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Nuclear Energy and Science Policy in Post-war Italy*

Pre-war Roots

The first Italian researcher to mention the possibility of producing energy by breaking atomic nuclei was Enrico Fermi:

> This relationship between mass and energy doubtlessly implies great numbers. As an example, if we could free up the energy contained in 1 gram of material, we would generate more energy than the amount produced by a 1000 HP motor working flat out for three years. It may be stated, quite reasonably, that at least in the near future it does not seem likely that we shall find a way to free up these vast quantities of energy. Indeed, this is something we should hope for, because the first thing that the explosion of such a vast quantity of energy would do is blow to smithereens the physicist who had the misfortune to discover the way of producing it.[1]

Fermi was appointed as professor of theoretical physics at the University of Rome in 1926. Backed by Orso Mario Corbino, who was at that time Director of the University's Physics Institute, in 1927 and 1928 he assembled a group of young and brilliant researchers.[2] These were mostly graduating students (Emilio Segrè, Edoardo Amaldi,

* The first part of this paper has benefited from some findings in the Marconi Archives, which occurred during a Byrne-Bussey Marconi Fellowship I was awarded in the Spring 2016 for research on the relationship of Marconi with Italy.

1 Enrico Fermi, "Nota", in August Kopff, *Fondamenti della relatività einsteiniana* (Milano: Hoepli, 1923). Translations are mine unless otherwise indicated.

2 On Enrico Fermi: Francesco Cordella, Alberto De Gregorio, and Fabio Sebastiani, *Enrico Fermi. Gli anni italiani* (Roma: Editori Riuniti, 2001); Giulio Maltese, *Enrico Fermi in America. Una biografia scientifica* (Bologna: Zanichelli, 2003); Maltese, *Il Papa e l'Inquisitore. Enrico Fermi, Ettore Majorana, via Panisperna* (Bologna: Zanichelli, 2010). On the history of the Physics Institute: Giovanni Battimelli and Maria Grazia Ianniello, *Fermi e dintorni. Due secoli di fisica a Roma (1748-1960)* (Milano: Mondadori, 2013); Giovanni Battimelli, *L'eredità di Fermi. Storia fotografica dal 1927 al 1959 dagli archivi di Edoardo*

Ettore Majorana, and, later on, Bruno Pontecorvo), with the exception of Franco Rasetti, who was Corbino's assistant, and would become professor of spectroscopy in 1930, and Oscar D'Agostino, postgraduate scholar in radiochemistry, who joined the group in 1934.

Corbino was aware of the state of relative backwardness suffered by physics in Italy. While maintaining experimental activity on a decent level, with peaks of recognized international prestige, Italian physicists were still lacking momentum in research on theoretical models related to the structure of matter, which in those years had led elsewhere to the birth of the new physics of relativity and quanta. Around the mid-1920s, Corbino's influential position as senator, and twice a cabinet member, enabled him to transform the Physics Institute in Rome into a center where the new physics would be properly cultivated and taught. The appointment of Fermi was a milestone on this path. Fermi and Corbino worked together to bring the Institute to the level of the best research centers of the time. The Rome Institute, hitherto a peripheral element in the landscape of European physics, became in a few years one of the centers carrying out groundbreaking research in the new field at an international level. It is not surprising, in this perspective, that Rome would host the first International Congress of Nuclear Physics, in September 1931.

In January 1934, Irène Curie and Frédéric Joliot-Curie announced the discovery of artificial radioactivity. Fermi immediately decided to try to produce new radioactive elements by using neutron sources, rather than the alpha particles utilized by French physicists. They were, however, very expensive, well beyond the means of a single Italian university institute, even a well-financed one, as the Rome Institute was by Italian standards. Once again, Corbino's foresight proved of invaluable help. In November 1920, soon after his appointment as senator, he had been part of a commission for the study of Italian mining resources and the unification of mining laws. In this capacity, he had taken an active interest in the search for a supply of natural radioactive substances, which were rare and expensive, and also valuable for research. He was aware of their potential medical use and of their intrinsic interest, as sources of radiation, for experiments in fundamental physics. He was determined not to let Italian physicists – first of all the Institute in Rome – be cut off from groundbreaking research due to the scarcity of such resources.

During his term as Minister for the Economy, Corbino established a special office for the supply of radioactive substances. The Radium Office (as it was then called) was located in the rooms of the Physics Institute of the University of Rome, and was directed

Amaldi (Roma: Editori Riuniti, 2003). On Corbino: Battimelli, *Orso Mario Corbino*, in *Enciclopedia Italiana*, VIII appendice, *Il contributo italiano alla storia del pensiero* (Roma: Istituto della Enciclopedia Italiana, 2013), 659-63.

by Corbino's former assistant Giulio Cesare Trabacchi. When Corbino resigned from the cabinet in 1924, the growing importance of radioactive substances for medical use motivated a transfer of the Radium Office from the Economy Ministry to the Interior Ministry, which was at that time in charge of Public Health. In 1925, the Office was renamed the Physical Laboratory of Public Health. Its director was still Trabacchi, and its location was still at the Physics Institute of the University of Rome. In fact, it was under Corbino's control from its inception to the mid-1930s, when it relocated to become part of the newly founded Public Health Institute,[3] and even then, it kept a privileged association with the work of the Physics Institute.

When in need of expensive equipment, beyond their ordinary means, the physicists in the Institute eagerly called for Trabacchi's help, whom they nicknamed the "Divine Providence". This is what they did in 1934. As soon as they had access to neutron sources, in the Spring of 1934, Fermi and his group started the systematic targeting of the elements in the periodic table, by ascending order of atomic number. D'Agostino worked on the chemical separation and identification of the resulting radionuclides, in itself an important part of the process. The results were soon published as a series of letters to *La Ricerca Scientifica*, the newly started journal of the Italian Consiglio Nazionale delle Ricerche (CNR). Abstracts were immediately circulated to pre-eminent international nuclear physicists, and their significance was widely recognized. The most important discovery, however, was the unexpected result of increased effectiveness of neutrons in producing artificial radioactivity, when slowed by hydrogenated substances. This came in October, and Corbino, who immediately realized its applicative potential in both the energy and medical fields, pressed the group to patent the process, and to extend internationally the patent, issued in October 1934.[4]

Corbino did not take part personally in this research. He did not have the time nor, at that point, the expertise needed to work actively in the new field. It is clear that, in terms of scientific results, all the credit for the prestige that came in those years to what became known as the "Via Panisperna Institute" goes to the exceptional qualities of Fermi and his group. However, a number of academic, financial, and organizational conditions had to be met, to let their creative potential unfold effectively. This is where

3 With the support of the Rockefeller Foundation, the Public Health Institute was created in 1934 and located in a new and well-equipped building. This was just outside the newly built "Città Universitaria", the university campus designed by Marcello Piacentini and inaugurated in 1935, where a new Physics Institute was also being built. Both the Physics Institute and the Physical Laboratory were relocated in 1937. In fact, even after the relocation they kept their de facto association and were at a few minutes walking distance.

4 Edoardo Amaldi, "Personal Notes on Neutron Work in Rome in the '30s and Post-War European Collaboration in High Energy Physics", in *History of Twentieth Century Physics*, ed. Charles Wiener (Cambridge, MA: Academic Press, 1977), 293-351; Amaldi, "From the Discovery of Neutron to the Discovery of Nuclear Fission", in *Physics Report* 111, no. 1-4 (1979): 1-332.

the influence of the ubiquitous Corbino proved decisive. His vision was not limited to the identification of Fermi as a trump card: he fully understood the importance and profound meaning of the new developments in physics. His speech of September 1929 on the tasks of new experimental physics, at the annual congress of the Italian Society for the Advancement of Science, gained wide resonance in the national community as a manifesto for research on the properties of the atomic nucleus, where the topic of nuclear energy also surfaced.

Coming from Corbino, one should not regard it as a casual remark. Early in his career, the passion for electricity and its uses, in energy and communications, had driven him toward industry-related leading circles. In 1910, he had entered the board of directors of the electricity company recently founded in Rome by the local council. By 1929, he was board member in prominent electricity and telephone companies (including major players like Edison and Società Meridionale di Elettricità, SME). In a few years, he would join the board of banks of national interest, and be the prominent technical consultant in the restructuring of electricity, telephone, and radio-broadcasting companies, in the aftermath of the 1929 crisis. Corbino effectively exploited his position as a state technocrat and a leading member of the industrial establishment to expand his academic project for the development of physics in Italy. Throughout his whole life, he supported a close relationship between fundamental research and industrial development. This vision was a substantial part of his legacy.

From Survival to "Reconstruction"

Research in nuclear physics underwent significant changes in the mid-1930s, with the introduction of the new early particle accelerators. To keep their lead, the group in Rome had to upgrade their experimental equipment. In 1936, Corbino and Fermi started drawing up plans to establish a facility equipped with a particle accelerator: once more, association with the Public Health Institute would prove instrumental, providing room and the money to build a Cockroft-Walton accelerator. However, Fermi wanted a cyclotron, the new type of particle accelerator that Ernest Lawrence was developing in Berkeley. Early in 1937, Corbino died of pneumonia. Antonino Lo Surdo, a prominent researcher in Geophysics, but not particularly close to Fermi, succeeded him as director of the Physics Institute. In July, a heart attack took away Guglielmo Marconi, who had also been, thanks to Corbino, an influential sponsor of the Rome Institute, soon renamed after him. Fermi was formally told that adequate funding would not be granted; in addition, since his wife Laura was Jewish, his family was directly affected by the anti-Semitic legislation passed by the Italian government in

1938. When he was awarded the Nobel Prize for Physics, later that year, Fermi knew he no longer had reasonable prospects for scientific work in Italy, and decided that his journey to Stockholm should be one-way.[5]

The Fermi group vanished: Majorana had mysteriously disappeared in 1938; Segrè and Pontecorvo, both Jews, emigrated, and so did Rasetti, weary of the Fascist regime; D'Agostino went back to chemical research. In 1939, after an unsuccessful attempt to emigrate to the United States, the task of keeping alive nuclear physics in Rome fell on Amaldi, together with Bruno Ferretti (in Rome since 1937); Giancarlo Wick joined in 1940. Under their lead, and in close connection with Gilberto Bernardini, who held a chair in Bologna but frequently came along, a new group of researchers assembled in Rome: Oreste Piccioni, Marcello Conversi, Bruno Nestore Cacciapuoti and Ettore Pancini; for shorter periods, Giuseppe Cocconi, Piero Caldirola and Antonino Borsellino were also in Rome. Their research was once more associated with the Physical Laboratory at the Public Health Institute, where the Cockroft-Walton accelerator was now in operation. There, new staff had joined Trabacchi: Daria Bocciarelli, and in 1940 Mario Ageno, later to succeed him as director, and to become one of the founding fathers of biophysical research in Italy.[6]

The group adapted to the existing context by gradually refocusing research activities from the study of uranium fission (totally discontinued in mid-1941) to the study of neutron-proton and neutron-deuteron collisions, and of cosmic rays. On the one hand, they lacked the resources to do groundbreaking work on fission; on the other, they did not want to be involved in the development of nuclear weapons, should any such plan arise on the German side of the war. Moreover, there was a favorable tradition in Rome – also rooted in Corbino's legacy – in electronics, at that time named "electro-acoustics",

5 Edoardo Amaldi, *Da via Panisperna all'America. I fisici italiani e la seconda guerra mondiale*, ed. Giovanni Battimelli and Michelangelo De Maria (Roma: Editori Riuniti, 1997), 63; Giovanni Battimelli and Ivana Gambaro, "Un laboratorio per le alte energie alla vigilia della seconda guerra mondiale", in *Atti del XIV e XV Congresso Nazionale di Storia della Fisica (Udine 1993 - Lecce 1994)*, ed. Arcangelo Rossi (Lecce: Conte, 1995), 475-87; Battimelli and Gambaro, "Da via Panisperna a Frascati: gli acceleratori mai realizzati", *Quaderni di Storia della Fisica* 1 (1997): 319-33; Giovanni Battimelli, "Le origini del laboratorio di fisica", in *Atti del Convegno in onore di Domenico Marotta nel 25° anniversario della morte (Roma, 9 luglio 1999)*, "Memorie di Scienze Fisiche e Naturali, Rendiconti della Accademia Nazionale delle Scienze detta dei XL", serie V, vol. XXIII, parte II, tomo I (1999): 149-60.

6 See: Edoardo Amaldi, "Sulle ricerche di fisica nucleare eseguite a Roma nel quadriennio di guerra", *Ricerca scientifica e Ricostruzione*, January-February 1946: 6 ff.; Giovanni Battimelli, "Edoardo Amaldi", in *Enciclopedia Italiana*, VIII appendice, *Il contributo italiano alla storia del pensiero* (Roma: Istituto della Enciclopedia Italiana, 2013), 726-30. Francesco Guerra and Nadia Robotti have given presentations on this subject at the annual meetings of the Società Italiana di Fisica in Bari (2009) and Bologna (2010): I would like to thank them for their kindness in making those presentations available to me before the publication of their detailed work.

to which Bernardini could contribute the very special expertise acquired in this field while working in Florence with Giuseppe Occhialini and Bruno Rossi. Some of the younger researchers in the group demonstrated an extraordinary ability in developing very sensitive particle detectors. In this case, in addition, Lo Surdo was interested, and ready to lend a helping hand, as director of both the Physics Institute of the University and the Institute of Geophysics of the CNR, which was located inside the Institute.[7]

In this context, Piccioni and Conversi, and later on Pancini, started an experiment on the absorption of "mesotrons", a particle that had been recently identified in cosmic rays. At a very early stage of research, the area of San Lorenzo (adjacent to a railway yard of great strategic importance and very close to the Città Universitaria) was bombed by the Allies (over 1,000 casualties). Some buildings inside the campus were hit, and though the Physics Institute was not, the group decided that the equipment built for the detection of particles should be moved somewhere more unlikely to be bombed. The work went on in the basement of a high school, the Liceo Virgilio, at walking distance from the Vatican. The experiment itself had become for the group a symbol of their strong willingness to keep scientific activity alive, notwithstanding the difficult working conditions and even the personal risks involved in doing electronic measurements at night, secretly, challenging Nazi rules on curfew, while some of them took part in the Resistance. Their results were published in the *Nuovo Cimento* in 1944, and in the *Physical Review* at the end of the war, in 1947.[8] They are now widely acknowledged as a milestone in the history of particle physics.[9]

In the meantime, nuclear physics was gaining front-page attention, and the name of Fermi was reaching unprecedented renown in the public domain. At the end of World

7 Franco Foresta Martin and Geppi Calcara, *Per una storia della geofisica italiana. La nascita dell'Istituto nazionale di geofisica (1936) e la figura di Antonino Lo Surdo* (Milano: Springer Italia, 2010).

8 Marcello Conversi and Oreste Piccioni, "Misura diretta della vita media dei mesoni frenati", *Nuovo Cimento* 2 (1944): 40-70; Conversi and Piccioni, "Sulla disintegrazione dei mesoni lenti", *Nuovo Cimento* 2 (1944): 71-87; Marcello Conversi, Ettore Pancini and Oreste Piccioni, "On the Disintegration of Negative Mesons", *Physical Review* 71 (1947): 209-10.

9 The acknowledgement comes from the Nobel Prize in Physics 1968: Luis W. Alvarez, "Recent Developments in Particle Physics", Nobel Lecture, December 11, 1968, in *Nobel Lectures, Physics 1963-1970* (Amsterdam: Elsevier, 1972), 241; available at *Nobelprize.org*, Nobel Media AB 2014, http://www.nobelprize.org/nobel_prizes/physics/laureates/1968/alvarez-lecture.pdf, last accessed May 23, 2016. See also: Amaldi, *Da via Panisperna all'America*; Marcello Conversi, "L'intricata storia del muone" *Il Nuovo Saggiatore* 1 (1985): 33-40; Oreste Piccioni, "The Observation of the Leptonic Nature of the Mesotron by Conversi, Pancini and Piccioni", in *The Birth of Particle Physics*, ed. Laurie M. Brown and Lillian Hoddeson (Cambridge: Cambridge University Press, 1983), 222-41; Piccioni, "The Discovery of the Leptonic Property", in *Present Trends, Concepts and Instruments of Particle Physics: Symposium in honour of Marcello Conversi's 70th birthday, Rome, 3-4 November 1987*, ed. Marcello Conversi, Luciano Maiani, Giorgio Salvini, and Giustina Baroni (Bologna: SIF, 1988), 171-93.

War II, in Italy as elsewhere, "nuclear physicists" (the "nuclear" label covering a range of physics partly overlapping with applied nuclear research and partly belonging to particle physics)[10] were lobbying in favor of their activity, not only within bodies institutionally mandated to support academic research, but also with industrial circles and with the government. In fact, some of them (in particular Amaldi in Rome, and Giuseppe Bolla in Milan) had a clear vision of how these different milieus were closely knit, and how the CNR might play a key role in this game. Fermi, though now deeply involved in science policy in the United States, kept a supporting attitude in favor of his former pupils, offering – whenever he could – political and academic support, along with a few important pieces of strategic advice.

To make a long story short, in 1945 the CNR created a research center in the Physics Institute in Rome, the Centro per lo studio della fisica nucleare e delle particelle elementari. In 1946, Amaldi gained the support of Fiat to create a laboratory for the study of cosmic rays located by the Rome group at the Testa Grigia peak, in the Alps near mount Cervino. The most important development, however, was the expansion of this research beyond Rome. In 1947, a Centro per lo studio degli ioni veloci was established in Padua, and directed by Antonio Rostagni. In 1951 two more centers were created: one in Turin, directed by Gleb Wataghin, and one in Milan. Though labelled as "nuclear research" centers, their common ground was – at least until the mid-1950s – research on cosmic ray physics. These centers were formally dependent on the CNR, which funded them, but in fact were under the scientific control of the university institutes that "hosted" them. An unprecedented step took place in 1951, when the CNR established a national institute to coordinate their activity. It was the first time that a national institute of the CNR brought together centers belonging to different universities: such was the birth of the Istituto Nazionale di Fisica Nucleare, which would gain international renown in the following years under the acronym INFN.[11]

At that point, what had been at the beginning a survival strategy, and characterized later on as an effort to "rebuild" a tradition in line with the legacy of Fermi (whence it claimed legitimization facing other disciplinary groups and the government), had silently became something new. The community of "nuclear physics" researchers had taken the shape of a widespread national network of scientific relations and collaborations, in a

10 See: Alberto Cambrosio, "The Dominance of Nuclear Physics in Italian Scientific Policy", *Minerva* 23, no. 4 (1985): 464-84; Giovanni Battimelli, "Circulation of Ideas and Migration of Scientists: Hints from the Early Times of Nuclear Physics", in *The Migration of Ideas*, ed. Roberto Scazzieri and Raffaella Simili (Sagamore Beach: Watson, 2008), 195-201.

11 On INFN history: Giovanni Battimelli, Giovanni Paoloni, and Michelangelo De Maria, *L'Istituto Nazionale di Fisica Nucleare: Storia di una comunità di ricerca* (Roma: Laterza, 2001); Giovanni Battimelli, "I fisici in rete: l'INFN", *Scienza e società* 5-6 (September 2008): 26-33.

reframed institutional context. It was involved in first class international collaborations, it was on the frontline of research, and it was regarded as a leading group in Italian science policy, notwithstanding underlying potential conflicts that would become apparent in the following years.

Industry, Academia, and the Nuclear Program

Italian engineers and electricity companies, on their part, had never totally dropped their interest in producing energy from atoms. To understand the significance of an Italian nuclear program in a historical perspective, and its role in the socio-economic development of the country, it is necessary to consider the constraints imposed on Italian growth, from the last decade of the nineteenth to the end of the twentieth century, by the scarcity of energy resources. Hydroelectric production, which had been the prevailing source since the beginning of the electricity industry, was an important factor in the success of the industrialist shift of Italian economic policy in the 1890s. In the first two decades of the following century, Italian policymakers perceived the hydroelectric source as virtually unlimited, capable of freeing Italy forever from energy constraints caused by the poor quality and scarcity of its coal. Hydroelectricity was renamed "*carbone bianco*" ("white coal"). However, by the end of the 1920s, severe droughts and the growth in demand for electricity made it clear that this source had certain disadvantages and suffered from a limited increase potential. Italian engineers were therefore on the quest for non-fossil production sources for integration/substitution.

Fermi's remark of 1923 echoed now and again for two decades. In 1928, *L'Elettrotecnica* (a journal closely associated with the Italian electricity industry), in a letter from the editor, published under the headline "Centrali termiche o centrali idrauliche?" (Thermoelectric or hydroelectric power plants?), expressed this view: "While waiting for physics to succeed in providing humanity with new energy sources, perhaps with the disintegration of the atom, we must still use, in order to meet the continually increasing needs of our life today, those classic sources, which, as we learned in our school years, all use solar energy, but transform it differently".[12] A few days before Corbino's aforementioned speech, in September 1929, Marconi pointed to the production of energy from the atom as one of the three impending most important technological advances, together with television and the wireless transmission of energy (the only one of these prophecies that did not come true).[13] Again, in 1941

12 *L'Elettrotecnica* (1928): 1.

13 Interview with George Sylvester Viereck, for the news agency Korda Angloamerican Newspaper Service, Marconi Archives, Bodleian Libraries, Oxford, box 53/2. It is also worth mentioning that Marconi played a substantial role in the organization of the first congress of nuclear physics in Rome, in 1931.

L'Elettrotecnica published an article on nuclear energy, ending with these words: "In any event, though it is true that the energy produced by disintegration [of the atom] is not yet in direct competition with that produced by combustion, and even if this is not likely to happen in the very near future, it would be wrong for engineers to completely dismiss the possibility that one day they may be working on veritable 'power plants' for the exploitation of nuclear energy".[14]

At the end of World War II, the Organisation for Economic Co-operation and Development (OECD) refused to give Italian electricity companies any Marshall Plan funds for the further development of hydroelectric projects. It pointed out that only a substantial shift of the Italian electricity industry to thermoelectric production could deal with the energy demand needed to support the reconstruction of the country, and any further process of economic growth. Accordingly, the United States would only support such a transition.[15] Thermoelectric production (from oil, and no longer from coal) actually grew at such a pace to cover the acceleration of energy demand caused by reconstruction, the growth of industrial production and the improvement of Italian lifestyle standards. It finally prevailed over hydroelectricity in 1966. In addition, oil was then extremely cheap, which favored the transition, while hampering the development of any other production source by making it too expensive, with the exception of the upgrade of already existing hydroelectric and geothermic projects. An objection often made against nuclear energy investments.

The shift to thermoelectric power, however, made Italy increasingly dependent on oil imports: policymakers deemed it a temporary price for American support, and for the benefit of the looming "economic miracle", but in medium-term plans it would be necessary to find an alternative to oil. Such was the industrial perspective of the Italian nuclear program. It is worth noting, in addition, that a similar perspective was at the roots of the French nuclear program, adopted in 1947 by the Commissariat à l'énergie atomique et aux énergies alternatives (CEA) and the Électricité de France (EDF), the state-owned electricity company resulting from the nationalization of electricity in 1946.[16] France was often quoted by Italian nuclear researchers and nuclear energy sup-

14 E. Severini, "Accenni sulla costituzione della materia e sul problema del combustibile atomico", multiple part paper, published in *L'Elettrotecnica*, vol. XXVIII (1941): 11-14, 94-97, 118-21, 144-45, 169-71; qt. in Carlo Lombardi, "La questione dell'energia nucleare", in *Storia dell'industria elettrica in Italia*, vol. 5, *Gli sviluppi dell'ENEL.1963-1990* (Roma-Bari: Laterza, 1994), 589-644, see 589.

15 On energy policy in post-war Italy: Silvio Labbate, *Il governo dell'energia. L'Italia dal petrolio al nucleare (1945-1975)* (Firenze: Le Monnier, 2010); Elisabetta Bini, *La potente benzina italiana. Guerra fredda e consumi di massa tra Italia, Stati Uniti e Terzo mondo (1945-1973)* (Roma: Carocci, 2013).

16 See: Gabrielle Hecht, *Le rayonnement de la France. Énergie nucléaire et identité nationale après la Seconde guerre mondiale* (Paris: Éditions Amsterdam, 2014); Yves Bouvier, "La mutation nucléaire d'EDF", in *Histoires électriques. EDF a 70 ans* (Paris: Fondation EDF, Comité d'histoire de l'électricité et de l'énergie, 2016), 32-53.

porters as a model Italy might follow, as other "nuclear" countries (not only the United States, but also the United Kingdom and even the Soviet Union) were out of reach in terms of dedicated financial resources. They did not take into account, however, the fact that France was among the winners of World War II, therefore counting on nuclear technology assets and military implications unavailable to Italy.

In 1942, Fermi secretly built in Chicago the world's first nuclear reactor, later renamed the "Chicago Pile". This was a substantial step in the development of the first atomic bomb under the Manhattan Project, and at the same time laid the foundations for a true nuclear industry. Obviously, Italian researchers (including those in Rome) were unaware of what was going on on the opposite side of the Atlantic. As soon as Hiroshima and Nagasaki reached the newspaper headlines in August 1945, however, Amaldi and his fellow nuclear physicists became immediately conscious of the nature of the work Fermi had been doing. According to Giorgio Salvini, who would become President of INFN in the mid-1960s, "At that time there was enormous interest in nuclear issues. It is not surprising, really, if you consider that it was 1945; the atomic bomb aftermath immediately set people to thinking about the potential use of nuclear reactors to generate power".[17]

Salvini, at the time assistant in the Physics Institute of Milan's State University, was in touch with Carlo Salvetti, who taught theoretical physics in the same Institute, and with Mario Silvestri, a young physics graduate working in the Edison Company. They asked for advice from their professor, Giuseppe Bolla: it was he who suggested that the development of nuclear energy could become an opportunity to foster cooperation between academia and industry. To make a long story short, again, this led to the establishment, in November 1946, of a research company (Centro Informazioni Studi ed Esperienze, CISE) where the largest Italian industrial groups, some of them state-owned, potentially interested in the development of the nuclear industry, became associated, and cooperated with academic researchers from universities and the CNR.[18] To prevent the misuse of human and financial resources in a competition, which would have been pointless at that time and in that context, the CISE and university/CNR centers reached an agreement on the differentiation of research tasks, negotiated by Amaldi and Bolla.[19]

Bolla was appointed CISE's director, with the mandate of taking the necessary steps to build a "national nuclear reactor" for electricity production. To achieve that goal, a

17 Interview in Giovanni Paoloni, ed., *Energia, ambiente, innovazione. Dal Cnrn all'Enea* (Roma-Bari: Laterza, 1992), 52.

18 On CISE's history: Sergio Zaninelli, ed., *Ricerca, innovazione, impresa. Storia del CISE: 1946-1996* (Roma-Bari: Laterza, 1996).

19 Edoardo Amaldi, "Gli anni della ricostruzione", *Giornale di fisica* 20, no. 3 (1979): 186-225, see 194-96.

vast number of issues needed to be resolved, since nuclear technology was strictly classified in the countries that had it. In addition, there was a lack of qualified staff. Such were the issues that cooperation between academia and industry had to deal with. By the end of 1951, the CISE was successfully dealing with the issue of qualifying specialized researchers and staff. In addition, it had built a pilot plant to produce heavy water through electrolysis, and created an experimental uranium metallurgy plant. In its laboratories, measurements of uranium fission had been undertaken, and leading-edge electronic instruments had developed.[20] In January 1952, Bolla declared in CISE's magazine, *Energia nucleare*:

> As things currently stand at CISE, it is safe to say that Italy has the scientific grounding and key technologies to build an experimental pile. In other words, we have a core of specialists capable of rapidly understanding work undertaken by other researchers. … Established … as a platform for academia and industry to solve the problem of research in Italy, CISE has delivered on all of the work that it has carried out. … Where it has not delivered is attracting official interest in the efforts undertaken by industrialists, academics and researchers.[21]

Such a declaration marked a turning point in the tireless lobbying strategy that scientists and industry executives had put in place to win government recognition and funding.

Beyond (and Behind) Nuclear Energy

Governmental recognition came in June 26, 1952, with the establishment (as a special committee of the CNR) of the Comitato Nazionale per le Ricerche Nucleari (CNRN), which was the outcome of economic, academic and political negotiations that had been going on behind the scenes for six years.[22] What matters here is the fact that the procedure had been hampered by the political difficulty of balancing a number of conflicting interests. The major political issue in the background was the nationaliza-

20 Roberto Maiocchi, "Il ruolo della ricerca", in *Ricerca, innovazione, impresa*, ed. Zaninelli, 43-88.

21 Giuseppe Bolla, "Il Cise", *Energia nucleare* January 31, 1952, 19-20.

22 On the origin and activity of the CNRN: Giovanni Paoloni, "Gli esordi del nucleare", in *Storia dell'industria elettrica in Italia*, vol. 4, ed. Valerio Castronovo, *Dal dopoguerra alla nazionalizzazione. 1945-1962* (Roma-Bari: Laterza, 1994), 383-408; Leopoldo Nuti, *La sfida nucleare* (Bologna: il Mulino, 2007), 53-70; Barbara Curli, *Il progetto nucleare italiano (1954-1962). Conversazioni con Felice Ippolito* (Soveria Mannelli: Rubbettino, 2000); for a less academic narrative: Giovanni Paoloni, *Il nucleare in Italia* (Roma: PRC, 2009), available at https://www.enel.it/it-it/Documents/azienda/sostenibilita/Nucleare_Enel_1_interattivo.pdf, last accessed May 23, 2016.

tion of the electricity industry. Who would make the final decision on the building of a nuclear plant? Major private players in the electricity industry feared that the need for state control over nuclear energy, though it could not be denied, might be used as a further pretext in favor of nationalization, as would the need for state funding. Half of the electricity industry, however, was already controlled by major companies belonging to the state-owned Finelettrica, the electricity financial holding of the Istituto per la Ricostruzione Industriale (IRI) Group, while other parts consisted of local council-owned electricity companies, and – not least important – "auto-producers" (among them, state railways). Moreover, on the Italian energy market there was another (controversial) state-owned player, the oil company Azienda Generale Italiana Petroli (AGIP), soon to become an industrial holding (Ente Nazionale Idrocarburi, ENI) involved in oil, petro-chemistry and gas, and aspiring to become the take-all state-owned player in energy, including electricity. Actually, in the mid-1950s nuclear energy would become precisely the ground where IRI and ENI would start competing, and behind the scenes conflicting.

In addition, other issues were also at stake. How should research and development in the nuclear energy industry be balanced with "fundamental" physics research? Should a future nuclear agency be controlled by the Ministry of Industry or the Ministry of Education (or both, somehow)? Which role would the CNR play? How should substantial state funding for "fundamental" research be secured? How far should the coverage of the "nuclear" label be extended to "fundamental" physics? With such issues in mind, physicists took part in the negotiations, and in fact, the establishment of INFN in 1951 must be regarded as a substantial move in their game. Securing funding was the prominent issue uniting the community under the "nuclear physics" label in the 1950s. However, there was an underlying competition on academic power, which in the 1960s would split that same community along different positions: political (nationalization pro/con), geographical (North/South, Rome/Milan), technical (fundamental/applied research), disciplinary (high-energy/solid state physics).

After its establishment, the CNRN funded the creation of a center for applied nuclear research in Ispra, in northern Italy. The CISE was the contractor for this center, which hosted the experimental reactor whose design and building was its mission since inception in 1946. In 1953-1954, however, US President Dwight D. Eisenhower inaugurated the Atoms for Peace program, also involving the United Nations. The CISE's mission was refocused on building the experimental reactor under a contract with a US firm, AC&F. The idea was to take advantage of the availability of commercial technologies, adapting them to a new research and development context. However, this strategy shift was the first step on a path which would lead in a short time to a break in relations between the CNRN and the CISE. In 1957, the CNRN took on directly

the building of the center in Ispra, to hand it over to the newly established Euratom as a Joint Research Center, immediately after the reactor went critical in 1959. In 1958, the CNRN started building a new center, in Casaccia near Rome, where it relocated the activities bound to leave the Ispra center. This move also fueled resentment among physicists working in northern Italy, who felt deprived of what they regarded as their common research facility.

While trying to promote applied research and the development of nuclear power in Italy, the CNRN also subsidized "fundamental" research through the INFN (in fact more or less 20 per cent of the budget), and took charge of the Italian participation in a newly established European research facility, the Centre Européen pour la Recherche Nucléaire (CERN). The INFN quickly expanded its network through the creation of centers and sections in most Physics Institutes at different universities, while taking on the task of creating national research facilities for the use of all its associated groups. The first of these was the electro-synchrotron built in Frascati, near Rome, which started its activity at the end of the 1950s. Immediately after its inauguration, researchers in Frascati designed and prototyped an innovative accelerator, ADA, the first-ever storage ring. The INFN was a promoter of the project to design and build a "national" computing machine (the Calcolatrice Elettronica Pisana, CEP) and the establishment of related facilities in cooperation with the CNR and with industry (Olivetti).

In the meantime, three nuclear power plants were under construction, two in southern[23] and one in northern Italy. In addition, the CNRN supported research in plant genetics at the Casaccia center, and in molecular biology through the establishment of an International Laboratory in Naples, cooperating with the CNR.[24] In 1960, the CNRN, after new political and institutional conflicts, became the Comitato Nazionale per l'Energia Nucleare (CNEN), a government agency independent from the CNR. Felice Ippolito,[25] the prominent operative member of the CNRN since its inception, was appointed secretary general (in fact, chief executive officer). The CNRN also funded education and training, in different universities, for nuclear engineers, nuclear physicists, and technical staff, and supported other activities in what is nowadays called Sci-

23 Barbara Curli, "Energia nucleare per il Mezzogiorno. L'Italia e la Banca Mondiale, 1955-1959", *Studi Storici* 37, no. 1 (1996): 317-51; Mauro Elli, *Atomi per l'Italia. La vicenda politica, industriale e tecnologica della centrale nucleare ENI di Latina 1956-1972* (Milano: Unicopli, 2011); Anna Rita Rigano, *La Banca d'Italia e il progetto ENSI. Fonti per la storia dello sviluppo energetico italiano negli anni Cinquanta nelle carte dell'Archivio della Banca d'Italia*, "Quaderni dell'Ufficio ricerche storiche", 4 (June 2002).

24 Interview with Gian Tommaso Scarascia Mugnozza, in *Energia, ambiente, innovazione*, ed. Paoloni, 184-91; Francesco Cassata, *L'Italia intelligente. Adriano Buzzati-Traverso e il Laboratorio internazionale di genetica e biofisica* (Roma: Donzelli, 2013), 77-143, 262-319.

25 On Felice Ippolito: Curli, *Il progetto nucleare italiano*; and more recently: Pietro Greco, "La battaglia di Felice Ippolito", *Le Scienze* 566 (October 2015): 70-77.

ence and Technology Studies. In fact, the CNRN had become the focal structure of a network of relations between academia, the industry, and policymakers, who shared a vision of the future of Italy.[26] It was a very promising landscape, notwithstanding looming academic tensions, and open political conflict with private electricity majors. However, the sky was clouding over.

The "Ippolito Affair" and Its Consequences on Science and Industry

By the end of the 1950s, the US attitude to the Italian nuclear program, which had been very positive after the take-off of the Atoms for Peace program, became covertly hostile. The reasons for this shift have been the object of much speculation, but only recently have they been investigated by academic research. No consensus has been reached yet. In 1963-1964, shortly after the electric nationalization, Ippolito was involved in alleged mismanagement of State funding to the CNRN-CNEN. The subsequent "affair" slowed the pace of Italy's nuclear program, with only one nuclear plant being built since then, in 1980: and this was the last one. Moreover, from the early 1970s, "green" movements appeared on the Italian political scene, first rallying against hydroelectric power plants, then against nuclear ones.

With all its shortcomings, the nuclear program had been an important driver for industrial innovation and scientific research in Italy, well beyond the boundaries of closely related fields. Its crisis hit Italian research. In addition, the slowing pace of the program had a very hard impact on the Italian electromechanical industry, where the IRI-owned Ansaldo Meccanico Nucleare (AMN)[27] had been making large investments. After the oil crisis of 1973, the Italian government adopted an energy plan based on the massive building of nuclear power plants. To minimize environmental risks, and downplay potential conflicts between industrial actors, a standardized national project for nuclear reactors (Progetto Unificato Nazionale, PUN) was adopted. Though the energy plan was clearly unrealistic, the industrial stakeholders of the nuclear program had prepared themselves for the reasonable perspective of building at least a part of those plants. In fact, only one plant was actually built, and the resulting unbalance was a major factor in the subsequent crisis of the IRI-Finmeccanica group. When a new start of the Italian nuclear program took place in 2008, it was first hindered by conflicts between its prospective actors, and then definitely stopped, in 2011, by the negative reactions to the

26 Giovanni Paoloni, "Lo sviluppo scientifico italiano nell'ultimo sessantennio: due modelli a confronto", *Meridiana* 54 (2005): 39-61; Cassata, *L'Italia intelligente*, 145-91.

27 Barbara Curli, "Il nucleare", in *Storia dell'Ansaldo*, vol. VIII, *Una grande industria elettromeccanica, 1963-80*, ed. Valerio Castronovo (Roma-Bari: Laterza, 2001), 109-42.

Fukushima accident, followed by a new referendum. In the last fifteen years, however, the denationalization of the electric industry and its process of internationalization in a European framework have conspicuously challenged the energy landscape and policies, changing the context of the Italian "nuclear" debate.