In the last sixty years, viewpoints on nuclear energy have been evolving from a broad feeling of confidence in its valuable contribution to the generation of cheap energy, increasingly independent of fossil fuels, toward growing skepticism or even open opposition. This was a multi-factor process, and a careful analysis would require a dedicated paper. Therefore, the following pages touch only on a few elements, in my opinion the most relevant ones.

What I have called “technological hubris” provoked an undue acceleration of nuclear development. Shippingport, the first American nuclear power plant, was a 60 MW pressurized water reactor (PWR). It was modelled on the submarine Nautilus nuclear propellant and, without any significant change, started operating in 1957. It was followed by the 205 MW Yankee plant and the 210 MW Dresden 1 plant, both in operation by 1960, which increased the initial capacity by 3.5 times. The escalation continued with the building of the San Onofre 1 (460 MW, 1967), the Haddam Neck (600 MW, 1968), and the Zion 1 and 2 (1000 MW each, 1973) plants. In just sixteen years, their capacity increased by almost twenty times.¹

Given that construction times were very long, companies had to start building their power plants before acquiring the necessary information from their forerunners, sometimes even before their start-up. The usual learning by error process was missed and larger size power reactors were built before obtaining and assessing the operational results from the previous smaller size plants. This led to design and manufacturing errors, which turned into malfunctions and cost increases.²

The paradoxical effect was a penetration rate much higher than usual in global electricity production. Historical energy transitions have been slow, spanning several dec-

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¹ G. B. Zorzoli, *Il sistema elettrico e le nuove sfide tecnologiche* (Roma: Editori Riuniti, 1997), 64.
Between 1970 and 1985, the nuclear growth rate was higher than 16 per cent per year, more than three times compared to oil during its first decades. Meanwhile, costs and malfunctions increased, instead of going down, as expected because of the combined impact of scale effect and learning by doing.

This decreased public confidence in nuclear technology, also because the issue of the ultimate disposal for long-term radioactive waste has not yet been solved.

When accidents happened (which technological hubris had categorically ruled out), doubts on the actual safety of nuclear power plants increased. Efforts to design safer reactors led to today’s evolutionary power reactors (EPRs), which are producing electric power at a price twice as high as that of the electricity market. Thus, the nuclear power share of world electricity generation, after reaching around 17 per cent at the end of the last century, decreased to 10.7 per cent in 2014.

If today’s nuclear perspectives are meager, in the past some industrialized countries succeeded in installing a remarkable set of nuclear power plants. The oddity of the Italian approach to nuclear energy is its failure to achieve any comparable result, even when nobody opposed such a policy.

The following sections will analyze the reasons for that failure.

**The Basis of an Effective Nuclear Policy**

After the 1973 oil crisis, France did not develop the most effective nuclear pattern by mere chance. Decision-makers were aware that installing nuclear power plants requires a complex organizational structure, where several players – both enterprises and public bodies – are allowed to interact inside well-designated boundaries.

Unlike conventional power plants, which are authorized only on the basis of an Environmental Impact Assessment and are fired by fossil fuels (coal, oil, natural gas), nuclear power plants:

1) are made up of many more and more sophisticated components and subsystems, which implies the parallel set-up of highly qualified suppliers;
2) must be linked to a nuclear fuel manufacturer;
3) have to deal with a Nuclear Safety Authority, which can require both a preli-
nary Safety Report (if accepted, the nuclear power plant can be built) and a final Safety Report (to authorize the plant operation); the same Authority can impose design or component changes during construction, and is entitled to control the plants throughout their operational lifetime;
4) are charged with the problems related to the plant decommissioning and radioactive waste disposal.

An interactive structure implies a roughly equipollent effectiveness from all the actors involved, since other players cannot cover big differences, as they have different skills and duties. Moreover, when the size of a country places limits on its resources, the huge investments required in developing a supply chain technology force decision-makers to choose a single technology. As a result, the most effective means to achieve these goals is through central planning, carried out by an authoritative government, which can select (or set up) appropriate players and impose its policy. This was the French way to nuclear.

The US nuclear program was the opposite of the successful French one. In spite of the huge know-how that was accumulated from the very beginning of the nuclear age, and the amount of public money poured into the development of civilian reactors, on the private side the organizational structure remained too loose and scattered among too many utilities. Their size was often insufficient to operate a nuclear power plant, leading to accidents such as the one in Three Mile Island.

Indeed, the free market does not fit nuclear policy requirements well, even less so when decision-makers’ behavior recalls the chaotic Brownian motion.

The Italian Nuclear Takeoff

In Italy, political and entrepreneurial engagement in the nuclear business began in the mid-1950s, i.e. ten years later than in countries such as France and the United Kingdom. It was to last less than ten years, from the first Conference on the Peaceful Uses of Atomic Energy (held in Geneva in August 1955) to December 1962, when the act to nationalize the electricity system was approved.

That engagement was tied to two concurrent factors: first, to the debate about the proposal to nationalize the electricity system, which was in its initial phases; second, to

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the belief, which spread in Italy after the Geneva Conference, that nuclear energy would become so cheap as to achieve a dominant share in electricity generation.

All the main players in the Italian energy field tried to control the nuclear option: while public enterprises (public utilities and the state-owned company Ente Nazionale Idrocarburi, ENI) became the institutional body in charge of implementing nationalization, private utilities aimed at stopping any move toward this option.8

At first, the struggle revolved around the attempt to control the Centro Informazioni Studi ed Esperienze (CISE), a nuclear research and development center set up by private enterprises shortly after World War II.9 An agreement signed in 1955 led to a fifty-fifty share between private enterprises and the Istituto per la Ricostruzione Industriale (IRI) and ENI, whereby CISE was assigned the task to build a nuclear research center in Ispra on behalf of a new public body, the Comitato Nazionale per le Ricerche Nucleari (CNRN).

Two years later, in October 1957, the agreement came to an end. More than one third of CISE’s scientists were hired by the CNRN and a few months later ENI left CISE to set up a new company, the Azienda Generale Italiana Petroli (AGIP) Nucleare. Two of CISE’s shareholders, the car manufacturer Fiat and Montecatini, then Italy’s leading chemical company, set up the nuclear research and development company Sorin. Suddenly, research and development resources, which had been concentrated around CISE, became fragmented, making it more unlikely to achieve a critical mass.

The CISE case was the first sign of a clash between different and incompatible strategies. On one side, there were people like ENI’s President Enrico Mattei and CNRN’s Secretary General Felice Ippolito, who had a vision of what Italy’s future should be, consistent with contemporary needs. On the opposite side, there was the old-fashioned culture of people managing private utilities, always opposed to any change to the status quo. Between them, there were the top managers of public utility companies, grouped inside IRI, whose positions were close to those of their colleagues working for private firms.

Even the traditional partnership between private and public utilities did not survive this clash. In 1957, IRI opted out of the Società Elettronucleare Italiana (SELNI), a joint company created in 1956 to enter the nuclear business, and set up its own firm, the Società Elettronucleare Nazionale (SENN), which received support from the CNRN.

Between 1956 and 1958, three nuclear projects were launched. SELNI, controlled by Edison, was assigned the task of building a first generation PWR power plant in the town of Trino Vercellese, in Piedmont. The American company Westinghouse was Edi-

son’s traditional supplier, via Franco Tosi and Ercole Marelli, who were Westinghouse licensees. SENN, on the other hand, which was owned by the IRI group, built a first generation boiling water reactor (BWR) power plant in Southern Italy, near Garigliano. In this case, the license owner was General Electric, whose Italian licensee was the firm Ansaldo, IRI’s main supplier. Following these decisions, ENI’s newly founded nuclear company Società Italiana Meridionale per l’Energia Atomica (SIMEA) built its own nuclear power plant, near Latina, using the only other technology available at the time, the British Magnox type nuclear reactor (natural uranium fueled, graphite moderated, gas cooled).

Italian firms used three different technologies, which were chosen for reasons unrelated to their inherent qualities, and did not follow any long-term strategy. The Italian government and lawmakers remained spectators or passive supporters of decisions that were taken elsewhere, making Italy an odd case study.

The Long Sleep

Three events led to the end of this struggle around nuclear power. In 1962, Mattei was killed. In 1963, a judiciary plot excluded Ippolito from the nuclear game, with the aim of challenging his project of a long-term nuclear policy for Italy.\(^{10}\) Between December 1962 and the Spring of 1963, in order to comply with the electricity system nationalization act, all electric utilities, with the exception of those owned by local municipalities, merged into the newly-created Ente Nazionale per l’Energia Elettrica (ENEL).

Once the three nuclear power plants were completed in the early 1960s, no additional nuclear capacity became operational until 1981. This long sleep depended neither on social opposition, which started only in the late 1970s, nor on economic concerns, since nuclear energy was still considered to be convenient.

A major turning point was Ippolito’s detention and his subsequent revocation from ENEL’s Board of Directors, which decided to get rid of the only person opposing the policies carried out by the company’s chief operating officer, Arnaldo Maria Angelini. Between 1963 and 1978, first as ENEL’s CEO, then as its President, Angelini decided to match Italy’s increasing electricity demand through heavy oil fired power plants, thus complying with the interests of oil companies.

In the same period, Italy became Western Europe’s oil refinery platform. To keep investment costs down, private and public companies involved in the oil business opted for processing plants that operated as simple distillers (as cracking remained quite lim-

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ited). Thus, the average composition of the oil processed in Italy was such as to produce 50-55 per cent heavy oil as output, a product with a limited market, which was definitely much lower than its yearly output.

The problem was solved selling heavy oil to ENEL, at a price low enough to make nuclear energy too expensive. An act that allowed the use of heavy oil with up to a 3 per cent sulphur content, along with the replacement of stack emission limits with land fall-down limits, which were respected by making stacks higher than usual, addressed the issue of the oil’s high content of polluting agents (above all sulphur).

As a result of these changes, Italy’s nuclear share of electricity generation decreased from a world record of 4.2 per cent in 1965 to a meager 1.2 per cent in 1980 (Table 1), while the thermal generation share (78 per cent heavy oil fired) increased from 40.8 per cent to 71.8 per cent.

<table>
<thead>
<tr>
<th>Year</th>
<th>Hydro</th>
<th>Geothermal</th>
<th>Thermal</th>
<th>Nuclear</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>43,008</td>
<td>2,576</td>
<td>33,874</td>
<td>3,510</td>
<td>82,968</td>
</tr>
<tr>
<td>1980</td>
<td>47,511</td>
<td>2,672</td>
<td>133,350</td>
<td>2,208</td>
<td>185,741</td>
</tr>
</tbody>
</table>

Table 1. Electricity production by source (GWh). Source: TERNA, Dati statistici sull’energia elettrica in Italia, dati storici, 2013.

In the meantime, Angelini became one of the main public supporters of nuclear power. His lectures, conference papers and public statements, always forecasting a medium-long term development of nuclear power (his favorite data was a 50 per cent nuclear share in the long term), would fill a library.

ENEL also continued to support nuclear projects, provided that they remain outside the commercial realm, which was increasingly made up of light water reactors (LWR). The most noteworthy projects, because of their cost and lifetime, were the following:

1) The CISE Reattore a Nebbia (CIRENE), a heavy water moderated, two-phase water-cooled reactor, developed by CISE. Its 40 MW prototype was built by ENEL, but after twenty years it was not yet in operation and was stopped by the 1987 referendum;
2) Participation in the Superphénix project, a 1200 MW fast breeder reactor (FBR), whose design began in 1968, was connected to the grid in December 1994 and was closed in September 1998.

When it was conceived in 1957, CIRENE looked very promising. However, soon after the decision to build its prototype was taken, both Canada and the United Kingdom gave up similar projects. Only Canada used heavy water technology, while other
Did the Italian Decision Makers Understand that Nuclear Is Not Business as Usual?

countries chose LWRs. The fast breeder technology remains a question mark, and forty years ago it was definitely a risky gamble.\(^\text{11}\)

In order to hush up political lobbying in favor of Ansaldo, in 1969 ENEL commissioned an 860 MW BWR plant, to be built near Caorso, in the Emilia-Romagna region. Its construction was lengthy and cumbersome, despite the active support granted by local authorities.\(^\text{12}\) It was connected to the grid in December 1981 and produced electricity until 1986. A twin unit, which should have been installed on the same site, was never commissioned.

**The Response to the Oil Crisis**

In the 1950s, too many people around the world considered nuclear power like manna from heaven. Therefore, Italian decision-makers should not be blamed, even if they did not understand that nuclear was not business as usual. A decade later, following the idea that ENEL would provide the tools to manage Italy’s electricity policy, the Italian government allowed the company to become a proxy, supporting it even in decisions that implied risks for the country’s security.

Given that sooner or later you can be sure your sins will find you, with the increase of oil price following the 1973 oil crisis, it became clear that the policy ENEL was following had very frail bases.

Forty years ago, nuclear technology was still the most promising alternative to fossil fuel electricity generation. The oil crisis revamped interest in renewable sources. However, in the early 1970s photovoltaics had limited applications, and only in the space sector, while the few existing wind energy installations were old fashioned. Therefore, the immediate response was to go nuclear.

In the 1970s, it was quite clear that nuclear was not a usual business,\(^\text{13}\) and that it required a system approach, i.e. a step by step build-up, which was the expression of a considered thought instead of something hurriedly thrown together.\(^\text{14}\) On the contrary, ENEL proposed an unrealistic program: to build 20,000 MW in ten years, split between ten power plants, each made up of two twin 1000 MW units. In September 1975, the project was included in the Piano Energetico Nazionale (PEN), which did not provide


any information about technologies or the plant siting, and omitted to indicate how responsibility should be shared among the operators.

Italy joined the European initiative to build a huge uranium enrichment unit at Pierrelatte, in France, and pre-purchased the enriched uranium required to fuel the planned nuclear power plants. Since these were never built, the enriched uranium was later sold at a loss.

Decision-makers knew the right pattern they had to follow in order to carry out a consistent and cost-effective nuclear program. However, they decided to ignore it so they would not displease anybody: a decision that was consistent with the way of acting preferred by Italian governments (business as usual in an unusual business).

ENEL supported the idea that competition between different technologies was the best economic solution. This argument worked in international auctions, but not in Italy, since all the power plants had to be built by Italian firms. Multiplying technological options prevented the achievement of cost benefits coming from scale effects and learning by doing. If a single technology had been chosen, ENEL would have been compelled to purchase that technology, but the company (like ENI) behaved as an independent body. It was inclined to refuse any external interference, due to the government’s weakness, which had to a great extent lost control over public companies.

Moreover, the legacy of the events of the 1950s was still alive. Fiat had become a Westinghouse PWR licensee and acted as the head of the main component suppliers (the firms Tosi and Marelli). Ansaldo was not only a General Electric BWR licensee, but after manufacturing the CIRENE prototype, it had acquired the Canadian license for the commercial heavy water reactor (HWR). An additional complication came from the Belleli group decision to become the licensee of another PWR technology, developed by the American Company Combustion Engineering.

The only actual decision was taken in 1976, when ENEL commissioned Ansaldo to build a BWR nuclear power plant, made up of two 982 MW units, near the town of Montalto di Castro, north of Rome. It was not an easy task:

1) both Ansaldo and ENEL had no previous experience building a plant of that size;
2) the site was technically well-suited, but it was surrounded by archaeological remains;
3) for the first time, a strong opposition to nuclear power emerged locally, and became stronger as a result of mistakes made by Ansaldo and ENEL, which were unprepared to deal with social movements.

When the 1987 referendum put an end to the Italian nuclear program, only 70-75 per cent of the plant had been completed.

The multi-technology option became so unbearable that in the early 1980s PWR was selected as the national technology and Ansaldo was charged with deploying it. In
theory, this was the best choice, since PWR was the winning technology. This decision, however, did not take into account that both Ansaldo and ENEL had gained manufacturing and operational experience only in the BWR technology, in Caorso, and were engaged in building the last BWR generation power plant at Montalto di Castro. Therefore, the previous learning by doing was mostly wasted.

Shortly thereafter the ENEL Board of Directors decided to change the previous industrial program: the future power mix had to be a balanced share of nuclear and new coal fired units, plus some of the operating oil fired plants converted to coal. The potential scale effect and learning by doing was therefore halved and the undisclosed, but clear cause of the new strategy – coal fired plants were easier to build – weakened nuclear perspectives even more.

When, after the Chernobyl disaster, the anti-nuclear movement collected the signatures needed to call a national referendum, politicians were so eager to remove what had become an embarrassing issue that Parliament passed an ad hoc act, allowing the referendum to be held even during an election year, in 1987.

Since there was no specific nuclear energy act to be repealed, the majority of people voted to cancel the incentives given to local municipalities for the building of new power plants and to revoke the authorization given to ENEL to join foreign ventures, which had allowed it to participate in the Superphénix project. Italians’ opposition to nuclear energy was clearly expressed by the referendum results. Willing to get rid of the whole nuclear issue, the vast majority of the Italian Parliament not only decided to stop building new nuclear plants, as expected, but went further, and shut down the operating units as well.

I can personally attest that the vast majority of ENEL employees sighed with relief.

Bad Things Come in Threes

Despite its death sentence, the Italian nuclear business behaved like a karstic river, which goes underground, but keeps on flowing.

A joint venture between Ansaldo and the Consorzio Interuniversitario per la Ricerca Tecnologica Nucleare (CIRTEN), a consortium among university departments engaged in nuclear research and development, joined an international project aimed at developing the International Reactor Innovative and Secure (IRIS), a small size (about 300 MW) nuclear reactor, with a passive safety system. Moreover, Ansaldo concurred in the construction of two HWR units, built by Atomic Energy of Canada Ltd. (AECL)

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at Cernavoda, in Romania, and joined Westinghouse-Toshiba in developing an AP1000 PWR reactor, and in constructing Chinese power plants based on this technology.  

The karstic river resurfaced in 2008, when the Italian government decided to revamp the nuclear option. Despite its inherent inconsistency – Italy was clearly running toward today’s overcapacity and it was already evident that third generation reactors were overpriced – like in the early 1980s, the decision was not based on the existing Ansaldo know-how (AP1000). Rather, it was political interests that led to the signing of an agreement with the French government, followed by a Memorandum of Understanding between Energie de France (EDF) and ENEL, aimed at promoting the building of four 1600 MW nuclear units, based on the French EPR technology, which was substantially different from the AP1000 one.

To keep Ansaldo quiet and open room for a potential second nuclear venture wisely put forth by A2A, the theory of the advantage granted by competition among several technologies was revamped. In the end, Ansaldo signed an industrial partnership agreement with Areva, the French EPR manufacturer.

This time, though, the farce did not last long. In 2011, the nuclear accident that took place in Fukushima led, once again, to a referendum, the result of which was explicitly against any nuclear power program.

It was a conclusion to be expected, even before the last trial of launching nuclear power in Italy. As I wrote a couple of years before the Italian nuclear revival, “people regretting the Italian happy nuclear season in the 1950s must be conscious that the happy season then lived by the persons who were genuine supporters of the nuclear choice was not sustained by a strategy widely shared by the Italian ruling class. It was a choice instrumental to different goals. In the absence of such awareness, the risk of repeating past errors and illusions is very high.”

Errors were repeated and illusions were again raised, but their cost (either material or immaterial) was luckily kept low.

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CONCLUSION

Besides its historical interest, understanding why nuclear failed in Italy is of the utmost importance to avoid similar errors today. For instance, the energy efficiency targets set by two European Directives\(^\text{18}\) can only be achieved by using a system approach.

In particular, buildings must in perspective turn to Quasi Zero Energy Buildings, which will be the basic cells of smart districts and, to a larger extent, of smart cities.

Such a target, which is a “must” to mitigate climate change, requires joint and integrated actions involving many public bodies, research and development and private companies: this is exactly what was lacking in the case of the Italian nuclear policy.

The same stands in the case of policies promoting renewables: in Italy their unplanned penetration was more costly than needed.