fluid transport technology.[115] MITI also supports research on gas-to-liquids technologies and technologies for extracting oil from shale and sands and refining the heavy oil from these reservoirs.[116]

Methane Hydrates *JFY1997 $4.1 - $4.7 million (¥727 - ¥827 million)*

The Japanese government believes that if it can economically develop the methane hydrate accumulations known to exist in marine sediments around Japan that these deposits would last Japan approximately 100 years at current natural gas consumption rates.[117] JNOC funds applied research relating to methane hydrate production, including the drilling of a test well in the Canadian permafrost region in the Mackenzie Delta in order to develop and validate proposed production methods. JNOC, in cooperation with the Geological Survey of Japan (GSJ), is also responsible for identifying and mapping the methane hydrate resource off the Japanese coast.[118] MITI's NIRE, the GSJ, and the Hokkaido National Industrial Research Institute (which receives its funding through the New Sunshine Program) is funding more basic and laboratory-based methane hydrate research.[119] NIRE's research is focused on laying the foundations for new mining methods for methane hydrates, including research on "a process control system of formation and dissociation of methane hydrates, fluid flow dynamics of dissociated gas and water in marine sediment, and disposal of CO_2 by its substitution into methane hydrates." [120] NIRE is also funding research to determine the origins of methane hydrates and the environmental impacts that might be associated with mining methane hydrates.[121]

Renewable Energy R&D

Solar Energy R&D *JFY1997 $45.63 million (¥7,955 million)*[122]

The MITI New Sunshine Program's[9] solar energy R&D program focuses on the development of (1) photovoltaic systems and their associated systems and (2) passive and active solar thermal processes.

- The Photovoltaic (PV) program is principally focused on lowering the cost of manufacturing solar cells and developing the associated technologies needed to deploy PV-based systems. The PV cell manufacturing R&D program is researching ways to lower the manufacturing costs of mass-producing modules based on amorphous silicon and cadmium telluride (CdTe) solar cells. Specific research areas include reducing the cost of manufacturing reinforced glass substrates with transparent electro-conductive film, research designed to reduce the conversion efficiency losses of amorphous solar cells over their lifetime, and manufacturing thin film polycrystalline solar cells and CulnSe2 solar cells. The program is also funding research on "super high efficiency solar cells" and methods for "manufacturing solar cells by joining III-V compound thin film (such as Ga, In, As, Ge and P) on to silicon substrate." R&D is also underway on associated systems needed to deploy PV systems in grid-connected applications as well as in residential applications. R&D underway includes multifunctional inverters and low-cost high performance batteries for grid-connected applications, and for the residential sector the program is carrying out research on incorporating composite PV cells with construction materials.[123]
- Solar Thermal Systems. The Japanese solar thermal program is focused on active solar thermal processes (e.g., systems to provide heat and hot water for industrial processes). Relatively little attention appears to be paid to passive building design research because the Japanese government believes that this is a fairly mature technology that requires little further research. The active solar thermal program is focused on the development of systems that are capable of using solar energy to provide either heating or cooling applications for use in areas of high insolation (e.g., work is underway on a solar freezing/refrigerating system that would provide cooling to -10 deg.C for use in desert areas). The program is also attempting to transfer solar heat energy utilization technologies formerly developed under this program to industry and to developing nations (e.g, an industrial dehydration system for wood products utilizing an air heating collector is being developed and deployed for use in Indonesia). [124]

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[9] The New Sunshine Program is the largest non-nuclear energy R&D program supported by the Japanese government, with a total JFY1997 R&D budget of $323.08 million (¥56,320 million). The program is managed by MITI's Agency of Industrial Science and Technology (AIST) and focuses on renewable energy R&D, energy efficiency R&D, fossil energy R&D, and energy technologies for global climate change. The "New" Sunshine Program was launched in 1993 by combining the formerly separate "Moonlight Project" (energy conservation R&D), "Sunshine Project" (renewable energy R&D) and the "Research and Development Project on Environmental Technology" (climate change energy technology development).

Ocean/Wave Energy R&D *Approximately$8 million/year*[125, 126]

Driven in large measure by its severe dependence upon imported sources of energy, Japan seems comfortable in investing in energy R&D and demonstration programs that other nations would view as having a low probability of paying off. One such example is the "Mighty Whale" wave energy conversion project supported the Japan Marine Sciences and Technology Center (funding provided by STA).[127] The Mighty Whale project has been under development since 1987. Currently, the Japanese are testing a prototype of this system, which is anchored in 40 meters of water. This system differs from other Japanese wave energy systems in that it floats in the water as opposed to being fixed on the seafloor. [128] The system uses the force of the waves to drive air out of three 12-meter high chambers and drive turbines set atop the chambers. The system, if successful, might be deployed to serve very isolated fishing communities.[129] The Mighty Whale belongs to a class of ocean wave energy projects that the Japanese refer to as "oscillating water column" energy systems. Japan has been studying these "oscillating water column" energy systems since the 1980s. Japanese R&D and even technology deployment and demonstration activities for wave energy systems dates back to the early 1980s.[130, 131] The Japanese government formerly funded the development of ocean thermal energy systems, which attempt to exploit the small temperature differences in an ocean water column. Current ocean thermal energy system research is confined to long-term studies of system concepts that might someday be more economically viable.[132]

Wind Energy R&D *FY1997 $3.18 million (¥555 million)*[133]

MITI's New Sunshine Program wind energy R&D program appears to be primarily based on technology demonstration and the optimization of existing large-scale wind energy power generation systems. The government recently completed construction of a 500 kW system in Tappi Promontory. This system is now in operation and its performance will be monitored. The government is also researching ways to optimize control techniques for a wind farm on Miyako Island, Okinawa.[134]

Geothermal Energy R&D *FY1997 $21.18 million (¥3,692 million)*[135]

Japan is one of the most volcanically active countries in the world and the government believes that it can tap this as a clean energy resource. Currently in Japan there are 16 geothermal steam plants in operation that are generating about 530,000 kW. MITI (through the New Sunshine Project) has an active geothermal energy R&D program that is focused along three broad areas of inquiry: the development of advanced exploration and resource characterization technologies, advanced drilling and production technologies, and geothermal power production cycles.

- The Geothermal Energy Exploration Technology program focuses on (1) technologies for reservoir mass and heat flow characterization, including the behavior of the fluid flows within fractures; (2) carrying out a survey of deep (up to 4000 meter depth) geothermal resources; and (3) basic research for advanced exploration technologies.
- The Drilling and Production Technology program is focused on the development of cost effective drilling and energy extracting technologies and supporting technologies such as (1) MWD (Measurement While Drilling) System for geothermal wells, (2) advanced drilling and production technologies for exploiting deep geothermal resources, and (3) basic research related to materials development for geothermal drilling and energy extraction applications.
- The third aspect of the Japanese geothermal R&D program is focused on developing power production technologies need to effectively exploit medium-temperature hot water and hot dry rock geothermal energy resources, both of which are currently non-economic resources. This power production program is developing (1) binary cycle power plant technology (the program has developed and deployed a down hole pump and facilities for the heat exchange experiment at the test site to evaluate their performance), (2) hot dry rock power generation system (a long-term circulation test will be carried out at a test site in order to evaluate the

basic system components needed for efficient heat extraction from a high temperature rock with little water), and (3) basic research for the further exploitation of these unused geothermal energy resources.[136]

Biomass Energy R&D *JFY199X7 $180,000 (¥31million)*

The New Sunshine Program funds a number of diverse biomass energy projects ranging from technologies designed to make more efficient use of current biomass resources to basic research designed to genetically engineer microorganisms and new plant species for advanced biomass production. The government is funding research relating to technologies for transforming biomass into gases and liquids and on advanced biomass combustion technologies. The program also sponsors research on direct catalytic (thermochemical) decomposition of biomass to produce hydrogen.[137, 138]

Hydrogen R&D *JFY1997 $14.2 million (¥2,473 million)*

The MITI World Energy NETwork (WE-NET) program is designed to build the capacity to cost-effectively produce hydrogen via electrolysis of water using renewable energy sources to produce an emissions-free energy system. The WE-NET program is investigating solid polymer electrolyte electrolysis of water as one potentially promising hydrogen production technology. The program is also carrying out research on methods needed to transport hydrogen spanning scales that range from purpose-built, open-ocean hydrogen tankers to basic research on metal hydrides for transporting and storing small quantities of hydrogen needed to run something like a fuel cell powered automobile. The Japanese government is also supporting research on microbes that could directly produce hydrogen and the efficient liquefaction of hydrogen for transport and storage.[139] The program is also funding research on of hydrogen-oxygen combustion turbines for future clean power generation systems and hydrogen co-generation applications, e.g., developing cooling technologies for the hydrogen turbine blades.[140] The government is also funding research on producing hydrogen and high-hydrogen fuels from coal (see Coal R&D) and fuel cell R&D (see Fuel Cells) that are accounted for in other sections of this report.

Waste-to-Energy *JFY1997 $9.92 million (¥1,730 million)*[141]

Research on waste-to-energy plants is important for Japan for two reasons: (1) these plants represent a (somewhat) renewable and (partially) domestic energy source and (2) land-fill costs in Japan are very high. MITI has two R&D programs focused on waste-to-energy systems. The larger of the two is "R&D for Generating Electricity that Is Utilizing Solidification of Waste Matter" and its budget was $9.47 million (1,650 million ¥). The smaller, related waste-to-energy program is "R&D technology for Changing Flammable Disposal (waste matter) to Fuel." This is a new program with a budget of $460,000 (80 million ¥).[142]

Energy Conservation

Fuel Cells *FY1997 $33.69 million (¥5,873 million)*[143]

MITI's New Sunshine Program supports Japan's fuel cell R&D program, including research on molten carbonate fuel cells, solid oxide fuel cells, and polymer electrolyte (i.e., ion exchange membrane) fuel cells. The program is also developing various fuel reformers that would allow these fuel cells to run on a number of different primary feedstocks. A wide variety of research efforts designed to develop materials that would extend the operating lifetimes and the efficiency of fuel cells are also being researched. In addition, the program is focused on developing supporting technologies needed to make better use of the waste heat generated by fuel cells. The program also funds a number of technology demonstration and proof-of-principal programs designed to speed the introduction of fuel cells into the marketplace.[144]

Advanced Ceramic Gas Turbine Technologies *FY1997 $12.05 million (¥2,101 million)* [145]
MITI, through the New Sunshine Program, is funding a program designed to improve the manufacturability and machinability of ceramic parts (e.g., turbine blades) for use in next-generation natural gas-fired power plant turbines. Of particular interest to the program is the development of small-scale modular turbines that would incorporate advanced ceramic parts in their high temperature zones, which would significantly improve the efficiency of these smaller distributed gas turbines. The program is also developing low NOx ceramic burners, ceramic heat exchangers and other related system components. In JFY1997, the program also supported the construction and testing of a 300kW class ceramic gas turbine with a 1350 degrees Celsius turbine inlet temperature to validate some of the ceramic parts developed previously through this program. This technology demonstration program is still ongoing.[146]

Waste Heat Recovery *JFY1997 $10 million (¥1,762 million)*
The "Eco-Energy City or Broad Area Energy Utilization Network System Technology" program is focused on waste heat recovery in the industrial and residential sectors as a way of improving energy end-use efficiencies. In 1996, this program was refocused away from large technology demonstration programs to a more long-term program of research designed to develop the system level components. The ultimate goal of this program is to bring about economical energy cascading and utilization of medium and low value waste heat streams. The program is researching waste heat recovery and conversion technologies, heat transport technologies, heat storage technologies, heat utilization technologies, and the necessary sensors and controls needed to deploy an advanced city-wide waste heat recovery and utilization system.[147]

Load Leveling Research *JFY1997 $51.43 million (¥8,965 million)*[148]
The Japanese government funds a wide variety of superconductivity research relating to energy storage, transmission, distribution and power quality. The government continues to fund research and demonstration activities relating to superconducting power generators and for superconducting cables for electricity transmission. The government also supports superconductivity research relating to power storage.[149]

Residential Building Energy Efficiency *JFY1997 $9.68 million (¥1,687 million)*[150]
The "House Japan Project" is a collaborative research and technology demonstration program between MITI and many of Japan's leading building companies. The program is designed to run from 1994-2001. To date, the government's contribution to this program has been approximately $100 million. The program's three main goals are to improve residential building energy efficiency, reduce construction costs, and improve indoor air quality. Specific energy efficiency R&D efforts include improved insulation materials, residential cogeneration systems, heat storage systems, and improved heating and cooling systems. The program has recently finished building four technology demonstration houses that incorporate many of the advances made in the program to date. These four houses will be used as testbeds to assess these technologies' performance until the end of the House Japan Project in 2001.[151]

Other Energy Technologies

Carbon Dioxide Separation, Capture and Sequestration R&D

JFY1997 $50 million (¥8,732 million)

The Japanese government is believed to be spending more than any other government on R&D for carbon dioxide (CO_2) capture and disposal (in particular in the oceans) and various ways of utilizing CO_2.[152] The relatively large investments in this area reflect the government's belief that with already low emissions per-unit-of-GDP ratio for Japan, it will be very difficult for Japan to further reduce emissions of greenhouse gases through further energy efficient measures. Therefore, the government believes that it must aggressively invest in ways of generating no or low-carbon sources of energy.[153]

CO_2 Storage in the Oceans – The Japanese government purportedly spent $5.16 million (¥900 million)[154] on ocean sequestration related research in 1997. One significant aspect of this research effort is the SEA-COSMIC R&D program, which will run from 1997 to 2001. SEA-COSMIC is designed to perform laboratory tests and in-situ measurements and construct numerical modeling tools to determine the efficacy and environmental impact of disposing of CO_2 via a dissolution mechanism at depths of approximately 1000-2000 meters.[155] As of 1995, there were at least 11 major facilities in industrial and government laboratories that had been established with high pressure cells to study the physical properties (and in particular the dissolution) of carbon dioxide in sea water. These facilities are being used to study the various temperature and pressure environments that might be encountered in disposing of carbon dioxide in the ocean.[156]

CO_2 Sequestration in Deep Aquifers -- The Japanese government is carrying out research to assess the stability of using deep saline aquifers as a potential disposal pathway for CO_2. The program is researching the behavior and fixation mechanism of CO_2 in deep aquifers and adjacent strata.[157]

Research on CO_2 Separation Techniques – The Japanese government is also funding research to efficiently separate CO_2 from flue gas streams.[158] One aspect of this program is the development of a high temperature (over 300C) ceramic membrane separation processes that would allow for a continuous stream of CO_2 to be separated from combustion waste gases. The government is also studying other membrane and solvent-based systems for removing CO_2 from flue gas streams.[159]

CO_2 Utilization – The Japanese government is also investigating processes that could "utilize" CO_2 to obviate the need to sequester or release some fraction of Japan's CO_2 emissions that would otherwise be released into the atmosphere. Research is being conducted to (1) examine chemical processes that would mimic photosynthesis (a.k.a. artificial photosynthesis) and that would use CO_2 and produce higher value hydrocarbons by using sunlight to drive the reaction, (2) develop processes that would produce useful organic compounds by reaction of CO_2 with hydrogen or reactive compounds at relatively low temperature, and (3) search for and breed photosynthetic microorganisms that fix CO_2 very efficiently and microorganisms that produce useful high value-added materials from CO_2 and other simple feedstocks. The program is also developing reactors where microorganisms are cultured in large quantities and on light collecting systems for these reactors.[160, 161]

The Climate Technology Initiative

Japan has also spearheaded the drive to bring together many industrialized nations to pool their expertise in climate-related energy technologies under the Climate Technology Initiative (CTI). The CTI aims to bring together scientists from Canada, Finland, German, Japan, the Netherlands, Norway and the United States.[162] At a ceremony that was held at the same time as the Kyoto climate negotiations, these countries signed agreements to begin research in three primary areas: (1) a study of ocean sequestration of carbon dioxide, (2) a study of geological sequestration of carbon dioxide, and (3) a study on large-scale solar power generation. Japan will lead the ocean sequestration project, which will investigate the technical feasibility and environmental impact of sequestering CO_2 in the ocean via dissolution of CO_2 in seawater. The United States and Norway will also participate in this project, which is expected to have a budget of approximately $4 million over 5 years. Canada and the United States have agreed to lead the geological sequestration of CO_2 project, which will initially focus on sequestration in deep unminable coal seams. This project will also have a similar budget of approximately $4 million over 5 years. The very-large-scale photovoltaic power generation system program will be led by Japan with participation by the Netherlands, Sweden, Switzerland, Italy, Spain, Norway and Korea, and will examine the economic and environmental impact and feasibility of constructing and operating 10MWe to 1GWe solar power systems. This solar program has a budget of approximately $2 Million over 4 years.[163]

"International Energy R&D Programs" *JFY1997 $131.79 million (¥22,973 million)*[164]
Many of the above described energy R&D programs contain some international collaborative focus. In addition to those funds which are embedded in a larger energy R&D program, the Japanese government (MITI) has three rather large programs that seem to focus exclusively on international aspects of R&D (technology deployment, collaborative research, etc). These programs and their funding levels in JFY1997 are: "International Cooperation for Energy and the Environment (Green Aid Plan)" $89.76 million (¥15,647 million), "Providing the Foundations for International Facilitation of Clean Coal Technology" $21.66 million (¥3,776 million), and "Promoting International Joint Research Projects with the Oil-Supplied Countries" $20.35 million (¥3,547 million).[165] The purpose and function of these programs is deserve further research.

List of Acronyms Used

CO_2	Carbon Dioxide
CRIEPI	Central Research Institute of Electric Power Industry
JAERI	Japan Atomic Energy Research Institute
JFY	Japanese Fiscal Year
JNOC	Japanese National Oil Company
LWR	Light Water Reactor
MITI	Ministry of International Trade and Industry
Monbusho	Ministry of Education, Science, Sports, and Culture
NIRE	National Institute for Resources and Environment
R&D	Research and Development
S&T	Science and Technology
STA	Science and Technology Agency

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http://www.odci.gov/cia/publications/factbook/index.html

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