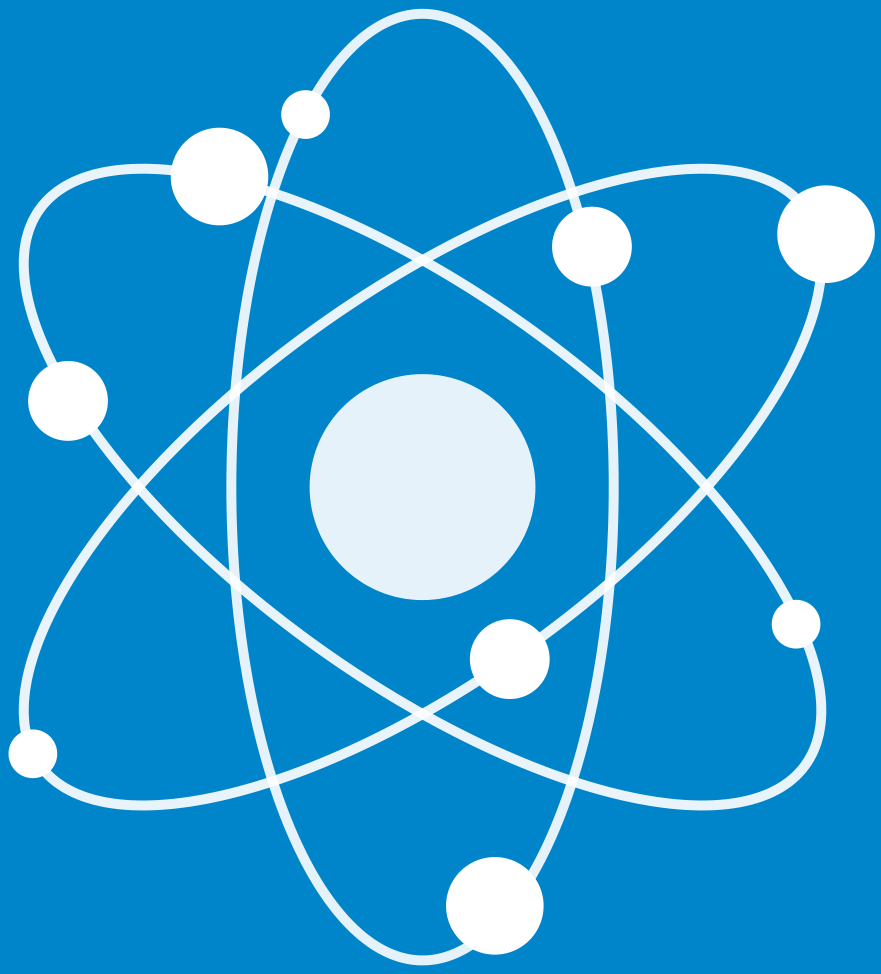


ASSOCIAZIONE ITALIANA NUCLEARE

POSITION PAPER

for a conscious and comprehensive reconsideration of the nuclear option in Italy

July 2023

The Association

The Italian Nuclear Association (Associazione Italiana Nucleare, AIN) is a non-profit **scientific** and **technical** association with legal personality representing all the **Italian entities** (universities, industries and research centres) **with expertise in the field of nuclear energy and related technologies**.

The association was established in Rome on November 12, 1958, as the Italian Nuclear Energy Forum (**FIEN**, Forum Italiano dell'Energia Nucleare) that operated until December 31, 1998. Then, in compliance with the new regulations on non-profit associations, the three historical Italian associations active in the field of nuclear energy – FIEN, **ANDIN** (Associazione Nazionale Di Ingegneria Nucleare) and **SNI** (Società Nucleare Italiana) – merged and founded AIN, transferring their respective activities, roles, and representations to the latter, thus consolidating its national and international presence.

The association obtained the **legal personality recognition** on September 14, 2005, with the registration number 355/2005 in the Register of Legal Entities (Registro delle Persone Giuridiche). In this capacity, it is authorised to engage in dialogue with governmental institutions.

AIN is explicitly established as a non-commercial cultural entity, not driven by profit. It is independent, non-partisan, and non-denominational and aims, in the interest of the country's civil progress, to serve as a meeting point, a forum for discussion, and a unifying force for all those – organizations, institutions, companies and individuals – interested in the development of nuclear energy and technology peaceful applications according to international and national safety regulations and the **EURATOM** treaty.

The Association's specific objectives include formulating and representing, at both the national and international levels, **qualified positions** and **opinions** related to nuclear initiatives and issues. It also aims to maintain relationships with national, international, and supranational nuclear entities, as well as similar organizations in other countries.

AIN represents the Italian nuclear system within the European Nuclear Society (**ENS**) and the European Atomic Forum (**nucleareurope**), established on July 12, 1960, holding consultative status with the ONU-IAEA, the European Commission, and the European Parliament.

Directive Board

President: MONTI Stefano
Board Members: ADINOLFI Roberto, AMBROSINI Walter, BOMBARDI Andrea, DODARO Alessandro, GASPARRINI Claudia, GINOLA Marianna, GOBBI Giancarlo, MAGGIONI Federico, NAVIGLIO Antonio, RICOTTI Marco, RIPANI Marco, TOSTO Luca
Observers: GIANNETTI Fabio, MASCOLINO Valerio, NOUCHY Fabio

THE INTERNATIONAL CONTEXT
AND CHALLENGES RELATED TO CLIMATE CHANGE AND ENERGY SECURITY

A comprehensive global debate is currently underway, also involving public opinion, on increasingly challenging issues related to energy security and environment, with a particular focus on the impact of the energy sector on climate change. This debate is influencing the strategies of those nations that have ratified the 2015 Paris Climate Agreement [1] and are committed to adopt measures that have a real impact on reducing the use of fossil fuels – major responsible for emissions of anthropogenic climate-altering gases into the atmosphere – and achieve carbon neutrality by 2050. This represents an extremely important and challenging transformation for both the economy and the entire energy sector, which is still massively dominated by oil, natural gas, and coal.

Various reports from the IPCC [2] remind us of the urgent need to implement relevant changes so that the energy transition towards the drastic reduction of use of fossil fuels (with a residual portion coupled with CO2 carbon capture and sequestration) be completed within the next three decades.

This already critical and challenging situation for all governments has been further exacerbated by the recent conflict in Ukraine, which has highlighted, among other things, the European Union's vulnerability in terms of energy supplies.

In this highly complex scenario, the European choices for 2030 and 2050 [3] have demonstrated that the most rational approach to the pressing issue of energy security and transition for Europe, and particularly for Italy, is to:

- Leverage each energy source for its advantages.
- Optimize the energy system by combining low-impact energy sources in the most cost-effective and efficient manner.

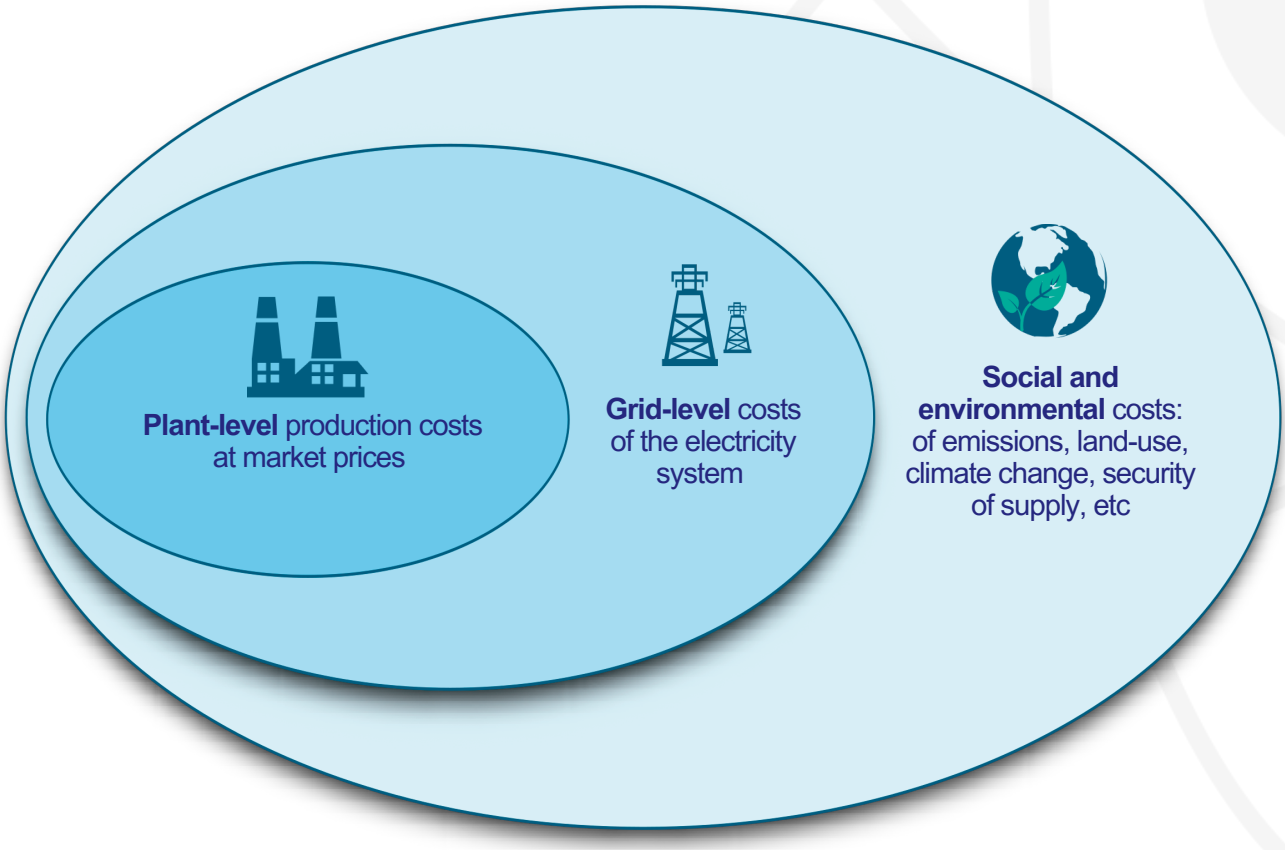


Figure 1 The cost of the electric energy system is not limited to production. Taken and adapted from Nuclear Energy Agency" System Costs of Electricity", 2021

Optimizing the energy system requires a correct assessment and allocation of appropriate system costs [4] for each energy source, particularly high in the case of variable and intermittent energy sources, currently not well recognized by the market (see figures 1 and 2).

Additionally, in the optimization process, consideration must also be given to the third part of the trilemma, namely energy independence, as described in various EU reports [5] and pursued in the recent Net-Zero Industry Act [6] and Critical Raw Materials Act [7] of March 2023.

Costs due to grid and transmission as a function of VRE (Variable Renewable Energy sources)

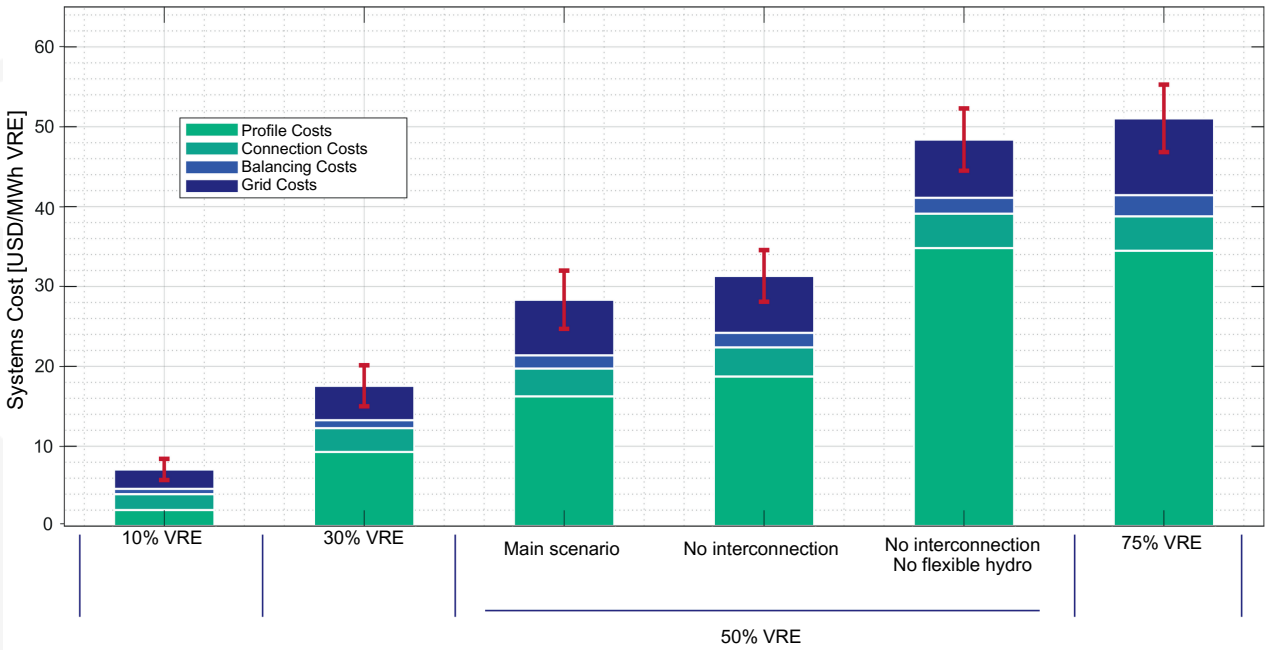


Figure 2 Electric energy system costs for different scenarios (limiting CO2 emissions to 50 g per kWh; Reference scenario considers 50% of VRE. Taken and adapted from Nuclear Energy Agency "System Costs of Electricity", 2021

Therefore, the fundamental step of the recent Italian parliamentary motion, approved by a large majority on May 9th, appears entirely agreeable, where it states:

> *Given the geopolitical context and the need to significantly reduce the contribution of fossil sources in the country's energy mix, it would be unwise to rule out the possibility of resorting to nuclear energy to ensure the nation's full energy autonomy.*

NUCLEAR ENERGY WORLDWIDE
WITH A FOCUS ON WESTERN EUROPE

Today, there are 437 operational nuclear power reactors in 32 countries worldwide, with 57 under construction in 17 countries [9] (Figure 3). According to the IAEA, another 30 countries have expressed their intention to adopt nuclear energy for the first time in their energy mix. Among these newcomer countries – those deciding to include nuclear energy in their energy mix for the first time – it is worth mentioning the cases of the United Arab Emirates and Belarus, which have recently connected large advanced nuclear power plants to the grid in just 10 years, essentially starting from scratch. Other newcomer countries such as Bangladesh, Egypt, Turkey, and Uzbekistan are making rapid progresses in constructing advanced third-generation nuclear plants. In various countries with a long history of nuclear power, such as China, South Korea, France, India, the United Kingdom, Russia, and the USA, advanced third-generation nuclear plants have either recently become operational or are in the process of doing so.

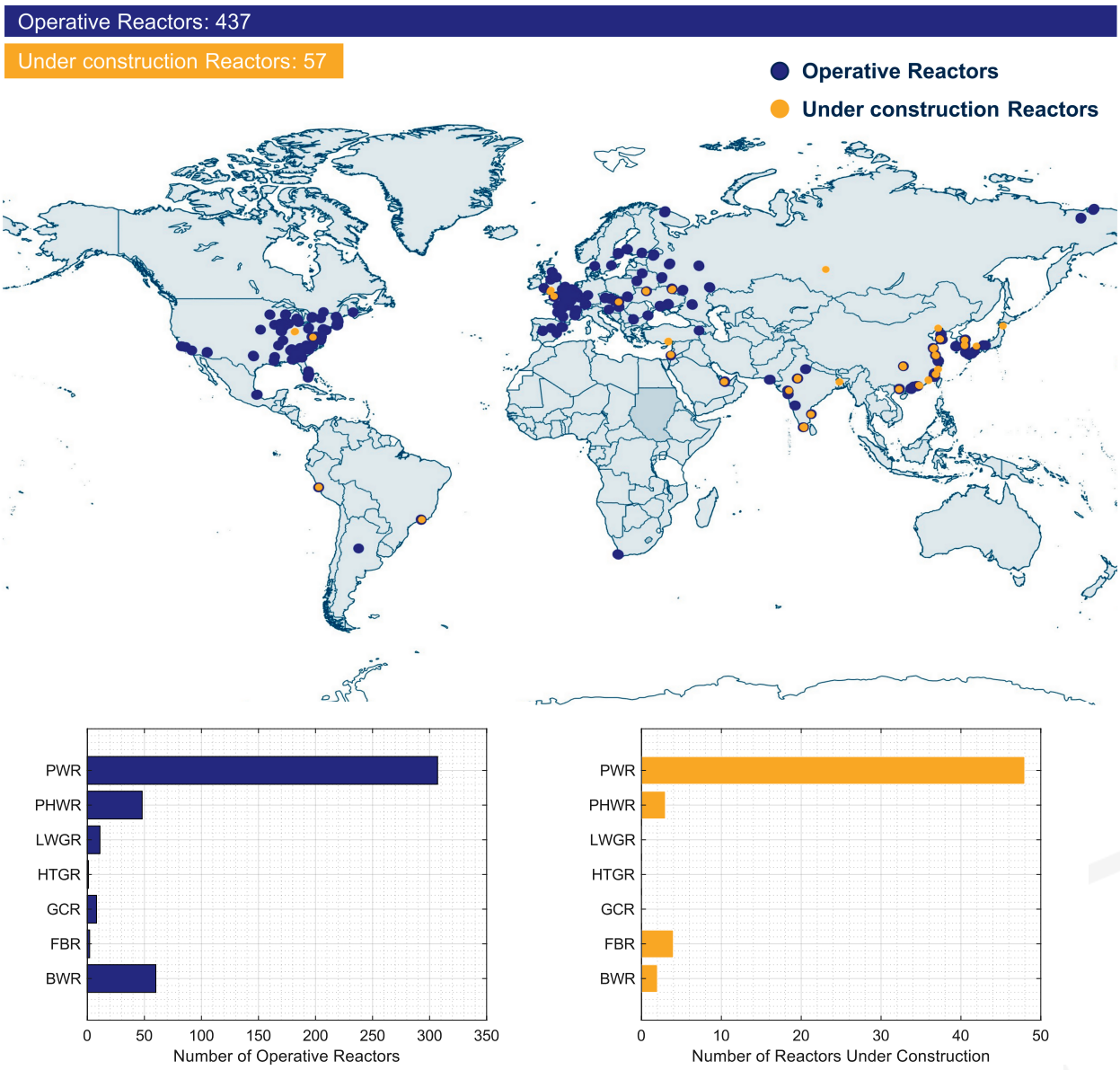
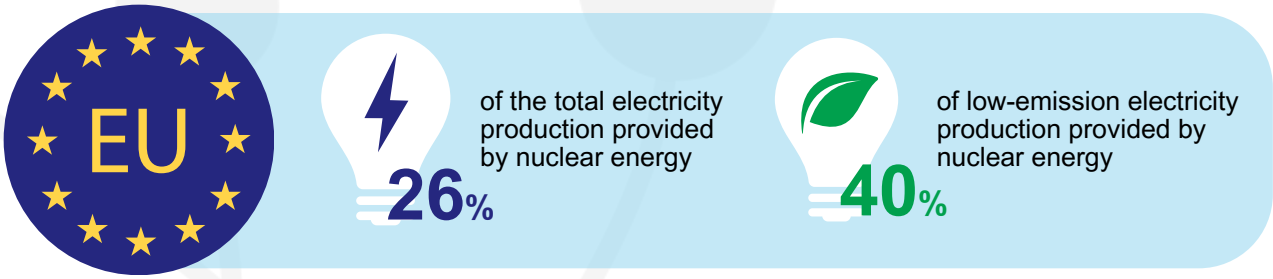


Figure 3 Operational and under-construction nuclear power reactors worldwide, data taken from the IAEA Power Reactor Information Systems (PRIS) database; PWR: Pressurized Water Reactors, PHWR: Pressurized Heavy Water Reactors, LWGR: Light-Water Cooled, Graphite Moderated Reactor, HTGR: High Temperature Gas Cooled Reactor, GCR: Gas Cooled, Graphite Moderated Reactor, FBR: Fast Breeder Reactor, BWR: Boiling Light-Water Cooled and Moderated Reactor.

The same countries, developers, and possessors of nuclear technologies for energy production, are engaged in extensive nuclear programs aimed at expanding the deployment of similar plants both domestically and globally. At the same time, they aim to make various Small Modular Reactor (SMR) and Micro Reactor concepts, including those of the so-called fourth generation, available on the market before the end of this decade [10]. The first models of SMRs are already in operation (e.g., in China and Russia), under construction (Argentina, China), or in the process of certification/licensing (Canada, China, South Korea, Russia, USA).

In the European Union, nuclear power generation already accounts for 26% of electricity production, which is well over 40% of the continent's low-carbon electricity. It has played a crucial role in alleviating the supply crisis from Russian gas pipelines in 2022. Furthermore, the role of the 121 European nuclear power plants is strategically significant in achieving emission reduction goals for 2030 and beyond, primarily due to the substantial amount of greenhouse gas emissions they help to avoid.



Apart from the recent grid connections of nuclear facilities in Finland and Slovakia, Western Europe has seen a proliferation of announcements regarding new nuclear programs in recent months. Bulgaria, Estonia, Finland, France, the Czech Republic, the Netherlands, Poland, Romania, Slovakia, Slovenia and Sweden have all announced plans for new constructions, including both large advanced reactors and Small Modular Reactors (SMRs), with construction set to begin by the end of this decade. In the United Kingdom, two EPR reactors are under construction, and the first SMR models are expected to be operational by around 2030. The only exception to this trend is Germany, which has gone against the grain by closing its last three nuclear plants in April 2023. However, Germany also stands out for its rising CO2 emissions despite significant resources being devoted to the Energiewende (energy transition) program.

The inclusion of nuclear energy in the European taxonomy [11] and the Net-Zero Industry Act will provide a strong incentive and motivation for its integration into the energy mix of EU member states. This is because it will be possible to access privileged public and private financing for the construction of new nuclear plants.

In this context, Italy, as the third-largest economy in Europe, is called upon to make a significant contribution to the ambitious goals of the European Union for sustainable development set by the Fit for 55 initiative and the commitments of COP26, which require a rapid reduction in carbon dioxide emissions. By 2050, the aim is to achieve complete decarbonization of the European energy sector. Recent national [12] and international [13] studies have shown that Renewable Energy Sources (RES), even in the most optimistic scenarios, will play a fundamental and predominant role but may not be sufficient to reach the ambitious targets set by the Paris Agreement on climate and the REPowerEU plan. Nuclear energy appears to be the low-carbon energy source that, due to its intrinsic characteristics of reliability, very high energy content of the fuel (minimizing the issue of strategic stockpiles), and the ability to provide large quantities of continuous energy (electricity, heat, and, in the near future, hydrogen) for both civil and industrial use, is best suited for integration with RES [14].

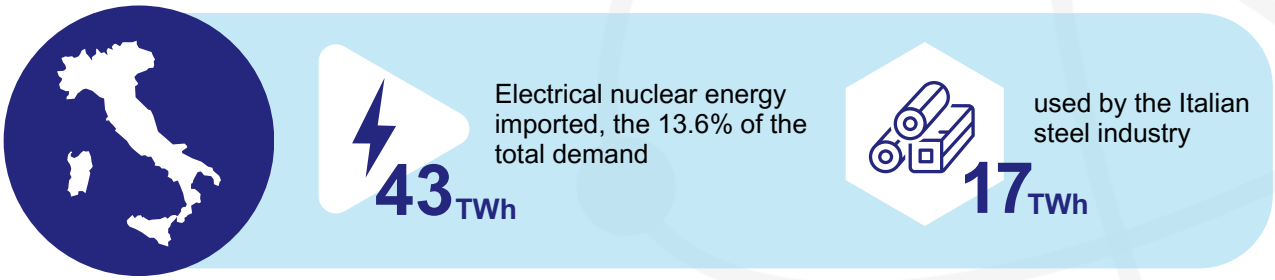
Despite the long period of substantial disinterest in nuclear energy following the 2011 referendum, Italy is indeed capable of contributing to the revival of nuclear energy in Europe and worldwide. This contribution can take the form of immediate participation in international programs for new constructions and the life extension of existing nuclear facilities. Additionally, looking forward, Italy has the potential to cover a significant portion of its national energy needs by 2050 through the establishment of nuclear power plants within its own territory.

AN OPERATIVE PROPOSAL
FROM THE ITALIAN NUCLEAR ASSOCIATION

In accordance with these potentialities, the proposal from the Italian Nuclear Association is structured around two main complementary lines of intervention, which can be summarized as follows:

1. **Italian participation in international**, and in particular **European**, **programs** aimed at maintaining and developing nuclear energy sources. This includes extending the operational life of existing nuclear plants and the construction of new facilities in the short term. Additionally, it involves ensuring access to the benefits of nuclear electricity production through targeted mechanisms that facilitate the import of low-carbon energy. This also includes the enhancement of infrastructure for the transmission and distribution of electric power and hydrogen, as well as the integration of nuclear energy with Renewable Energy Sources.
2. **Development of National Infrastructure** to enable the production of electricity, heat, and hydrogen through nuclear means in Italy after 2030.

In relation to the first line of intervention, it is important to emphasize that with the announcement of 29 new nuclear power plants and the decision to extend the operational life of approximately 60% of current plants, Western Europe recognizes the essential role of nuclear energy in the energy transition. Italy's Government, through initiatives such as the Mediterranean gas hub, a strategic resource for the entire European Union, is one of the most active proponents of the concept of "energy in common" as a pillar of European integration. Similarly, Italy can advocate for the energy produced by European nuclear power plants, whether existing or under construction, to be considered a shared European resource. Within this framework, there is a proposal, already supported by some major Italian users like Federacciai, to participate in the construction of a new nuclear power plant in a neighbouring European country in exchange for immediate access to carbon-free and continuous electric power from operational plants. Italy already heavily relies on the import of electric energy, primarily from neighbouring countries' nuclear plants, accounting for 43 TWh in 2022, equivalent to 13.6% of the total demand. The Italian steel industry alone consumes around 17 TWh/year, ranking it as the largest industrial consumer in Italy. Therefore, it is entirely reasonable for the Italian industrial sector to focus on controlling price variability, especially considering potential competitive advantages available in other European countries. In this regard, Interconnector has already committed to financing the interconnection line with Slovenia, with a total capacity of 500 MWe (as per Article 32, paragraph 3, of Law No. 99 of July 23, 2009). The approach proposed by Federacciai could extend to other projects in Europe, involve other users, and become a reciprocal and common practice in Europe. Considering European nuclear generation as a common resource would present an extraordinary opportunity, not only for the present but also for the future.



A necessary but not sufficient condition to implement such a European approach is the strengthening of electric power transmission networks and, in perspective, European infrastructure for the transmission and distribution of hydrogen, produced also through nuclear means. Simultaneously, it will be advisable to introduce market rules aimed at promoting the exchange of clean energy among European Union countries, favouring, for example, the signing of *Power Purchase Agreements* (PPAs), including potential equity participation for new plants.

In addition to these concrete and immediate benefits, this approach would undoubtedly have a significant impact on the national GDP through an increasingly extensive participation of the Italian system and manufacturing industry in the realization of new nuclear power plants abroad and supply of components and systems for the life extension of current European nuclear facilities. In parallel, the participation of a renewed and strengthened safety authority in joint reviews of such projects should be promoted, either through structured collaborations with counterpart authorities or through the training of its own personnel.

Regarding the second line of intervention, i.e. pursuing nuclear energy production in Italy with a solid foundation starting from the next decade, it is necessary to fully implement the previous line of intervention and, simultaneously, develop and strengthen basic infrastructures. This is of paramount importance for the implementation of a national nuclear program complying with the highest safety, safeguard, and sustainability standards recommended by international organizations.
The goal is the full development and consolidation of these infrastructures by 2030, enabling the construction of new nuclear power plants in Italy at the beginning of the next decade and their operation from 2035 onwards. Following the recommendations of the International Atomic Energy Agency (IAEA) in Vienna [15] and its methodology known as the Milestone Approach, which consists of three successive phases of development and respective milestones (see Figure 4), there are 19 infrastructure elements to be developed and enhanced:

Infrastructures to be developed and strengthened according to the IAEA

- National position
- Legal framework
- Regulatory framework
- Nuclear Safety
- Nuclear Security
- Safeguards
- Radiological protection
- Environmental protection
- Management
- Electrical grid
- Funding and financing
- Human resource development
- Stakeholder involvement
- Site and supporting facilities
- Emergency planning
- Nuclear fuel cycle
- Radioactive waste management
- Industrial involvement
- Procurement

In Italy, some of these infrastructures, such as the adequacy of the industrial system, are already well-developed, thanks to the vitality of our nuclear industries, which have achieved top-notch results in foreign markets. Others require significant enhancement and consolidation.

To manage and coordinate such a diverse and complex program, it would be advisable to have a "system coordinator/integrator" reporting directly to the political decision-maker. Referring once again to the milestone approach suggested by the IAEA, it would be necessary to establish a so-called *NEPIO: Nuclear Energy Programme Implementing Organization*. This would be a government-based organization tasked with assessing the status of the 19 infrastructures and advising the government on the actions required for their complete development and operability. The NEPIO would also be responsible for involving and coordinating all relevant public and private entities to ensure a well harmonized, coherent, and timely development of all 19 infrastructures.

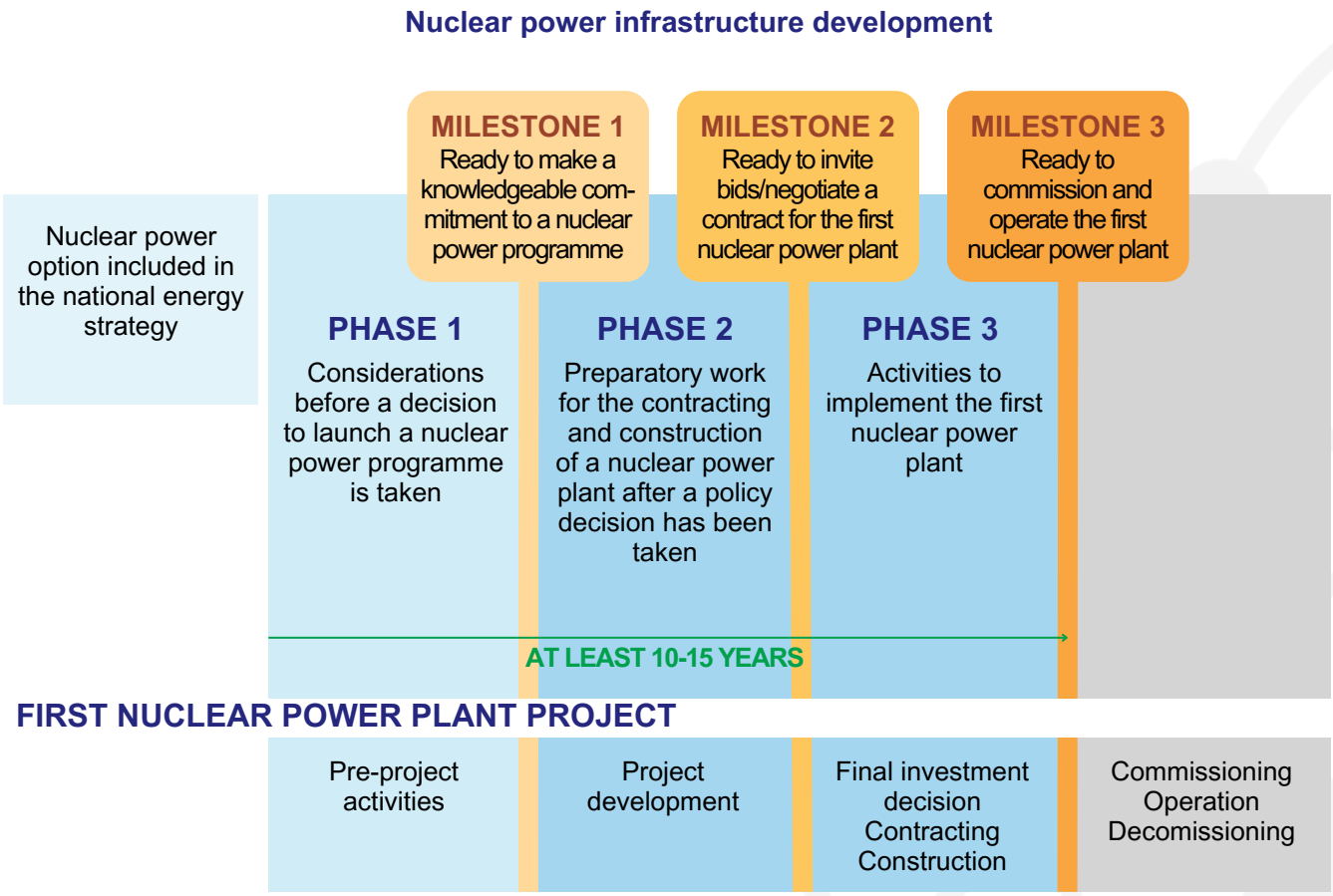
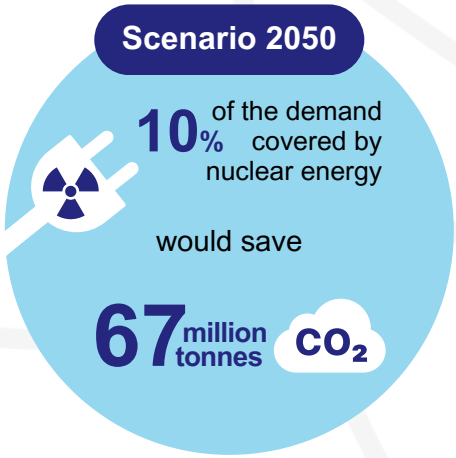


Figure 4 Development of the infrastructures to develop a national nuclear power programme, taken and adapted from the IAEA "Milestones in the Development of a National Infrastructure for Nuclear Power, IAEA Nuclear Energy Series No. NG-G-3.1 (Rev. 1), 2019".

Regarding the share of nuclear energy production by 2050, it should be evaluated within the context of optimizing the entire energy system, in which each energy source must contribute in a manner that doesn't create additional costs or risks. Typical examples include connection, distribution, and transmission costs, future storage costs, as well as the stabilization of the electrical grid. These costs increase significantly when the share of non-programmable energy sources exceeds 50-60%.

As of today, a reasonable estimate could suggest a contribution of nuclear energy of at least 10% of the total energy demand by 2050. Assuming the replacement of approximately 140 TWh/year of energy production from natural gas with nuclear energy by 2050, the emissions avoided by 2050 would amount to 67 million metric tons of CO2 equivalent per year.

The following median values for emissions have been assumed:
12 g CO2eq/kWh for nuclear energy, 490 g CO2eq/kWh per natural gas.



In addition to the benefits related to the reduction of greenhouse gas emissions, supply security, and energy price stability, there are other advantages offered by a nuclear construction program.

Historically, and as confirmed by recent studies, for example in Europe [16], nuclear energy is particularly labour-intensive and requires a highly skilled workforce, especially in the planning, design, manufacturing, and construction phases (see Figure 5). During the operation of a nuclear power plant, fewer highly skilled professionals are required, but they are needed in significant numbers per unit of energy produced. A considerable number of specialized workers are also required for the management of the fuel cycle backend (spent fuel and radioactive waste) as well as for the final decommissioning phase of the plant at the end of its life.

To provide a rough idea of the impact of nuclear energy on the economy of a developed region like the EU, which has a nuclear power plant capacity of approximately 120 GWe, consider the following (2019 data):

- In the EU alone, the nuclear sector supports 1.1 million workers, with 47% having high levels of training and professionalism.
- The GDP generated in the European Union by the nuclear sector amounts to 3-3.5% of the entire EU GDP (over 500 billion Euros annually). Every Euro contributed by the nuclear industry generates 4 Euros in indirect contributions to the EU GDP, resulting in an overall impact of 5 Euros on the EU GDP.
- In 2019, the European nuclear sector generated 124 billion Euros in public revenue (taxation).
- Each installed GWe in Europe generates: 4.3 billion Euros in GDP, approximately 10,000 jobs, of which about 4,500 are high-skilled, and 1 billion Euros in annual public revenue.

It's worth noting that these figures at the European level are consistent with estimates for the Italian case made in 2010 by European House Ambrosetti on behalf of ENEL, under the title "*Il nucleare per l'economia, l'ambiente e lo sviluppo*" (Nuclear for the Economy, Environment, and Development).

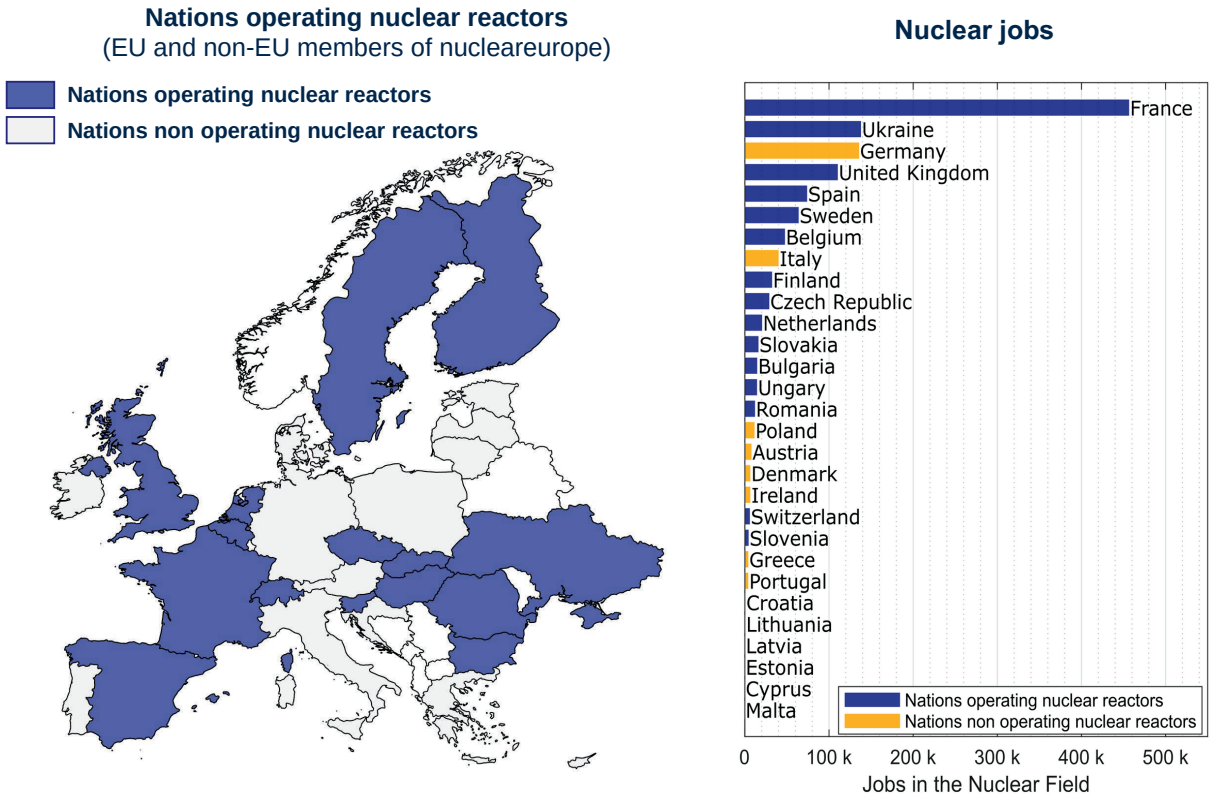


Figure 5 Overview of the civilian nuclear industry workforce related to the installation of nuclear power plants, taken and adapted from Nucleareurope: Pocket guide, 2023

THE EXPERTISES IN ITALY
TO SUPPORT THE NEW NUCLEAR PROGRAM

Italy, despite not having indigenous nuclear electricity production since the late 1980s, still owns relevant competencies and capabilities in the nuclear field that were maintained and, in some cases, further developed over the years. This has been possible thanks to participation in nuclear research and development (R&D) projects both domestically and internationally, as well as through the extensive decommissioning program and management of radioactive waste originating from energy production and nuclear fuel cycle facilities that operated until their closure. This situation provides a solid foundation for broader Italian involvement in nuclear initiatives and projects in Italy and abroad, especially in Europe, with expected benefits extending beyond 2030.

Italy still maintains world-class experimental “cold” facilities (meaning they do not contain nuclear materials), which support important R&D programs at the European and international levels. Italy has a successful track record in acquiring Euratom-funded R&D projects, particularly in the field of Small Modular Reactors (SMRs) and innovative fourth-generation reactors, such as Lead-cooled Fast Reactors. However, since 2018, national funding for fission nuclear R&D has been reduced to zero. This situation, unparalleled in Europe, weakens the country's position in competing for European R&D funding.

In a European context where significant developments in advanced nuclear plants construction are expected in many countries in coming years and substantial development programs on Small Modular Reactors and Micro Reactors for forthcoming energy markets are being initiated, it is essential to move swiftly to keep existing expertise up to date and, even more importantly, to suitably develop infrastructures. In particular, the Italian nuclear industry, still capable of competing on equal footing in Europe (as evidenced by its significant presence in the ITER project, the experimental thermonuclear fusion reactor under construction in France), must prepare in advance to meet the new market requirements, not only in terms of product quality but also in terms of production processes (e.g., SMRs require the organization of mass production of standardized components, similar to what is done in the aerospace industry).

Regarding system infrastructure for the construction of nuclear power plants in Italy, in some cases, such as the electric grid necessary to accommodate combined renewable and nuclear production, they are already in a more than satisfactory state of development and consolidation. In other cases, such as a regulatory authority capable of supervising the licensing program for new advanced nuclear plants, basic infrastructures need substantial enhancement and updating.

CONCLUSION

Regardless of the energy scenario adopted by Italy for the energy transition by 2050, action is required as soon as possible. The *International Energy Agency* (IEA) report from May 2021, commonly referred to as "*Net Zero*" [17] highlights to policymakers that nearly 50% of greenhouse gas reductions envisioned by 2050 are based on technologies which are at the demonstration or, at most, prototypical phase.

In this context, it's essential to consider that:

1. Nuclear fission technology is available, and Italy can contribute to maintaining and expanding it in other European countries for the benefit of the national economy.
2. The available nuclear technology or that which will become available in a few years (including SMRs and MMRs) can be installed in Italy starting from the next decade if the necessary infrastructures are established as soon as possible.
3. For advanced technologies already available (e.g., advanced third-generation reactors) or becoming available in a few years (e.g., SMRs and MMRs), market mechanisms should be put in place to facilitate their rapid use and deployment, recognizing that system costs, if properly assessed and attributed, vary significantly depending on technological choices.
4. More innovative technologies (e.g., fourth-generation reactors) will require more time to be market-ready for deployment. Therefore, research and innovation must be enhanced, essential to support industrial demonstration of such innovative technologies in the next decade to make them available in the market in about 15 years. Only with this accelerated program they will be able to significantly contribute to decarbonisation and energy supply by 2050.
5. The development of nuclear fusion, on which Italy is already heavily engaged, still requires significant R&D efforts, as well as experimental confirmations of the technical feasibility of various proposed solutions and processes under study. This phase should be followed by adequate technical-economic assessments and an industrialization phase to allow this highly innovative technology to compete in future energy markets.

As reiterated in various international forums and recommended by all international agencies (IPCC, OECD-IEA, OECD-NEA, IIASA, IAEA, UNECE), economically viable decarbonization of the entire energy sector, while ensuring energy supply at sustainable prices, requires the rapid availability and use of all low-carbon energy technologies. Banning some of these technologies for purely ideological reasons or due to lack of knowledge will certainly not help achieve the challenging goals the world has set for.

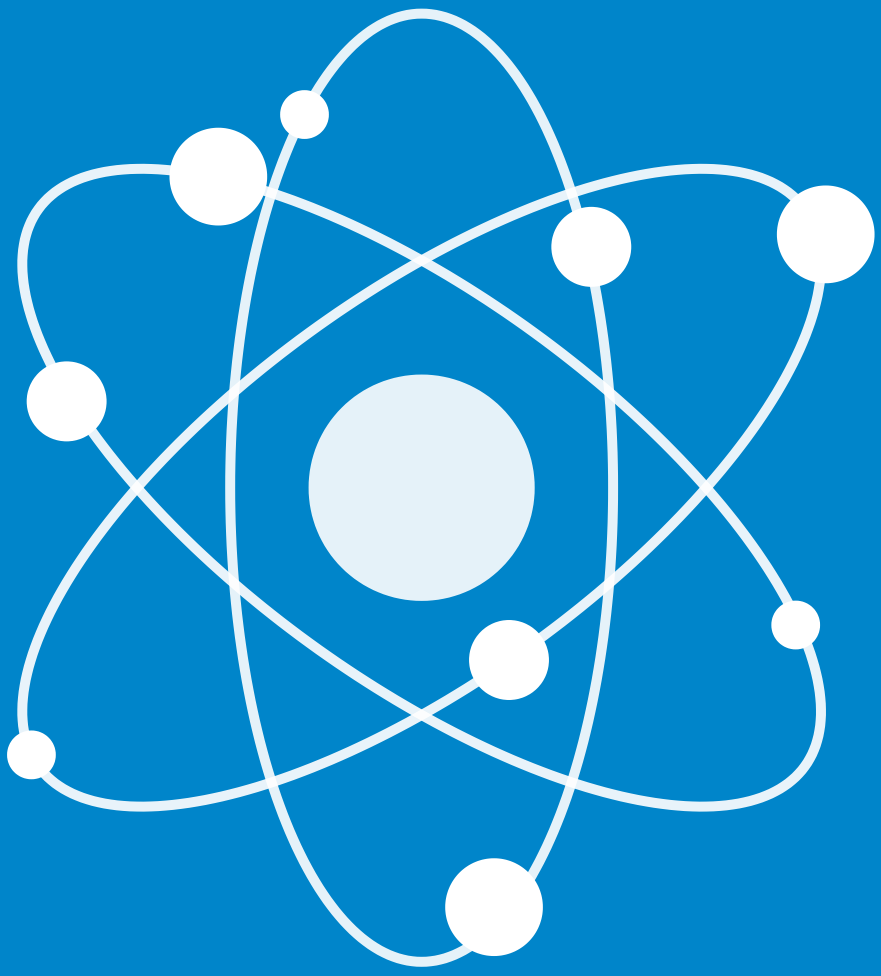
References

[1] United Nations Framework Convention on Climate Change (UNFCCC), 2016, The Paris Agreement. https://unfccc.int/documents/184656
[2] IPCC Intergovernmental Panel on Climate Change, https://www.ipcc.ch
[3] Fit for 55, the EU's plan for a green transition https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/
[4] OECD-NEA, 2021, System Costs of Electricity https://www.oecd-nea.org/jcms/pl_61519/system-costs-of-electricity?details=true
[5] EC, EU strategic dependencies and capacities: second stage of in-depth reviews, https://ec.europa.eu/docsroom/documents/48878/attachments/2/translations/en/renditions/native
[6] EC, Net Zero Industry Act, https://single-market-economy.ec.europa.eu/publications/net-zero-industry-act_en
[7] EC, Critical Raw Materials Act, https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials/critical-raw-materials-act_en
[8] Atti Parlamentari XIX legislatura – allegato A ai resoconti – seduta del 9 maggio 2023. https://documenti.camera.it/leg19/resoconti/assemblea/html/sed0100/leg.19.sed0100.allegato_a.pdf

[9] PRIS - IAEA, International Atomic Energy Agency https://pris.iaea.org/pris/home.aspx
[10] IAEA, 2022 Edition; Advances in SMR Technology Developments: A Supplement to the IAEA ARIS https://nucleus.iaea.org/sites/smr/SitePages/HomeSmrPlatform.aspx
[11] EC, EU taxonomy for sustainable activities, https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en
[12] Réseau de Transport d'Electricité, octobre 2021, Energy Pathways to 2050
[13] UNECE, 2020, Technology Brief – Nuclear Power; IEA, May 2019, Nuclear Power in a Clean Energy System; NICE Future, September 2020, Flexible Nuclear Energy for Clean Energy Systems; IAEA, 2020, International Conference on Climate Change and Nuclear Power; OECD-NEA, 2019, The Costs of Decarbonization: System Costs with High Shares of Nuclear and Renewables
[14] IAEA Nuclear Energy Series, 2022, Nuclear-Renewable Hybrid Energy Systems

[15] IAEA NES, 2015, Milestones in the Development of a National Infrastructure for Nuclear Power
[16] Impact Report – Vision to 2050, 2019, Deloitte study for Foratom 2019, data taken from EC, EP, Eurostat, IAEA, WNA

[17] OECD IEA, May 2021, Net Zero by 2050: A Roadmap for the Global Energy Sector



ASSOCIAZIONE ITALIANA NUCLEARE

www.associazioneitaliananucleare.it