THE NEW NUCLEAR POWER IN ITALY FOR CITIZENS AND BUSINESSES

The role for decarbonization, energy security and competitiveness

EXECUTIVE SUMMARY

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THE ROLE FOR DECARBONIZATION, ENERGY SECURITY AND COMPETITIVENESS

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PREFACES

Nicola Monti
CEO, Edison

The global context of recent years, with a staggered and multifaceted post-pandemic recovery, high energy price volatility further exacerbated by the Russian-Ukrainian conflict, and the climate crisis, has not only reignited interest in nuclear energy from countries that had abandoned or were on the verge of abandoning this energy source, but has also strengthened the commitments of countries that already include nuclear in their energy mix.

In Italy, where nuclear energy has always been a complex topic, this energy is also experiencing renewed interest thanks to the opportunities offered by new technologies, in particular smaller reactors that combine enhanced safety with better economic and financial prospects (the "new nuclear"). Advanced 3rd generation plants (Small Modular Reactors – SMR) will be commercially available by 2030, while 4th generation plants (Advanced Modular Reactors – AMR) will enter the market by 2040.

New nuclear is complementary to renewable energy sources and, together with them, contributes to decarbonizing the energy system effectively and efficiently. The energy produced by new nuclear has the advantage of being programmable and adjustable, ensuring a stable supply at fixed costs, complementing the intermittency of renewable sources. Moreover, the cost of nuclear energy is competitive when compared to a renewable energy source made programmable through a storage system. Additionally, unlike renewable energies, which are primarily located in Southern Italy where suitable environmental conditions exist (such as sun, wind, and water), nuclear power can be located near major consumption centers, predominantly in the North, thus reducing the investments necessary to strengthen the electrical grid to transport energy produced from renewables from the South to the North of the country. Finally, in addition to decarbonizing the electricity mix, small nuclear reactors can contribute to decarbonizing the heat and hydrogen used in industries, thus enabling the green transition of energy-intensive industries at a competitive cost and fostering the export of carbon-neutral "Made in Italy" final products.

The renewed interest in nuclear energy in the public debate, which has highlighted significant technological advancements in recent decades (notably SMR, AMR, and nuclear fusion), has allowed Italy to gain new awareness regarding decarbonization goals and greater openness towards the role that nuclear energy could play in ensuring a timely and secure transition.

New nuclear enables multiple systemic and differential benefits compared to large traditional plants. Firstly, it has shorter construction times due to its modular design, which allows for the serial production and pre-assembly of various modules in factories. Additionally, it improves project financing: the reduction in the size of plants and their corresponding construction times translates into lower capital requirements and financial costs, as well as limiting the possibilities of delays, ensuring greater certainty in project completion timelines. Finally, new nuclear allows for greater flexibility in site selection due to its smaller size (comparable to that of a thermal power plant), limited land use, and lower water consumption. Because of these characteristics, new nuclear can replace part of the gas and coal plants essential for ensuring the base load of the electricity grid, reusing some of the existing infrastructure that will reach the end of its useful life between 2030 and 2035.

The adoption of new nuclear technology can also bring macroeconomic benefits to the country. Investments in the construction of new nuclear plants in Italy can directly, indirectly, and inducedly activate multiple production sectors that make up the national economic fabric, creating jobs and generating positive impacts on the territory. The modularity of small nuclear reactors allows for the production and assembly of components in factories, enabling the development of the Italian supply chain. Our country already boasts a nuclear supply chain that has demonstrated excellence and resilience over time: we have over 70 companies specialized in the nuclear sector, more than half of which are medium to large-sized. These companies supply key components of high technological importance across Europe, contributing to current new construction projects in the UK, France, and Romania, as well as the modernization of existing plants in France and Slovenia. The strong relevance of the nuclear supply chain for Italy has also been demonstrated by the widespread participation of Italian companies in the European Industrial Alliance on SMRs, with Italy ranking second in terms of the number of participating companies, second only to France.

Furthermore, new nuclear limits Europe's dependence on foreign markets from multiple perspectives. For the same electricity production, it has a lower demand for critical raw materials compared to renewables. It also has diversified and non-geopolitically risky sources for fuel supply (uranium), such as Australia and Canada, which are among the main exporters. Finally, it can be developed by leveraging established European technical and industrial expertise.

To play a leading role in the new nuclear sector in Europe and benefit from it, both in terms of contributing to decarbonization and developing the Italian supply chain, it is necessary to implement a national nuclear strategy now. Italy does not start from scratch, as it already boasts a globally competitive supply chain and centers of excellence. However, it is essential to strengthen these aspects by defining an industrial plan with a medium to long-term vision that integrates and supports the entire Italian nuclear industrial supply chain, while simultaneously outlining specialized training plans at all levels of education with a vision extended to all the professional figures necessary for a nuclear program. It is equally important to structure the missing elements, such as the management of the fuel and waste cycle, the definition of a regulatory framework, and an incentive scheme to support the development of new nuclear energy in Italy.

In summary, new nuclear is not only a valuable resource for achieving the 2050 energy transition goals but also represents an important industrial revival opportunity for Italy. Therefore, this study outlines the perspective for reintroducing nuclear energy in Italy, highlighting the opportunities it opens up for the country and the choices we must make today to ensure its concrete development by 2030 through a responsible and informed approach by businesses, communities, and institutions.

Daniela Gentile
CEO, Ansaldo Nucleare

A sustainable energy transition leading to net zero by 2050 is a goal no longer in question, and every country is committed to revising its energy strategies to reduce carbon dioxide emissions and ensure a sustainable future. The recent commitment of 22 countries to the Declaration to Triple Nuclear Energy as part of COP28 obligates these nations to triple global nuclear capacity by 2050, demonstrating broad international consensus on the importance of nuclear energy in the global energy mix. This declaration highlights the collective determination to undertake concrete and innovative actions to address the climate crisis.

In this context, Europe has also embarked on a path of rapprochement with nuclear energy, highlighted by the EU Taxonomy for Sustainable Activities, which recognizes nuclear energy as a low-carbon source, encouraging investments and development in the sector. Supporting this orientation is the recently launched European Industrial Alliance on SMR, which promotes the development initiatives of Small Modular Reactors (SMR), a promising technology for Europe's energy future.

In this changed international and European scenario, Italy too is reopening a reflection on the beneficial role that the new nuclear technologies available or under development can play in the Italian energy mix, integrating renewable energies and ensuring continuity and security of electricity supply.

The Ansaldo group, faithful to the centrality of technology in its industrial vision, has never ceased, even after the abandonment of nuclear energy in our country, to operate in the nuclear sector, maintaining expertise and execution capabilities (consider the construction of the two 700 Mwe nuclear units in Romania, as well as the contribution to the modernization of plants in Argentina or Slovenia) and developing new technologies for third and fourth-generation reactors, as well as for fusion.

The renewed interest in nuclear energy at the international level supports this choice, allowing our Group to be well-prepared for the new engagement with European markets.

However, we are well aware that a technologically advanced response alone, nor a more favorable international context, is sufficient to ensure a confident and lasting revival of nuclear energy in our country. It is necessary that this reflects the actual needs of our society and is supported by transparent information at all levels, to create a broad grassroots consensus on which to rely to develop a reliable national program.

There are positive signs in this direction.

The active participation of Italian companies, universities, research centers, and institutions in the European Industrial Alliance on Small Modular Reactors demonstrates confidence in their industrial capabilities and sees this initiative as an opportunity for technological development in a rapidly evolving sector.

The new energy model proposed by Small Modular Reactors may prove particularly suitable for the Italian scenario, responding to the demands of energy-intensive industrial sectors by providing them with a low-carbon electrical and thermal energy contribution, thus enabling the completion of the decarbonization process and supporting competitiveness in the international market.

We believe the time is ripe for a reflection on the role that Italian industry can and must play in the non-postponable process of energy transition, not passively suffering its consequences but engaging to make this challenge a real opportunity: and the return of nuclear energy in Italy offers significant advantages in this direction, such as the growth of expertise and the strengthening of the national supply chain.

With great resilience, numerous Italian companies, not just our group, have maintained and developed capabilities in the field of energy component manufacturing and plant engineering, contributing to the construction of nuclear plants abroad, and now have the opportunity to become key players in the development of the new nuclear energy in the broader European and international market, creating jobs and technological and manufacturing expertise, and stimulating the economic growth of our country.

Collaboration between industry, institutions, and scientific research can support the development of a nuclear innovation hub, maximizing the competitiveness of the Italian supply chain so that it can export cutting-edge solutions and products globally.

The construction and management of new nuclear plants requires highly qualified personnel, and in this sense as well, the Italian industry, in synergy with universities and research centers, can play a key role in training the future generations of nuclear engineers and technicians, supporting the creation of skilled jobs.

These insights lead us to believe that with the necessary institutional support, targeted investments to scale up industrial production capacities, and strong international collaboration, nuclear energy can once again play a fundamental role both in the Italian energy mix and in the revival and strengthening of the national industrial fabric, thereby creating a virtuous growth path.

However, it is essential to ensure that these considerations are understood and widely shared by civil society, in all its components that can represent the needs and expectations of our society.

We therefore consider it important to stimulate an objective reflection on the potential and benefits of the new nuclear energy for Italy, analyzing how this energy source, also by virtue of ongoing technological and industrial developments, can contribute to the environmental sustainability, energy security, and economic development of the country.

Valerio De Molli
Managing Partner & CEO, The European House – Ambrosetti and TEHA Group

"Nuclear technologies can play an important role in the clean energy transition."

Ursula von der Leyen

Europe and Italy are currently at a decisive moment for the future of their energy system, where the decisions on policies to be implemented to achieve the 2050 decarbonization targets will determine not only the speed with which these objectives will be reached but also the competitiveness of our economy and the energy security of the country.

In this historical juncture, the technological development of "new nuclear" – a category that includes Small Modular Reactors (SMRs) and Advanced Modular Reactors (AMRs) – is opening up important new possibilities in terms of efficiency, flexibility, and sustainability thanks to a significant technological discontinuity compared to traditional nuclear power. The development of "new nuclear" brings with it multiple distinctive characteristics compared to traditional technology, which are particularly functional for achieving the 2050 decarbonization targets in an optimal integration with the development of renewables.

Indeed, "new nuclear" represents the electricity generation technology with the lowest carbon intensity and is capable of ensuring a stable supply. These characteristics integrate well with renewables, which, on the other hand, can meet demand peaks, especially during the central hours of the day – when solar panels receive the strongest irradiation and can generate more energy – or during periods of higher wind activity.

Delving deeper, the Study "New Nuclear in Italy for Citizens and Businesses" explores the potential of "new nuclear" for the national economy, with particular attention to the significant contribution that this technology can offer in terms of decarbonization, strategic security, and competitiveness. The Study also aims to provide a detailed, qualitative and quantitative, assessment of the potential benefits that "new nuclear" can activate. These benefits are analyzed considering the overall impact on the national economy, as well as the positive effects on industry, citizens, and local territories.

Among the most significant findings from the Study are the economic impacts that "new nuclear" can have on the country system. According to TEHA's analyses, "new nuclear" could generate a potential market for Italian companies worth up to 46 billion euros, with an activatable Added Value of 14.8 billion euros by 2050. Considering also the indirect and induced benefits, investing in "new nuclear" could enable an overall economic impact for the country exceeding 50 billion euros (about 2.5% of Italy's 2023 GDP) and create up to 117,000 new jobs by 2050.

Another reflection developed in the Study concerns the need to seize the moment to establish European leadership in "new nuclear" with a strong contribution from the Italian industrial sector. The launch of the European Industrial Alliance on SMRs on May 29^{th}, the intervention of European Commission President Ursula von der Leyen at the Nuclear Energy Summit in March, and the inclusion of nuclear development scenarios within Italy's PNIEC (National Integrated Plan for Energy and Climate) are all signs of renewed European and national interest in this technology. In a context of strong international competition, with over 80 "new nuclear" projects under development worldwide, it is necessary to seize the favorable moment to accelerate investments and consolidate Italian and European value chains that can compete globally.

To initiate a path that maximizes the potential of “new nuclear” in Italy, the Study has identified a roadmap to promote the implementation of a nuclear program in Italy, highlighting the development levers to accelerate the process of implementing “new nuclear” in Italy – supply chain and skills, financing, licensing and permitting pathways, that is, the process of obtaining authorizations for the construction and management of plants – and the enabling factors that are necessary and decisive for the development of “new nuclear” in Italy – regulatory framework, nuclear waste management, and social acceptability.

Before inviting you to read this report, I would like to thank the Advisory Board for their valuable contribution in supervising the development of the Study, including Nicola Monti (CEO, Edison), Daniela Gentile (CEO, Ansaldo Nucleare), Ferruccio De Bortoli (President, Longanesi; Columnist, Corriere della Sera), Andris Piebalgs (Professor, Florence School of Regulation – European University Institute; former Energy Commissioner, European Commission), and Ferruccio Resta (President of the National Center for Sustainable Mobility MOST; President, Politecnico di Milano Foundation).

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Ferruccio Resta
Professor, Politecnico di Milano; President, National Center for Sustainable Mobility; President, Bruno Kessler Foundation; President, Milan Polytechnic Foundation

How much energy is consumed annually in Italy? How is it produced and what would be the consequences of greater energy autonomy?

Given the growing environmental and security of supply concerns, these questions prompted the creation of this study, which focused on analyzing the role of “new nuclear” power in the Italian energy landscape and its possible implications for the entire Italian economic system.

According to the most recent data from the Ministry of the Environment and Energy Security, Italy consumed about 109,307 thousands of tons of oil equivalent in 2022. This demand, mainly concentrated in the transportation, residential, industrial and service sectors, is mainly met by fossil fuels such as oil, natural gas, coal and, only to a lesser extent, electricity. Although renewables have experienced significant growth in recent years, covering an increasing share of the national energy mix, Italy remains heavily dependent on imports, exposing the national economy to price fluctuations in global markets. Recent years have been characterized by rapid increases in gas and electricity costs, linked to a fragile global geopolitical and climate system; a situation that has impacted and strained households and businesses, underscoring the urgency of diversifying energy sources and promoting energy efficiency.

It follows that even these elements alone would be sufficient to understand the multiple challenges we are facing: dependence on fossil fuels, which are responsible for climate change and air pollution; geopolitical phenomena; vulnerability; and the growing demand for electricity, fueled especially by the advent of disruptive technologies such as Artificial Intelligence, High Performance Computing, Cloud and Data Centers. Faced with such a complex scenario, Europe is rethinking its energy model, looking for safe, reliable solutions with a reduced carbon footprint, and Italy cannot afford to be left out.

In this context, nuclear energy, a source we have known for almost a century, emerges as a potential game-changer. Compared with the previous generation of reactors, the “new nuclear power” presents a discontinuous technological change; in fact, it is characterized by greater safety and lower environmental impact due to its smaller size and simplified modular design, ensuring stable and sustainable energy production in line with decarbonization goals.

The Study aims to provide a pragmatic and scientific assessment, providing objective elements for an informed debate on the function of next-generation nuclear power in Italy’s energy transition. A rigorous analysis of the technical, economic, environmental and political aspects, aimed at defining the potential of this technology for the country’s energy resilience and independence, overcoming the often-polarizing ideological preconceptions that have always characterized the debate on the subject.

However, it is important to emphasize that the “new nuclear power” is not a one-size-fits-all or final solution, but rather an important piece to be evaluated within a broader and more diverse strategy, in synergy with other clean energy sources. Indeed, the energy transition is a complex process that requires balancing several factors, including energy autonomy, environmental sustainability, system reliability and social equity.

The objective of the Study is therefore to promote an open and inclusive dialogue on the issue, involving all stakeholders: citizens, businesses, scientific institutions, environmental associations and policy makers.

For this reason, I would like to thank Ansaldo, Edison, and The European House – Ambrosetti for their valuable contributions, which made it possible to carry out this work and thus initiate a constructive reflection on the "new nuclear" in Italy.

Ferruccio De Bortoli
President, Longanesi; Columnist, Corriere della Sera

In the second half of the last century, Italy was an industrial power in the field of civil nuclear energy, partly due to the long-lasting influence of its scientific research, beginning with the "Via Panisperna boys" and the investments made by both public and private enterprises. In 1964, when the scandal exploded that unfairly implicated Felice Ippolito, then president of Cnen (the National Committee for Nuclear Energy), who was later pardoned by the President of the Italian Republic, Giuseppe Saragat, Italy could compete with the UK and the USA in terms of gross production and installed capacity. Even before two referendums (in 1987 following the Chernobyl disaster and in 2011 after Fukushima) marked its decline, Italian nuclear energy fell victim to power struggles between various interests, starting with those of the oil lobbies. During the Cold War years, the pursuit of energy independence by our country (as the Mattei case clearly shows) was seen as a threat, both domestically and abroad. This issue even divided the main governing parties of the First Republic, including within their own coalitions. Regardless of one's stance, it was a major lost opportunity for industrial development and growth. A significant loss.

Whatever one's opinion on nuclear energy today, it cannot be seen as a positive choice to remain excluded from nuclear power on the eve of a technological paradigm shift made possible by advances in research. Fortunately, despite everything, our country still has valuable industrial assets, excellent research institutes, high-level universities, and visionary and courageous entrepreneurs. Are we willing to miss out on another important opportunity now that next-generation nuclear power – safer, producing less waste, and with fusion on the horizon – appears essential for achieving the energy transition? Renewable energy alone, despite all efforts, will not suffice, especially for a country with limited space for photovoltaics and deeper waters for offshore wind.

The latest version of the NECP (National Energy and Climate Plan) reaffirms the strategic choice to push as much as possible towards electrification from renewable sources, but it projects two scenarios for 2050 regarding nuclear energy usage, with contributions ranging between 11 and 22 percent. Nuclear power, therefore, is a complement to renewables, not an alternative. According to Fraunhofer, in the first half of 2024, France emitted 30.6 grams of CO2 for every kWh generated to meet its own electricity needs, even considering its exports of which we are buyers despite every referendum. Germany, which has three times as much renewable energy as France and also imports electricity from France, emitted 367 grams of CO2 per kWh into the atmosphere. That is 12 times more than France. Italy, during the same period, emitted 20 percent less than Germany, but still 10 times more than France.

A report commissioned by the European parliament and Council concluded that "there experiences no scientific evidence that third-generation nuclear power causes more harm to human health or the environment than other technologies within the European green taxonomy". Among these, renewables have the characteristic of being dispersed, as well as intermittent, while nuclear power is by nature concentrated and continuous. It has been calculated that a multi-reactor nuclear plant, totaling 5 GW, would occupy 200 hectares, without the need for storage systems. To achieve the same energy output, 40,000 hectares covered with photovoltaic panels would be required. In the face of the climate emergency, it is necessary to overcome prejudices and unfounded fears. No ideological choices, just an evaluation of costs, risks – which are part of human activity – and future benefits. Many of these benefits concern future generations, who must inherit a cleaner environment without sacrificing too much of their well-being.

Andris Piebalgs
Professor, Florence School of Regulation – European University Institute; Former European Commissioner for Energy, European Commission

Since December 20, 1951, when Argonne National Laboratory in the U.S. produced the world's first usable amount of electricity from nuclear energy—enough to light a string of four light bulbs—nuclear energy has served humanity. Just three years later, the first nuclear power station was connected to the grid. Today, nuclear power accounts for about 10% of global electricity generation, rising to nearly 20% in advanced economies. Historically, it has been one of the largest contributors to carbon-free electricity globally and holds significant potential for furthering power sector decarbonization. With approximately 413 gigawatts (GW) of capacity operating in 32 countries, nuclear energy currently helps avoid 1.5 gigatonnes (Gt) of global emissions annually. The International Energy Agency (IEA) underscores that nuclear energy, with its dispatchability and growth potential, can play a crucial role in ensuring secure, diverse, low-emission electricity systems. The IEA recommends establishing robust policy frameworks for nuclear power to reduce investment risks and accelerate the development of Small Modular Reactors (SMRs).

Nuclear policy has been integral to the European Union from its inception, and nuclear energy remains a vital part of the EU's energy mix. The EU depends on nuclear power for about one-quarter of its electricity and a higher proportion of base-load power, with nuclear providing about half of the EU's low-carbon electricity. The Treaty on the European Atomic Energy Community (Euratom Treaty) of 1957, one of the EU's three founding treaties, remains largely unchanged, and all current EU Member States are signatories. Despite the existence of common rules and standards governing nuclear energy, each Member State independently determines whether to include nuclear energy in its energy mix.

EU Member States have diverse perspectives on nuclear energy. Currently, 12 Member States host nuclear power plants. While Germany has recently decided to phase out nuclear energy production entirely, several other Member States plan to build new reactors. France has announced a goal to construct 14 new reactors by 2050. Bulgaria and Romania have advanced plans for two sites, while Finland, Bulgaria, and Czechia plan to build one each. Poland, meanwhile, has ambitious plans to start nuclear energy production, aiming to build six large pressurized water reactors by 2040, with construction of its first plant set to begin in 2026 and finish by 2033. Although power generation capacity is primarily managed at the national level, a significant 10pproxt of electricity trading occurs across national boundaries within the EU, making each country's energy policies impactful for its neighbours.

The debate on nuclear energy within the EU revolves around both its opportunities and challenges. SMRs are increasingly seen as potential solutions to energy supply issues and are likely to become commercially viable by the early 2030s. These reactors could serve diverse roles, including district heating, desalination, energy-intensive industrial processes, and hydrogen production.

The discussion around nuclear energy's role in the EU's path to decarbonization is becoming less polarized. The European Commission has committed to technological neutrality, acknowledging during the negotiations on the recast of the Renewable Energy Directive (RED) that other fossil-free energy sources, beyond renewables, can contribute to reaching climate neutrality by 2050 for Member States that choose to rely on such energy sources. In recent years, public support for nuclear energy has gradually risen, although opinions remain divided across Member States. Debates have intensified following Russia's invasion of Ukraine, leading to the formation of a ‘nuclear alliance’ among Member States that view nuclear power as a means to ensure energy sovereignty, achieve decarbonization, and stimulate economic growth. This alliance has become a fixture in EU energy discussions, with a signed declaration laying out a framework for enhancing cooperation on nuclear energy across five key areas: positioning nuclear power within Europe’s energy strategy, safety and waste management, industrialization and sovereignty, skills, and innovation.

In March 2023, the European Commission proposed the Net-Zero Industry Act (NZIA) to scale up manufacturing of clean technologies within the EU as part of the clean-energy transition. The NZIA sets a target for Europe to produce 40% of its annual deployment needs in net-zero technologies by 2030 and aims to capture 25% of the global market value for these technologies. Among the ten proposed technologies are “advanced technologies to produce energy from nuclear processes with minimal waste from the fuel cycle, small modular reactors, and related best-in-class fuels”. In May 2024, the European Alliance on Small Modular Reactors was launched, with the goal of facilitating and accelerating the development, demonstration, and deployment of SMRs in Europe. Technical working groups have already been established, and it is expected that the forthcoming Clean Industrial Deal for competitive industries and quality jobs will also highlight the role of nuclear energy.

This Study is timely, as Europe faces unprecedented challenges in achieving the goal of climate neutrality by 2050 while ensuring a safe and affordable energy supply for both industry and households, all while remaining at the forefront of technological innovation. The Study analyzes the current and prospective role of nuclear power in European and Italian energy security and transition, focusing particularly on the potential contribution of “new nuclear” technologies, such as small reactors, compared to traditional nuclear power. As one of Europe’s industrial powerhouses, Italy must not miss the opportunities presented by these developments while effectively managing the associated risks.

This Study provides a solid foundation for discussion and a stable platform for Italian stakeholders to advance along the path of new technological opportunities, ensuring that the energy transition leads to job creation and economic growth. The Study offers concrete policy proposals aimed at enhancing social acceptability, creating the necessary regulatory frameworks, facilitating financing, and establishing supply chains and the requisite skills.

New technological developments present an opportunity to seriously reconsider nuclear energy. Europe is already doing so, and Italy cannot afford to wait. As EU Member States prepare to make decisions on the 2040 GHG emissions target, with the European Commission proposing a 90% reduction, it is imperative that these decisions consider the role of the best available technologies in achieving this ambitious goal.

EXECUTIVE SUMMARY OF THE STRATEGIC REPORT

The study carried out by TEHA Group in collaboration with Edison and Ansaldo Nucleare aims to contextualize the **reference scenario** of nuclear power at a global and European level, analyzing the ongoing **technological advances** and the **growing demand for decarbonized electricity**, which today make the **development of "new nuclear" power** (Small Modular Reactors and Advanced Modular Reactors) **crucial** in achieving the climate neutrality goals set at the international and European level.

The Study also aims to provide a **detailed** qualitative and quantitative **assessment** of the **benefits potentially offered by "new nuclear" power**. These benefits are analyzed by considering the **overall impact** on the country system, but also the positive effects on **industry**, **citizens** and **local areas**.

Specifically, the benefits of "new nuclear" power for the **country system** are analyzed, qualifying and quantifying how the technology can effectively contribute to supporting **decarbonization** processes (through decarbonized stable and modular power generation) while simultaneously pursuing increased **energy security** and national **competitiveness**, quantifying the potential **economic and employment benefits** for the country.

An12pprox.1212t element of the analysis regards the benefits of "new nuclear" power for **energy-intensive industries**, identified as a strategic area where "new nuclear" technologies can help support industrial decarbonization processes while ensuring business competitiveness through **reduced energy costs** and **thermal** and **hydrogen power generation**.

The benefits of "new nuclear" power for **citizens** and **territories** are also estimated, highlighting the **direct impacts** on local development and enhancing the **characterizing elements** of **smaller** plants to **improve social acceptability** (e.g., less land consumption, limited impact on the landscape, integration with production districts, development of skills throughout the country, etc.).

Finally, specific actions necessary to develop "new nuclear" power in Italy are outlined in order to **maximize the benefits for end users and the national economy** and **enhance the expertise of the industrial supply chain and the research sector**. In particular, the main **drivers of development** – supply chain and expertise, financing and permitting procedures – that can **accelerate** the implementation process of "new nuclear" power in Italy and the main **enabling factors** – regulatory framework, nuclear waste management and social acceptability – that are **necessary and decisive** to develop nuclear energy in Italy are identified.

TEN KEY MESSAGES OF THE STUDY

1. Nuclear production has historically supplied a significant share of the world's electricity (averaging 12.5% of the total over the past 50 years). Although Europe has reduced its share of the global total, nuclear power remains the main source of electricity generation in the EU today (22% of the total), and 10 of the 16 countries globally where nuclear power is most relevant are in the EU.

Nuclear energy has contributed significantly to **electricity generation** for **over 50 years**. Starting in **1971**, when **2.1%** of global electricity generation came from **nuclear sources** (vs. **40%** from coal, **23.6%** from renewables, **21.1%** from oil and **13.2%** from natural gas), the use of nuclear power trended **upwards** until **1996**, when it **peaked in terms of generation** (**17.7%** of global electricity). Since 1996, other sources have increased their role in the energy mix, and nuclear power's contribution to electricity generation **has slowed**: by **2022** it accounted for **9.1%** of global power generation (approx. **2,600 TWh**). In this context, it is worth noting that nuclear technology can boast **a cumulative experience** of nearly **20,000 years**, totaling approx. **7.7 million days of operation**.

Looking at generation by **macro-area**, **Europe** and **North America** have been the main **contributors** to the development of nuclear power, especially in the period between **1971** and **1990**, generating **86.1%** of the world's total nuclear-generated electricity (vs. **13.2%** from Asia, **0.3%** from Africa and **0.4%** from South America). In the following years, the contribution of **Europe** and **North America fell** to **78.3%** (**-7.8 p.p.** compared to 1971-1990) while **Asia**'s contribution **increased**, reaching a total of **20.5%** of global nuclear power generation in 2022 (**+7.3 p.p.** compared to 1971-1990). Specifically, it was the countries in the **APAC region**[1] that improved their position in the **global scenario**.

[1] The Asia Pacific (or APAC) countries are the Asian and Oceanic nations in the Pacific Ocean that include: American Samoa, Australia, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, Christmas Island, Cocos (Keeling) Islands, Cook Islands, Fiji, French Polynesia, Guam, Hong Kong, India, Indonesia, Japan, Kiribati, North Korea (Democratic People's Republic of Korea), South Korea (Republic of Korea), Lao People's Democratic Republic, Macau, Malaysia, Maldives, Marshall Islands, Micronesia (Federated States of), Mongolia, Myanmar, Nauru, Nepal, New Caledonia, New Zealand, Niue, Norfolk Island, Northern Mariana Islands, Pakistan, Palau, Papua New Guinea, Philippines, Pitcairn, Russian Federation, Samoa, Singapore, Solomon Islands, Sri Lanka, Taiwan (Province of China), Thailand, Timor Leste, Tokelau, Tonga, Tuvalu, Vanuatu, Vietnam, Wallis and Futuna.

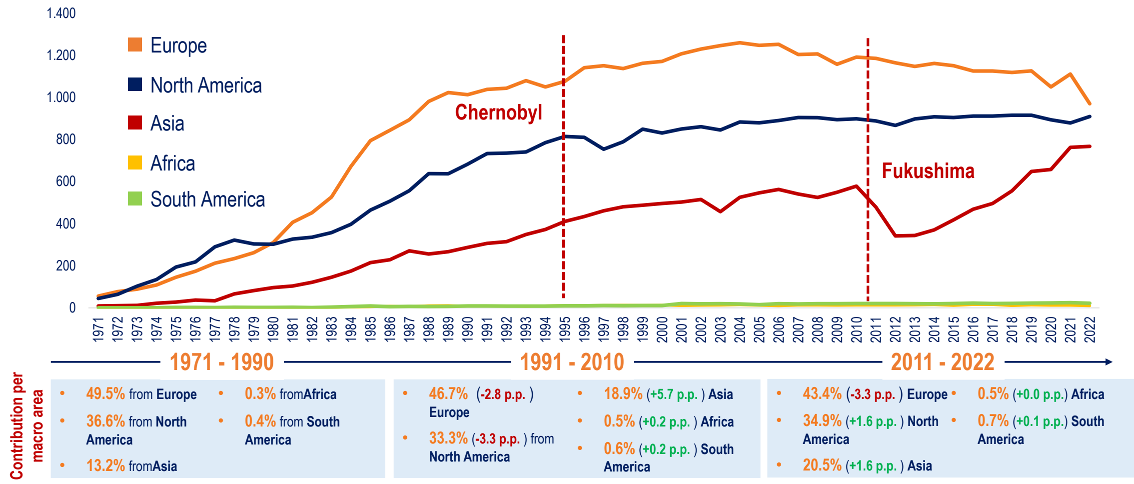

Figure I. Electricity generation from nuclear sources by macro-area (TWh), 1971-2022. *Source: TEHA Group elaboration of Ember and Energy Institute – Statistical Review of World Energy data, 2024.*

Shifting the focus now to **Europe** and considering the time horizon of the past **20 years**, it is clear that nuclear power has stably been the **main electricity generation technology**. From **2001** to **2022**, on average, **30.1%** of electricity in the EU-27 was generated from nuclear power, ranking above **generation from coal** (on average **25.1%**) and **natural gas** (on average **19.4%**).

Despite Europe's **reduced** use of nuclear power, to date, it remains one of the regions that rely most heavily on electricity generated from this source, accounting for **23.5%** of total electricity generation in the **EU-27** in **2022**. Confirming this, among the **16 countries globally** where nuclear power is most relevant (Armenia, Belgium, Belarus, Bulgaria, South Korea, Russia, Finland, France, Czech Republic, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine and Hungary), **14** are on the **European** continent and **10** are members of the **European Union**.

In particular, **France**, **Slovakia** and **Ukraine** are the **top 3 countries** in terms of nuclear energy's **share** in their electricity **generation** mix, accounting for **65%**, **61%** and **56%** respectively. In these countries, as well as in **Hungary**, **Finland**, **Belgium**, **Bulgaria** and **Slovenia** (with nuclear energy's shares of **48%**, **42%**, **41%**, **40%** and **37%** in their electricity generation) nuclear power is currently the **main source of** electricity **generation**.

2. Nuclear power is now experiencing a phase of expansion and a gradual shift towards Asia: Forty of the sixty-one reactor projects under construction in the world are located in APAC countries, propelling this area towards becoming the world's leading producer of nuclear power as early as 2030. In this context, at the European level, 18 countries have planned nuclear energy development projects.

The nuclear power sector is now experiencing a worldwide expansion, with several countries investing in **nuclear power development strategies** and new reactor construction projects. At present, there are **61** nuclear reactor projects in the world under construction (for a total gross capacity of **68.4 GW**)[2], **111** planned reactors[3] (for a total gross capacity of **113.9 GW**) and **337** reactors under proposal[4] (for a total gross capacity of **378.2 GW**).

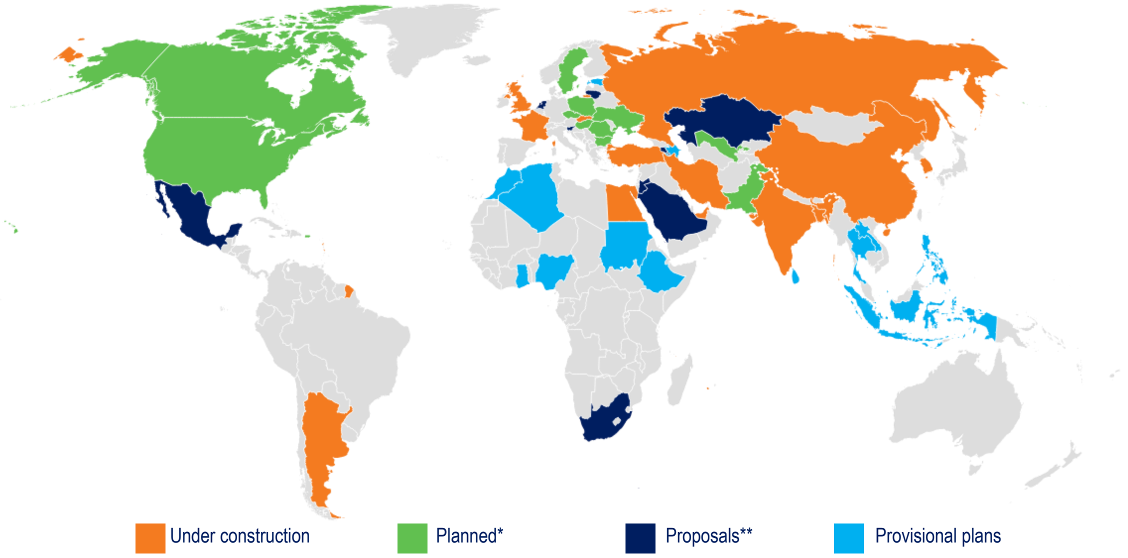

Figure II. "New nuclear" reactor projects per progress status, March 2024. (*) Planned reactors = Approvals, funding or commitments in place, most reactors are expected to be in operation within the next 15 years. (**) Proposals = Specific program or new plant proposals with very uncertain timeframe. *Source: TEHA Group elaboration of "World Energy Outlook 2023", IEA and World Nuclear Association data, 2024.*

The **APAC region** is the most active geographic area in the development of new projects in the nuclear sector, with **40 of the 61** projects currently under construction globally. Under the foreseen development plans, **the APAC region would have, as early as 2030, the largest share of nuclear power generation in the world** (37.8%), surpassing North America - current market leader with a share of 33.5% in 2022 (vs. Europe's 28.0% and APAC's 27.9%). **China**, in particular, **stands out** with an ambitious plan that positions it as a **global leader in the**

[2] Source: "World Energy Outlook 2023", IEA and World Nuclear Association.

[3] These are projects that have been approved and/or have funding or spending commitments in place, with most of the reactors in question expected to come into operation within the next 15 years.

[4] These are projects that have been proposed but with no estimates of spending commitments and with approval timeframes still considered very uncertain.

sector, having already **doubled** its share of nuclear power in its energy mix over the past 20 years (5.0% in 2022 vs. 2.2% in 2003, with a production of 417.8 TWh).

Looking at Europe, in order to meet decarbonization goals, several countries have begun to **diversify their energy mix**, reducing the share of fossil fuel-based energy production and focusing on a balanced mix of low-carbon technologies, including nuclear power. To date, there are **18 countries** in Europe that have **ongoing development projects or that are planning strategies to strengthen nuclear power in the future**. Of these, France, Poland, Sweden, Finland and the Czech Republic above all are investing in the construction of new reactors, including SMRs[5]. **The Netherlands and Belgium**, moreover, after an initial decision to interrupt nuclear power generation, have revised their policies and **redirected their national energy plans towards nuclear development**.

In contrast to these nuclear development programs, Germany, Switzerland and Spain have prepared national nuclear decommissioning strategies. However, despite these phase-out choices, **nuclear power remains a key technology for the energy transition that Europe is focusing on**, with special attention to **"new nuclear"**.

In addition, the combination of a leading position in terms of the projects currently under construction in the world (**27 out of 61**) and the **strengthening of the** domestic **supply chain** pursued by China over the years is leading to a **progressive shift in nuclear technologies**: while the leading countries in nuclear technology for reactors currently in operation in the world were the **United States** (29.2%) and **France** (17.8%), China's ranking for projects currently under development is growing and, with a **42.9%** share of reactors under construction, **it ranks first among technology providers**[6], **followed by Russia with a 28.6% share**.

3. "New nuclear" power—consisting of Small Modular Reactors (SMR) and Advanced Modular Reactors (AMR)—represents a "revolution" for nuclear power development, with multiple unique features compared to traditional technology. Amid strong international competition (there are more than 80 projects under development in the world), Europe is taking concrete steps to promote the development of "new nuclear" energy and has launched the European Industrial Alliance on SMRs in March 2024.

Since the first generation of nuclear reactors developed in the 1950s, nuclear technology has evolved significantly, culminating in **huge technological advances in terms of plant efficiency and safety**. Today, nuclear technology is specializing in the **development of small**

[5] Small Modular Reactors.

[6] China's emerging role is characterized by growing technological self-sufficiency. According to the "China Nuclear Energy Development Report 2024," the Blue Book presented in April 2024 by the Chinese Nuclear Energy Industry Association, for the construction of nuclear power plants, especially regarding the design of new developing projects, China utilizes almost entirely Chinese-made components.

modular reactors that can offer greater flexibility, adaptability and be used for multiple industrial applications. In this sense, **"new nuclear" technologies represent a technological discontinuity compared to the past**, enabling their safe adoption on a large scale thanks to a **simplified modular design**.

Within the context of the development of the so-called "new nuclear", the Study considered Small Modular Reactors (SMR) and Advanced Modular Reactors (AMR). Specifically, **SMRs employ the latest evolution of 3rd generation technology** focusing on small size, economies of scale, and modular construction to ensure shorter construction time and shorter payback period on investments. Following the concept of **technological relay**, **AMRs are complementary to SMRs**, encompassing 4th generation nuclear technology in a small modular design. The key elements of this technological relay are the expected commercialization of AMR post-2040, the complementarity of uses (based on the different temperatures achieved) and the management of fuel and waste aiming at **closure of the fuel cycle** to allow the use of spent fuel to power new reactors.

At the technical level, **SMRs are reactors with power ranging from about 100 to 450 MW**, with a land consumption per energy produced of 0.04 m^2/MWh_{year}, **2 times** higher than CCGT power plants (combined-cycle gas turbine, with a land consumption of 0.02 m^2/MWh_{year}) and **100 times** lower than a utility-scale PV plant (4.4 m^2/MWh_{year})[7]. Considering the same installed capacity (m^2/MW), an SMR occupies about 2.4 times the space of a CCGT plant with CCS (350 m^2/MW vs 145 m^2/MW) and 5 times the area of a CCGT plant without CCS (350 m^2/MW vs 70 m^2/MW). Commercial availability of these solutions is expected **from 2030**, but they have already reached a **technology readiness level of 7/8**[8], with some SMR designs at operational demonstration phase. The development of "new nuclear" power offers multiple **special features** compared to traditional technology that are particularly important in achieving 2050 decarbonization targets in a **logic of optimal integration with the development of renewables**.

[7] The analysis considers a 340 MW SMR plant with a total land area of 12 hectares and about 7,880 hours of operation in one year. For a PV plant, 1,800 hours of operation and a land consumption of 0.8 hectares per MW installed were considered. The comparison with gas-fired combined cycle power plants (CCGTs) considers an 850 MW plant, a land consumption of 6 hectares and 3,500 hours of operation (estimated prospectively to 2035). In the case of a CCGT combined with a CCS system, the analysis considered 7,000 hours of operation and a plant size of 11 hectares. Source: Edison data.

[8] The Technology Readiness Level (TRL) is a method for assessing the degree of maturity of a technology (from 1 to 9), ranging from the initial concept and experimentation phases (TRL 2-3) to the demonstration of the technology in an operational environment (TRL 7) and, finally, reaching commercialization and large-scale validation in an operational setting (TRL 9).

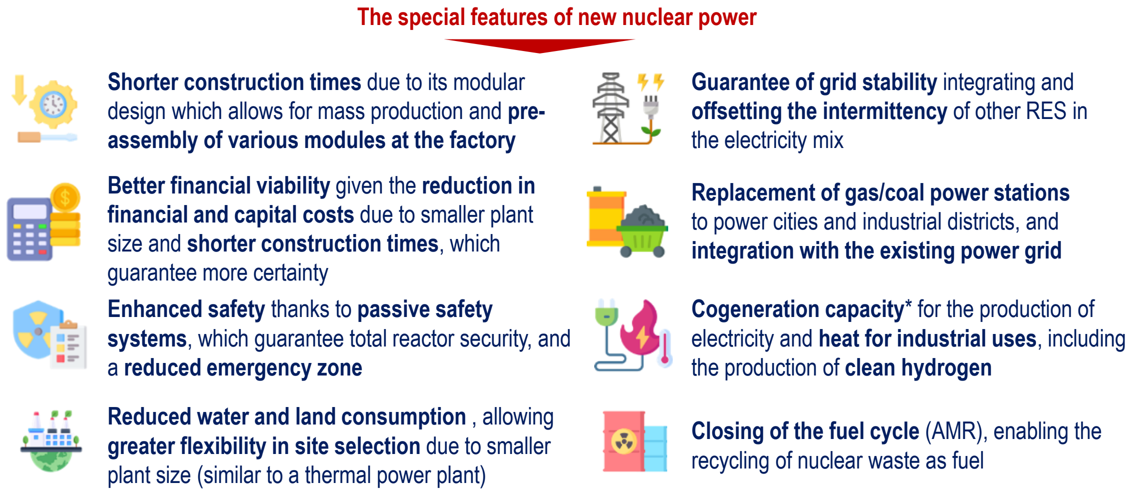

Figure III. The special features of "new nuclear" power compared to traditional large power plants (illustrative). Source: TEHA *Group* elaboration based on a number of sources, 2024. (*) Allows to modulate the production of plants from 100% electric to a mix of electricity and heat according to the needs of the country and industrial sectors.

Globally, there are currently **more than 80 projects under development** associated with "new nuclear" power, with **China and Russia at the technological frontier** and representing the only 2 countries to have developed the first operational models. However, there are also "new nuclear" projects under development **in Europe** (France and the UK), **North America** (Canada and the US) **and other countries** (including, for example, South Korea, Japan and Argentina), which are currently positioned at a less advanced stage of TRL and may see strong development in the coming years.

In particular, with reference to Europe, during the recent Nuclear Energy Summit, **European Commission President Ursula von der Leyen reiterated the importance of SMRs for the energy transition**. To this end, in March 2024, the European Union launched the **European Industrial Alliance initiative on SMRs** with the aim of promoting a **common European program** and creating the best conditions for the deployment of SMRs throughout the European Union, while **maximizing the skills and know-how of the European nuclear supply chain**. The European Alliance aims **to build the first SMR models in 2030** and plans **to draw up a strategic roadmap by March 2025**.

In April 2024, Italy also joined the European Industrial Alliance on SMRs, through the Ministry of the Environment and Energy Security (MASE). This choice is based on an industrial logic that **has anticipated the inclusion of nuclear development scenarios in the NECP** (National Energy and Climate Plan) sent to the European Commission in July 2024. Italy's central role in the European development of "new nuclear" power is evident from the **high membership of Italian companies in the European Industrial Alliance on SMRs**, second in number only to France.

4. Scenarios at 2050 predict a significant increase in electricity demand, both at the European level (2.0-2.9 times compared to 2023) and at the Italian level (almost 2 times compared to 2023), in light of the increasing penetration of electricity in final energy consumption and the rise in computational capacity, driven by new digital technologies. In this framework, "new nuclear" power stands out as a key solution, being the least carbon-intensive power generation technology while ensuring a stable and continuous supply throughout the day and year.

The growing electrification of final energy consumption is leading to **projections for 2050** of electricity consumption in the European Union ranging from 4,900 TWh to 6,922 TWh (equivalent to a **2.0 to 2.9 times** the current electricity consumption). **Italy's electricity consumption dynamics closely mirror those of the EU**, in particular, a more conservative estimate[9] indicates consumption of **520 TWh by 2050** (**1.7 times** the electricity consumption in 2023), while the June 2024 NECP (National Energy and Climate Plan) forecasts consumption of just over **583 TWh**[10] **by 2050** (**1.9 times** the electricity consumption in 2023).

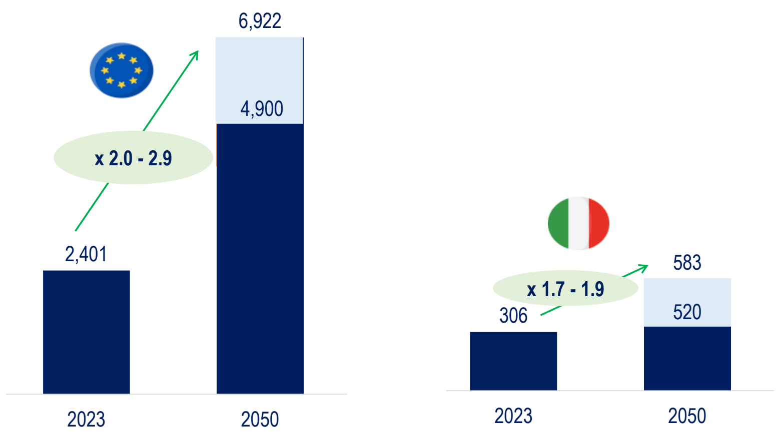

Figure IV. Electricity consumption in the European Union and Italy (TWh), 2023 and 2050. *Source: TEHA Group elaboration based on data from the European Commission, the Italian Ministry of the Environment and Energy Security, Terna and a number of sources, 2024.*

The estimated increase in electricity demand for the EU and Italy between **2023** and **2050** can be attributed to **two main structural factors**. First, there is a growing **penetration of electricity in final energy consumption**, particularly in the **transportation** sector (from **1%** in **2023** to nearly **50%** in **2050** in Italy) and in the **residential** sector (from **5%** in 2023 to **66%** in 2050 in Italy). Second, thanks to the spread of digitalization processes, we are witnessing an **increase in the need for computational capacity**, which will be significantly accelerated by advancements in technologies such as **artificial intelligence**, the proliferation of **High Performance Computing (HPC)** and emerging **quantum technologies**. These are all technologies that require a growing number of **data centers with high electricity**

[9]Source: "Il nuovo nucleare in Italia: perché, come, quando", Edison, Ansaldo Nucleare, ENEA, Politecnico di Milano and NE, 2023.

[10] In the scenario where nuclear power contributes 11% of electricity demand.

consumption, thus amplifying the energy requirements that the electrical system must meet: while in 2023 the electricity consumption of data centers in Italy amounted to 3.8 TWh (1% of national electricity consumption), by 2030 an electricity consumption of 15.4 TWh is estimated (6.7 times the entire pharmaceutical industry in 2022).

5. Nuclear power can play a key role in decarbonization processes. Considering its entire lifecycle, it is in fact the electricity generation technology with the lowest emission factor. Moreover, thanks to its characteristics, it is able to guarantee a stable and constant supply throughout the day, acting as a "system stabilizer" in complementarity with the development of intermittent renewables and thus enabling an integrated and decarbonized electricity production.

"New nuclear" power is a fundamental solution to the challenges facing the power sector from now to 2050, being the **least carbon-intensive power generation technology** while at the same time able to **ensure a steady supply**, ideal for providing the energy needed to handle a constant demand for power. These characteristics integrate well with **renewables** which, on the other hand, can meet demand **peaks**, especially during the **central** hours of **the day** (when solar panels receive the strongest irradiation and can generate more energy) or during periods of higher **wind activity**. Thanks to its **load-following capability**[11], "new nuclear" power is able to **modulate the supply of energy** to the electricity grid, **limiting curtailment** and the **storage capacity required for grid stability**. By operating in load-following mode, the energy produced by new nuclear power can be **reduced**, to make room for renewables, or **repurposed**, for example, for heat supply to power thermal storage systems, or to fuel decarbonized hydrogen production plants.

Recognizing its **significant contribution to decarbonization**, "nuclear power", including "new nuclear" technologies, was **included in the European NZIA** (Net Zero Industry Act) on **February 16, 2024**. This act encompasses all technologies that can significantly contribute to the EU's legally binding commitment to reduce net greenhouse gas emissions by at least **55%** by 2030 compared to **1990** levels. Considering its **entire lifecycle**, nuclear energy is capable of limiting emissions to approximately **5.8 $gCO_{2\text{-}eq}$ per kWh** produced, a level of emissions that is 79 times lower than that of natural gas (**458.0 $gCO_{2\text{-}eq}$ per kWh** produced).

Moreover, "new nuclear" power **perfectly complements** the **development of renewable energy sources**. During nighttime hours or periods of **low solar irradiance** and **insufficient wind availability**, renewable energy production can rely on the stable generation of nuclear power to meet demand. In an **integrated energy system**, nuclear power can thus provide a

[11] Load-following capability refers to the ability to adjust the supply of energy to the electrical grid, which is essential to ensure grid stability given the intermittency of renewables.

stable and flexible generation base[12], depending on the penetration of renewables in the system, to **complement the contribution of renewables that can primarily meet peak demand**, creating an **efficient and low-carbon energy mix**.

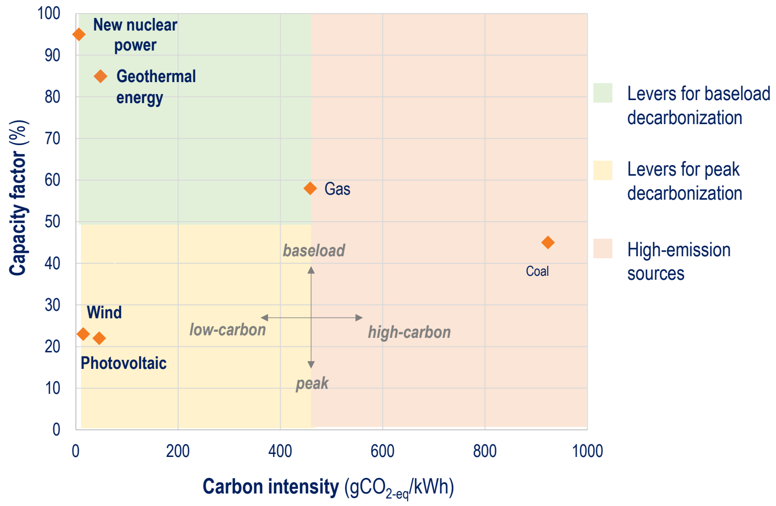

Figure V. Main energy sources per capacity factor (%) and carbon intensity (gCO_{2-eq} per kWh). N.B.: The capacity factor is the ratio of the energy produced over a period of time to the energy that could have been produced if the plant had operated at its nominal power during the same period. Life cycle GHG emissions from renewables such as geothermal, photovoltaic and wind power refer to emissions caused by their manufacture, construction and operation. In particular, in the case of geothermal energy, power plants release small amounts of CO2, nitrogen oxides, and particulate matter. These gases occur naturally in geothermal reservoirs and can be released to the surface and the atmosphere during power plant operation. *Source: TEHA Group elaboration of Eurostat and UNECE data, 2024.*

The **complementarity** of new nuclear power with the development of renewables is also evident in terms of reducing the additional **system costs** associated with the expected increase in the share of renewables in the national energy mix. Renewables, particularly photovoltaic and wind energy, which are non-dispatchable and generate power when the sun and wind are available, require **energy storage systems** to make the electricity produced available when end consumers need it. Additionally, they require an **upgrade of the grid infrastructure** to transfer electricity to the north, where two-thirds of Italy's electricity demand is concentrated, from the south, where solar and wind resources are more abundant. As the share of renewables in meeting Italy's electricity demand increases, the costs for storage systems and infrastructure upgrades rise **more than proportionally**. Beyond a share of approximately **80%**, a significant over-sizing of renewable electricity generation plants **becomes necessary** to address the intermittent nature of these sources, even when

[12] New nuclear power is also being proposed in contexts characterized by a high penetration of renewable energy sources. In such scenarios, the excess net production in certain periods, both daily and seasonal, rather than causing curtailment or requiring a significant storage capacity, could be managed by modulating the nuclear power injected into the grid through the so-called load-following cogeneration, or by using thermal storage systems and plants for the production of hydrogen, which can be considered in turn as a chemical storage system. Currently, modulation scenarios such as the one described are being studied through simulators and optimizers that model the system and simulate the demand.

extended. Therefore, a scenario of **100% renewables** by 2050 would result in a significant increase in **system costs**, which would be unsustainable in terms of the country's economic feasibility and competitiveness.

To efficiently achieve decarbonization targets by 2050, it is therefore necessary to **complement renewables** with the development of dispatchable, decarbonized electricity generation sources, ideally located near major consumption centers, covering about 20% of national demand. In this context, "**new nuclear**" power can play an important role, as highlighted in the June 2024 PNIEC scenario, which envisions a share of new nuclear power between **11%** and **22%** by 2050. New nuclear would allow renewables to unleash their full potential through:

- the **programmability and stability** in energy production, which would significantly reduce the need for large-scale storage systems. This characteristic enables renewables to operate more efficiently, utilizing their output when conditions are optimal, without the need to cover the entire energy demand at all times;
- the **reduction in grid upgrade costs**, facilitated by the localization of new SMR/AMR reactors near consumption centers. This would decrease the need for extensive transmission infrastructure enhancements;
- the reduction of **over-investment in renewable electricity generation plants** to cope with extended periods of renewable energy production intermittency.

6. "New nuclear" power represents one of the safest and most reliable energy sources to drive strategic autonomy. This technology, in fact, simultaneously presents a low need for fuel and a limited dependence on critical raw materials. Moreover, considering the importance of the European Union in the global nuclear industry, the potential dependence on third countries is further reduced.

Nuclear power is **one of the safest and most reliable energy sources**. Specifically, the strategic autonomy of "new nuclear" power can be broken down into **3 key factors**: **fuel**, **critical raw materials** and **technology**.

When considering **fuel sources**, uranium-producing nations exhibit a higher degree of geopolitical stability (compared to gas and coal-producing countries). **Natural gas production** is concentrated in countries with **low to medium-low geopolitical risk**[13] **levels**, accounting for **28.8% of global output**. In contrast, a significant **70%** of **coal production** originates from countries classified as having **medium to high geopolitical risk**. **Uranium**

[13] As a proxy variable for geopolitical risk, the Fragile State Index (FSI) was used. This is a composite index that measures the political, economic, and social stability of 179 countries. The FSI assigns each country a score from 0 (no geopolitical risk) to 100 (extremely high geopolitical risk). TEHA has divided countries into five categories, ranging from countries with very low geopolitical risk (FSI ≤ 35) to those with very high geopolitical risk (FSI > 80).

production, however, is dominated by nations with **exceptionally low geopolitical risk**, such as **Canada** and **Australia**, which collectively account for nearly a quarter (**24.2%**) of global uranium production. The advantage of uranium becomes even more apparent when considering **fuel reserves**, a key indicator of future production potential. **Australia** and **Canada** possess substantial uranium reserves, representing a combined **41%** of the **world's total reserves**.

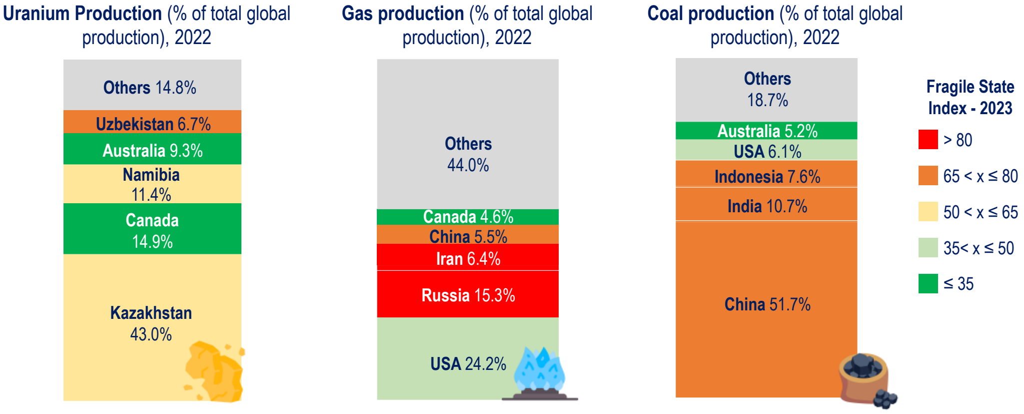

Figure VI. Major Countries in Terms of Uranium, Gas, and Coal Production (% of total global production) and Associated Geopolitical Risk (Score in the Fragile State Index), 2022. *Source: TEHA Group based on data from the World Nuclear Association, Energy Institute, The Fund for Peace, and USGS, 2024.*

With reference to **critical raw materials**, nuclear power emerges as a **technology that provides a high level of strategic autonomy**, in terms of the volume of critical raw materials required per unit of electricity generated. Indeed, for **every GWh of electricity produced**, solar energy requires **207.8 kg** of critical raw materials (mainly copper and silicon), wind energy requires **162.9 kg**, coal **14.1 kg**, **nuclear energy 9.3 kg** and gas **3.9 kg.** These data highlight how "new nuclear" power, compared to other energy technologies contributing to decarbonization, requires a significantly lower amount of critical raw materials for electricity production, **thereby reducing dependence on foreign sources even in this regard**. Furthermore, **53.5% of the critical raw materials needed for nuclear power have a low supply risk**[14], **43.7% have a medium-low supply risk and only 2.9% have a medium-high supply risk**. The low percentage of materials with medium-to-high risk reflects the **stability and resilience of nuclear supply chains** compared to other energy technologies that rely more heavily on high-risk critical raw materials.

[14]Source: European Commission, "Study on the critical raw materials for the EU 2023".

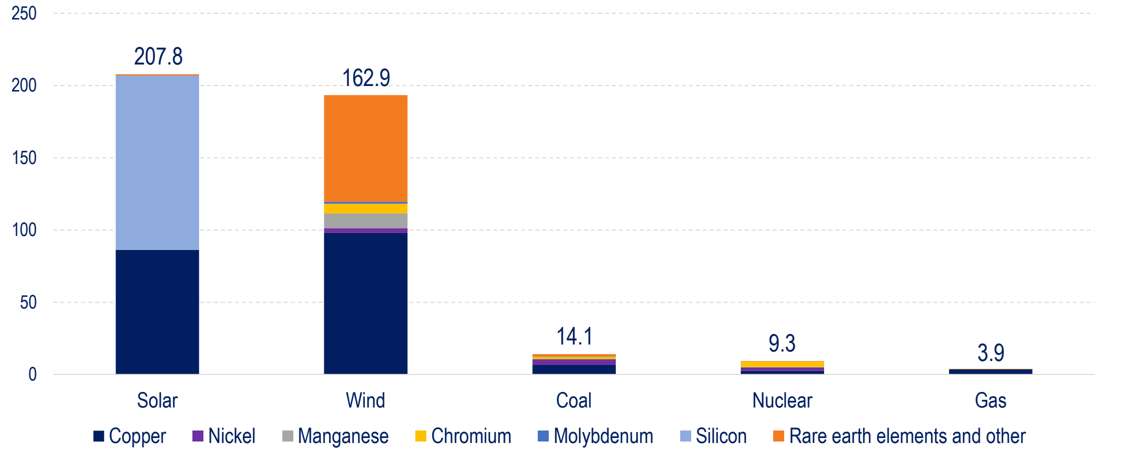

Figure VII. Critical and strategic raw materials required for the construction of energy infrastructure by type of energy source (kg per GWh), 2021. N.B. Copper and nickel do not meet the supply risk threshold to be classified as critical raw materials according to the European Commission's Critical Raw Materials Act, but they are however included as "strategic raw materials". *Source: TEHA Group elaboration of IEA and Eurostat data, 2024.*

Finally, as regards the third dimension of strategic autonomy, related to **technology**, the value chains of the nuclear sector in the EU are **among the most well-established in the world**. The EU has not only maintained its position in the global market but has also strengthened its export capacity, demonstrating remarkable resilience and **advanced technological expertise**. One way to **assess** a country's **technological autonomy** in the energy sector is by its **level of exports**. If a country exports a significant amount of energy technology, it implies that **it has well-developed and integrated value chains capable of meeting both national and international needs**. Therefore, export capacity is indicative of the level of technological autonomy, which, as mentioned, is one of the three dimensions of strategic security. Taking the 2018-2022 five-year period as a reference, **the European Union** is the top exporter in the world, with **more than €1.6 billion in export value**, followed by the United States (€**1.5 billion**) and Russia (€**1.4 billion**)[15].

[15] Unlike the export of photovoltaic modules, which is dominated by China with a value of 42.3 billion Euros in 2022 (source: Bloomberg NEF), China's dominance in the export of photovoltaic technology can be explained by its high domestic manufacturing capacity: from 2017 to date, nearly 172 GW/year of photovoltaic module production capacity has been built globally, of which 134 GW (78%) is in China. In comparison, Europe continues to record much lower numbers, with photovoltaic module exports in 2022 amounting to only 0.8 billion Euros (source: Eurostat).

7. Considering the estimated development scenarios in the European Union (60 GW) and Italy (6.8 GW) by 2050, “new nuclear” power could generate a potential market of up to €46 billion for the Italian industrial supply chain, with a potential Value Added of up to €14.8 billion. Considering also indirect and induced impacts, investing in “new nuclear” power could activate a potential total economic impact for the national economy of ~€50 billion (~2.5% of Italy's 2023 GDP) and create 117,000 new jobs.

Despite the lack of development in nuclear energy in Italy over recent decades, the Italian industrial sector still demonstrates **expertise across almost the entire supply chain**, with the exception of uranium supply and fuel production. Overall, the **total economic value** (“extended value”) generated in **2022** by Italian companies specializing in the nuclear sector amounts to approximately **€4.1 billion**, with **€1.3 billion in Added Value** produced and around **13,500 employees**[16]. Limiting the analysis to the “**core value**"[17] of the industrial supply chain attributable to the nuclear power sector alone, the turnover generated by Italian companies in 2022 stands at **€457 million** and **€161 million in Added Value**, with **around 2,800 employees**.

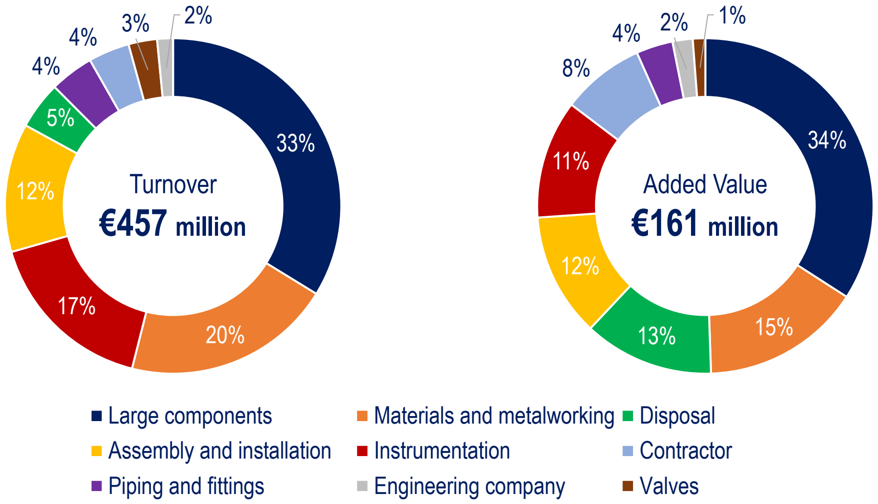

Figure VIII. Sectoral breakdown of turnover (left chart) and Added Value (right chart) for the core Italian nuclear supply chain (% values), 2022. *Source: TEHA Group elaboration based on data from ISTAT, AIDA and a number of sources, 2024.*

[16] The total values of the industrial supply chain of companies active in nuclear power ("extended value") report the reference data for the total revenues and employees of those companies. Based on this information, through analysis of the literature and individual company financial statements, a "core value" of the nuclear supply chain was obtained that considers only the economic and employment values supported by nuclear power within the company.

[17] The core value estimates turnover, Value Added and employee data attributable to the nuclear power sector alone through analysis of the individual financial statements of the 70 companies included in the Italian industrial supply chain. ENEL's know-how in managing nuclear power plants abroad also adds to these values, with a turnover associated with nuclear power amounting to €1.57 billion in 2022.

In order to quantify the benefits for the domestic economy associated with the development of "new nuclear" power, the Strategic Study also developed a proprietary *ad hoc* analysis to estimate the **development potential of "new nuclear" power** for the Italian industrial supply chain according to the **scenarios estimated for the European Union by 2050** (60 GW) and for **Italy** (6.8 GW[18]).

The development of "new nuclear" power at the European level could unlock a **potential market of over €20 billion for Italian companies**, provided that the supply chain also specializes in other segments where Italy can leverage its solid expertise and know-how (e.g., turbines and components). Concurrently, **if Italy were to implement a "new nuclear" development program**, it could unlock an additional **potential market** estimated at around **€25 billion for Italian companies** by 2050. This scenario would allow Italy to specialize in the "new nuclear" supply chain and gain the **skills and economies of scale** needed to contribute actively to the development of this technology in Europe, **promoting greater local content** during the development and construction phases and also benefiting from the local indirect impacts as well[19].

Looking ahead to 2050, the development of "new nuclear" power in Europe and Italy could generate a total market for the Italian industrial supply chain of approximately **€46 billion.** From the market value, the analysis then estimated the **potential Value Added for the direct supply chain** linked to the development of "new nuclear" energy, with the aim of quantifying the economic and employment impacts on the country system. Overall, investment in "new nuclear" energy could generate **Value Added of €14.8 billion** for the direct supply chain in Italy[20].

Thanks to the **high economic multiplier** of the nuclear power sector in Europe, investing in "new nuclear" energy and supporting the competitiveness of the Italian supply chain could result in a potential **total economic impact for the country system of €50.3 billion** (~2.5% of the Italian GDP), benefiting from around **€35.5 billion in indirect and induced benefits**. Indeed, the development of "new nuclear" power by 2050 would allow Italy to benefit from a **high economic and employment multiplier** capable of **amplifying the economic and employment spin-offs for the domestic economy.** "New nuclear" power could play a strategic role at the employment level as well, enabling approximately **39,000 direct jobs** in the supply chain and over 78,000 new indirect and induced jobs, with a total impact on the country system of approximately 117,000.

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[18] Elaborated in the Study (excluded from the EU scenario), considering the construction of 20 SMR plants by 2050, capable of meeting **10%** of Italy's **electricity consumption**.

[19] Local indirect impacts consider local labor and contracts for construction materials, as well as factory tools and equipment.

[20] The value added generated by investments in the development of "new nuclear" power is calculated by applying the current ratio between turnover and added value of companies in the Italian nuclear industrial supply chain.

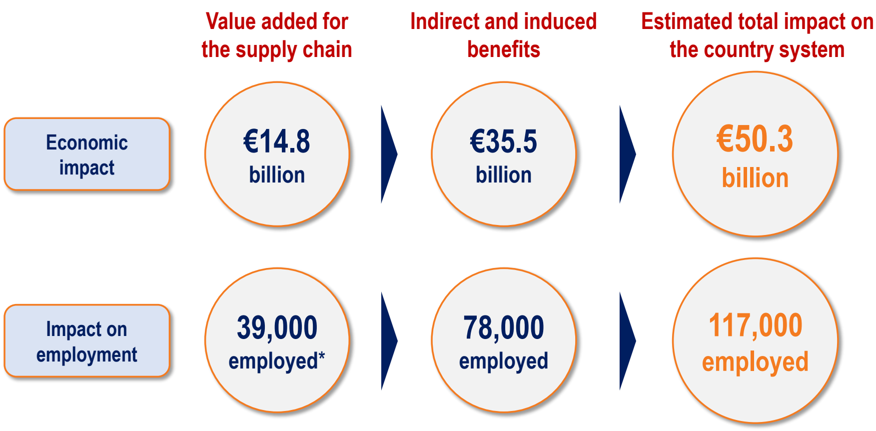

Figure IX. Estimate of the total economic and employment impact by 2050 for the country system achievable through Investments in the construction of "new nuclear" power in Europe and Italy (billions of euros and number of jobs), 2024. (*) Elaboration on Edison-Ansaldo data. *Source: TEHA Group elaboration, 2024.*

8. Energy-intensive industries play a crucial role in the decarbonization process in Italy: in 2022 they accounted for 15% of GHG emissions and 16% of national energy consumption. In this context, "new nuclear" power emerges as a strategic solution, as it does not produce CO_2 emissions during the operational phase, ensures a stable and continuous energy supply and offers multiple applications (electricity, heat for industrial uses and hydrogen).

Industry plays a **crucial role** in the energy transition and decarbonization process. For example, it is currently **responsible for over 20% of greenhouse gas emissions in Italy and Europe**, trailing only behind the transportation and energy production sectors. Similarly, industry represents **more than one-fifth of final energy consumption** both in Italy and Europe, ranking third after the transportation and residential sector.

In Italy, **energy-intensive industries**[21] accounted for **15%** of GHG emissions and **16%** of national energy consumption in 2022. Energy-intensive sectors are responsible for over **70% of greenhouse gas emissions and final energy consumption in the Italian industry**. High emissions in these sectors are partly due to the still predominant presence of **fossil fuels in the energy mix**. In Italy, fossil fuels still account for **95%** of total final energy consumption in energy-intensive industries, with renewables making up just over 5%. **Natural gas** is particularly dominant among the energy sources for these sectors, covering on average **37%** of final energy consumption in energy-intensive industries[22].

[21] The energy-intensive industry includes the sectors of steel, non-metallic minerals (glass, cement, and ceramics), paper, chemicals, mining, and food products.

[22] The data refers to the direct use of natural gas in industrial processes. There is also a significant portion of natural gas used in electricity production.

The availability of stable, affordable, and decarbonized energy thus becomes a **key factor for businesses** to maintain their competitiveness in domestic and international markets. In this context, **"new nuclear" power** emerges as a **strategic solution**, as it does not produce CO_2 emissions during the operational phase, thereby providing industries with an **effective way to reduce their carbon footprint** and the costs associated with emission allowances of the EU Emission Trading System.

Moreover, "new nuclear" power offers the possibility of producing not only **electricity**, but also **decarbonized industrial heat**. Small Modular Reactors (SMRs) and Advanced Modular Reactors (AMRs) enable the supply of medium to **high temperature industrial heat**, reaching temperatures up to **950 °C (AMR**) and **300 °C (SMR**), suitable for many **industrial processes**.

Finally, "new nuclear" technology offers an opportunity for the **efficient production of hydrogen** by continuously powering electrolyzers with the electricity and high-temperature steam it generates, resulting in hydrogen production with significantly higher efficiency compared to other energy sources. The efficiency of hydrogen production through nuclear can reach **45%**, significantly exceeding the **40.4%** achievable with traditional thermal sources and the **16.3%** from solar power[23].

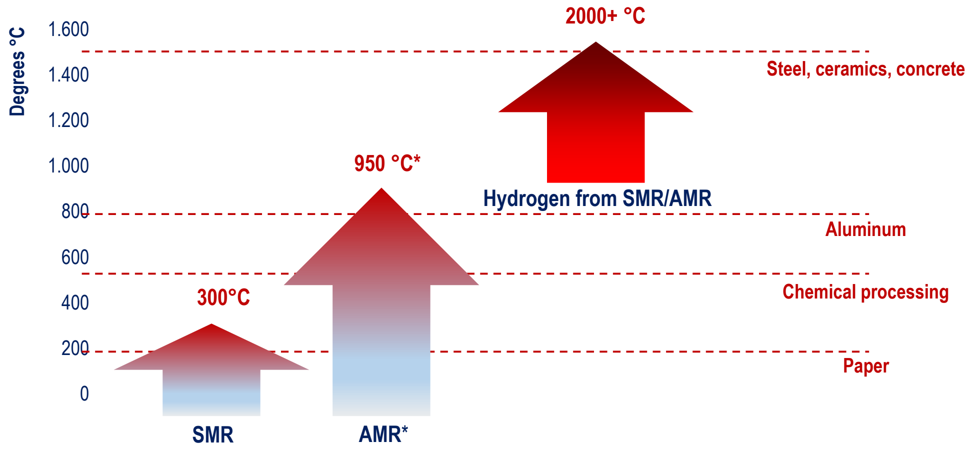

Figure X. Temperature for industrial heat from "new nuclear" power and temperature required for industry (illustrative). *Source: TEHA Group elaboration of data from NEA, DoE and a number of sources, 2024.*

[23] Younas M et al. (2022) "An Overview of Hydrogen Production: Current Status, Potential, and Challenges", 2024.

9. Nuclear power is a local development tool that brings with it numerous economic and social benefits for the territories and citizens that host it. Moreover, "new nuclear" power ensures enhanced safety, ease of installation and reduced land consumption.

One of the pivotal issues driving public debate on the use of nuclear power in Italy is related to the **social acceptability of the technology by citizens and territories**. However, it should be noted that nuclear energy is a local development tool that offers numerous economic and social benefits for the territories and citizens that host it.

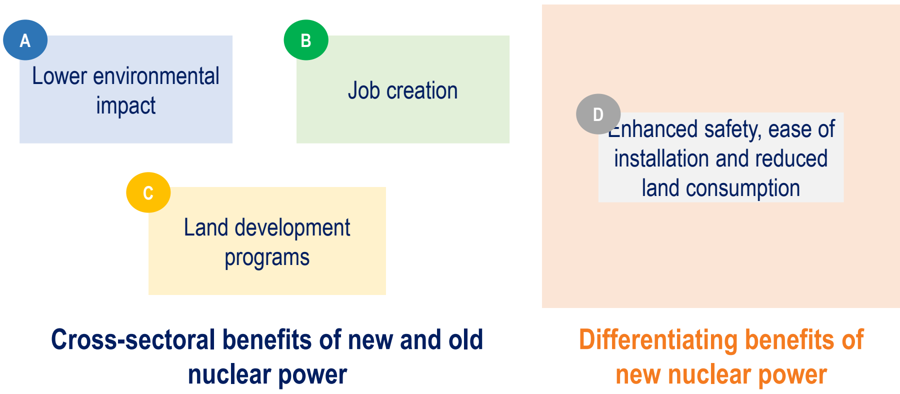

Figure XI. The benefits for territories and citizens of "traditional" and "new nuclear" power (illustrative). *Source: TEHA Group, 2024.*

The presence of nuclear energy generates many impacts in terms of **enhancing the territory**. Several countries in Europe—such as France, Belgium, and Hungary—have implemented **local development programs** that include infrastructure systems, social progress initiatives, training programs, monitoring plans for safety and quality of life, and financial support for all areas affected by nuclear energy. In **Italy**, a fund has also been established for territories hosting former nuclear plant sites, from which resources totaling **€14.5 million** euros were disbursed in **2022** (allocated for targeted environmental interventions).

In addition to these benefits, compared to traditional technology, **"new nuclear" power** offers a number of advantages such as: a) development of **new designs** compared to traditional nuclear power; b) **enhanced safety**, ensured by a lower reactor power and innovative solutions for core cooling; c) **installation agility**, made possible by greater modularity, smaller size, simpler design, serial manufacturing of components, standardization, and site identification given the reduced size; d) **reduced land consumption**, equal to about 0.04 m^2/MWh_{year} for an SMR (350 m^2/MW in terms of installed power).

10. To promote the development of “new nuclear” energy in Italy and accelerate the decarbonization process, a clear medium to long-term industrial vision is needed to maximize benefits and savings for end users and the country system and enhance the know-how of the industrial supply chain and research sector in Italy.

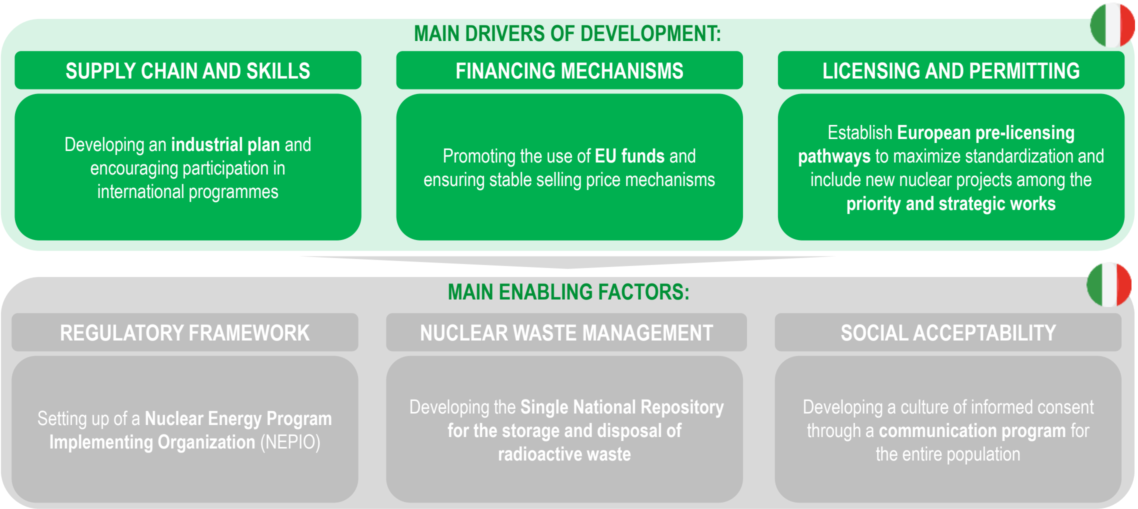

Figure XII. Areas of intervention for the development of “new nuclear” power in Italy (illustrative). *Source: TEHA Group elaboration, 2024.*

To maximize the benefits and industrial opportunities of “new nuclear” power and promote the role of the Italian supply chain, it is essential to develop a **clear medium to long-term strategic vision** capable of addressing certain challenges in the development of “new nuclear” power and supporting industrial competitiveness. In particular, **three main drivers of development** are highlighted that can **accelerate** the implementation of “new nuclear” energy, which Italy must take into consideration if it wants to play a leading role in the nuclear renaissance in Europe.

First and foremost, to ensure the proper launch of nuclear energy in Italy, it is necessary to develop an **industrial plan with a medium- to long-term vision** (2030, 2040, and 2050) aimed at supporting the growth of the Italian industrial supply chain. This includes introducing **support mechanisms** for company investments to stimulate industrial innovation and increase production capacity. At the same time, a **skills development plan** should be outlined with a focus on all the professional roles required for a nuclear program.

Moreover, adequate **public support** for the development of new nuclear energy in Italy is essential, through **state guarantees on loans** and **stable pricing mechanisms** for the sale of nuclear energy in the medium to long term (CfD and PPA). This could include the use of **European Union community funds** (supported by the states that are part of the EU Nuclear Alliance) specifically aimed at **supporting** a **common development** of **new nuclear energy** at the international level.

In addition, it would be advantageous to initiate **joint pre-licensing processes** among nuclear regulatory agencies in different European states, to enable **greater standardization** of safety and performance requirements across countries. Harmonization of standards at the European level is pivotal to enabling **serial economies** and maximizing the benefits of new nuclear power in terms of construction time and cost, while ensuring **greater predictability for investors**. Further, participating in the **Joint Early Reviews**[24] would allow Italy to **contribute** to and **integrate** into the creation of a **common European pre-licensing framework** aimed at **reducing the time needed** to complete the projects. In addition, it would be necessary to include "new nuclear" projects among the **priority and strategic works** for the country to **expedite** their **implementation** and adopt an **efficient public-private partnership model**. Regarding **permitting**, indeed, new nuclear projects should be included among the **priority and strategic projects** for the country in order to **accelerate their implementation** and adopt an efficient public-private partnership model. Finally, the creation of a **National Safety Authority** is fundamental for the development of new nuclear power in Italy in order to **guarantee compliance with the highest safety standards**, conform to **international regulations**, and ensure rigorous control over operations, minimizing risks to the population and the environment. Such an authority acts as an **independent body**, responsible for the regulation, supervision, and management of critical issues related to nuclear energy

In addition to the development drivers, Italy must also focus on some **enabling factors**, which are **necessary and decisive** for the successful development of "new nuclear" energy in Italy. First and foremost, it is necessary to establish a regulatory framework, which includes the creation of a **NEPIO** (Nuclear Energy Program Implementing Organization) with the task of assessing the state of the basic infrastructure required to launch a national nuclear program and providing the government with the necessary guidance for their full development and operation.

Additionally, it is necessary to establish a **clear management plan for radioactive waste**, particularly by identifying the site and constructing the **National Repository** for the storage and disposal of radioactive waste. This includes **defining incentives** and enhancement measures for the territory hosting the **future Repository** and setting up a working group with the **stakeholders from the selected territories** (citizens) and other interested parties (institutions, communities, industry experts, environmental associations, etc.) to **build consensus** for the construction of the National Repository.

Finally, it is advisable to enhance the **social acceptability** of new nuclear projects in the affected areas as much as possible. Therefore, it is proposed to develop a **culture of informed consent** through a **communication program** aimed at the entire population (for example, by organizing free informational events and maintaining an open and ongoing dialogue with

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[24] Joint Early Reviews (JER) in the nuclear sector are collaborative assessments between regulators and developers, conducted in the early stages of projects to identify and address potential issues at an early stage. These reviews expedite approval timelines through international harmonization, which aligns regulatory requirements across different countries, reduces duplication, and facilitates the adoption of common standards.

citizens) about the **impacts** and **benefits** for the territories resulting from the **construction of nuclear plants**, as well as the differences between **new nuclear technologies** and those of the **previous generation**.