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Energy R&D in Italy

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ASTRACT: The Italian public and private sectors invested $13.3 billion in research and development in 1998. The private sector funds the majority of R&D in Italy. Overall, Italy has one of the lowest R&D investment spending rates of all industrialized countries. In 1998, Italy spent 1.19% of its gross domestic product on R&D, compared to 2.55% in the United States. R&D spending in Italy shrunk in the first half of the 1990s and has only recently recovered to 1990 levels. Italy's R&D investments are spread over a range of fields, with no single research field accounting for more than 20%. However, general university funds, which universities use for non-directed research across a broad range of scientific fields, accounted for 48% of Italian public R&D in 1998.

Italian public and private investments in energy R&D totaled $551 million in 1996. These investments have declined significantly compared to their level in the mid-1980s. Much of this decline relates to government cuts in fission funding. Italy has banned nuclear power production since 1987 and this has had a significant impact on government nuclear fission research. Nuclear research (both fission and fusion) is still the single largest area of Italian public energy R&D. Other areas of energy research such as fusion, fossil fuels, energy efficiency and renewable energy have also seen declines in funding. Only expenditures on general energy research have increased in real terms since 1990. The Italian government policy calls for increases in energy efficiency and renewable energy R&D expenditures for environmental and other reasons, though this policy has not yet been fully reflected in funding appropriations. Italian corporate spending on energy R&D has also declined in recent years. Most Italian corporate energy R&D relates to fossil fuels or energy efficiency. Italy's major energy companies have been privatized this decade; their R&D expenditures declined significantly after privatization although the long-term impacts these privatizations will have on private sector energy R&D spending are not yet clear.

Italy

Population: 56,778,031 (1998)[1]
GDP: $1.36 trillion (2,058 trillion lire) (1998) [2,a]

National R&D Effort 1998:

- $13.3 billion (24,575 billion lire)[3]
  - 43.2% of which was supported by the public sector
  - 56.8% of which was supported by the private sector
- R&D as a percentage of GDP: 1.19%[4]
- Total Public R&D: $5.8 billion (10,612 billion lire)

National Energy R&D Effort 1996:[5]

- $551 million
  - 29% of which was supported by the public sector
  - 71% of which was supported by the private sector[b]

Chapter Overview:

[a] All dollar figures shown are 1995 dollars based on purchasing power parity calculations made using currency deflators published by the Organization for Economic Cooperation and Development (OECD). See OECD, Statistics Directorate, *National Accounts 1960-1996: Main Aggregates Volume 1* (Paris: OECD, 1998).

[b] Private sector includes all corporations, both state-owned and private. Private sector R&D excludes government and foreign funding for corporate R&D. In other words, it includes only R&D funded by a company's own earnings, the earnings of its group or those of other Italian companies.

SUMMARY OF ANALYTICAL FINDINGS

Italian public and private organizations invested a total of $13.3 billion in research and development (R&D) in 1998. A sluggish economy and government budget balancing have had a significant impact on the size of the Italian R&D effort this decade, though spending has begun rising again. Overall, Italy has one of the lowest R&D investment rates of all industrial countries, and this concerns the government. In 1998, Italy spent 1.19% of its gross domestic product (GDP) on R&D. Corporations fund the majority of research in Italy.

The Italian government realizes that the low level of investment in R&D is a growing problem for Italy's international competitiveness. In fact the five-year budget plan beginning in 2000 highlights R&D as one of the top government priorities. The government has already begun increasing funding for R&D while at the same time trying to keep its budget balanced according to strict European Union standards for the new European currency, the Euro. (Italy was at great risk of failing to meet Euro-qualifying criteria and has made major cuts throughout its budget as a result). The government has also responded to these concerns by reorganizing the research and educational infrastructure to make it more effective and focused. Reforms include financial incentives for good performance, more streamlined organizations, and an effort to develop national R&D priorities for spending limited resources wisely.

Italian energy policy continues to focus on deregulation and environmental protection. EU directives on competition in the electricity and gas markets have forced Italy to de-regulate its internal energy markets. At the same time, budgetary pressure prompted Italy to privatize its main energy assets: ENEL (the national electricity company) and ENI (the national oil and gas company). Since the late 1980s, Italy has had a moratorium on generating nuclear power, making it the first country in the world to shut down all its operating nuclear power plants. In the ensuing decade, environmentalists and others have used new laws fostering competition in the energy sector as mechanisms to encourage green power and clean energy sources.

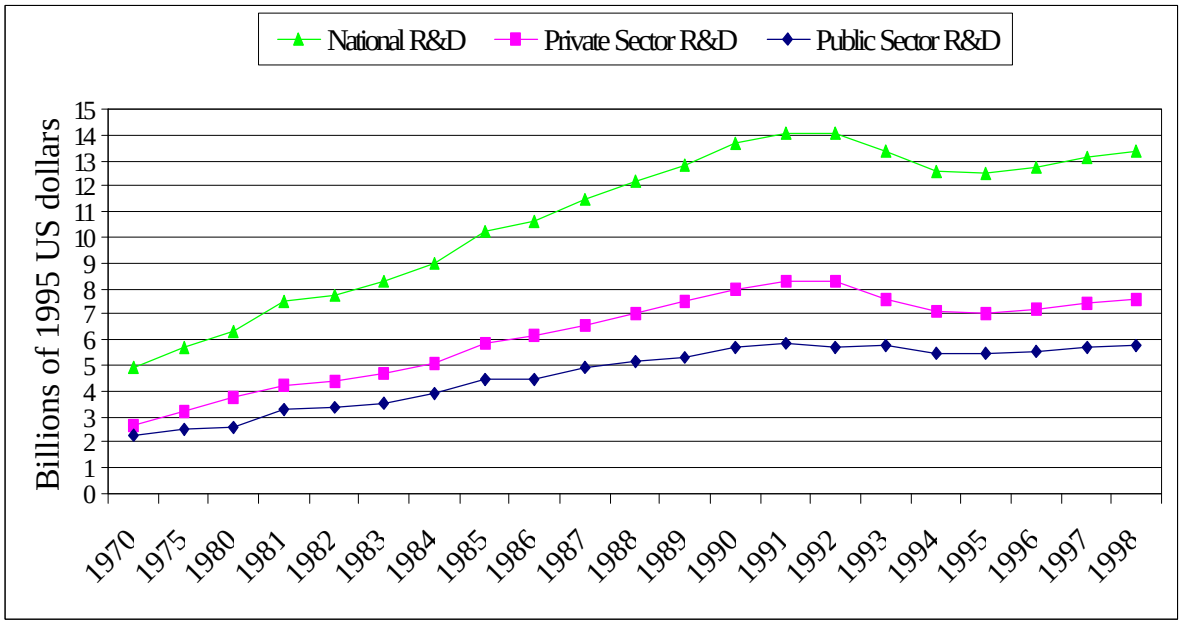
Energy R&D accounts for only 3% of public R&D spending, and just over 4% of total R&D spending (public and private). Public energy R&D investment has dropped significantly since the late 1980s, primarily because of major funding cuts for fission and fusion. Nuclear fission and fusion still accounted for 49% of public energy R&D spending in 1996, followed by energy efficiency (23%) and renewable energy (10%). Most R&D relating to fossil energy and energy efficiency is paid for by the private sector. The government sees little reason to promote the use of fossil fuels through R&D when at the same time it is trying to discourage their use because of environmental and energy security concerns; fossil accounts for less than 3% of public energy R&D. However, fossil research appears to be the single largest area for total energy R&D research in Italy, primarily because of private-sector investments.[c] Italy's two largest energy companies, ENEL and ENI, are both major R&D investors.

[c] Italian statistical data indicate that fossil fuels are the largest area of corporate energy research, though these data may undercount energy efficiency.

THE ITALIAN NATIONAL SCIENCE AND TECHNOLOGY EFFORT

The Italian government funded 43% of the national R&D effort in 1998 and this proportion of the total funding has remained stable over the last 25 years. As Figure 1 shows, the Italian government spent $5.8 billion on R&D in 1998, while corporations spent $7.6 billion on R&D for a total R&D effort of $13.3 billion.

Figure 1: Italian National S&T Effort 1985-1998[6]



The total Italian national R&D effort grew steadily from the end of World War II until the 1990s. The early 1990s, however, saw a significant decline in R&D spending in both the public and private sectors. Public funding for R&D fell by 6.1% from 1991 to 1995.[7] At the same time, many private firms cut their research budgets because of sluggish economic performance and/or increased competition within the larger European market. Throughout most of the 1990s, R&D spending levels have seen slower growth than GDP. The Italian government is concerned that Italy is losing ground in this area compared with other industrialized countries.[8] National R&D spending levels have recovered somewhat since 1995, but are still below their 1991 peak.[9] Energy R&D, however, has seen a much greater drop in funding than most other research areas.

The Italian government funds a relatively large portion of the R&D conducted by Italian corporations (12.2% in 1995), particularly for technologies that would benefit small and medium-sized enterprises. The government's share of these expenditures has been dropping since 1985, but Italy is still one of the top ten countries globally providing public funding for such expenditures.[10]

Corporate R&D is concentrated in large companies, particularly in very large industrial groups. Only 9% of companies carry out 80% of corporate research.[11] This is in part because a large portion of Italy's private sector is in the hands of small, family-owned

enterprises. Such firms also dominate the portion of the private sector experiencing considerable growth. These firms rarely fund major innovative technological research, which limits the potential growth of private-sector R&D in the near to medium term. Most of the growth in R&D expenditures from the late 1960s until the early 1990s was in spending by state-owned firms. Many of these firms have now been privatized, which may have long-term implications for growth of R&D in Italy.[12]

The following points describe several other key R&D trends in Italy:

- While Italy has relatively strong programs in government-funded basic research and, to a lesser degree, in physics and pharmaceuticals, overall its science and technology effort lacks strong specialization. Italy tends to invest in R&D in numerous sectors without concentrating its effort in priority sectors or sectors in which it excels.[13]
- Italy does not tend to rank highly in most research impact indicators compared to other EU countries. For example, it generally ranks average on indices of bibliometric impact.[14]
- Corporate R&D activity is most intense in the chemical, pharmaceutical, telecommunications and automobile industries.[15]
- Italian R&D is heavily concentrated in a few regions, particularly Lombardy, Piedmont and Lazio. The former two regions see the greatest share of corporate research, while Lazio, where Rome is located, sees the largest share of government-sponsored research. The Italian government is trying to increase its R&D spending in Southern Italy as part of its economic development campaign there.

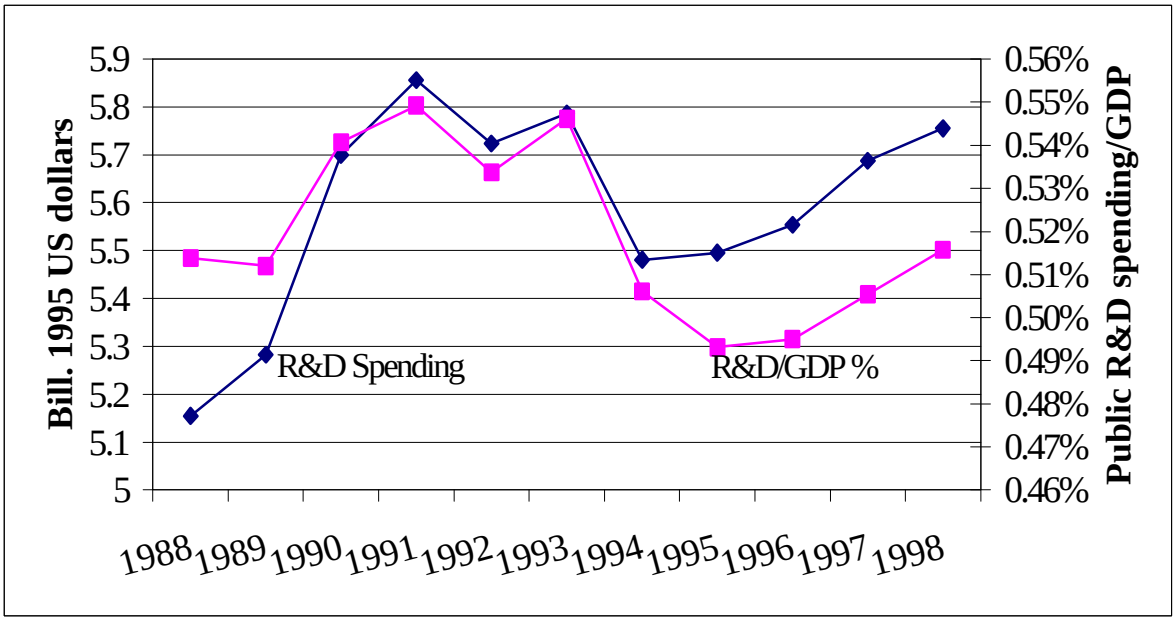
Trends in Public Sector Support for R&D

The Italian government's R&D expenditures have declined since the early 1990s both in real terms and as a percentage of GDP, as seen below in Figure 2. Public R&D spending as a percentage of GDP reached its lowest point in 1995 and 1996 at 0.49%.

Italian R&D expenditures, both public and private, are again rising in real terms. Nonetheless, Italy has not yet again reached its 1990 levels for total R&D spending. For example, total R&D spending in real terms was $14.1 million in 1991, while in 1997 and 1998 it was only $13.1 and $13.3 million, respectively.[16]

The decline of the early and mid 1990s was a result of several factors, including decreasing tax revenue due to the economic recession; pressure to reduce taxes, particularly from Northern Italian politicians; Italy's need to reduce its budget deficit to qualify for the Euro; and public spending cuts in response to the "Clean Hands" anti-corruption campaign. The Italian government has expressed growing concern about Italy's need to increase R&D expenditures to help its economy remain competitive internationally. In the government's budget plan for 2000-2003, improving education and R&D systems is listed as the number one strategic objective of the government's fiscal policy for development and jobs. One of the government's main research goals is to increase public funding for R&D conducted in corporations.[17]

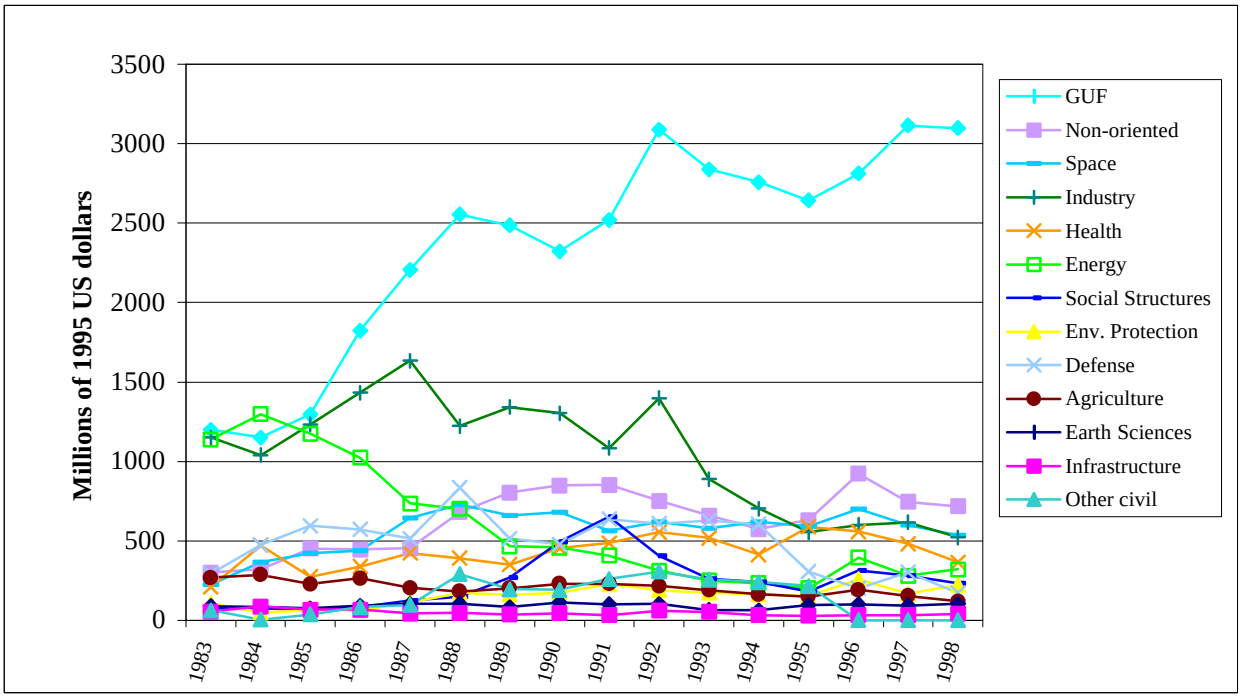
Figure 2: Italian Public Administration Support for S&T: 1985-1996[18]



The Italian government has committed specifically to increasing its R&D expenditures in certain areas, such as public health, space and climate change mitigation technologies. As Figure 3 describes, public health R&D spending has gone up, but R&D expenditures for space have remained level. Energy R&D has declined overall, although the Italian government may soon refocus its remaining energy R&D portfolio to concentrate on the technologies it feels have the most commercial promise. Italy has also recently included several renewable energy technologies in its National Research Plans. Specifically, Italy has launched National Research Plans for photovoltaics, solar storage and biomass. National Research Plans receive special funding, generally from the National Research Council. These plans are used to concentrate resources and provide better coordination in key technological areas.

Figure 3 also shows that the majority of the Italian government's support for R&D is for General University Funds (GUF). These funds are large block grants distributed to universities and other state-sponsored research institutions for research activities and capital expenditures. Thus, it is difficult to know what specific areas of research or what broad socio-economic areas are supported with GUF.

Figure 3: Major Socioeconomic Areas of Italian Governmental S&T Support[19,d]



R&D Policy Goals

The Italian government has several stated goals driving its R&D funding decisions. These goals include international economic competitiveness, environmental protection, job creation, and European integration. Regarding international competitiveness, the Italian government focuses its attention on two areas in particular. The first is publicly funded R&D for private companies, particularly small and medium-sized companies. The Italian National Research Council begins its 1998 annual report by stating, "Italy's research is neglected. If there were a Maastricht[e] exclusively of research, Italy could not be part of Europe… Unable to compete, Italy will miss the opportunity to reap the benefits of Europe in terms of wealth and jobs."[20] Italy's economic growth in recent years has been driven by small, often family-owned companies concentrated in the north.[21] These companies are usually too small to fund R&D themselves, but the government believes they could benefit from technological advances when competing on the European market. This is one of the reasons that Italian government funding of R&D performed in the private sector is high compared to other countries.[22] The second area of

[d] The data in this chart are based on the State Budget information. The numbers contain budget authorization numbers, as opposed to actual expenditures. This chart also includes amounts transferred directly from the state budget to state companies for R&D. Therefore, the data in this chart will vary somewhat from the government and public sector R&D expenditures given elsewhere in this report.

[e] The Maastricht Treaty, concluded in 1992, cleared the way for closer European integration and aims "to promote economic and social progress which is balanced and sustainable, in particular through the creation of an area without internal frontiers, through the strengthening of economic and social cohesion and through the establishment of economic and monetary union, ultimately including a single currency in accordance with the provisions of this Treaty." The Maastricht Treaty also laid the foundation for the creation of a single European currency and a common foreign and defense policy among Member States. For those countries participating in Economic and Monetary Union, Maastricht sets strict macroeconomic guidelines regarding price stability, debt-to-GDP ratios, and currency fluctuations.

focus is R&D and technology transfer in the south, or Mezzogiorno. The Mezzogiorno is economically depressed compared with the rest of Italy and the European Union; the Italian government is trying to improve the economic situation there by sponsoring technological innovation projects and centers.[23]

Trends in Private Sector Support for R&D

Italian companies funded $7.6 billion (14.0 trillion lire) of Italian R&D in 1998. This number has been growing steadily since 1995, and, in fact, companies now spend more on R&D than they did in 1990. The industrial sectors that funded the largest portion of R&D in 1997 are electric and electronic machine manufacturing, including turbines (24.3% of total corporate R&D spending), automobile manufacturing (15.6%), chemicals (14.1%) and other transportation means (13.5%). Research by electricity companies accounted for only 3.4% of total corporate R&D in 1997.[24]

The key driver behind overall Italian economic growth has been small, family-owned companies, particularly in the North.[25] These companies are able to adapt quickly and flexibly to new market conditions, and they account for a growing share of Italian exports. However, these firms are not as likely as larger firms to invest in R&D or even in major innovations within their own facilities. The bulk of Italian private sector R&D, thus, comes from large multinational companies such as FIAT (automobiles) and ENI (energy).

A significant share of Italian corporations is state owned, and, traditionally, many of the largest companies have been state owned. The share of state ownership in the economy, however, has been declining as the government privatizes its holdings in companies like ENEL and ENI. As companies privatize, their priorities change. On the one hand, they feel a greater need to compete with state-of-the-art technology and products, yet they have increased pressure from shareholders to cut costs. It is still too early to assess the long-term impact of privatization on Italian R&D investment.

As Table 1 shows, state-owned firms, many of which have been privatized in recent years, funded the majority of their research with their own earnings in 1990, although a larger share of their R&D is funded by the government than in the case of private firms. This tradition of funding R&D internally should make it easier for firms to continue financing R&D even after privatization.

Table 1: Corporate R&D Expenditures by Source of Funds, 1990[26]

Funding Source	Private Firms	State-Owned Firms
Total Expenditures (million 1995 US$)	5.24	2.73
Own Funds	77.9%	61.8%
Government	4.3%	15.4%
Public Institutions	11.2%	11.3%
Abroad	5.8%	10.1%
Public Firms	0.8%	
Private Firms		1.4%

Italy keeps very detailed statistics on corporate R&D spending and recently has begun polling the most innovative of these companies on their opinions about environmental technologies. Of the most innovative firms in Italy, 57% of them feel that recent innovations to reduce atmospheric pollution are irrelevant in terms of their effect on reducing emissions. Large firms and energy-related firms have a greater than average tendency to feel that environmental technologies are beneficial, but still almost half of energy-related firms felt technologies to reduce air pollution were not important. Likewise, innovative Italian firms rank both energy efficiency and environmental protection very low among their objectives for innovation.[27,f]

[f] ISTAT determined whether firms were innovative or not based on the firms' responses to a questionnaire, and, in particular, whether they stated that they introduced innovative technologies in the time period under study.

NATIONAL ENERGY AND ENERGY POLICY OVERVIEW

Almost 60% of Italy's energy comes from oil, most of which is imported. Gas accounts for another 30% of energy use. Coal, hydro and renewables provide for most of the rest, as shown in Figure 4. Most electricity is generated with oil, though natural gas and, to a lesser extent, renewables are increasingly important sources of power. Table 2 provides information on Italy's dependence on imports, its energy intensity and its greenhouse gas emissions.

Figure 4: Total Primary Energy Use by Fuel Type[28]

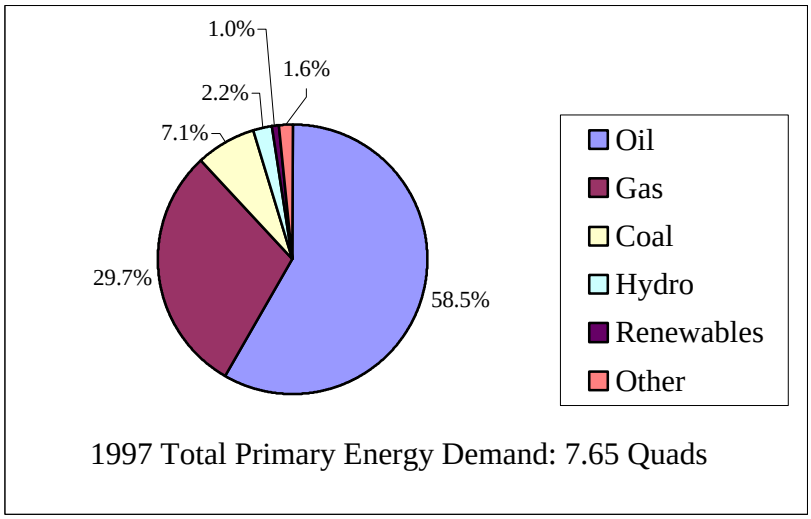


Table 2: 1997 Energy Snapshot[29]

Dependence on Energy Imports: 80%	Energy-Related Carbon Emissions: 116 million metric tons (1.86% of world carbon emissions)
Energy Consumption per Capita: 130.7 million Btu	Carbon Emissions per Capita: 1.98 metric tons
Energy Consumption per $1 of GDP: 5,658 Btu	Carbon Emissions per $1 GDP: 85.6 metric tons
"Kyoto Commitment": 6.5% reduction in GHG emissions by 2008-2012[g]	

Italy is one of the least energy intensive countries in the world.[30] Nonetheless, its energy policies are very complex, which is partly a result of the complex energy pressures facing Italy and partly a result of the Italian political process. There are more than 300 energy laws in Italy at the national level. A compendium prepared for the National Conference on Energy and Environment in 1998 sums up the evolution of energy legislation and

[g] Under the Kyoto Protocol, the European Union as a whole committed itself to an 8% reduction in greenhouse gas emissions between 2008-2012. Under a separate EU agreement, the Community Strategy on Climate Change, however, individual member states committed themselves to different greenhouse gas emission reduction trajectories in support of the EU's overall commitment.

planning in Italy with this statement: "Too many laws, some well done, others less so, often in contradiction with one another: what is needed are simplification, coherence, flexibility and separation between the legislation and the technical regulations."[31] The Ministry of Industry, Commerce and Handicraft (MICA) is the main body responsible for implementing Italian energy policy.

Italian energy policy has changed dramatically since 1988, the year in which the last National Energy Plan (PEN) was issued. The issues that are in the forefront of Italian energy policy today include energy deregulation, environmental protection, energy security, taxation and economic growth. Before each of these issues is discussed individually, however, it is worth highlighting a few unique aspects of Italian energy policy.

- Italy is one of the few countries in the world to have closed down operating nuclear power plants following a moratorium on nuclear power generation. Italy took this decision by referendum in 1987 in the wake of Chernobyl. Prior to the ban, 3.8% of Italy's domestic power was nuclear and Italy had 1.15 GW of nuclear capacity. The moratorium was in effect through 1992; however, the Italian government has extended it indefinitely.[32]
- Italian energy taxes are quite high, even by European standards. This has helped Italy achieve its low energy intensity. The taxes are a result of several policy drivers including the 1973 oil shock, continued energy security concerns, and a desire to protect the environment.
- While European integration has encouraged Italy to make its energy industry more competitive, at the same time Italy has taken several steps to make its energy use more efficient and less carbon-intensive. This includes progressive electricity tariffs in which households must pay higher tariffs when they consume more electricity, and requirements that electricity producers sell a certain volume of electricity from renewable sources to the grid. Electricity producers also reap benefits when they sell cogenerated electricity to the grid.

Energy Deregulation: Competition in Italy's energy industry has been very limited. Until recently, most of Italy's energy sector was in the hands of state corporations, most notably ENEL and ENI (the state electricity and hydrocarbon companies, respectively). Both companies were transformed into joint stock companies in the early 1990s, and major share blocks were sold in the mid 1990s. Both firms are now primarily privately held. ENEL and ENI were privatized in anticipation of retail competition in the European Union.

European integration has meant that European Union members must open their electricity and energy markets to other member states. In February 1997 and March 1999, the Italian parliament passed new decrees regarding the domestic electricity market. The 1999 decree breaks the state electricity monopoly, ENEL, into generation and distribution companies and introduces competition between providers. In addition to ENEL, there are also municipal electric companies and self-producers in industry; ENEL accounts for over 80% of total power production in Italy.

Before 1999, there was no retail competition although there were laws favoring cogeneration in industry. In fact, until 1991, even companies in the same group could not exchange electricity.[33] "Law 9/91" enacted in 1991 allowed industrial companies and municipal utilities to produce power for their own needs and sell any excess to the national grid.[34] The March 1999 legislative decree regarding the power market opened the way for retail competition. Under this law, no single company will be allowed to produce or import more than 50% of Italy's electricity production or imports. Large consumers will be able to purchase electricity from distributors or wholesalers in Italy or abroad, though smaller consumers will be tied to a single distributor. Entities throughout Europe will have equal access to sell power to the grid or serve as wholesalers. The government will still maintain control of the power grid, though it may sign concessions for operation of it.[35] The 1999 decree also encourages cogeneration and production of renewable energy.[h]

In addition, Italy has been introducing competition into its natural gas and oil sectors. It has sold off large packets of ENI shares, so that now less than 40% of the company is state-owned.[36] The Italian government has also established an Authority for Electricity and Gas that will ensure fair competition and access to the grid in these energy markets.[37] This is a significant innovation because it breaks the energy monopolies' hold on the market.

Environmental Protection: While European competition has been driving Italy's efforts to reform its energy sector, Italy has taken advantage of this situation to introduce environmentally friendly energy policies. Italy's commitment to reduce carbon emissions by at least 6.5% of its 1990 level is helping to crystallize this policy. Italy is committed to increasing its use of renewable energy and natural gas and improving energy efficiency to meet its Kyoto commitments. Table 3 below summarizes Italy's greenhouse gas emission goals.

Table 3: National Actions to Achieve Greenhouse Gas Emission Goals and Associated Emission Reductions (in Mt CO_2)[38]

Action	2002	2006	2008-2012
Increased Efficiency of Electricity Generation	4 to 5	10 to 12	20 to 23
Reduction of Energy Consumption in the Transport Sector	4 to 6	9 to 11	18 to 21
Energy Production from Renewables	4 to 5	7 to 9	18 to 20
Reduction of Energy Consumption in the Industrial, Residential and Service Sectors	6 to 7	12 to 14	24 to 29
Emission Reductions from Non-Energy Sectors	2	7 to 9	15 to 19
CO_2 Absorption by Forests			0.7
Total	20 to 25	45 to 55	95 to 112

[h] The renewable energy clauses of this law are particularly interesting. All companies producing or importing non-renewable power in one year must introduce into the grid in the next year new renewable power equivalent to 2% of the non-renewable power sold in the first year.

Because Italy's energy intensity is already quite low, the task of reducing emissions is even more challenging. Most of the items listed in Table 3 have implementation plans that spell out how Italy will reduce emissions in that area. Renewable energy strategies and goals, for example, are described in the Italian "White Book" on renewable energy.[39] The Ministry of Environment has also signed a voluntary agreement with FIAT on reducing greenhouse gas emissions from cars, an agreement that supports the second action item listed. This was the first voluntary agreement in Italy relating to greenhouse gas emissions. According to the agreement, FIAT cars in 2010 will emit 23% less carbon dioxide per kilometer than the average 1990 models.[40]

Italy has also introduced a series of laws, decrees and regulations in recent years to reduce local atmospheric pollution from fossil fuel combustion. The Italian government first signed a Clean Air Act in 1966, which set guidelines for controlling pollution. Additional regulations and decrees in 1983 and 1988 established the maximum allowable concentrations of certain air pollutants. Italy has made great gains in reducing sulfur dioxide emissions primarily by substituting natural gas for coal. The Ministry of Environment in Italy was established only in 1986; in 1994 Italy established the Environmental Protection Agency, which co-exists with the Ministry. Environmental organizations have grown in strength in Italy over the past decade. The largest of these is Legambiente (Environmental League), a former leader of which is now a prominent parliamentarian.[41]

Environmental laws have actually prompted much of ENEL and ENI's research in recent years. ENEL's research program in 1995, for example, was geared primarily toward reducing emissions or environmental impact and improving conversion efficiency.[42]

Energy Security: Like most OECD nations, Italy faced major energy shortages during the 1970s oil crisis. Since then, Italy has improved its efficiency, reducing import requirements, although it still imports a high percentage of its total energy consumed. This is particularly true for oil and coal (93% and 84% imported, respectively). Italy also imports the majority of its gas.[43] Thirty-one percent of Italy's oil imports comes from Libya, 41% from various countries in the Middle East, 11% from the former Soviet Union and 17% from other countries. Its natural gas imports come from a similar mix of countries, with a slightly higher reliance on the North Sea.[44] Its coal comes primarily from the U.S., Australia and South Africa.[45]

Because of its heavy reliance on energy from the Mediterranean basin, Italy has tried to promote regional cooperation and development with most of its Southern neighbors. This cooperation is through bilateral technical assistance, assistance under the Mediterranean regional sea convention, and commercial contracts for developing regional hydrocarbon resources. While more comprehensive and integrated energy networks in the European Union could help Italy weather short-term supply disruptions, such integration is unlikely to help Italy in long-term supply disruptions; the government has not highlighted this integration as a key component of its long-term energy security policy.[46]

The government and domestic energy companies have also tried to increase domestic energy production. Large gas and oil fields, however, are not always in the most environmentally benign locations. One of Italy's largest domestic natural gas reserves is located in the Northern Adriatic, but because of environmental concerns and the potential subsidence of Venice, the government has decided not to allow gas prospecting in that area. Italy is also promoting renewable energy, cogeneration and energy efficiency to reduce energy imports and the risks these imports entail.

Energy Taxes: Italy's energy taxes are high compared to most other nations. In 1995, Italy levied taxes of up to 76% on gasoline and up to 74% on fuel oil, for example.[47] Taxes are, thus, a key element of Italy's energy policy. High energy taxes promote energy efficiency. This in turn can help reduce energy imports (improving energy security) and reduce energy-related pollution.

Economic Growth: One of the goals of Italy's energy policy is to promote economic growth and create new jobs. Italy's policy for promoting renewable energy, for example, specifically outlines how this policy will improve employment.[48] Job and economic growth are also some of the factors motivating Italy's efforts to reduce energy imports. Likewise, the move toward energy competition is an effort to stimulate economic growth in industry and other sectors.

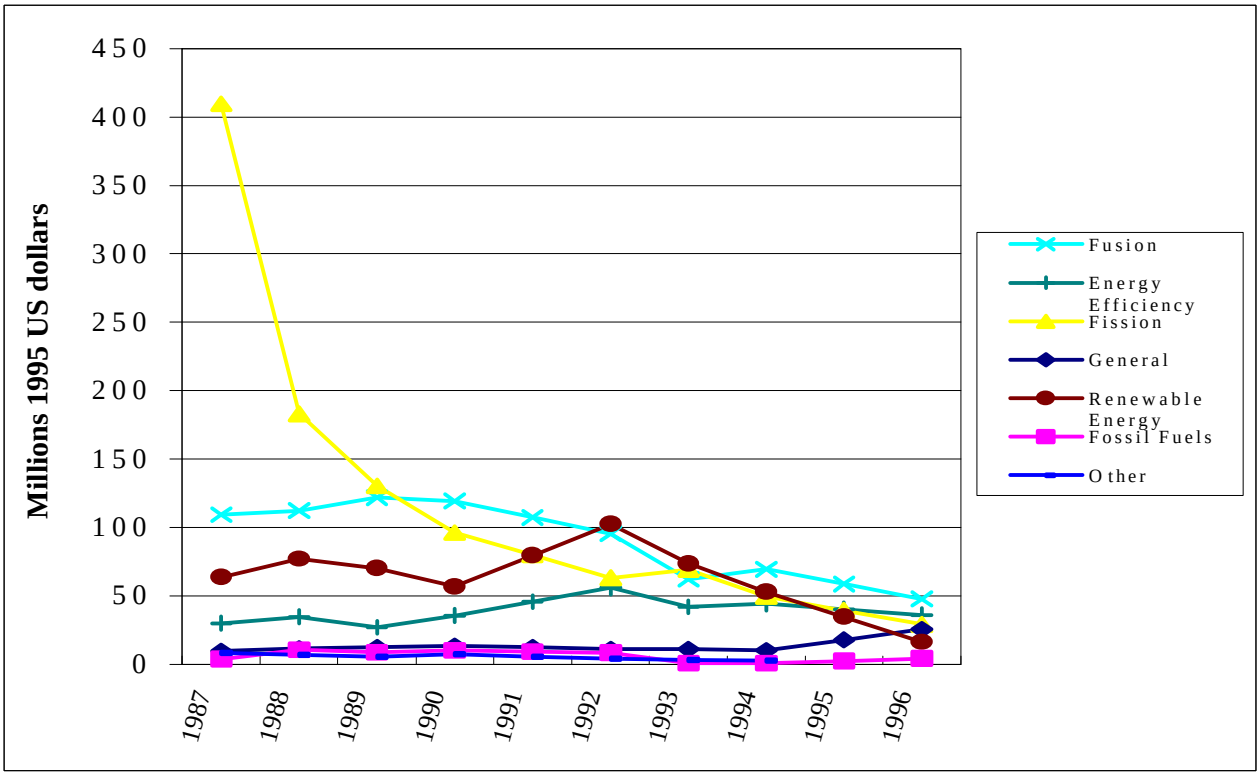
ENERGY R&D PROGRAMS

Italian spending on energy R&D has dropped sharply since the late 1980s. This is a result of several factors, including budget cuts, energy company privatization and economic recession. Government spending on energy R&D has declined by 75% from 1987 to 1996. Even government funding for priority programs, such as renewable energy and energy efficiency, has decreased. Corporate energy R&D has also declined and is not likely to recover soon in terms of volume and long-term focus because of the significant restructuring of the energy sector. Corporations fund over half of Italian energy R&D. The private sector plays a particularly important role in fossil fuel and energy efficiency research.

Government Energy R&D Programs

Italian government support for energy R&D stood at $158 million in 1996.[49] As Figure 5 depicts, Italian public energy R&D has seen a considerable decline since the mid-1980s, falling from $634 million in 1987. Fission has seen greater cuts than other energy sectors, and its funding has been cut by 93% from 1987 to 1996. This decline correlates with Italy's moratorium on nuclear power. Even renewable energy has experienced a 74% cut since 1987. Only general energy research has seen a real increase in R&D spending compared to levels in the late 1980s; as the title indicates, it is difficult to understand exactly how this funding is being spent.

Figure 5: Government Energy R&D by Fuel Type[50,i]



[i] 1991 and 1995 data were extrapolated.

The major energy R&D funding agencies in Italy are the Ministry of Industry, Commerce and Handicraft (MICA), the Ministry for Universities and Scientific and Technological Research (MURST) and the National Institute for Nuclear Physics (INFN) (which is a subset of the National Research Council or CNR). MICA is responsible for setting energy policy, including energy R&D policy. It also provides oversight of all aspects of research at the Agency for New Technologies, Energy and the Environment (ENEA), including its nuclear research funded by the INFN. (ENEA is the main public body conducting energy research.) MURST sets the Italian government's R&D policy as a whole, including energy R&D policy, and funds a large portion of energy R&D. The CNR and ultimately the INFN both report to MURST. Other agencies that play a role in energy R&D include the Ministry of Environment and, to a lesser extent, the Ministry of Agricultural Policy.[51]

The majority of government-sponsored energy R&D in Italy has traditionally been in applied research and experimental development, and only 5% of the R&D budget is used for basic research.[52] This is in part because of the Italian government's desire to fine-tune technologies that are close to commercialization, rather than promote riskier investments earlier in the development cycle. Also, efficiency and renewable energy R&D involve less basic research than other types of energy research in Italy; the Italian government has been shifting its research focus toward energy efficiency and renewables, so it is likely that basic energy research has decreased.

The individual energy research areas are described in more detail below. Nuclear energy is described first because the Italian government spends the largest share of its energy research dollars on nuclear energy, despite its stated policy shift toward developing renewable energy and energy efficiency.

Nuclear Energy R&D *$109.9 million in 1998 (110.0 million ECU)*[53]
Fission *$49.9 million in 1998 (50.0 million ECU)*[54,j]

In a referendum following the Chernobyl accident, Italy decided to place a moratorium on nuclear power. The moratorium covered both power generation and construction of new nuclear power plants from 1988 to 1992, though the government has since extended the policy. Since the referendum, the Italian government has sharply reduced funding of fission research. While there is some discussion of lifting the moratorium, the Italian environmental movement has only grown stronger in the decade since the referendum, and Italy has shown that it can meet its energy needs without nuclear power. Most of Italy's current fission research is focused on decommissioning the existing reactors, nuclear safety and disposing of nuclear waste.[55] The rationale for continuing to fund fission research despite the moratorium is that:

- It is important to keep the option of nuclear energy open for the future, particularly given the risk of climate change.

[j] This funding level is significantly higher than that reported by ISTAT in 1996, although it is very consistent with nuclear energy funding levels from 1994.

- Italy needs to deal with the nuclear waste problem in any event, if only to decommission the existing nuclear power plants.
- Italy must continue to make progress on several advanced technologies, including accelerators, neutron absorbers and subcritical systems to support the competitiveness of Italian companies in the medium-term.
- The competencies required for fission research are also important to meet the rising demand for nuclear physics technologies in a wide range of applications.[56]

The National Institute of Nuclear Physics (INFN) is the main funding source for all types of nuclear energy research in Italy. Oddly, however, INFN does not mention fission or fusion research in its detailed Five-Year Plans for its research activities and operations. The Applied Nuclear Energy Laboratory (LENA), which receives funding from the INFN and from the University of Pavia, has a small experimental reactor. LENA's research topics include nuclear safety and radiation protection.[57]

ENEA also conducts research on nuclear safety, radioactive waste and nuclear plant engineering, including depressurization systems and reactor containment analysis. For example, ENEA is working on a project to identify and assess a national site for nuclear waste disposal. [58] Ansaldo Nucleare and several universities are also involved in Italy's fission research.[59]

Table 4 provides more details on Italy's fission research spending.

Table 4: Italian Spending on Fission R&D in 1998[60,j,k]

Research Program	Mill. 1995 US $
Amplifier Driven System (for waste transmutation)	5
Nuclear Fission Safety Studies	15
Waste Treatment and Decommissioning of Nuclear Plants[l]	30
Total	50

Fusion

$59.9 million in 1998 (60.0 million ECU), of which 25% was a contribution from Euratom[61,j]

Most of the Italian government's expenditures on fusion are made in collaboration with Euratom, the European Union's atomic energy agency. ENEA has been assigned the task of coordinating the Italian part of the European fusion program. ENEA operates three facilities under an agreement with Euratom. The main facility is called the Frascati Research Centre near Rome; the other, smaller facilities are in Brasimone and Bologna.[62] The Frascati Research Centre employs about 600 people to study fusion physics and develop engineering and technologies for an eventual European fusion reactor. Frascati has projects to develop materials resistant to radiation and high temperature; to construct superconducting and low-temperature magnets; to develop fusion reactor engineering;

[k] The numbers in this table represent average annual funding in 1998 and 1999.
[l] Figures for this line item include only funding spent at ENEA laboratories.

and to study the irradiation of materials. The Frascati Research Centre houses one of the main Italian-based fusion experiments. The experiment, called the Frascati Tokamak Upgrade, is a pilot study of plasma streams with high-density radio-frequency waves.

Other important Italian fusion research includes:

- The Reverse Pinch Machine (RFX) experiment, which is the largest experiment in the world of its type on magnetic confinement reactor studies; it aims to put three new systems into operation for optimizing high-stream performance
- Studies on plasma theory
- Research on inertial confinement
- Analyses of new energy from hydrogen and plasma applications
- Collaboration on broader European programs including the Joint European Torus (JET).[63]

Because the European Union will make a decision in the next few years about whether to continue its major fusion programs in their current form, the Italian fusion research program is also in a state of uncertainty. If the European Union decides not to extend the Engineering Design Activities for the International Thermonuclear Experimental Reactor (ITER), Italy will need to reshape its fusion program, though there are currently no plans to do away with it, regardless of what happens.[64]

Energy Efficiency R&D *$36.0 million in 1996 (60.0 billion lire)*[65]

Most Italian R&D for energy efficiency is oriented toward technical demonstrations and solutions for existing facilities rather than the development of new technology. The line between energy efficiency R&D programs and promotion programs is rather fine. Little research in this area seems to be aimed at major, long-term technological advances.

Industrial Energy Efficiency *$13.5 million in 1996 (22.6 billion lire)*[66,m]

MICA is the major public source of funding for industrial energy efficiency research in Italy. Its program concentrates on projects that will improve both energy efficiency and industrial competitiveness. MICA supports research both to improve end-use energy efficiency in industry and to help manufacturers produce more efficient products, such as appliances. Although the latter does not directly affect industrial energy use, the Italian government sees such research as an important means of stimulating industrial competitiveness.

The government's R&D program for end-use industrial energy efficiency focuses primarily on improving the efficiency of small and medium-sized enterprises, although some of the technologies and software developed could be useful in larger plants as well. The rationale is that these companies are less able to fund innovative research on their own, as larger industrial groups might, so they offer an opportunity to save energy that is less frequently tapped by the markets. Italian R&D to improve end-use energy efficiency in industry includes R&D on:

[m] R&D spending information for energy efficiency in industry, transportation and buildings is extrapolated using the total energy efficiency R&D figure compiled by ISTAT and ratios based on EU-SENSER data.

- New process technologies and material process controls, particularly for the production of aluminum, pig iron and other metallurgical products
- Modeling of industrial energy consumption to optimize production cycles and efficiency
- Software packages to help industry quickly select the most efficient technology for an application
- Cogeneration, use of waste fuels and waste heat recovery
- Energy-saving processes for brick and ceramic ovens
- High-efficiency electric motors.[67]

In addition, MICA finances R&D to improve the efficiency of natural gas boilers, turbines, burners, and other energy-consuming equipment in industry.[68]

The Italian government also funds technical assistance to small and medium-sized manufacturers to help them improve their end-use efficiency. While the program does not involve R&D in the traditional sense, it does involve some research for technological adaptations to specific facilities. ENEA coordinates this program through its network of Integrated Energy Consulting Centers.[69]

The majority of industrial energy efficiency R&D in Italy appears to be funded by the private sector. High energy prices compared to other countries provide a strong stimulus for companies to invest in energy efficiency, which in turn drives energy efficiency R&D, at least for incremental improvements.[70]

Energy Efficiency in Buildings *$9.3 million in 1996 (15.5 billion lire)*[71]
The Italian government funds R&D to improve the energy efficiency of both the building envelope and building components. The emphasis is on retrofits because new construction adds only 0.6% to the building stock each year. R&D on the building envelope includes research on insulation systems and advanced controls, while R&D on building components covers refrigerators and other domestic appliances, lighting systems, and HVAC equipment. Research on lighting systems emphasizes the role of daylighting. An important aspect of the refrigerator program is a laboratory called ICELAB that is used to test refrigerator and freezer efficiency and improve refrigerator design. The Italian government is also developing innovative new cooling systems that use adsorption as well as seasonal heat storage using water tanks.[72]

The government also funds research to improve the efficiency of buildings as an integrated system. One such initiative is called "Bioclimatic Architecture." A key component of this initiative is software that allows building designers to easily calculate the energy use of a building and compare the impacts of various high-efficiency technologies.[73] ENEA has built a bio-climatic building in Ispra to house ENEA staff. R&D is also conducted on improving energy efficiency in large public buildings such as schools and hospitals.[74] A related initiative is the "10,000 Photovoltaic Roofs" program, discussed in more detail in the photovoltaic section. "10,000 Photovoltaic Roofs " promotes sustainable building practices that incorporate photovoltaics as an energy source.

Transportation Energy Efficiency *$13.2 million in 1996 (22.0 billion lire)*[75]
Transportation is the fastest growing sector of Italian energy demand, increasing 135% from 1971 to 1993.[76] Because this growth has often been in relatively inefficient modes and infrastructure (cars and roads), the Italian government feels that there is room for energy and carbon reductions in this sector. Italy plans to achieve over 18% of its GHG emission reductions required under Kyoto through energy efficiency in the transportation sector.[77] Most of these reductions will be through reductions in energy consumption of the vehicle fleet on the roads, introduction of biofuels and better management and design of traffic systems.[78] The focus of Italy's publicly funded transportation R&D is on urban transportation systems.

ENEA has researched better designs of transportation systems and integrated traffic management as a means of saving energy. Some of ENEA's projects in this area include research on Mobility Managers, car sharing, environmentally sustainable mobility planning, and a low environmental impact fleet of public transportation vehicles. The Ministry of Environment provides the majority of funding for this research.[79]

The Italian Ministry of Industry also supports transportation R&D. ENEA is also conducting research for MICA on new generation electric and hybrid vehicles, and on innovative electric battery systems for cars.[80] Another area of focus has been the development of innovative batteries for electric vehicles, particularly lithium batteries. ENEA and several universities conduct this research. ENEA is setting up a test station for electric and hybrid vehicles. The MICA has also funded research aimed at introducing hybrid buses for transportation in three Italian cities.[81]

Alsaldo Ricerche, a private Italian company, has also conducted significant research in the transportation energy sector, including research on electric, hybrid and hydrogen-fueled vehicles. Ansaldo has also set up a joint venture with Iveco, an Italian bus and truck maker, to develop and field-test hybrid buses.[82]

Renewable Energy R&D *$16.3 million in 1996 (27 billion lire)*
Italian government documents have placed increasing emphasis on renewable energy R&D in recent years, though funding levels do not necessarily reflect this yet. In fact, funding levels decreased in real terms from $102 million in 1992 (or 144 billion lire) to $16 million in 1996.[83]

In April 1999, MICA released its renewable energy strategy, called the "White Paper," as Italy's response to the EU White Paper on renewable energy. Italy plans to double its production of energy from renewable sources by 2012, adding over 7,000 MW of renewable power generation capacity and additional heat production capacity.[84] While meeting this goal will primarily involve deployment of existing technology, the White Paper also lays out priorities for renewable energy research necessary to meet emission reduction goals under the Kyoto Protocol both in the short and long term. The R&D strategy puts heavy emphasis on technologies that are close to commercialization, which is necessary because of the short time frame. Photovoltaics, biomass and solar energy storage are all priority areas; National Research Programs with special funding are being

established for each of these technology areas.[85] Table 5 summarizes Italian public and private R&D spending on renewable energy R&D.

Table 5: Italian Spending on Renewable Energy R&D in 1996 (in Mill. 1995 USD)[86]

R&D Program	Public	Private	Total
Photovoltaics	7.8	11.4	19.2
Solar Thermal[n]	0.4	--	0.4
Wind	4.1	24.9	29.0
Biomass[o]	4.0	3.3	7.3
Hydroelectric	0.0	13.5	13.5
Geothermal	0.0	1.0	1.0
Total	16.3	54.1	70.4

Photovoltaics *$7.8 million (13.0 billion lire in 1996)*[87]

Given Italy's bounty of sunshine, particularly in the South, it is no surprise that the Italian government has chosen to develop solar energy technologies. According to a European Union study, Italy funds a quarter of all photovoltaic research occurring in European Union countries.[88] The Italian government sees photovoltaics as a key part of its renewable energy strategy, including its renewable R&D strategy. The government has launched a program called "10,000 Photovoltaic Roofs," the goal of which is to install 10,000 photovoltaic facilities with public or private funds by 2003. These facilities will have a total power capacity of 50 MW. The Italian government will provide economic incentives for individuals or organizations that participate.[89] Italian photovoltaic research focuses on:

- Integrating photovoltaics into buildings by creating thin films that can be installed over a wide area
- Bringing costs of photovoltaic technologies down, for example by developing innovative processes to fabricate polycrystalline silicon cells and modules
- Applying photovoltaics to several niche applications, such as street lighting and telecommunications installations.

ENEA has a major photovoltaic research facility in Portici. It is called the Experimental Area of Monte Aquilone; its 70 full-time staff experiment on and demonstrate small and medium-sized photovoltaic installations. This facility is linked to the power grid. Besides ENEA, other organizations involved in photovoltaic research in Italy include universities, industry and laboratories of the CNR.[90]

[n] The public photovoltaic and solar thermal numbers are extrapolated based on ISTAT, ENEA and EU data: official Italian statistics combine these two areas into one line item. Moreover, private data for solar thermal R&D were not available; anecdotal evidence indicates that private spending in this area is small.
[o] The public biomass numbers listed here include a very small portion of funding spent on hydro and wave research. Italian statistics aggregate these three categories.

The government's long-term photovoltaic research goals include developing new photovoltaicly active materials, engineering new conversion devices and reducing the costs of conventional photovoltaic components.[91]

Solar Thermal Energy *$0.7 million in 1998 at ENEA (1.2 billion lire)*[92]
The Italian government is also trying to expand Italy's use of solar thermal energy. The government has launched a major incentive program called "The Solarized Town Hall," the goal of which is to install 70,000 cubic meters of solar panels on public buildings by modifying local building codes to encourage renewable energy.[93] However, Italy's solar thermal research program is small compared to its other renewable energy R&D programs. The foci of this program are technology deployment and development of lower-cost materials. The single largest R&D expenditure in Italy in this field is a laboratory that ENEA is setting up to test solar thermal panels.[94]

Solar Energy Storage[p]
Solar energy storage has recently been declared one of the Italian government's top renewable energy R&D priorities. The government is dedicating special funding to this area and including it in the list of National Research Programs. The rationale is that Italy cannot fully capture its solar energy potential unless it finds a way to store this intermittent energy source. The main lines of research in this area are:

- Storage of seasonal solar thermal energy in large underground tanks
- Stand-alone photovoltaic energy storage system using hydrogen
- Balancing of renewable energy power loads from various sources to ease the problem of intermittent renewable power (primarily solar power)
- Storage of intermittent renewable power.[95]

Storage technologies that Italy is researching include hydrogen and large-to-medium scale superconducting energy storage systems.[96]

Biomass Energy *$4.3 million appropriated in 1999 (8 billion lire)*[97]
Biomass is the third renewable energy field in which the Italian government is establishing a National Research Program, and, in addition, Italy has launched a National Program on Renewable Energy from Biomass, which deals with promoting biomass more generally. The focus of this National Program is to develop new genetic varieties of plants that will maximize the yield of combustible matter (harvest index). This will help reduce the cost of generating energy with biomass. Particular attention will be given to the following technical areas:

- Chlorophyll photosynthesis and processes to transport and store the products of photosynthesis
- The capacity of plants to produce in marginal terrain and in adverse environmental conditions[98]

[p] Public spending on solar energy storage R&D is likely under $1 million. More specific data were not available.

- Criteria or technical norms for characterizing biomass fuels for energy production
- Industrial technologies for energy conversion.[99]

Public spending for biomass R&D in Italy (including EU allocations) will be $4.3 million (8 billion lire) in 1999, rising to $6.5 million (12 billion lire) in 2003. The total spending for this period will be the equivalent of $26 million.[100]

The Italian government's biomass research program began in 1993, although components of the research began earlier.[101] Research to date has focused on converting biomass into energy and biomass cultivation. Conversion technologies on which Italy has conducted research include fluidized-bed gasification, flash pyrolysis of bio-fuels, and biotransformation of cellulose in ethyl alcohol.[102] The government's PRISCA and Energy Cultivation programs, on the other hand, focus on biomass cultivation and genetic engineering. The Ministry of Agriculture Policy funds PRISCA, and ENEL supports Energy Cultivation. Together, these programs have developed new species, varieties and techniques for biomass cultivation.[103]

Wind Energy *$4.1 million in 1996 (6.8 billion lire)*[104]

The governmental wind energy R&D program focuses on commercialization of technologies, certification of wind energy products, and assessment of wind energy resources. It is relatively small compared to other publicly funded renewable energy R&D in Italy. This is because wind is an intermittent energy source and wind resources are not great compared with Italy's solar energy potential.[105] Moreover, because Italy has not traditionally been very active in wind energy R&D on an international scale, it does not have the same research capabilities in this field as the global leaders. Nonetheless, the Italian government plans to increase Italy's wind power generation capacity from 119 to 2,500 MW by 2012.[106] Italy's major wind energy programs involve developing wind farms in Apulia and Sicily, both in the South where the wind resources are greatest.[107] Public-sector wind R&D focuses on integrating wind energy in the national power grid and assessing wind potential and environmental impacts.[108] Italy's private-sector wind R&D program actually appears to be larger than its public-sector program. Riva Calzoni is the largest windmill manufacturer in Italy and it produces 330 kw single blade wind turbines for domestic use and export. WEST, a subsidiary of Ansaldo, also produces several types of small and large wind turbines. The original research for these turbines was conducted for ENEL in partnership with ENEA.[109]

Geothermal Energy *Public spending is close to zero*

Italy is one of the largest producers of geothermal energy in the world with an installed geothermal capacity of 550 MW in 1997.[110] Most geothermal research in Italy is privately funded; only 1% is government supported. ENEL is the major funder of geothermal research. Italian geothermal equipment producers also fund research; Italy is an important supplier of such equipment to developing countries. According to an assessment of world geothermal power production, Italy spent $260 million on geothermal R&D from 1985-1995.[111] In 1998, ENEL spent approximately 5 billion lire, or $2.7 million, on geothermal research.[112] Geothermal energy is not listed as a priority area for renewable energy R&D in the Italian government's strategic plan for renewables,

called the "White Book." This is most likely because geothermal energy costs in Italy are at or near commercial levels.[113] One of the largest Italian geothermal research organizations is the International Institute for Geothermal Research, which focuses on practical assessments of geothermal systems and resources.[114]

Fossil Energy R&D *$4.1 million in 1996 (6.9 billion lire)*[115]

Because of Italy's high reliance on imported fossil fuels and the environmental impact of burning these fuels, the Italian government is not making a significant effort to increase their use through new technology.[116] Government funding for fossil fuel research is limited as a result.

Combustion Efficiency

ENEA and the Institute on Combustion Research in Naples are the main publicly funded Italian research organizations in this field. MICA provides most of the funding for this work. MURST also finances specific projects, particularly in the areas of modelling, simulation and calculation--all areas in which Italy has notable expertise. The main objectives of the combustion efficiency research are to increase energy efficiency, decrease emissions and allow for a wider range of non-traditional fuel types. Specific areas of research include cogeneration, combined cycle power generation equipment, new diagnostic equipment, models to simulate flame structure and combustion processes, and more efficient combustion equipment components including burners, post-combustors and boiler drums. The Institute on Combustion Research also conducts research on combustion and control equipment to reduce emissions. Italy conducts significant research on efficient gas turbines, but most of this work is funded by the private sector. For example, Italy is working on new aeroderivative gas turbines with new blade structures that are 10% more thermally efficient than current turbines.[117]

Oil and Natural Gas

The majority of Italian spending on oil and natural gas R&D is in the private sector. ENI is the largest organization in Italy funding research in this area; ENI's research is described in more detail below. The publicly funded R&D on fossil fuels focuses on ways to use natural gas more efficiently and to reduce emissions from oil combustion. The Italian government also finances some research on oil and gas exploration and development.

Coal

The Italian government has eliminated its research programs on coal extraction and clean coal because of public opposition to coal-fired power plants and Italy's small and poor-quality domestic supply of coal.[118]

Fuel Cell R&D *$6.1 million in 1998 (11.2 billion lire)*[119,q]

Italy has a robust national fuel cell program coordinated by ENEA. The program has created a fully operational 1.3 MW fuel cell power plant in Milan. The plant runs on natural gas, which is processed on-site to create a hydrogen-rich gas for the fuel cells.

[q] This number includes both government and industry investments and is a calculated average of spending from 1994-98.

The size of the plant, the largest in Europe, was selected because it will provide useful experience for the future development of both larger and smaller facilities. The project is a result of collaboration between ENEA, the Municipal Energy Company of Milan (AEM) and Ansaldo Ricerche in Genoa.[120]

Since 1994, the Italian fuel cell program has concentrated primarily on developing two types of fuel cells: molten carbonate and polymer exchange membrane fuel cells (MCFC and PEM, respectively). From 1990-1994, the Italian government invested 40 billion lire (approximately $22 million) in fuel cell R&D, the greatest portion of which was spent on phosphoric acid fuel cell (PAFC) technology to build the Milan power plant, though the PAFC program has declined since then. Table 6 provides more details on Italian expenditures for fuel cell R&D.

Table 6: Total Expenditures on Fuel Cell R&D from 1994-98[121,r]

Fuel Cell Technology	**Expenditures (in billion lire)**
Phosphoric Acid Fuel Cells	5
Polymer Exchange Membrane Fuel Cells	20
Molten Carbonate Fuel Cells	30
Solid Oxide Fuel Cells	<1
Total	56

The PEM program has involved close collaboration between government and industry since 1990. Italy has conducted unique research in ways to reduce the immobilized cost of the catalyzer, and to use hydrogen and methanol as fuels.[122] The program for 2000-2004 will involve close cooperation between government, and the fuel cell, automobile and oil industries with the objective of developing a fuel cell vehicle by 2004. (The goal for 2005-2009 will be to commercialize this vehicle.) Several fuel options will be considered, including traditional fuels as well as hydrogen and methanol. The budget request for 2000-2004 is approximately $108.5 million (200 billion lire).

The MCFC program also has involved close industry collaboration. Under this program, The Italian government has developed MCFC stacks with capacities up to 100 kw. Italy has also increased the MCFC stack life and simplified the fabrication process. The main goal of the next five-year period will be to develop stacks with capacities up to 500 kw; the technology would be commercialized by 2008. The budget request for this work ranges from $5.4 to 24.4 million (10 to 45 billion lire) per year for the next five years.[123]

Italian corporations have collaborated on and cost-shared much of this R&D. DeNora and Ansaldo have formed partnerships to work on several EU and Italian government projects. ENI has an alliance with Siemens to develop solid oxide fuel cells; ENI's role focuses on developing internal gas reformers.[124]

[r] Expenditures were divided approximately equally in each of the five years included.

Corporate Energy R&D Programs

Most Italian energy R&D is financed by corporations. Corporate energy R&D expenditures in 1996 equaled $392.9 million. In 1996, corporations funded 78% of total energy R&D.[125] Electricity companies and turbine manufacturers account for the largest share of this R&D. This section will cover general corporate energy R&D trends and will provide a more in-depth look at the R&D programs of Italy's largest energy companies.

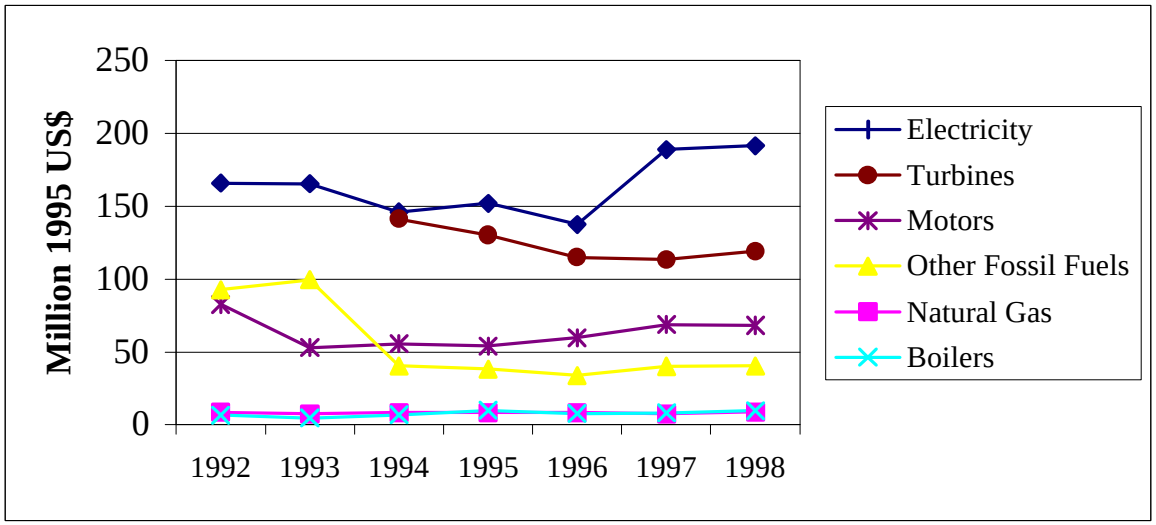
Corporate energy R&D spending declined even faster than government energy R&D expenditures in the first half of the 1990s, but its level has been recovering in recent years. There are two main factors behind this trend. The first factor is the privatization of several large state-owned energy companies in preparation for competition. As energy companies were privatized, they reduced their R&D expenditures to improve their balance sheets. Private companies in a competitive energy market also may have less incentive to spend their resources on R&D than do state-owned monopolies.[126] The second factor is the decline in the Italian economy in the early and mid 1990s. With the recession over, corporate R&D has begun to increase.

Italian energy companies typically spend a large portion of their R&D funding outside of Italy. It is important to note, however, that during the early 1990s, Italian companies decreased their spending on energy R&D abroad at a faster rate than they decreased this spending within Italy.

Figure 6 describes the relative concentration of corporate energy R&D in different economic activities. The majority of Italian corporate energy R&D relates to electricity production and turbine manufacturing. Italian companies have captured 4-5% of the world turbine market, so they are interested in funding technological improvements to maintain their competitive edge.[127]

Italian corporate R&D statistics are broken out not only by economic area, but also by company ownership (state or private), as well as by product and stage of research. When considering electricity, for example, almost all the R&D from 1992-94 was conducted by state-owned companies (primarily ENEL). This trend holds true for natural gas production and distribution, and to a lesser extent, to the petroleum and coal industries. Turbine and power plant manufacturers also fund a large share of private energy R&D. In recent years, however, Italian orders for new power plants have been very limited due to the slow growth in energy demand. A large share of turbine sales is to developing markets in the Middle and Far East.[128] The European Union has also calculated some figures for corporate R&D spending by socio-economic objective. These data indicate that energy efficiency and fossil energy receive the overwhelming majority of Italian corporate energy R&D funding.[129]

Figure 6: Italian Intramural Corporate Energy R&D by Economic Activity[130,s]



The two largest private-sector funders of energy R&D in Italy are ENEL and ENI; descriptions of their research activities follow. Other major companies involved in energy research include Centro Sviluppo Materiali (Center for Material Development), Ansaldo Ricerche and Centro Elettrotecnico Sperimentale Italiano G. Motta (G. Motta Italian Electrotechnical Experimentation Center). Centro Sviluppo Materiali focuses on research for the steel industry, and has seen a major drop in revenue with privatization in the steel sector. Ansaldo Ricerche is a division of Ansaldo, which is a major electromechanical engineering group.[131]

ENEL *$222.6 million in 1996 (370 billion lire)*[132]

ENEL has traditionally been one of the largest funders of energy R&D in Italy. Prior to privatization, it owned a large research network with numerous laboratories throughout Italy, but assets and expenditures have been reduced following privatization. ENEL produced a detailed report on its R&D activities and assets in 1995, ironically, to showcase them to potential equity investors in ENEL's stock offering.[133] ENEL's research focused on the following sectors:

- Thermoelectric generation technologies
- Electric power technologies and hydraulic engineering
- Geothermal power

[s] The numbers in this figure include government allocations for R&D to corporations. Government allocations have typically been under 10% of total corporate R&D for the economic activities listed. These numbers are for spending within Italy only. Italian energy companies generally spend a significant portion of their R&D budgets outside of Italy. The categories given are for economic activity and, as such, cover all domestic R&D expenses of companies in that economic category. The full titles of the categories given are production and distribution of electricity; production and distribution of gas; extraction of solid liquid and gaseous fossil fuels and the petroleum industry; construction of boilers and tanks; construction of motors, generators, transformers and other electrical materials; and construction of turbines, pumps, compressors, valves, faucets, etc.

- New renewable sources
- Environment.

It appears that the largest investments went into technologies to reduce emissions, such as sulfur dioxide, from fossil-fired power plants. ENEL writes in its 1995 research report, "An increased awareness of environmental protection and the enforcement of severe regulations on plant emissions have motivated ENEL's R&D Department to focus its efforts toward combustion optimization and emission controls."[134] A few specific research projects of particular note include advanced methodologies and modeling to improve power plant efficiency, development of molten carbonate fuel cells, development and commercial demonstration of several renewable energy technologies (geothermal, biomass gasification and pyrolysis, wind and photovoltaics) and studies of climatic changes caused by greenhouse gases. In 1997, ENEL employed 1,400 researchers and technicians and spent $211 million (370 billion lire) on R&D; by 1998 these numbers were down to 1,300 staff and $176 million (325 billion lire).[135]

Since privatization began in 1992, ENEL has divested many of its research holdings. For example, it has recently sold a renewable energy laboratory to the Politecnico di Milano (Milan Polytechnical Institute). ENEL has also sharply decreased its investments in those facilities that it has retained.

ENI *$244.0 million in 1998 (450 billion lire)*[136]

ENI is the leading Italian oil and gas company, and Italy's largest industrial company. It is a holding company made up of units for oil production and refining (Agip), natural gas production and distribution (Snam), and others. As shown in Table 7, ENI spent $405 million on R&D in 1993 and only $244 million in 1998.

Table 7: ENI R&D Expenditures and Staff, 1993-98[137]

Year	Expenditures (in million $)	Expenditures (in billion lire)	Research Staff
1993	405	592	3268
1994	320	484	2860
1995	264	419	2118
1996	257	429	1996
1997	271	475	1998
1998	244	450	1858

Privatization is an important factor in these budget cuts; ENI now tends to concentrate on research with short-term returns and relatively low risk. In recent years, ENI has spent 49% of its research budget on energy and hydrocarbons, 41% on chemicals and 6% on environmental controls. Research on chemicals used to receive the majority of ENI's R&D budget, but the focus has shifted toward ENI's core oil and gas business in recent years.[138]

One of ENI's companies is called EniTecnologie, which coordinates the R&D conducted for the ENI group. EniTecnologie has laboratories near Milan and Rome, and scientific

observatories in New York and Tokyo, as well as a network of smaller R&D facilities throughout Italy. ENI's main research goals currently are to optimize production cycles, improve product quality and develop technologies to reduce its environmental impact.[139]

Box 1: ENI's Principal Areas of Research in 1998[140]

Reduction of exploration and development costs
- High resolution prospecting techniques
- Field simulation models (*)
- Field productivity enhancement methods (*)
- Advanced drilling systems
- Deep water technology (*)

Process performance and product differentiation
- Advanced process control
- Innovative polymerization catalysis (*)

Feedstock enhancement
- Long distance gas lines (*)
- Conversion of gas into liquid products (*)
- Conversion of heavy crudes into light products (*)

Environmental protection
- New formulas for fuels and lubricants (*)
- "Clean" catalytic processes (*)
- Air quality monitoring (*)
- Reclaiming of polluted soil (*)

(*) Project financed by ENI's intercompany research fund.

Appendix 1: The Italian State Research Network

The Ministry for Universities and Scientific and Technological Research (MURST) defines the Italian government's overall research and technology policy. It provides universities with General University Funds, and it funds research projects supporting most major socioeconomic objectives. The National Research Council (CNR) is the single largest R&D funding agency in Italy. It is responsible for a large network of research institutes and laboratories throughout the country, and it also sponsors individual projects in energy and environment.[141] Other ministries provide additional research funding in specific areas such as health or transportation. The Ministry of Industry, Commerce and Handicraft (MICA) funds energy research, particularly research on energy efficiency, renewables, and oil and gas exploration. The Agency for New Technologies, Energy and the Environment (ENEA) reports to the Ministry of Industry and conducts a large percentage of Italy's energy R&D. ENEA receives money both from contracts and from direct line items in the Italian budget. A final body worth noting here is the National Institute for Nuclear Physics (INFN) which funds nuclear physics research throughout Italy and runs several prestigious national laboratories in this field. Most INFN funding is for basic research.[142] Table 8 provides information on Italian R&D allocations by funding agency.

Table 8: R&D Budgets of Key Italian Public-Sector Organizations, 1996[143]

Organization or Organization Type	Funding	
	Bill. 1995 US$	**% of total Italian R&D**
Public Administration	**6.58**	**49.7**
State Administration (government agencies)	1.10	8.3
Universities	2.81	21.2
National Research Council (CNR)	0.77	5.8
Agency for New Technologies, Energy and the Environment (ENEA)	0.37	2.8
National Institute for Nuclear Physics (INFN)	0.29	2.2
Other public research bodies	0.61	4.6
Italian Space Agency (ASI)	0.57	4.3
Regions	0.06	0.2
State-Owned Companies	**1.79**	**13.5**
National Electricity Company (ENEL)	0.22	1.7
Companies with state ownership	1.56	11.8
Total Italian R&D[t]	**13.25**	**100.0**

[t] The total given is the total for all of Italy, including private companies. Thus the other lines will not add up to the total given. The percentage of the public share of R&D expenses provided earlier differs somewhat from the total for all R&D funded by the government or companies with government ownership. This is because some companies with government ownership are not considered public sector if the government's ownership share is small.

Appendix 2: Note on Italy's System of Higher Education

Italy's system of higher education differs somewhat from systems in other countries and this difference likely has an impact on the research conducted at Italian universities and institutes. In Italy, universities are open for all at the undergraduate level, so numerous students attend but completion rates are somewhat lower than in other industrialized countries.[144] The competition for spaces and scholarships to enter graduate school is intense. Students often continue working with their undergraduate advisor in graduate school as a means of increasing their chances of acceptance. After receiving their Ph.D's, many Italian doctoral students remain in the same institutions in which they received their degrees, often, once again, working with a key advisor. This system has advantages in terms of continuity and academic concentration, but it does limit researchers' abilities to associate with other researchers and build on new ideas. An international review of the National Institute for Nuclear Physics (INFN) identified these limited opportunities for young researchers to make new contacts as the single greatest flaw in the INFN system.[145] As noted earlier, MURST and the CNR have both recently instituted major organizational changes in their research and educational systems to increase the effectiveness of Italian R&D.

Appendix 3: List of Frequently-Used Acronyms

CO_2	Carbon Dioxide
CNR	National Research Council
ENEA	Agency for New Technologies, Energy and Environment
ENEL	National Electric Company
ENI	National Hydrocarbon Company
INFN	National Institute for Nuclear Physics
ISRSD	Italian Institute for Studies on Scientific Research and Documentation
ISTAT	National Statistics Institute
MICA	Ministry of Industry, Commerce and Handicraft
MURST	Ministry of Universities and of Scientific and Technological Research
R&D	Research and Development
S&T	Science and Technology

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