Environmental Report 2024

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Report by the Direzione Servizio Salute e Ambiente with the involvement of the National Laboratories and CNAF.

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1. ABOUT INFN

The National Institute for Nuclear Physics (INFN) is a public research organization operating under the supervision of the Ministry of Universities and Research (MUR). It is devoted to the investigation of the fundamental constituents of matter and the forces that govern their interactions. Its research activities, both theoretical and experimental, span the domains of subnuclear physics, nuclear physics, and astroparticle physics.

The INFN places particular emphasis on the applications of basic research that have a significant impact on society, the local territory, and the productive sector, thereby contributing to the country's technological innovation.

INFN's research is conducted within a framework of international collaboration and competition, in close cooperation with the Italian university system, based on long-standing and well-established partnerships. Many research projects are carried out in synergy with other national research institutions. Fundamental research in INFN's areas of interest requires the use of advanced technologies and cutting-edge research tools, which the Institute develops both in its own laboratories and in collaboration with industrial partners.

1.1. KEY FACTS

In 2024, the INFN further strengthened its position as a center of excellence in international scientific research, achieving significant results across all major areas of activity. The year was marked by a high volume of scientific output, enhanced international collaborations, and notable technological advancements, supported in part by funding from the National Recovery and Resilience Plan (PNRR).

In the field of experimental physics, INFN played a pivotal role in experiments conducted at CERN, particularly within the ATLAS and CMS projects, which yielded high-quality data and above-average scientific impact. Technological upgrades to detectors progressed successfully, although some challenges were encountered regarding implementation timelines.

In astroparticle physics, INFN reinforced its international leadership through advancements in the DarkSide project and in research programs on double beta decay without neutrinos. Of particular importance was Italy's involvement in the Einstein Telescope project, with the proposal to host the infrastructure in Sardinia receiving broad scientific support.

In nuclear physics, there was a 60% increase in high-quality scientific output, with major collaborations underway at international facilities such as CERN and the Facility for Rare Isotope Beams (FRIB) in the United States. The AGATA experiment, hosted at the Legnaro National Laboratories, was extended through 2028, and the new Bellotti infrastructure was brought online.

In theoretical physics, INFN maintained a robust and innovative research program, with growing attention to emerging technologies such as artificial intelligence and quantum computing.

Technological research yielded tangible results: in 2023, 29 projects were completed and 23 new ones approved, with a success rate of 60%. The CSN5 Commission accounted for 72% of INFN's patents, reaffirming the Institute's central role in technology transfer.

1.2. STRUCTURES

INFN's activities are structured around two complementary types of research facilities: national laboratories and divisions (Figure 1). The four national laboratories form the backbone of the Institute's initiatives, hosting large-scale equipment and advanced research infrastructures that serve both the national and international scientific communities.

The 20 divisions, along with 6 associated groups, are embedded within university physics departments across Italy. This organizational model fosters a strong and enduring connection between INFN and the academic world, promoting close collaboration in both research and education.

Figure 1. Organization of the INFN in the Italian territory.

Laboratori Nazionali di Frascati (LNF)

LNF are the oldest and largest INFN laboratory in terms of personnel. A longstanding reference point for the design and operation of particle accelerators, LNF is also distinguished by its expertise in the construction of large-scale detectors and its contributions to fundamental physics.

In 2024, activities were primarily centered around two major facilities:

- DAΦNE, the only operational electron-positron collider in Europe, which operates at a center-of-mass energy near the Φ(1020) meson peak, with an instantaneous luminosity of approximately 1 x 1032 cm-2 s-1. The collider currently supports the SIDDHARTA2 experiment, focused on the study of kaonic atoms.
- SPARC_LAB, an advanced infrastructure dedicated to research on novel acceleration techniques, including plasma acceleration, and the development of Terahertz and Compton radiation sources.

These are complemented by:

- DAΦNE-Light, a synchrotron light laboratory featuring seven beamlines that span the spectrum from soft X-rays to infrared;
- The Beam Test Facility (BTF), which includes two beamlines used for detector testing, irradiation, and diagnostics, and has recently supported the PADME experiment, aimed at the search for new particles.

LNF also hosts numerous specialized laboratories (in areas such as plasmas, cryogenics, and spatial characterization), mechanical workshops, and a high-performance computing center. Furthermore, LNF is actively involved in major international projects, including: participation in the construction of the Inner Tracker (ITK) for the ATLAS experiment at CERN, as part of the LHC Phase-2 upgrade; and the development of a component of the near detector for the DUNE experiment at FERMILAB, which will incorporate a key element from the KLOE detector, currently being dismantled at LNF.

As part of its long-standing commitment to reducing energy consumption, a large photovoltaic plant (approximately 1.1 MW) was installed in 2024 and is expected to become operational by the end of 2025.

LNF also houses the Administrative HQ of the INFN. It carries out tasks related to policymaking, coordinating, and overseeing decentralized administrative activities. Additionally, it ensures the provision of central technical, professional, and surveillance services. Furthermore, it is responsible for the preparation and execution of deliberative acts within its competence, based on the directives of the Executive Committee.

Below are the main data of the laboratory.

Table 1. Data of LNF.

	UM	2021	2022	2023	2024
Machine time (DAφNE)	hours	3 063	1 475	4 176	2515
Employees (only staff LNF+AC)	n°	477	479	519	504
Built area	mq	28 512	28 512	28 512	28 512

Laboratori Nazionali del Gran Sasso (LNGS)

LNGS represent the world's most significant underground infrastructure dedicated to scientific research. Their unique features—including an experimental area exceeding 180 000 m^2, direct access via the A24 highway, and natural shielding provided by over 1400 meters of rock—offer exceptional protection and extremely low environmental radioactivity, making the site ideal for fundamental physics experiments.

The external facilities house the administrative center, offices for staff and visiting researchers, as well as workshops and laboratories that support experimental activities. These facilities provide high-level technical and engineering services, including safety systems, chemical and electronic support, prototyping, mechanical processing, and advanced computing resources.

Within the underground area, highly specialized laboratories have been developed to exploit the natural shielding and achieve extremely high sensitivity levels. Among these, the STELLA laboratory stands out for its ability to detect minute traces of radioactive contaminants in materials, using gamma spectroscopy with high-purity germanium (HPGe) detectors. LNGS is actively involved in the development of new HPGe detectors, establishing itself as an international reference point in this field.

In nuclear astrophysics, LNGS inaugurated the Enrico Bellotti Ion Beam Facility in 2023, equipped with a 3.5 MV accelerator. This infrastructure enables detailed studies of nuclear reactions occurring within stars, contributing to our understanding of the origin of elements in the Universe. In parallel, the 400 kV accelerator continues to deliver significant results and is currently undergoing a technological upgrade.

Finally, the installation of a new High Performance Computing center is nearing completion. This system will enhance the computational and data storage capabilities of the experiments and will also support the High-Performance Computing for Disaster Resilience consortium, dedicated to advanced research on natural disasters. In collaboration with local universities, initiatives are underway to further strengthen the computing center, with the goal of establishing a strategic hub for scientific research in Central Italy.

In this context of continuous improvement, in order to maintain a role of leadership, the LNGS is carrying out a series of infrastructure upgrades within the PNRR project LNGS FUTURE. The project aims to modernize and strengthen the technical and safety infrastructure of the LNGS with a focus on energy efficiency; the ongoing upgrades foresee the installation of solar panels, a complete revamping with the led light and the replacement of the UPS systems with more efficient ones. The goal is to reduce the environmental impact of the laboratory achieving a technically/economically efficient and environmentally and socially more sustainable facility.

Table 2. Data of LNGS.

	UM	2021	2022	2023	2024
Machine time	hours	NA	NA	NA	NA
Employees (only staff)	n°	131	138	148	145
Built area	mq	32 800	32 800	32 800	32 800

Note: NA: not available.

Laboratori Nazionali di Legnaro (LNL)

LNL are a center of excellence dedicated to fundamental research in nuclear physics and astrophysics, as well as to the development of advanced technologies with applications across interdisciplinary fields. Among LNL's key strengths are its innovation in particle accelerator technologies, the design of cutting-edge detectors, materials science, environmental physics, and the study of cultural heritage. Currently, five accelerators are in operation at LNL, regularly used by both national and international scientific communities for nuclear physics experiments and cross-disciplinary research.

A particularly notable achievement was recorded at the TAP complex (Tandem-ALPI-PIAVE), where performance improvements were observed in terms of maximum energy reached and the mass of accelerated elements. Specifically, the acceleration of 208Pb beams to energies exceeding 1.3 GeV stands out as one of the most significant results in accelerator performance. The AGATA experiment, which has been collecting data at LNL since spring 2022, has greatly benefited from these enhanced conditions.

Experimental activities using the smaller Van de Graaff accelerators (CN and AN2000) have focused primarily on:

- Elemental microanalysis of archaeological samples and pigments using nuclear techniques;
- Target characterization, and testing of detectors such as flexible organic scintillators sensitive to thermal neutrons, and microdosimeters for Boron Neutron Capture Therapy (BNCT);
- Radiation damage studies on materials and instrumentation;
- Measurements in nuclear astrophysics and neutron physics.

The improved reliability of the larger machines has also enabled the signing of a contract for beam supply to an external company, further demonstrating the laboratories' operational excellence and industrial relevance.

In the coming years, the completion and operation of SPES will enable the production of unstable ion beams for fundamental nuclear physics and innovative and experimental radionuclides for medical diagnostics, therapy, or other applications.

Table 3. Data of LNL.

	UM	2021	2022	2023	2024
Machine time*	hours	3 797	4 856	6 436	5 332
Employees (only staff)	n°	206	210	206	184
Built area	mq	29 600	29 600	29 600	29 600

Note: * Calculated as the sum of the machine time (beam on target) of the Tandem-Pieve-Alpi system and the AN+CN system.

Laboratori Nazionali del Sud (LNS)

LNS serve as a key scientific hub for research in nuclear physics and nuclear astrophysics, with significant extensions into medical applications, environmental and energy research, cultural heritage preservation, and the development of acceleration systems and ion sources.

In 2024, LNS was actively engaged in major projects in fundamental nuclear physics, while also playing a leading role in multidisciplinary initiatives such as KM3NeT—a project that integrates expertise in astrophysics, particle physics, oceanography, and environmental sciences, promoting a unified vision of the universe and the marine environment.

Research in nuclear astrophysics benefited from increased intensity of exotic beams, enabling the study of nuclear reactions associated with extreme astrophysical phenomena. A distinctive feature of LNS is the use of long-lived radioactive beams, such as ^10Be, ^26Al, and ^44Ti, produced in batch mode through collaborations with external institutions.

To expand access to these new beams, a new experimental beamline is being designed in the area of the former CICLOPE and 0° halls. This facility will provide stable and fragmentation beams with intensities more than an order of magnitude higher than previously available.

LNS also operates a multidisciplinary beamline, and the introduction of high-intensity Radioactive Ion Beams (RIBs) is expected to open new avenues for experiments under extreme conditions, high dose-rate measurements, and simulations of laser-driven or high-power pulsed beams.

Table 4. Data of LNS.

	UM	2021	2022	2023	2024
Machine time	hours	0	0	0	0
Employees (only staff)	n°	169	172	186	165
Built area	mq	22 163	22 163	22 163	22 163

CNAF

CNAF is INFN's national center dedicated to research and development in computing and telematics technologies, as well as to the management of digital services supporting the Institute's scientific activities. It serves as a key node in INFN's digital infrastructure, offering advanced resources and expertise in distributed scientific computing.

At the heart of CNAF is the Tier-1 data center, INFN's primary computing facility and one of ten global centers in the Worldwide LHC Computing Grid (WLCG)—the international network for data analysis from the Large Hadron Collider (LHC) experiments at CERN. The Tier-1 center provides computing and storage resources to over 100 scientific collaborations, offering approximately 80 000 cpu cores, 100 petabytes of disk storage, and 250 petabytes of tape storage for long-term archiving. It is interconnected with other INFN centers and the WLCG network via a high-capacity 400 Gbps link.

CNAF actively participates in national and international research and development projects in distributed computing, collaborating with public institutions and ICT sector companies. Among its most notable infrastructures is EPIC, a cloud instance certified under ISO 27001, 27017, and 27018, designed for the secure management of sensitive data. Through EPIC, CNAF collaborates with institutions in the biomedical, genomic, and oncological fields.

In 2024, particular focus has been placed on the evolution of the Identity and Access Management (IAM) system, which is set to become a key tool for managing authorizations in biomedical research projects. In parallel, CNAF is involved in the CHNET network for Cultural Heritage, contributing to European projects such as Ariadneplus and 4CH.

Table 5. Data of CNAF.

	UM	2021	2022	2023	2024
Power Usage Effectiveness (PUE)	hours	NA	NA	NA	NA
Employees (only staff)	n°	60	55	62	61
Built area	mq	2 600	2 600	2 600	2 600

Note: NA: not available.

2. ENVIRONMENTAL SUSTAINABILITY

In recent years, the INFN has embarked on an increasingly conscious and structured path toward integrating environmental sustainability into its research and development activities. This commitment stems from the awareness that science, and fundamental physics in particular, can no longer overlook its environmental, economic, and social impact. As a public research institution, INFN recognizes its responsibility to contribute to a more sustainable future, not only by adopting best practices in the management of its infrastructures but also by transferring knowledge and technologies to society.

INFN's approach to sustainability is cross-cutting and multidimensional. It is not limited to sector-specific actions or isolated initiatives, but rather takes the form of an integrated strategy that involves the entire organization — from national laboratories to divisions, from large international projects to interdisciplinary collaborations. Sustainability is understood as a dynamic balance among three core dimensions:

- the environmental, focused on reducing the ecological footprint of scientific activities;
- the economic, aimed at the efficient and responsible use of resources;
- and the social, which promotes collective well-being and equitable access to knowledge.

One of the areas in which INFN has invested most significantly is technology transfer. Technologies developed for research in particle physics, astroparticle physics, and nuclear physics are being applied in key sectors for sustainability, such as energy efficiency, environmental monitoring, radioactive waste management, and advanced diagnostics. This transfer process is not only an opportunity to enhance the value of research outcomes but also a concrete contribution to the country's ecological and digital transition.

Another central aspect is the sustainable design of large scientific infrastructures. INFN is involved in high-profile international projects such as the Future Circular Collider (FCC) and the Einstein Telescope (ET), where sustainability is a fundamental criterion from the earliest design phases. In these contexts, INFN promotes the adoption of ecodesign principles, energy consumption optimization, material reuse, and minimization of overall environmental impact. The challenge is to combine scientific ambition with environmental responsibility, demonstrating that cutting-edge research can be pursued without compromising the planet's balance.

As part of this process, INFN is continuing to report on its environmental impact in 2024, having already reported on the environmental impact of 2021–23 in an earlier report. This document serves not only as a monitoring tool but also as an act of accountability toward the scientific community and civil society. Through the collection and analysis of key environmental performance indicators (KPIs), INFN is committed to continuously improving its environmental performance and setting measurable goals for the future.

2.1. ENVIRONMENTAL KPIs

For the analysis of environmental impacts, five material themes have been identified, representing the most significant aspects that influence the environment and require careful monitoring and management. This section examines the material themes identified for the research institute, emphasizing their importance and the strategies to address them.

1. **Energy consumption.** Research laboratories are often among the most energy-intensive facilities due to the specialized equipment and controlled environments required for scientific research. High-performance computers, particle accelerators, analytical instruments, and climate-controlled spaces consume large amounts of electricity. Reducing energy consumption in laboratories is crucial for minimizing their environmental impact.

2. **Greenhouse gas emissions.** The carbon footprint of a research laboratory measures the total greenhouse gas emissions generated by its operations, including direct emissions from on-site activities, that are relevant in laboratories where electrostatics accelerators operate, and indirect emissions from energy consumption and supply chains. Understanding and reducing the carbon footprint is essential for mitigating the impact of research laboratories on climate change.

3. **Water use.** Water is a critical resource in research laboratories, used in processes or cooling systems. Efficient water use and management are important for reducing the environmental impact of laboratory operations and conserving this vital resource. Implementing water-saving technologies and practices, recycling and reusing water where possible, and monitoring and reducing water consumption are essential measures.

4. **Waste management.** Research laboratories generate various types of waste, including hazardous waste, electronic waste, and general solid waste. Proper management of these waste streams is vital to minimize environmental harm and ensure compliance with regulatory requirements. Reducing waste generation through sustainable procurement and usage practices, implementing effective waste segregation and recycling programs, and ensuring the safe and compliant disposal of hazardous waste are crucial strategies.

5. **Ionising radiation.** Research laboratories use particle accelerators, radiogenic machines, and radioactive sources that generate ionizing radiation. The use of such ionizing radiation sources takes place within buildings equipped with the necessary prevention, protection, and alarm systems.

Figure 2. The Large Volume Detector (LVD) at the LNGS.

3. ENERGY CONSUMPTION

Energy consumption represents one of the key material KPIs for assessing the environmental impact of INFN. It significantly affects both the depletion of non-renewable natural resources, particularly fossil fuels, and the emission of greenhouse gases, which are among the main drivers of climate change.

3.1. METHODOLOGY

Energy consumption was assessed using a single indicator, expressed in tonnes of oil equivalent (toe), with total values also reported in gigawatt hours (GWh). Data on various energy sources – including electricity, natural gas, liquid fuels, and vehicle fuel – were collected and converted into toe using the standard conversion factors provided by the Italian Federation for Energy Efficiency (FIRE). This approach ensures consistency in comparison and aggregation across different energy types. The conversion factors used are listed below (Table 6), and the complete inventory dataset supporting these calculations is provided in the Appendix A.

Table 6. Primary energy conversion factors in toe.

	UM	Conversion Factor
Electricity	toe/kWh	0.187×10^{-3}
Natural gas	toe/Smc	0.836×10^{-3}
Diesel oil	toe/l	0.860×10^{-3}
Gasoline	toe/l	0.765×10^{-3}
LPG	toe/l	0.616×10^{-3}

3.2. RESULTS

The analysis of the institute's energy consumption reveals a decrease in total energy use in 2024, bringing it in line with the average annual values from the previous period (Figure 3). After the peak observed in 2023, when consumption increased from 9 853 to 11 587 toe, a decline was recorded in 2024, with total consumption decreasing to 10 929 toe.

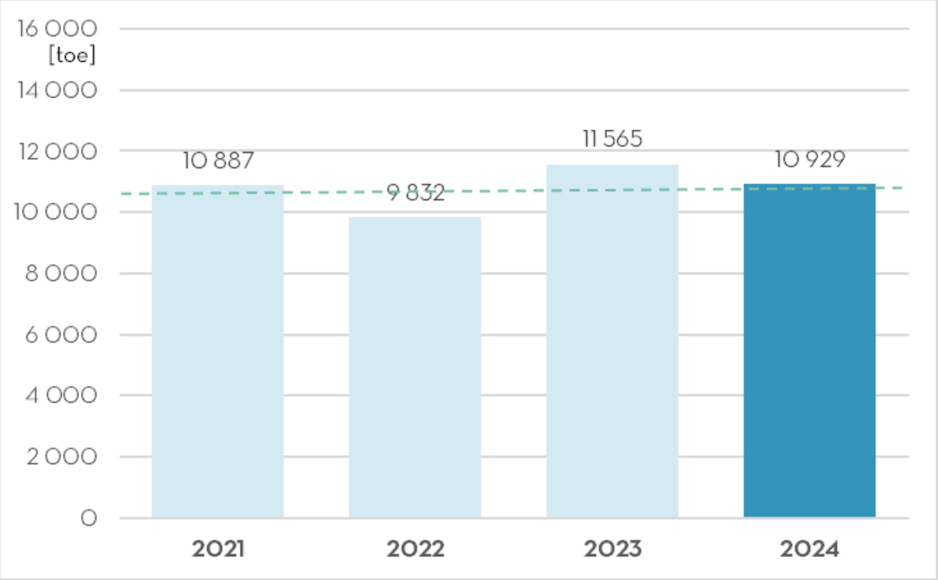

Figure 3. Trend of total energy consumption of INFN [toe].
Note: dashed line indicates the average energy consumption value calculated for the period 2021-2023.

The following presents data on INFN's total consumption, both in absolute and relative terms, broken down by energy type.

Table 7. Total energy consumption of INFN.

	um	2021		2022		2023		2024	
Electrical energy (EE)	toe	10 307	94.7%	9 350	95.1%	11 107	96.0%	10 465	95.8%
Thermal energy (TE)	toe	574	5.3%	476	4.8%	452	3.9%	456	4.2%
Fuel (Transportation)	toe	5	0.0%	6	0.1%	6	0.1%	7	0.1%
TOTAL	toe	**10 887**		**9 832**		**11 565**		**10 929**	
	GWh	62.86		55.61		64.72		61.35	

Electricity represents the dominant component of the energy mix in all years considered, maintaining a stable share above 94%. Specifically, a significant increase is observed in 2023, when consumption reaches 11 107 toe, before slightly decreasing in 2024 to 10 465 toe. Despite this modest reduction, the overall trend underscores a strong and structural dependency on electricity, which is intrinsically linked to the operation of technological and scientific processes that require intensive electricity usage, such as accelerators.

Thermal energy, while accounting for a much smaller share of the total, shows a degree of stability over time. After a slight decrease in 2023, consumption marginally increases again in 2024. Finally, fuel consumption for transport remains negligible in absolute terms and, in 2024, amounted to 7 toe, showing an increase compared to previous years.

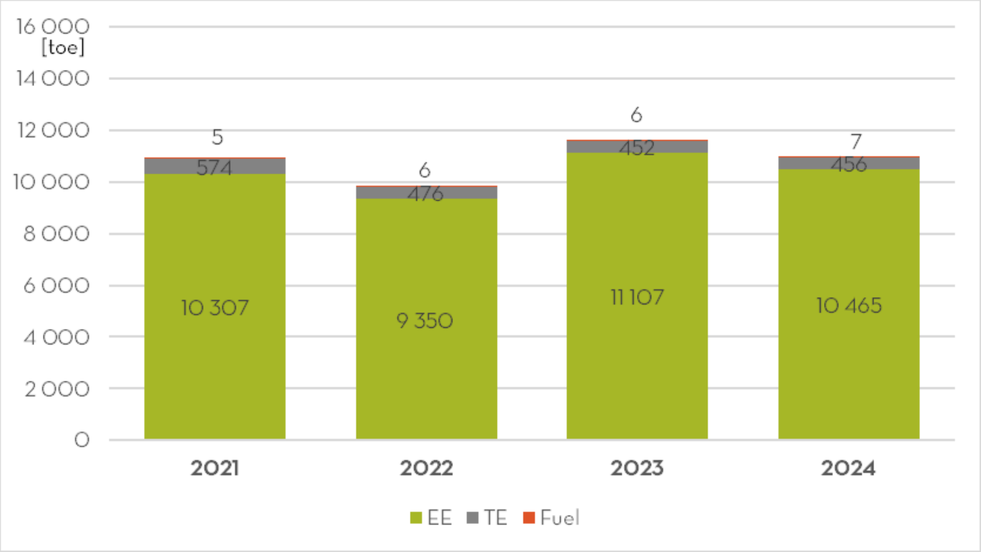

Figure 4. Trend of total energy consumption of INFN by energy source [toe].

An analysis of the contribution of different structures to the total reveals a stable trend over the period under consideration. Some structures represent a significant share, while others contribute to a lesser extent. The LNF represents the highest contribution (on average, 32% of the total), followed by the LNL (on average, 29%), and then the LNGS (on average, 18%).

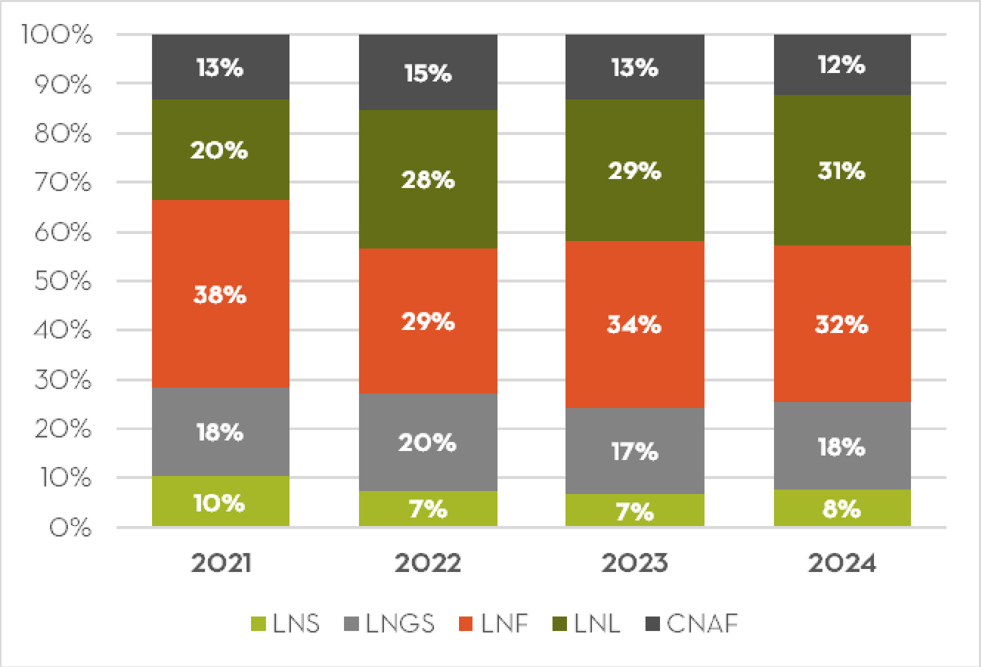

Figure 5. Breakdown of energy consumption compared to the total of facilities.

3.2.1. Insights by site

- **LNF**

The table below shows energy consumption over the reference period, broken down by energy source in both absolute and relative terms. Most of the consumption is attributable to electricity, which on average accounts for 98% of the total.

Table 8. Total energy consumption of LNF.

	um	2021		2022		2023		2024	
Electrical energy (EE)	toe	4 066	98.21%	2 850	98.73%	3 900	99.10%	3 451	98.89%
Thermal energy (TE)	toe	72	1.73%	34	1.18%	32	0.81%	35	1.00%
Fuel (Transportation)	toe	2	0.05%	3	0.09%	3	0.08%	4	0.11%
TOTAL	toe	**4 140**		**2 886**		**3 936**		**3 489**	
	GWh	22.60		15.67		21.27		18.90	

In 2024, total energy consumption declined from 3 936 toe in 2023 to 3 489 toe, corresponding to an 11% reduction. This decrease is primarily attributable to a significant drop in electricity consumption (approximately 450 toe), resulting from the reduced operating hours of the DAΦNE collider. Thermal energy consumption remained relatively stable, demonstrating the effectiveness of the efficiency measures implemented in 2022, which led to a significant reduction in methane consumption, from 72 toe in 2022 to an average of 34 toe. Finally, fuel consumption for transport has shown a rising trend, reaching approximately 4 toe.

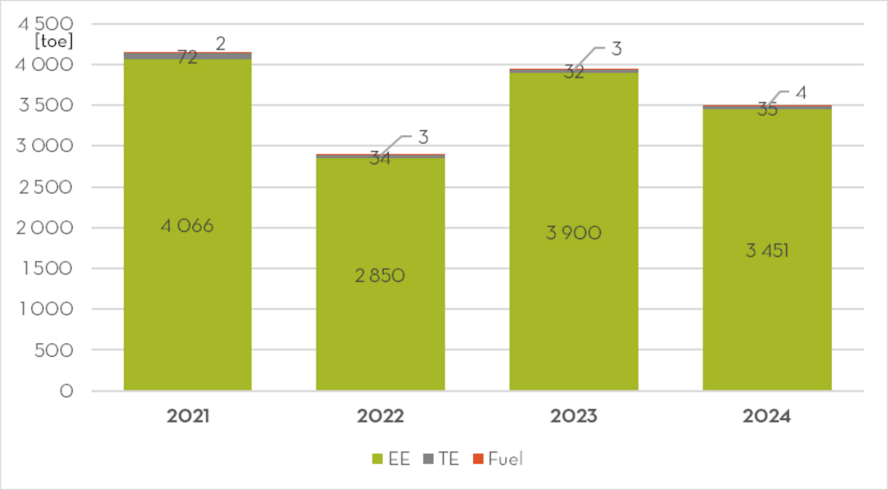

Figure 6. Trend of total energy consumption of LNF by energy source [toe].

• LNGS

The analysis of energy consumption at LNGS over the period 2021-2024 reveals a picture of substantial stability, with total values remaining virtually constant: 1 973 toe in 2021, 1 935 toe in 2022, 2 016 toe in 2023, and 1 920 toe in 2024 (Table 9).

Electricity continues to be the dominant energy source, accounting for approximately 90% of the total energy demand each year. Thermal energy, while representing a smaller share, shows slight variability: an increase is recorded in 2023, with a consumption of 199 toe, followed by a reduction in 2024, when the value drops to 177 toe. Its percentage share remains modest, stabilizing around 9%, while fuel consumption for transportation remains negligible, both in absolute and relative terms.

Table 9. Total energy consumption of LNGS.

	um	2021		2022		2023		2024	
Electrical energy (EE)	toe	1 804	91.46%	1 760	90.94%	1 816	90.07%	1 741	90.71%
Thermal energy (TE)	toe	167	8.45%	174	8.97%	199	9.85%	177	9.22%
Fuel (Transportation)	toe	2	0.08%	2	0.08%	2	0.08%	1	0.07%
TOTAL	toe	**1 973**		**1 935**		**2 016**		**1 920**	
	GWh	11.61		11.45		12.04		11.39	

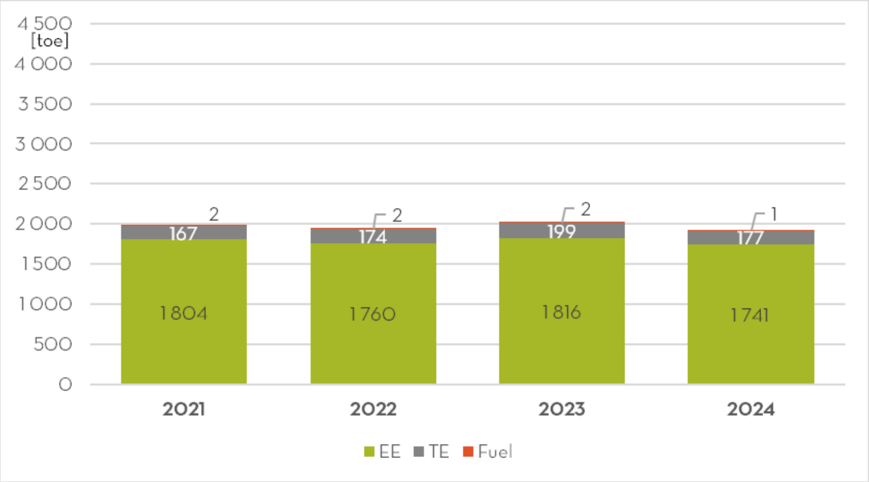

Figure 7. Trend of total energy consumption of LNGS by energy source [toe].

- **LNL**

In 2024, total energy consumption amounted to 3 337 toe, marking a slight increase compared to 2023 (3 300 toe) and a more significant rise compared to 2022 (2 782 toe).

Table 10. Total energy consumption of LNL.

	um	2021		2022		2023		2024	
Electrical energy (EE)	toe	1 949	87.41%	2 559	91.99%	3 119	94.51%	3 144	94.22%
Thermal energy (TE)	toe	280	12.55%	222	7.97%	180	5.46%	192	5.75%
Fuel (Transportation)	toe	1	0.04%	1	0.04%	1	0.03%	1	0.04%
TOTAL	toe	**2 230**		**2 782**		**3 300**		**3 337**	
	GWh	13.69		16.28		18.78		19.06	

Electricity remains the primary energy source, with a consumption of 3 144 toe, accounting for 94.22% of the total. Although there is a slight increase in absolute terms compared to 2023 (+25 toe), its percentage share shows a small decrease compared to the peak in 2023 (94.51%). This reduction is attributed to thermal energy, which, after a significant decline in 2023 (180 toe), sees growth in 2024, reaching 192 toe. Fuel consumption for transportation remains stable and negligible, with an unchanged value of 1 toe in all years, representing less than 0.1% of the total.

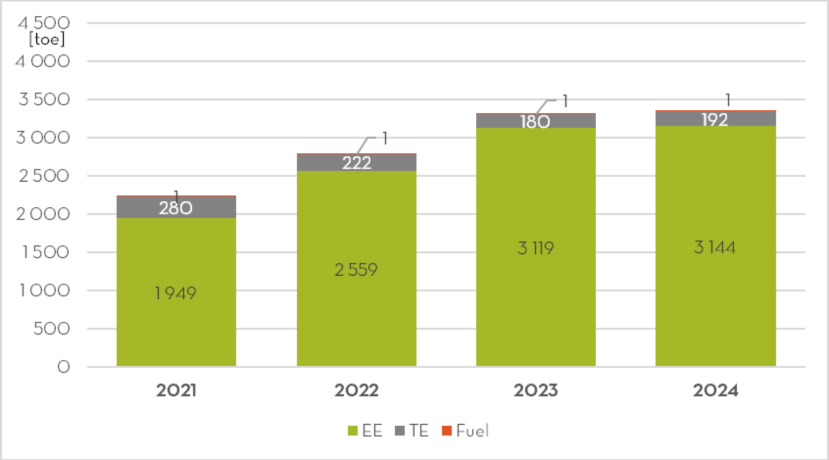

Figure 8. Trend of total energy consumption of LNL by energy source [toe].

- **LNS**

LNS's energy consumption reached 847 toe in 2024, confirming a progressive upward trend in overall energy use, with an average annual increase of 8% over the period considered. This growth is primarily attributed to the resumption of scientific activities, including testing phases and preparations for new experiments. Nevertheless, current consumption levels remain below the 1 116 toe recorded in 2021.

Table 11. Total energy consumption of LNS.

	um	2021		2022		2023		2024	
Electrical energy (EE)	toe	1 068	95.69%	683	93.76%	734	94.92%	795	93.82%
Thermal energy (TE)	toe	48	4.28%	45	6.20%	39	5.04%	52	6.15%
Fuel (Transportation)	toe	0	0.03%	0.3	0.04%	0.3	0.04%	0.3	0.04%
TOTAL	toe	**1 116**		**728**		**773**		**847**	
	GWh	6.27		4.18		4.38		4.86	

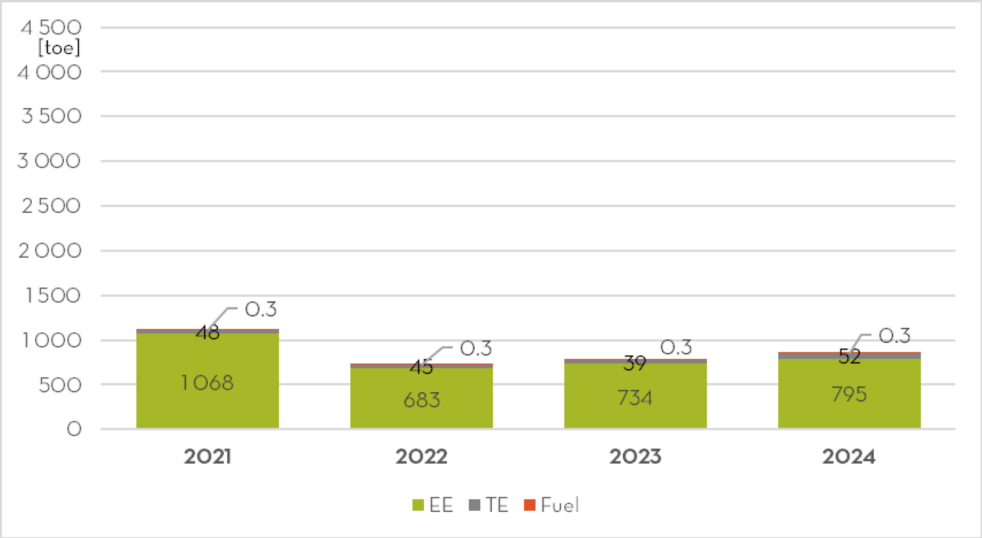

Figure 9. Trend of total energy consumption of LNS by energy source [toe].

Electricity continues to represent the primary energy source, consistently accounting for over 93% of total consumption each year, with a stable growth trajectory. Although secondary, thermal energy displays a more variable pattern: following a slight decline in 2023, consumption rose again in 2024, reaching 52 toe.

• CNAF

In 2024, total energy consumption amounted to 1 335 toe, representing a significant decrease compared to previous years: a 13% reduction from 2023 (1 539 toe) and an 11% decrease from 2022 (1 500 toe). This reduction is primarily attributable to the transfer of some operations to the Tecnopolo, which resulted in lower energy consumption.

Table 12. Total energy consumption of CNAF.

	um	2021		2022		2023		2024	
Electrical energy (EE)	toe	1 420	99.40%	1 498	99.89%	1 537	99.85%	1 334	99.94%
Thermal energy (TE)	toe	8	0.57%	1	0.07%	2	0.14%	0.4	0.03%
Fuel (Transportation)	toe	0.3	0.02%	0.7	0.04%	0.3	0.02%	0.4	0.03%
TOTAL	toe	**1 429**		**1 500**		**1 539**		**1 335**	
	GWh	7.69		8.03		8.25		7.14	

The reduction is almost entirely attributable to the decrease in electricity consumption, which fell from 1 537 toe in 2023 to 1 334 toe in 2024. Nevertheless, electricity remains the dominant energy source, accounting for 99.94% of total consumption in 2024—an even higher share than in previous years. Secondary sources, already marginal, declined further: thermal energy dropped from 2 toe in 2023 to just 0.4 toe in 2024, while fuel for transportation remained virtually unchanged at 0.4 toe.
Note: for greater clarity in data interpretation, this report continues to present the energy consumption figures for the CNAF infrastructure in Viale Berti Pichat; starting from 2025, the reported data will refer exclusively to the new infrastructure at the Tecnopolo.

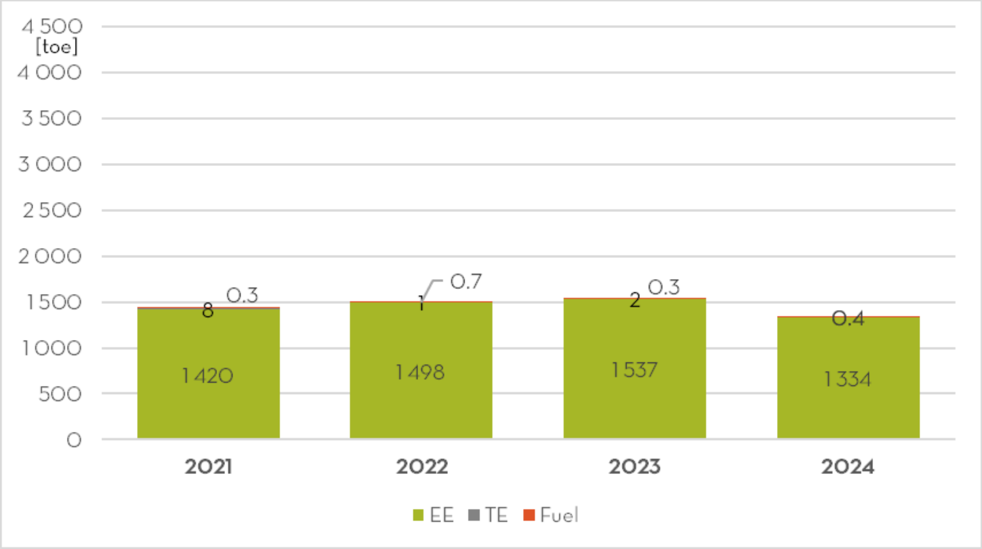

Figure 10. Trend of total energy consumption of CNAF by energy source [toe].

Figure 11. The Dafne accelerator in the LNF.

4. GREENHOUSE GAS EMISSIONS

Following the assessment of energy consumption, greenhouse gas emissions have been quantified for the four National Laboratories and the CNAF of the INFN.

4.1. Methodology

The quantification and reporting of INFN's greenhouse gas (GHG) emissions have been developed in alignment with the GHG Protocol and the ISO 14064-1 standard. In accordance with these frameworks and the IPCC guidelines, the GHGs considered include: Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Hydrofluorocarbons (HFCs), Sulphur Hexafluoride (SF_6), Nitrogen Trifluoride (NF_3), and Perfluorocarbons (PFCs). These gases are aggregated and reported in terms of CO_2 equivalent (CO_2e), allowing for a unified measure of total emissions. The emissions inventory does not include biogenic emissions, nor does it account for absorption or storage.

The carbon footprint is calculated by combining three key elements: the quantity of activity performed, the emission factor associated with that activity, and the global warming potential of the greenhouse gas emitted. This approach is the most commonly used methodology for compiling greenhouse gas inventories and reporting emissions. It also serves as the standard framework for compliance with regulatory systems such as the European Union Emissions Trading System (EU ETS). For transparency and completeness, the activity data used in these calculations are detailed in Appendix B.

Organizational boundaries

The assessment encompasses the years 2021, 2022, 2023, and 2024 as the reference period and specifically focuses on the evaluation of emissions from the four National Laboratories (i.e., LNF, LNGS, LNL, and LNS) as well as the National Centre, CNAF.

The organizational boundaries are defined based on an operational control approach. Under this framework, an organization is responsible for 100% of the greenhouse gas emissions arising from operations over which it has control, meaning it has full authority to implement and enforce its own operational policies. Emissions from operations in which the organization holds an interest but lacks operational control are not included in the assessment.

Reporting boundaries

In 2024, the reporting boundaries were expanded to include all emissions of the Institute, unlike in previous years, when the reporting was limited solely to emissions falling within the Scope 1 and Scope 2 boundaries. This expansion provides a more comprehensive and accurate view of the Institute's total emissions, enabling a more detailed assessment of their environmental impact.

Specifically, the emissions considered, in accordance with the GHG Protocol, are:

- Scope 1 includes direct emissions from sources owned or controlled by the organization, such as fuel combustion in facilities, vehicle fleets, and industrial processes. In this study, the category related to direct emissions from land use, land use change, and forestry (hereafter referred to as 'LULUCF emissions and removals') does not include any potential CO_2 sequestration associated with the tree stock present at the various Institute sites.

- Scope 2 covers indirect emissions from the generation of purchased electricity, heat, or steam consumed by the organization. Although these emissions occur off-site, they are attributable to the organization's operations.
  The emissions assessment considered both the market-based and location-based approaches, in accordance with the GHG Protocol. However, in this report, the total results refer exclusively to the location-based methodology. To ensure greater clarity, an asterisk is used when Scope 2

emissions are calculated using the location-based approach [e.g. (Scope 2)*]. Scope 2 emissions for the period 2021–2023 have been recalculated using the location-based approach.

- Scope 3 emissions refer to all other indirect greenhouse gas emissions that occur outside the boundaries of an organization's direct operations. These emissions arise throughout the entire value chain and are not directly controlled by the organization, yet they are a consequence of its activities. Scope 3 includes, but is not limited to, emissions from the production and transportation of purchased goods and services, capital goods, waste generated in operations, employee commuting, and business travel. In the context of the study, a comprehensive assessment was conducted to quantify Scope 3 emissions associated with several key categories. Specifically, the analysis focused on emissions resulting from:
    - the procurement of goods and services: it includes emissions associated with the production and delivery of all goods and services purchased by the organization. It covers a wide range of items, such as office supplies, equipment, raw materials, and outsourced services. To estimate these emissions, a spend-based approach was adopted, whereby the monetary value of purchases is multiplied by sector-specific emission factors derived from environmentally extended input-output models. The data utilized in this analysis were directly extracted from the financial statements of the various laboratories. The principal expenditure categories examined include catering services, security services, cleaning services, maintenance, and the purchase of consumables. Due to the complexity of the Purchase of scientific equipment category, a cut-off threshold was applied, excluding items below €10 000. Despite this, the analysis encompassed 93% of the total expenditure for this category. Similarly, a cut-off was applied to the Capital expenditure for facility systems category, excluding items below €20 000, which allowed for the analysis of 88% of the total expenditure within this category.
    - upstream activities related to fuel extraction and energy generation: these emissions arise from the extraction, production, and transportation of fuels and energy prior to their use by the organization. They are distinct from Scope 2 emissions, which account only for the consumption of purchased energy. A quantity-based approach was used, relying on the actual amounts of fuel and electricity consumed.
    - the management and disposal of waste produced during operations: it includes emissions resulting from the treatment and disposal of waste produced during the organization's activities. Emissions were estimated using a quantity-based method, where the weight of waste by type was multiplied by disposal-specific emission factors.
    - travel undertaken for business purposes refer to those generated by transportation used for work-related purposes, excluding commuting. This includes air travel, train journeys, car rentals, and taxi services. The analysis was conducted using a hybrid approach, combining both recorded quantities and reported expenditures. Data were extracted from the management system tracking employee business travel, and include information on hotel stays (number of nights and country), distances travelled by car, and expenses incurred for travel by air, train, bus, and rental car.
    - commuting by employees between their residences and the workplace: it includes emissions generated by daily travel to and from the worksite, as well as those associated with remote working arrangements. The estimation was based on data collected through structured employee surveys and considered various factors, including the modes of transport used, average commuting distances, and patterns of work attendance—whether in-person or remote.

Emission factors

The global warming potential of the greenhouse gas (GWP) is a measure used to evaluate the potency of greenhouse gases (GHGs) in contributing to global warming over a specified timeframe relative to carbon dioxide (CO2). It quantifies the amount of heat trapped in the Earth's atmosphere by a particular greenhouse gas compared to the same mass of CO_2. GWP values are expressed as multiples of CO_2's warming potential, with higher values indicating greater warming potential.

In this report, the updated Global Warming Potentials from the IPCC's 2021 Sixth Assessment Report, calculated with reference to a 100-year time frame, have been used. The main GWP values are listed below.

Table 13. GWP factors.

GAS	GWP (AR6 IPCC - 100y)
CO_2	1.0
CH_4 - fossil	29.8
CH_4 - non fossil	27.0
N_2O	273.0
R134a	1 530
R-227ea	3 600
R407c	1 908
R410a	2 256
R-448a	1 494
SF_6	24 300
CF_4	7 380

The emission factor associated with a given activity represents a numerical value used to estimate the quantity of GHGs emitted per unit of activity, process, or product. These factors reflect the average emission rate of GHGs resulting from specific sources or operations, such as energy consumption, transportation, or industrial processes.

For this study, two distinct types of emission factors were applied, each based on a different methodological approach. The quantity-based approach relies on physical activity data and uses emission factors expressed in units of mass of GHGs per unit of activity—for example, kilograms of CO_2 equivalent per kilowatt-hour of electricity consumed or per kilometer travelled by a vehicle. In contrast, the spend-based approach was employed in cases where physical data were unavailable. Under this method, emissions are estimated based on the monetary value of goods or services purchased, using average emission factors expressed per unit of currency (e.g., kg CO_2e per euro spent).

The main emission factors utilized in the analysis are presented below, categorized by emission type.

EF for combustion in stationary sources. Regarding emission factors for combustion in stationary sources, the values from the “Table of national standard parameters for monitoring and reporting greenhouse gases”, defined annually by the Ministry of the Environment and Energy Security (MASE), have been used.

EF for combustion in mobile sources. Emission factors for proprietary mobile sources have been derived from the ISPRA database concerning road transport. These values are based on estimates made for the preparation of the national emissions inventory, conducted annually by ISPRA as a tool for verifying international environmental protection commitments.

EF for electricity consumption. The location-based method relies on the organization's location and analyses emissions from the local power grid. For the emission factors calculation, the national estimate, prepared by ISPRA based on the national energy mix, was used. The market-based method, on the other hand, calculates emissions based on the specific energy composition of the electricity purchased by the various facilities. For this calculation, the emission factors were extracted from the AIB dataset.

Table 14. Electricity emission factor [gCO$_2$/kWh].

	2021	2022	2023	2024
Location-based approach	267.90	303.40	257.20	215.90
Market-based approach	456.56	457.15	500.57	441.20

EF for Scope 3. The emission factors used to estimate GHG emissions were selected from qualified and internationally recognized sources, ensuring a high level of reliability and accuracy. The use of validated databases is a critical component in maintaining methodological robustness and ensuring transparency throughout the emissions calculation process. The primary sources consulted include: *Government GHG Conversion Factors for Company Reporting, EXIOBASE, Ecoinvent, Hotel Footprints* and *EPA Database.*

4.2. RESULTS

The total greenhouse gas emissions for the year 2024, pertaining to INFN, amount to 58 292 tons of CO_2 equivalent, with an uneven distribution across the three activity areas considered in the inventory (Table 15).

Table 15. Total GHG emissions of INFN [ton CO_2e].

	2024	
Direct GHG emissions (SCOPE 1)	22 137	38%
Electricity indirect GHG emissions (SCOPE 2)*	12 329	21%
Indirect GHG emissions (SCOPE 3)	23 826	41%
TOTAL	**58 292**	

Indirect emissions related to Scope 3 account for half of the total, indicating that the majority of the climate impact arises from activities not directly controllable by the organization, such as the procurement of goods and services, business travel, and waste management. Emissions generated from sources directly controlled by the organization (Scope 1), such as those arising from the use of fuels and industrial processes, represent 38% of the total; similarly, indirect emissions associated with electricity consumption (Scope 2) also constitute 21% of the total.

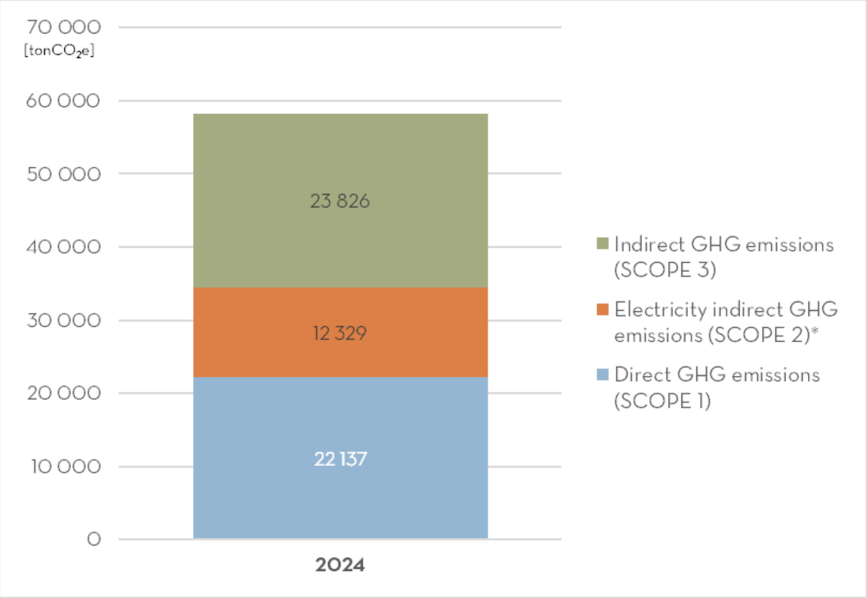

Figure 12. Total GHG emissions of INFN [ton CO_2e].

The analysis of the various emission categories clearly shows that a substantial portion of INFN's total carbon footprint is attributable to a limited number of sources (Figure 13). Specifically, three categories alone account for approximately 82% of total emissions: direct emissions from fugitive emissions, estimated at 21 012 tons, indirect emissions from the purchase of goods and services, totalling 14 723 tons of CO_2e; and finally, indirect emissions associated with imported electricity, amounting to 12 329 tons. The remaining categories, although contributing to a lesser extent, should not be overlooked. Among these, emissions related to staff mobility – both for business travel and commuting – collectively account for about 6% of the total emissions.

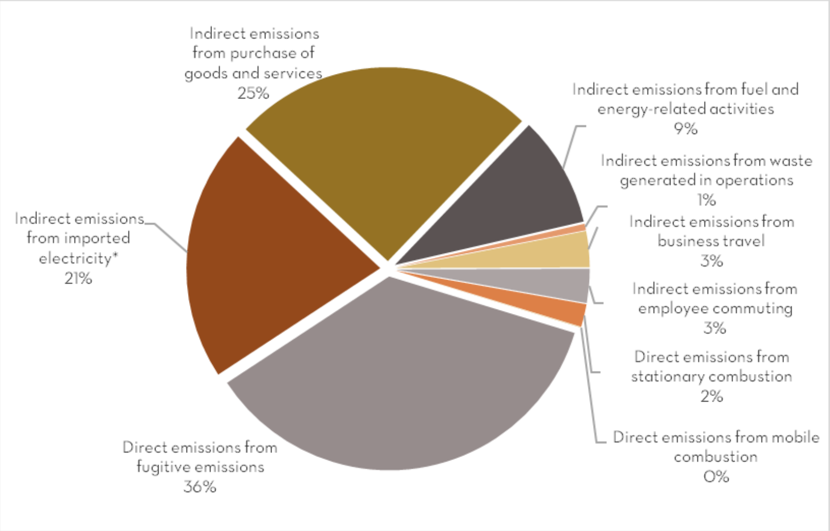

Figure 13. Breakdown of the total GHG emissions by emission category.

Analysing the various facilities, it is evident that the distribution of emissions is not homogeneous (Figure 14). LNL clearly stands out as the main contributor, with 18 900 tons of CO_2e, accounting for 32% of the total emissions. This is followed by LNS, with 15 145 tons, representing 26% of the total and LNF, with 10 871 tons, representing 19% of the total. The remaining two facilities, however, present relatively similar carbon footprints, each around 10% of the total: CNAF with 12% and LNGS with 11%.

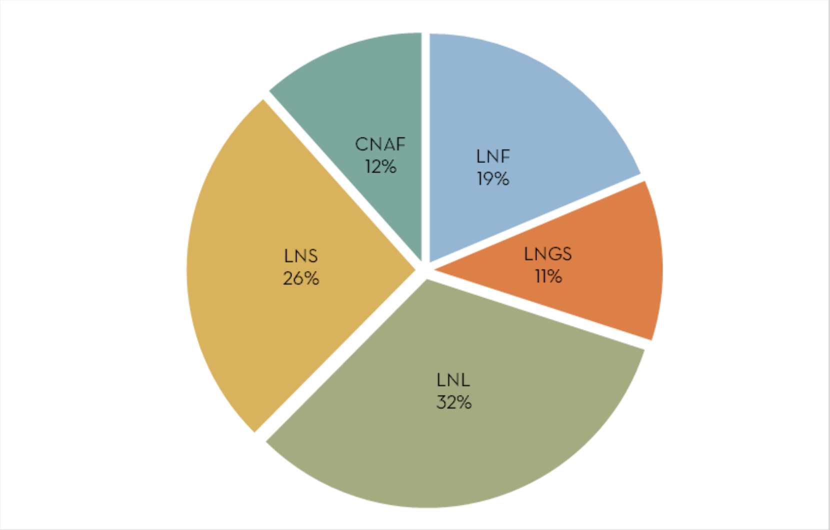

Figure 14. Breakdown of the total GHG emissions by facilities.

Finally, the analysis of GHG emissions over the past four years reveals a marked reduction in 2024, following elevated levels recorded in 2022 and 2023 (Figure 21). This improvement is largely attributable to the marked decrease in fugitive emissions, particularly those associated with SF_6, as a direct consequence of fewer maintenance interventions during the year. Indirect emissions from electricity consumption also declined, driven both by a reduction in overall energy use and by improvements in the national energy mix. It is also noteworthy that, despite the expansion of the system boundaries in 2024 to include Scope 3 emissions, overall GHG emissions remained relatively low compared to the previous two years.

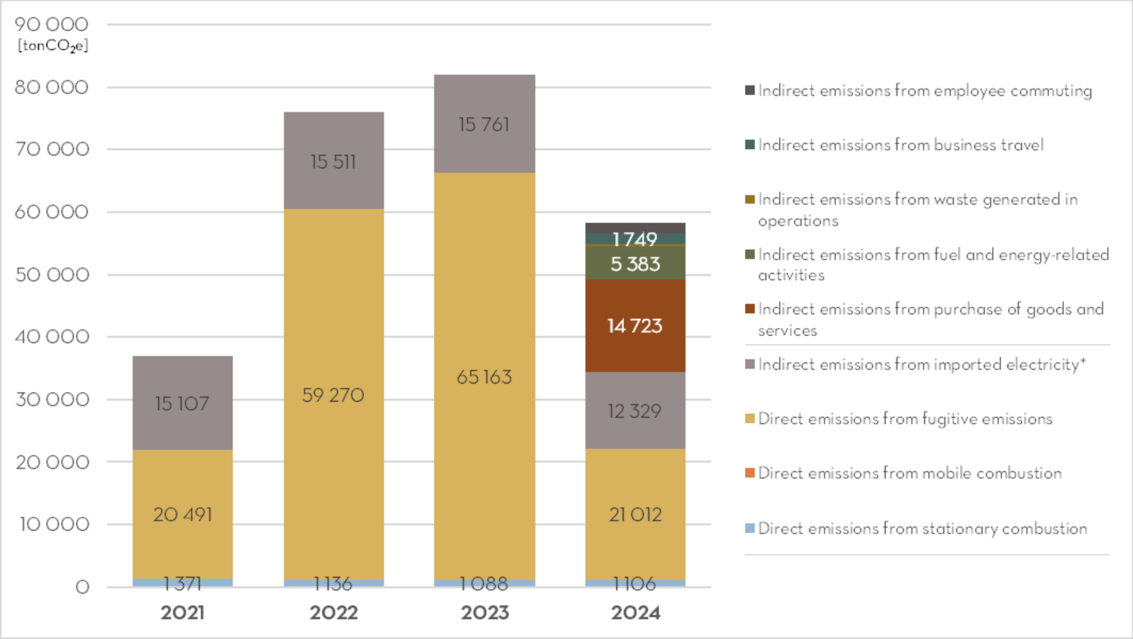

Figure 15. Trend of emission categories of INFN [ton CO$_2$e].

The details and impact of the different emission categories are shown below.

- Direct GHG emissions (Scope 1)

In 2024, a significant change in the direct GHG emissions profile is observed compared to previous years, with a marked overall reduction. The total direct emissions decrease from 66 268 tons in 2023 to just 22 137 tons in 2024, reflecting a substantial decline.

Table 16. Total direct GHG emissions (Scope 1) [ton CO$_2$e].

	2021		2022		2023		2024	
Direct emissions from stationary combustion	1 371	6%	1 136	2%	1 088	2%	1 106	5%
Direct emissions from mobile combustion	15	0%	19	0%	17	0%	19	0%
Direct process emissions from industrial process	0	0%	0	0%	0	0%	0	0%
Direct fugitive emissions	20 491	94%	59 270	98%	65 163	98%	21 012	95%
LULUCF emissions and removals	0	0%	0	0%	0	0%	0	0%
TOTAL	**21 874**		**60 424**		**66 268**		**22 137**	

The primary driver of this reduction is the direct fugitive emissions, which had been the predominant component in previous years and are significantly reduced in 2024, from 65 163 to 21 012 tons. Although they still account for the majority of total emissions (95%), their decrease in absolute terms is the key factor behind the overall contraction. This improvement is mainly attributable to the reduction in SF$_6$ emissions, resulting from lower maintenance operations required for the LNL electrostatic accelerators. Emissions from stationary combustion show a slight increase compared to 2023, rising from 1 088 to 1 106 tons, representing a 1.7% increase. Emissions from mobile combustion also rise, from 17 to 19 tons of CO$_2$ equivalent.

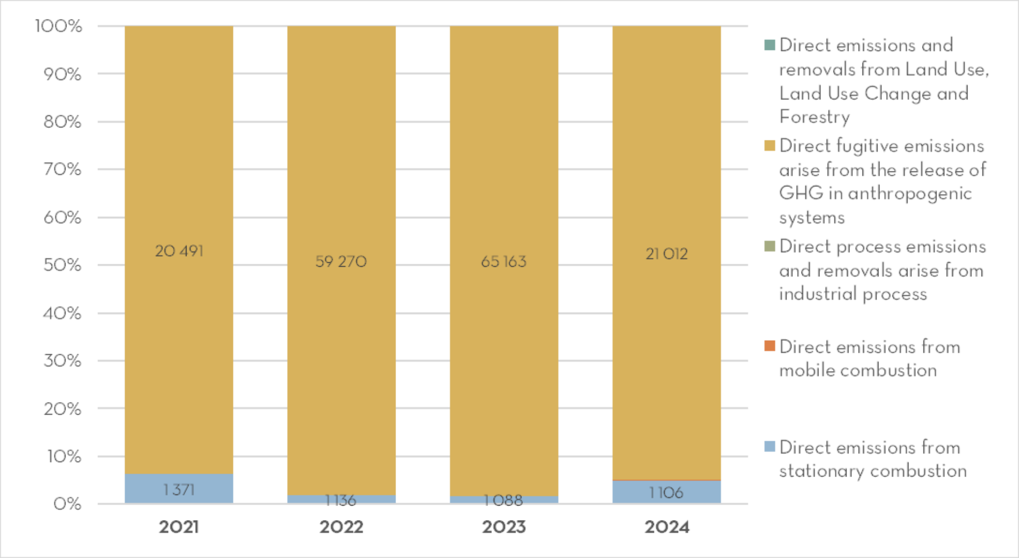

Figure 16. Breakdown of indirect GHG emissions in relation to total emissions.

Table 17 shows direct fugitive emissions arise from the release of GHG broken down by different gases in the years 2021 to 2024.

Table 17. Direct fugitive emissions arise from the release of GHG in anthropogenic systems [ton CO_2e].

	2021	2022	2023	2024
C_4H_{10}	6.60E-05	6.60E-05	6.60E-05	0.00E+00
CF_4	4.32E+02	4.33E+02	4.32E+02	1.10E+00
CH_4	0.00E+00	4.27E-04	0.00E+00	0.00E+00
CO_2	1.20E-01	1.76E-01	1.48E-01	1,60E-01
Experimental gas mixtures	2.42E-01	3.07E-01	6.72E-05	1,54E-01
Hydrostar gas	7.44E-03	1.49E-02	0.00E+00	0.00E+00
R-134a	5.05E+01	1.04E+02	5.05E+01	9,49E+01
R-227ea	2.51E+03	0.00E+00	0.00E+00	0,00E+00
R-407C	2.23E+02	2.75E+01	7.63E+00	4,78E+01
R-410A	6.99E+01	5.68E+01	0.00E+00	0,00E+00
R-448A	4.93E+01	0.00E+00	0.00E+00	0,00E+00
SF_6	1,68E+04	5,83E+04	6,44E+04	2,09E+04

The data reveals that the majority of gases emitted in significant quantities in previous years show no emissions in 2024. These include methane (CH_4), Hydrostar gas, and various refrigerants such as R-410A and R-448A. In 2024, only six gases are still present: tetrafluoromethane (CF_4), carbon dioxide (CO_2), experimental gases, R-134a, R-407C, and sulfur hexafluoride (SF_6). The latter continues to represent the primary source of emissions, with a value of 20 868 tonCO_2e, confirming its environmental criticality despite the reduction compared to previous years. Indeed, thanks to the reduced maintenance required on the LNL electrostatic accelerators, GHG emissions from SF_6 have been reduced by approximately 83% compared to 2023. CF_4, while still present, shows a negligible value (1.1 tons), whereas R-134a registers a significant increase compared to 2023, rising from 50.5 to 190 tonCO_2e. Finally, R-407C decreases to 47.8 tonCO_2e.

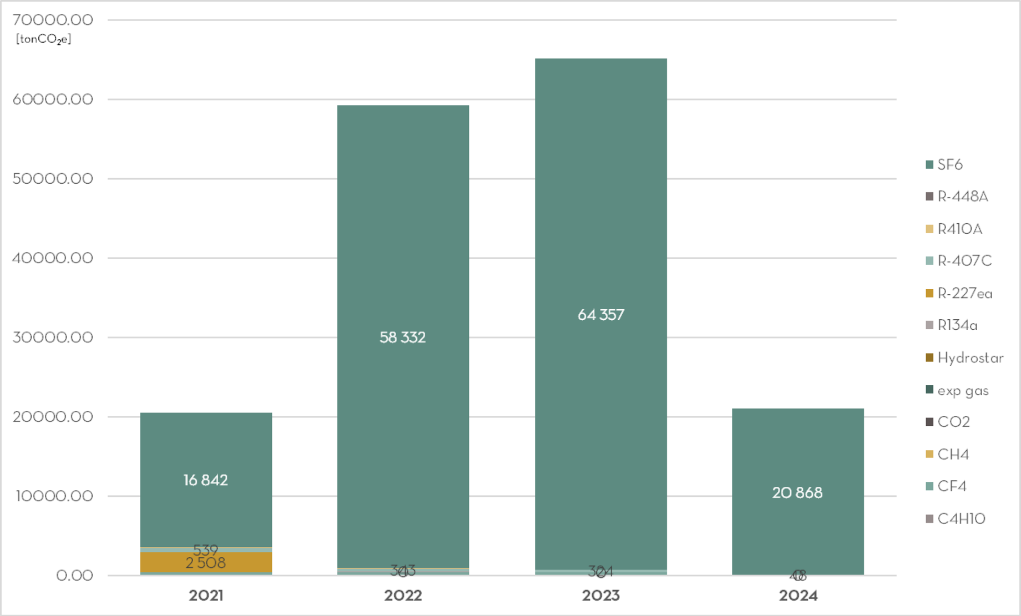

Figure 17. Trend of the direct fugitive emissions arise from the release of GHG [ton CO_2e].

- Electricity indirect GHG emissions (Scope 2)

For the indirect emissions related to electricity consumption, the results of the calculations are provided according to both the market-based and location-based methodologies, in addition to the category related to energy imports, which is zero for all sites (Table 18).

In 2024, a reduction in indirect emissions from electricity imports is observed compared to the previous year, both under the market-based and location-based approaches. Emissions calculated using the market-based method decrease from 29 838 tons in 2023 to 24 790 tons in 2024, reflecting a reduction of approximately 16.9%. The location-based approach also shows a significant decrease, with emissions falling from 15 761 to 12 329 tons, representing a reduction of about 21.8%.

Table 18. Total electricity indirect GHG emissions (Scope 2) [ton CO_2e].

	2021	2022	2023	2024
Indirect emissions from imported electricity (market-based approach)	25 269	22 956	29 838	24 790
Indirect emissions from imported electricity (location-based approach)	15 107	15 511	15 761	12 329
Indirect emissions from imported energy	0	0	0	0

These differences in emission trends are attributable to two factors: the variability of emission factors associated with different sources of electricity, which change from year to year to account for variations in the energy mix, and fluctuations in electricity consumption. In particular, the composition of the electricity grid and the carbon intensity of energy sources have changed over the period due to transitions to renewable sources or other changes in energy production.

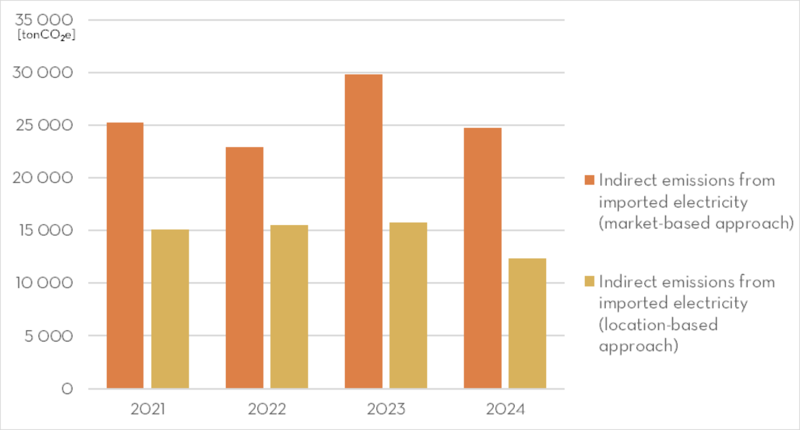

Figure 18. Trend of electricity indirect GHG emissions (Scope 2) [ton CO_2e].

- Indirect GHG emissions (Scope 3)

Below is Table 19, which presents the Scope 3 indirect emissions, broken down by the main emission source categories analysed.

Table 19. Total indirect GHG emissions (Scope 3) [ton CO_2e].

	2024	
Indirect emissions from purchase of goods and services	14 723	62%
Indirect emissions from fuel and energy-related activities	5 383	23%
Indirect emissions from waste generated in operations	315	1%
Indirect emissions from business travel	1 749	7%
Indirect emissions from employee commuting	1 656	7%
TOTAL	**23 826**	

The detailed analysis of indirect emissions highlights that the primary source of these emissions is represented by the purchase of goods and services, which alone accounts for a total of 14 723 tons, or approximately 62% of the total indirect emissions. Following this, emissions related to activities involving fuel and energy consumption amount to 5 383 tons, while emissions from business travel and employee commuting together represent 14% of total emissions.

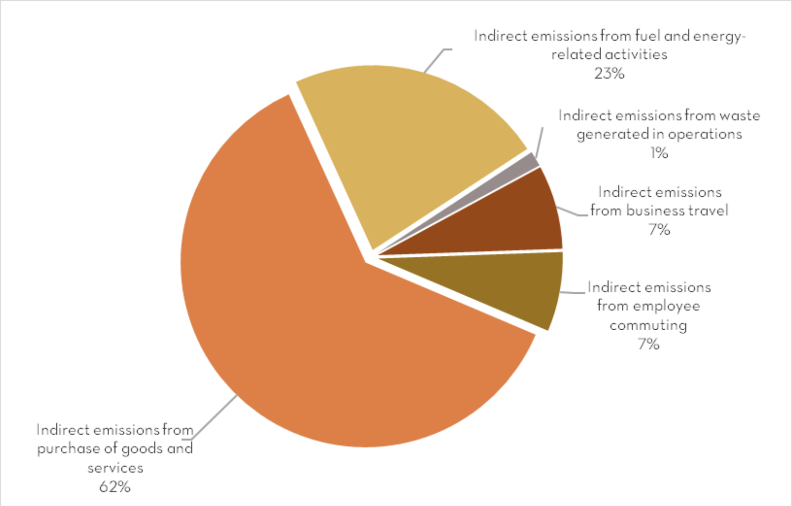

Figure 19. Breakdown of the indirect GHG emissions (Scope 3).

A detailed examination of the category '*Indirect from purchase of goods and services*' clearly shows that the main source of emissions comes from the purchase of scientific equipment, which alone accounts for 57% of the total (Figure 20). This figure underscores the significant impact that investments in technological equipment and research-specific tools have on the overall balance of indirect emissions. Another relevant category is emissions associated with the capital expenditure for facility systems, contributing 22% to the total emissions in this category.

The other categories, on the other hand, account for smaller shares, partly due to lower expenditure amounts compared to those for equipment and plants, and partly due to the nature of the goods or services purchased, which have a reduced carbon footprint.

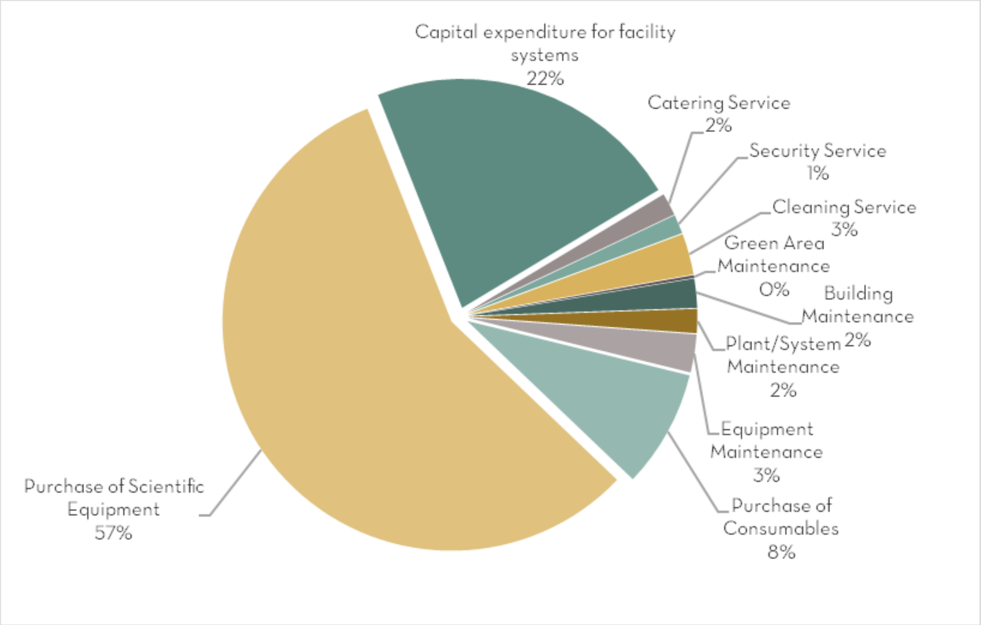

Figure 20. Breakdown of the indirect GHG emissions from purchase of goods and services.

IMPROVEMENT TARGET

In line with the overall policy aimed at sustainability and resource optimization, designed to combine scientific innovation with environmental responsibility, INFN has established improvement targets focused on reducing CO_2 emissions.

Recognizing that Scope 1 accounts for a significant share of the Institute's carbon footprint, INFN has committed to cutting direct CO_2 emissions by 25% by 2026, compared to the average of the past three years. Since fugitive emissions constitute the main source of these emissions, achieving this goal will involve targeted actions to limit the use of SF_6, a gas with a high global warming potential. Specific actions will be implemented at the LNF, LNL, and LNS laboratories, including comprehensive monitoring plans and restrictions on SF_6 usage.

4.2.1. Insights by site

• LNF

The overall LNF's carbon footprint in 2024, including indirect emissions, amounts to 10 871 tons (Table 20).

Table 20. GHG emission of LNF [ton CO_2e].

	2021	2022	2023	2024
Direct emissions from stationary combustion	171	81	77	85
Direct emissions from mobile combustion	7	9	8	10
Direct process emissions from industrial process	0	0	0	0
Direct fugitive emissions	968	798	798	48
LULUCF emissions and removals	0	0	0	0
Indirect emissions from imported electricity*	5 866	4 653	5 402	4 016
Indirect emissions from imported energy	0	0	0	0
Indirect emissions from purchase of goods and services	NC	NC	NC	3 274
Indirect emissions from fuel and energy-related activities	NC	NC	NC	1 729
Indirect emissions from waste generated in operations	NC	NC	NC	2
Indirect emissions from business travel	NC	NC	NC	751
Indirect emissions from employee commuting	NC	NC	NC	956
TOTAL	**7 011**	**5 541**	**6 285**	**10 871**

Note: NC: not calculated.

Analyzing the trend of emissions over the years, it is observed that direct emissions have generally remained stable or have slightly decreased. In particular, emissions from stationary and mobile combustion have stabilized at relatively low levels, with a slight increase in 2024, reaching 85 and 10 tons, respectively. Fugitive emissions, which had previously represented a significant share, have undergone a drastic reduction, dropping from 798 tons in 2023 to only 48 tons in 2024. Similarly, indirect emissions from imported electricity show a significant decrease, falling from 5 402 tons in 2023 to 4 016 tons in 2024, confirming the positive trend already established in previous years.

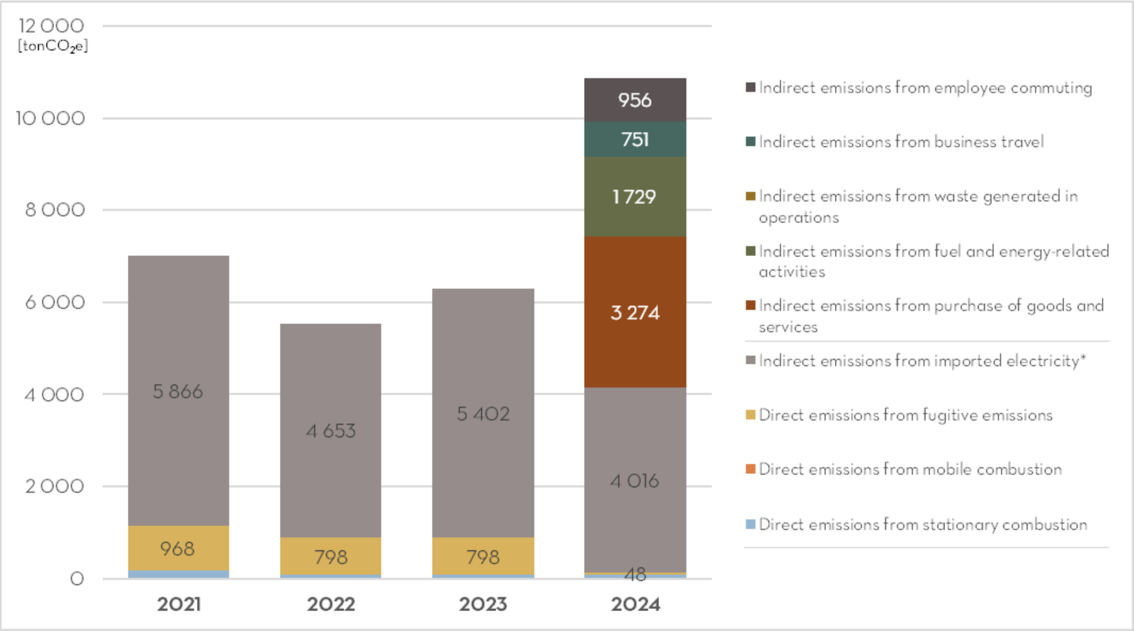

Figure 21. Trend of emission categories of LNF [ton CO_2e].

Regarding indirect emissions, the main categories are those related to the purchase of goods and services, which in 2024 account for 30% of total emissions, followed by activities related to fuel and energy consumption, and finally, emissions from employee commuting and business travel, which represent 16%, 9% and 7% of total emissions in 2024, respectively.

• LNGS

The Table 21 shows the trend of the carbon footprint of the LNGS over the past four years.

Table 21. GHG emission of LNGS [ton CO2e].

	2021	2022	2023	2024
Direct emissions from stationary combustion	396	414	477	429
Direct emissions from mobile combustion	5	5	5	4
Direct process emissions from industrial process	0	0	0	0
Direct fugitive emissions	97	0	0	0
LULUCF emissions and removals	0	0	0	0
Indirect emissions from imported electricity*	2 701	2 982	2 610	2 103
Indirect emissions from imported energy	0	0	0	0
Indirect emissions from purchase of goods and services	NC	NC	NC	2 511
Indirect emissions from fuel and energy-related activities	NC	NC	NC	937
Indirect emissions from waste generated in operations	NC	NC	NC	201
Indirect emissions from business travel	NC	NC	NC	223
Indirect emissions from employee commuting	NC	NC	NC	208
TOTAL	**3 199**	**3 400**	**3 092**	**6 615**

Note: NC: not calculated.

Direct emissions display a relatively stable trend. Emissions from stationary combustion, despite a slight decrease compared to the peak in 2023, remain at high levels, totalling 429 tons. A reduction in emissions from company vehicles is also observed, decreasing by 17%, down to 4 tons. Indirect emissions from imported electricity follow a decreasing trend, dropping from 2 982 tons in 2022 to 2 103 tons in 2024, marking a reduction of nearly 30% over two years. This decline is mainly attributed to the improvement in the national energy mix, which has led to a greater use of energy sources with a lower environmental impact.

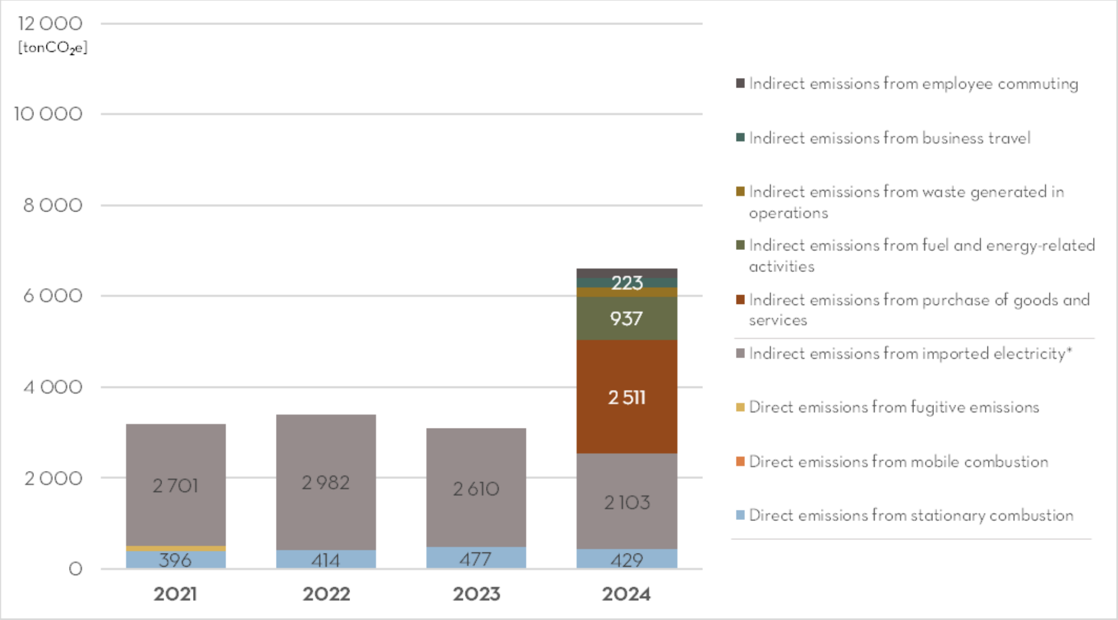

Figure 22. Trend of emission categories of LNGS [ton CO2e].

Regarding indirect emissions, the predominant category at LNGS is represented by purchases of goods and services, which generate 2 511 tons of CO_2e, followed by activities related to fuel and energy consumption. Emissions resulting from waste management, business travel, and employee commuting represent smaller, but still significant, shares, contributing notably to the total indirect emissions.

• LNL

In 2024, the carbon footprint of the LNL sees a significant reduction compared to the previous two years, despite the expansion of the reporting boundaries. It stands at 18 900 tons of CO_2e, marking a substantial decrease from the peak of 62 275 tons recorded in 2023 (Table 22).

Table 22. GHG emission of LNL [ton CO_2e].

	2021	2022	2023	2024
Direct emissions from stationary combustion	665	529	434	465
Direct emissions from mobile combustion	2	3	3	3
Direct process emissions from industrial process	0	0	0	0
Direct fugitive emissions	12 712	50 632	57 356	10 839
LULUCF emissions and removals	0	0	0	0
Indirect emissions from imported electricity*	2 816	4 179	4 483	3 661
Indirect emissions from imported energy	0	0	0	0
Indirect emissions from purchase of goods and services	NC	NC	NC	1 689
Indirect emissions from fuel and energy-related activities	NC	NC	NC	1 639
Indirect emissions from waste generated in operations	NC	NC	NC	111
Indirect emissions from business travel	NC	NC	NC	242
Indirect emissions from employee commuting	NC	NC	NC	251
TOTAL	**16 195**	**55 344**	**62 275**	**18 900**

Note: NC: not calculated.

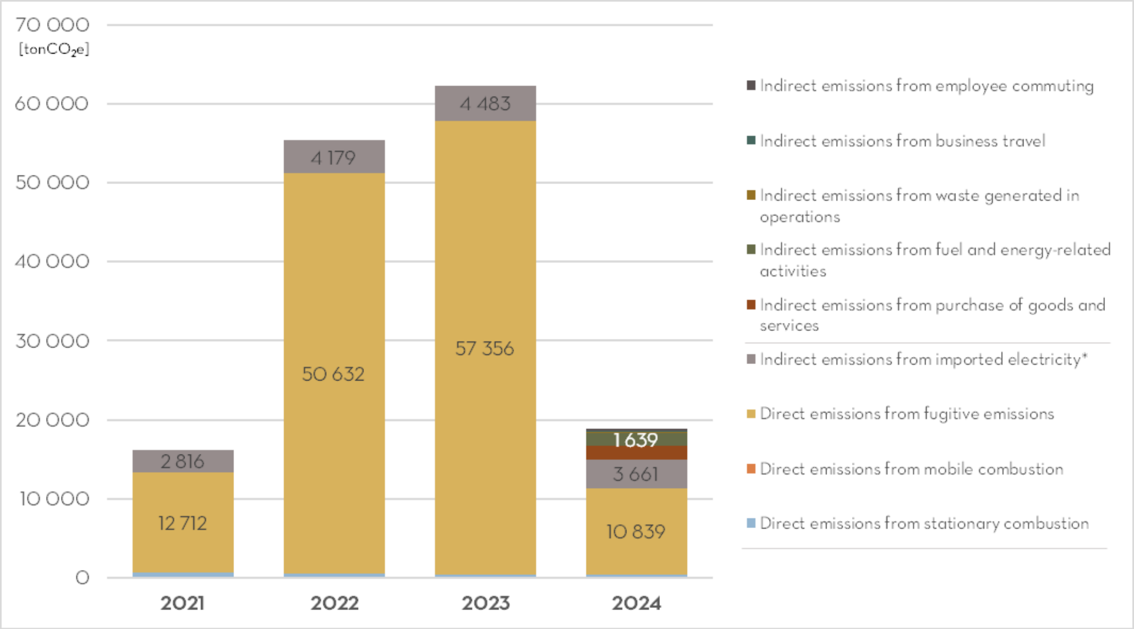

Figure 23. Trend of emission categories of LNL [ton CO_2e].

Direct emissions show varying trends. Stationary combustion, which had followed a declining trend in previous years, recorded a slight reversal in 2024, with a 7% increase, bringing emissions to 465 tons, although this value remains lower compared to the levels of 2021 and 2022. Fugitive emissions, which had previously accounted for a significant share of the total, have decreased drastically, dropping from over 57 000 tons in 2023 to just under 11 000 tons in 2024. Regarding indirect emissions, a reduction in emissions from imported electricity is observed, which decreased to 3 661 tons.

Indirect emissions are primarily attributable to two categories: emissions from the purchase of goods and services, and those related to energy-related activities, which represent 41% and 40%, respectively, of the total indirect emissions.

• LNS

In 2024, the total emissions amount to 15 145 tons of CO_2 equivalent, considering the expanded reporting boundary to include indirect emissions.

Table 23. GHG emission of LNS [ton CO_2e].

	2021	2022	2023	2024
Direct emissions from stationary combustion	114	108	94	126
Direct emissions from mobile combustion	1	1	1	1
Direct process emissions from industrial process	0	0	0	0
Direct fugitive emissions	4 206	7 840	7 009	10 125
LULUCF emissions and removals	0	0	0	0
Indirect emissions from imported electricity*	1 600	1 159	1 057	938
Indirect emissions from imported energy	0	0	0	0
Indirect emissions from purchase of goods and services	NC	NC	NC	2 892
Indirect emissions from fuel and energy-related activities	NC	NC	NC	416
Indirect emissions from waste generated in operations	NC	NC	NC	1
Indirect emissions from business travel	NC	NC	NC	462
Indirect emissions from employee commuting	NC	NC	NC	184
TOTAL	**5 920**	**9 107**	**8 161**	**15 145**

Note: NC: not calculated.

The analysis reveals an overall increase in emissions compared to previous years, primarily driven by direct fugitive emissions. This category has shown a consistent upward trend over the past four years: from 4 206 tons of CO_2 equivalent in 2021 to 7 820 tons in 2022 (+86%), reaching a peak of 10 25 tons of CO_2 equivalent in 2024 (+44% compared to the previous year). Moreover, regarding Scope 1 emissions, direct emissions from stationary combustion, after a period of relative stability, show an increase, reaching 126 tons. As for indirect emissions, the downward trend in emissions from imported electricity continues, falling below 1 000 tons.

The expansion of the analysis boundaries to include Scope 3 indirect emissions highlights how certain categories are significantly more relevant than others in LNS. In particular, the category of purchases of goods and services stands out, contributing nearly 2 900 tons of CO_2e on its own (57% of the total footprint). Following this, emissions arising from energy-related activities, business travel and employee commuting are also noteworthy.

Figure 24. Trend of emission categories of LNS [ton CO2e].

• CNAF

The carbon footprint of CNAF is consistently aligned with the nature of its activities, being strongly focused on indirect emissions associated with electricity consumption and, starting in 2024, also emissions along the value chain. Specifically, emissions from imported electricity (Scope 2) show a declining trend over time: after reaching a peak of 2 539 tons of CO_2 equivalent in 2022, they progressively decrease to 1 611 tons in 2024.

Table 24. GHG emission of CNAF [ton CO2e].

	2021	2022	2023	2024
Direct emissions from stationary combustion	25	3	6	1
Direct emissions from mobile combustion	1	1	1	1
Direct process emissions from industrial process	0	0	0	0
Direct fugitive emissions	2 508	0	0	0
LULUCF emissions and removals	0	0	0	0
Indirect emissions from imported electricity*	2 126	2 539	2 209	1 611
Indirect emissions from imported energy	0	0	0	0
Indirect emissions from purchase of goods and services	NC	NC	NC	4 357
Indirect emissions from fuel and energy-related activities	NC	NC	NC	662
Indirect emissions from waste generated in operations	NC	NC	NC	0
Indirect emissions from business travel	NC	NC	NC	70
Indirect emissions from employee commuting	NC	NC	NC	58
TOTAL	**4 661**	**2 543**	**2 217**	**6 761**

Note: NC: not calculated.

With the expansion of the analysis scope, the most significant category in 2024 is represented by the purchase of goods and services, which generates 4 357 tons of CO_2 equivalent. Following this, with a smaller but still notable contribution, are emissions related to indirect energy activities, employee commuting, and business travel.

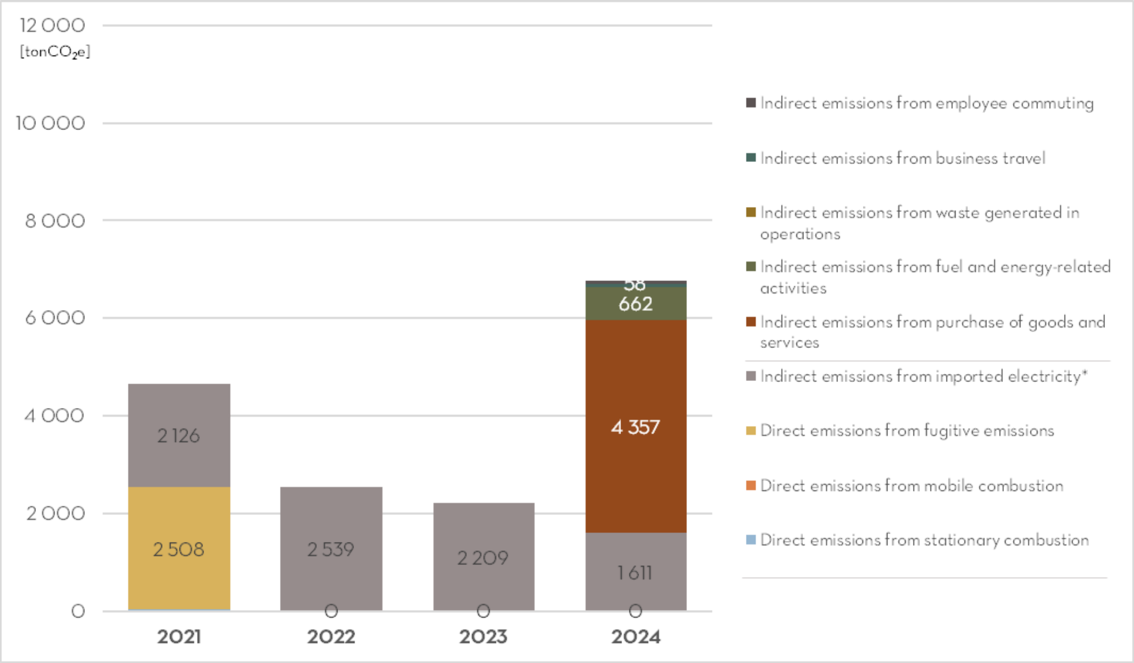

Figure 25. Trend of emission categories of CNAF [ton CO$_2$e].

4.3. INTERPRETATION

4.3.1. Uncertainty assessment

In order to enhance the accuracy and transparency of greenhouse gas (GHG) emissions and removals quantification, an uncertainty assessment was conducted.

This analysis was performed in accordance with the principles established by the GHG Protocol and ISO 14064-1, employing a qualitative approach that assigns numerical scores. Given that, in most cases, the uncertainties associated with individual parameters are not known, the Pedigree Matrix approach was adopted. This method is based on five key data quality indicators: precision, completeness, temporal representativeness, geographical representativeness, and technological representativeness. Each indicator was assigned an uncertainty factor, categorized into four qualitative levels (very good, good, fair, poor), which were then used to calculate the square of the geometric standard deviation.

The result of the uncertainty analysis of the overall carbon footprint, expressed as a 95% confidence interval, using the square of the geometric standard deviation, is presented in the figure below. The column represents the carbon footprint value for the year 2024, while the associated uncertainty is shown by the error bar. The combination of these values produces a range for the carbon footprint between 42 162 and 55 246 tons of CO2e (Δ ≅ ± 14%).

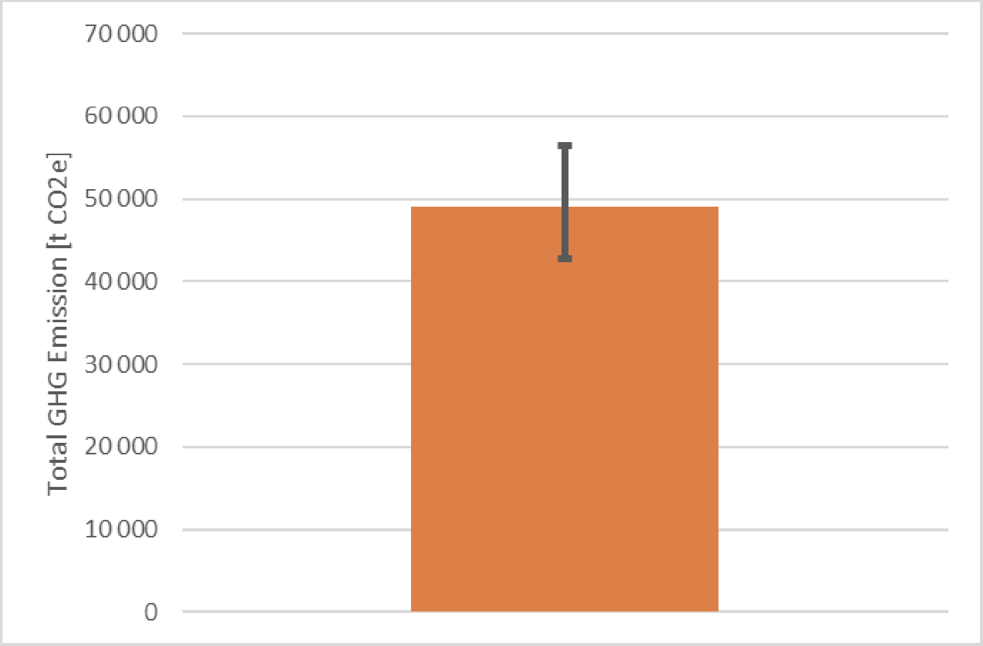

Figure 26. Carbon footprint and uncertainty analysis of INFN (2024) [ton CO$_2$e].

Figure 27. SPES (Selective Production of Exotic Species) project at the LNL.

5. WATER USE

The indicator measures the total volume of freshwater directly consumed by the facilities for various activities, such as cooling, laboratory processes, and domestic use.

5.1. METHODOLOGY

Water consumption was monitored by evaluating the total volume used, as well as the sources of supply. In contrast, the environmental impact of wastewater discharges was assessed by monitoring wastewater management practices. In detail:

- **Total annual water consumption:** measured in cubic meters, this indicator provides a direct measure of the amount of water used by the facilities over a specific period, allowing for the assessment of any changes in consumption over time. Water consumption refers to the portion of water withdrawn from a source that is not returned to the same drainage basin (ISO 14046).
- **Sources of supply:** this indicator analyses the proportion of water used that comes from renewable or sustainably managed sources, such as collected rainwater or greywater recycling systems, or from local sources, such as wells or municipal water systems.
- **Total annual water discharge:** this indicator provides a direct measure of the amount of water released into the environment or wastewater treatment systems.
- **Wastewater quality:** assessed through the treatments that wastewater undergoes before being discharged into the receiving body. This indicator helps evaluate the environmental impact of water discharge and compliance with environmental regulations. The treatments are divided into the following categories: no treatment; public sewer and internal wastewater treatment which removes and eliminates contaminants.

Data were obtained from corporate accounting records and dedicated meters, which measure the specific consumption of various utilities. CNAF is not included since it has no water consumption. In comparison to the previous version of the report, water consumption data from LNS have been included, leading to a recalculation of the INFN's total consumption for prior years. This adjustment ensures consistency and uniformity of the data across the entire period under review

5.2. RESULTS

In 2024, INFN's water consumption increased by approximately 8% compared to the previous year, reinforcing the growth trend already observed in prior years. Total water volumes extracted rose from 133 390 cubic meters in 2022 to 150 103 cubic meters in 2024, indicating a steady upward trajectory (Table 25).

At the same time, a notable shift in the composition of water sources is evident: water supplied by the public network, which accounted for 80% of total consumption in 2022, increased to 91% in 2024, further solidifying its dominance. In contrast, the share of water sourced from wells or groundwater declined both in absolute terms and as a percentage, decreasing from 27 101 cubic meters (20%) to 13 735 cubic meters (9%).

Table 25. Water consumption [mc].

	2021		2022		2023		2024	
From the water supply	97 211*	98%	106 289	80%	120 738	87%	136 368	91%
From groundwater or well**	2 047*	2%	27 101	20%	18 400	13%	13 735	9%
TOTAL	**99 258***		**133 390**		**139 138**		**150 103**	

Note: * Data does not include the water consumption of LNS; ** Data does not include LNGS cooling groundwater (see the paragraph for details).

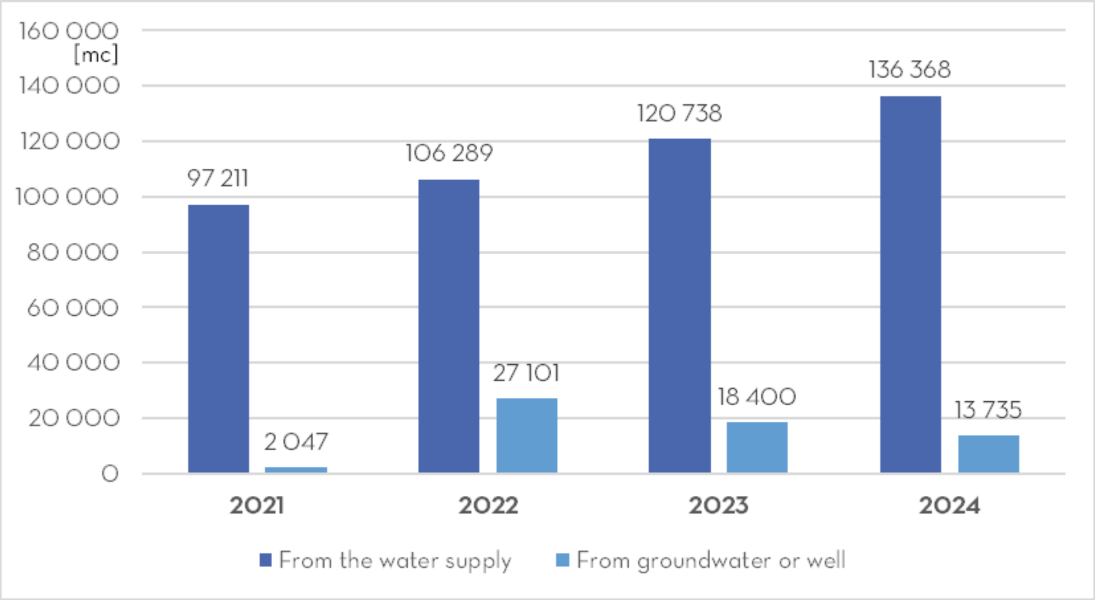

*Figure 28. Total amount of water consumed** [mc].*

IMPROVEMENT TARGET

As part of a comprehensive strategy focused on process optimization and environmental protection, with the objective of harmonizing advanced scientific research with a strong sense of responsibility toward the surrounding environment, the INFN is committed to reducing its water consumption from water supply to the levels recorded in 2022 by 2027. This goal will result in an estimated 22% reduction in current consumption, making a significant contribution to the sustainability of its operations. The planned actions include a detailed and thorough assessment of existing water networks, aimed at identifying and swiftly addressing any leaks.

Regarding wastewater management, in 2024, the total volume of wastewater reached 140 612 cubic meters, reflecting a 33% increase compared to 2022. The portion discharged into the local wastewater treatment systems (Public sewer) continues to represent the predominant share, accounting for 94.97% of the total, although this marks a slight decrease from the 97.91% recorded in 2022. The fraction of untreated wastewater, while remaining marginal, fluctuates between 0.55% and 0.81%, with a value of 0.6% in 2024.

Table 26. Wastewater management [mc].

	2021		2022		2023		2024	
No treatment	0*	0%	855	1%	683	1%	841	1%
Public sewer	97 211*	98%	103 366	95%	118 451	95%	133 534	95%
Internal wastewater treatment**	2 047*	2%	5 134	4%	5 005	4%	6 237	4%
TOTAL	**99 258***		**109 355**		**124 139**		**140 612**	

Note: * Data does not include the wastewater management of LNS; ** Data does not include underground LNGS wastewater (see the paragraph for details).

5.2.1. Insights by site

• LNF

Between 2022 and 2024, the upward trend in water consumption by the LNF was confirmed, continuing the pattern already observed during the 2021-2023 period (Table 27). In 2022, water usage amounted to 86 947 cubic metres, rising to 96 338 cubic metres in 2023—an increase of 10.8% compared to the previous year. The trend further intensified in 2024, with consumption reaching 110 240 cubic metres, representing a 14.4% increase over 2023. This growth is attributable both to higher production levels and to a leak in the water supply system that was initially difficult to identify. The source of the leak was located in 2024, and corrective measures will be implemented as soon as possible.

Table 27. Water consumption by LNF [mc].

	2021		2022		2023		2024	
From the water supply	79 892	100%	86 947	100%	96 338	100%	110 240	100%
From groundwater or well	0	0%	0	0%	0	0%	0	0%
TOTAL	**79 892**		**86 947**		**96 338**		**110 240**	

Regarding wastewater management, LNF discharges all wastewater to the local wastewater treatment system (public sewer), which processes it through various processes before releasing it back into receiving bodies of water.

Table 28. Wastewater management by LNF [mc].

	2021		2022		2023		2024	
No treatment	0	0%	0	0%	0	0%	0	0%
Public sewer	79 892	100%	86 947	100%	96 338	100%	110 240	100%
Internal wastewater treatment	0	0%	0	0%	0	0%	0	0%
TOTAL	**79 892**		**86 947**		**96 338**		**110 240**	

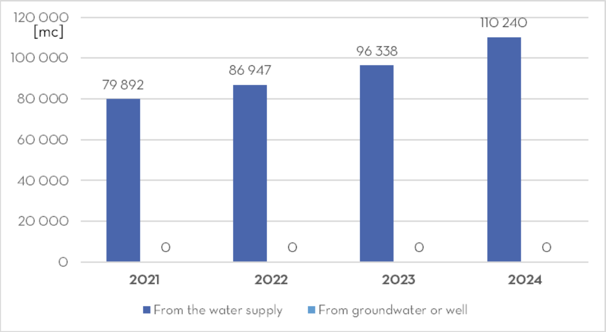

Figure 29. Water consumption by LNF [mc].

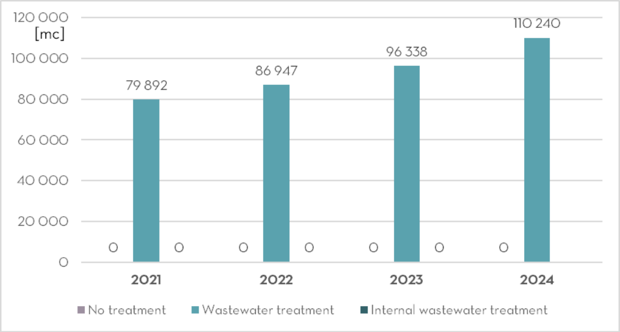

Figure 30. Wastewater management by LNF [mc].

• LNGS

The period from 2022 to 2024 reflects an uneven trend in water consumption, both in terms of quantity and the composition of sources used. The total volume of water extracted increased from 8 534 cubic meters in 2022 to 12 883 cubic meters in 2023, reaching 12 927 cubic meters in 2024. The most significant rise occurred between 2022 and 2023, with an increase of over 50%, while consumption levels in 2024 remained largely stable. At the same time, a gradual shift in the distribution of sources is evident: although water from the public supply remained predominant, its share decreased from 94% in 2022 to 91% in 2024, while the use of well or groundwater rose from 6% to 9% over the same period. The Table 29 provides the data for the considered years.

Table 29. Water consumption by LNGS [mc].

	2021		2022		2023		2024	
From the water supply	6 371	92%	8 010	94%	12 279	95%	11 794	91%
From groundwater or well**	528	8%	524	6%	604	5%	1 133	9%
TOTAL	**6 899**		**8 534**		**12 883**		**12 927**	

Note: ** Data does not include LNGS cooling water used by LNGS.

It should be noted that the water consumption from groundwater or well is a small portion of the water that comes from the collection of rock water (approximately 100 liters per second) that percolates through the walls and therefore does not have the appropriate characteristics to be considered potable. The collection does not result in an increase in the extraction from the aquifer but solely utilizes the flow of water that, due to the excavations for the construction of the tunnel, would have been destined for removal, treatment, and discharge into a suitable receiving water body. A part of this water (approximately 40 liters per second) is used within the laboratories for cooling experimental equipment, taking advantage of its naturally low temperature (approximately 6 °C), making them more energy efficient.

Table 30. Cooling water used by LNGS [mc].

	2021	2022	2023	2024
From groundwater or well	1 260 912	1 260 916	1 260 836	1 260 307

The management of wastewater reflects the water consumption. The water drawn from groundwater or well (in the internal laboratories), after use, is purified in a biological treatment plant with activated sludge and forced oxidation and then discharged into the receiving water body. Conversely, the water drawn from the water supply (in the external laboratories) is disposed of through the local wastewater treatment. All the water in the underground laboratories (100 l/s) is treated in an external treatment plant before being released into a river.

Table 31. Wastewater management by LNGS [mc].

	2021		2022		2023		2024	
No treatment	0	0%	0	0%	0	0%	0	0%
Public sewer	6 371	92%	8 010	94%	12 279	95%	11 794	91%
Internal wastewater treatment**	528	8%	524	6%	604	5%	1 133	9%
TOTAL	**6 899**		**8 534**		**12 883**		**12 927**	

Note: ** Data does not include LNGS cooling water used by LNGS.

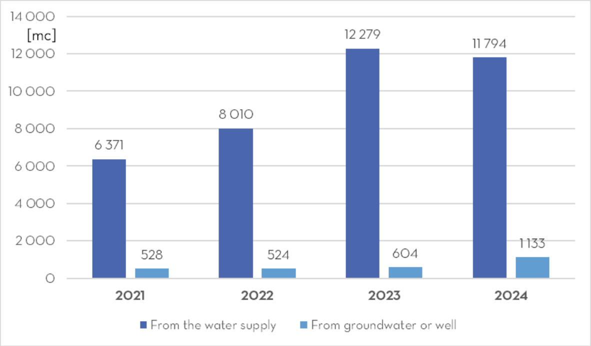

*Figure 31. Water consumption by LNGS** [mc].*

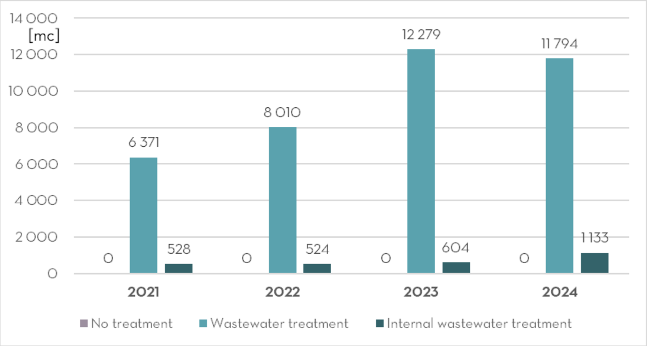

*Figure 32. Wastewater management by LNGS** [mc].*

- **LNL**

The analysis of water consumption during the specified period highlights a steady increase in the total volume of water used, rising from 10 096 cubic meters in 2022 to 13 770 cubic meters in 2024. This growth is evenly distributed across the years, suggesting a progressive trend. The breakdown of water sources shows a clear dominance of water from the public supply, which constituted 83% in 2022, 82% in 2023, and 84% in 2024. While these percentages remained largely stable, a slight decrease in the use of well or groundwater is noticeable, with its share dropping from 17% in 2022 to 16% in 2024, after peaking at 18% in 2023.

Table 32. Water consumption by LNL [mc].

	2021		2022		2023		2024	
From the water supply	10 948	88%	8 409	83%	9 834	82%	11 500	84%
From groundwater or well	1 519	12%	1 687	17%	2 114	18%	2 270	16%
TOTAL	**12 467**		**10 096**		**11 948**		**13 770**	

Wastewater management is strictly dependent on the type of water source. Wastewater from water supply is discharged through the local wastewater treatment (public sewer) while wastewater from wells is treated internally through a wastewater treatment system before discharge to the receiving body.

Table 33. Wastewater management by LNL [mc].

	2021		2022		2023		2024	
No treatment	0	0%	0	0%	0	0%	0	0%
Public sewer	10 948	88%	8 409	83%	9 834	82%	11 500	84%
Internal wastewater treatment	1 519	12%	1 687	17%	2 114	18%	2 270	16%
TOTAL	**12 467**		**10 096**		**11 948**		**13 770**	

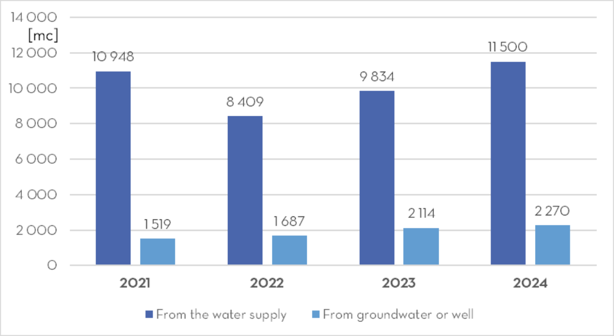

Figure 33. Water consumption by LNL [mc].

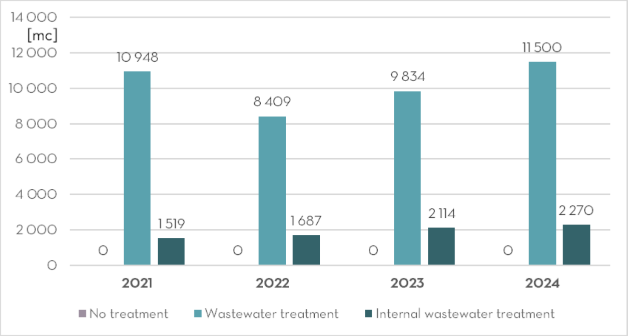

Figure 34. Wastewater management by LNL [mc].

- **LNS**

In the LNS, a significant reduction in overall water consumption is observed, with total usage declining from 27 813 cubic meters in 2022 to 13 166 cubic meters in 2024 —a decrease of over 50% within the three-year period (see Table 34). These results are the outcome of optimization measures implemented by the laboratory in recent years to reduce water consumption, such as the installation of a chiller and the conversion from an open to a closed system, which has enabled a significant reduction in water use.

This notable decline affects both sources of supply, albeit to varying degrees. Water extracted from wells or groundwater, which accounted for 89% of the total in 2022, has gradually decreased both in absolute terms and as a percentage, reaching 78% by 2024. Conversely, water supplied by the public network, while experiencing an initial drop in 2023, began to rise again in 2024, both in volume and as a percentage, increasing from 11% in 2022 to 22% in 2024.

Table 34. Water consumption by LNS [mc].

	2021		2022		2023		2024	
From the water supply	NA	-	2 923	11%	2 287	13%	2 834	22%
From groundwater or well	NA	-	24 890	89%	15 682	87%	10 332	78%
TOTAL	**NA**		**27 813**		**17 969**		**13 166**	

Note: NA: not available.

With regard to wastewater management, a more in-depth analysis has revealed that the majority of effluent is conveyed to the treatment plant operated by the University of Catania, where it undergoes processing. A small portion of the wastewater is instead managed through an Imhoff tank, which is subject to regular monitoring to ensure proper operation and to prevent potential issues. As for well water, it is primarily used to replenish evaporative cooling towers, with an average evaporation rate of approximately 70%. The remaining portion, which does not evaporate, is discharged together with stormwater.

Table 35. Wastewater management by LNS [mc].

	2021		2022		2023		2024	
No treatment	NA	-	0	0%	0	0%	0	0%
Public sewer	NA	-	855	23%	683	23%	841	23%
Internal wastewater treatment	NA		2 923	77%	2 287	77%	2 834	77%
TOTAL	**NA**	-	**3 778**		**2 970**		**3 675**	

Note: NA: not available.

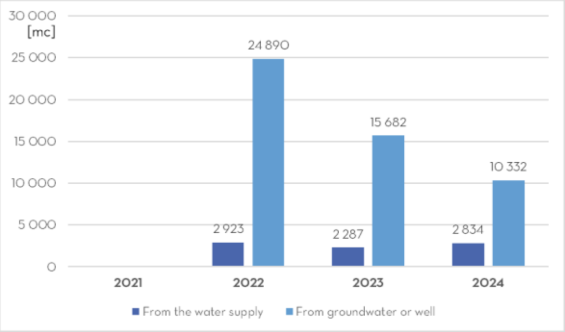

Figure 35. Water consumption by LNS [mc].

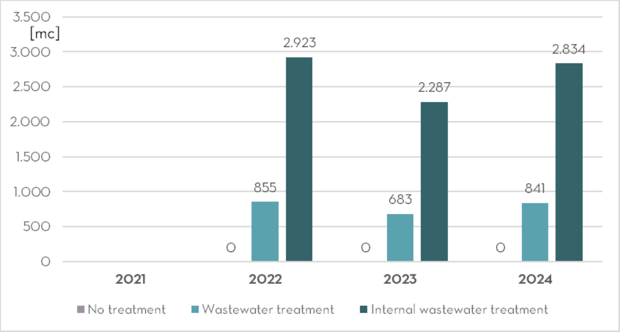

Figure 36. Wastewater management by LNS [mc].

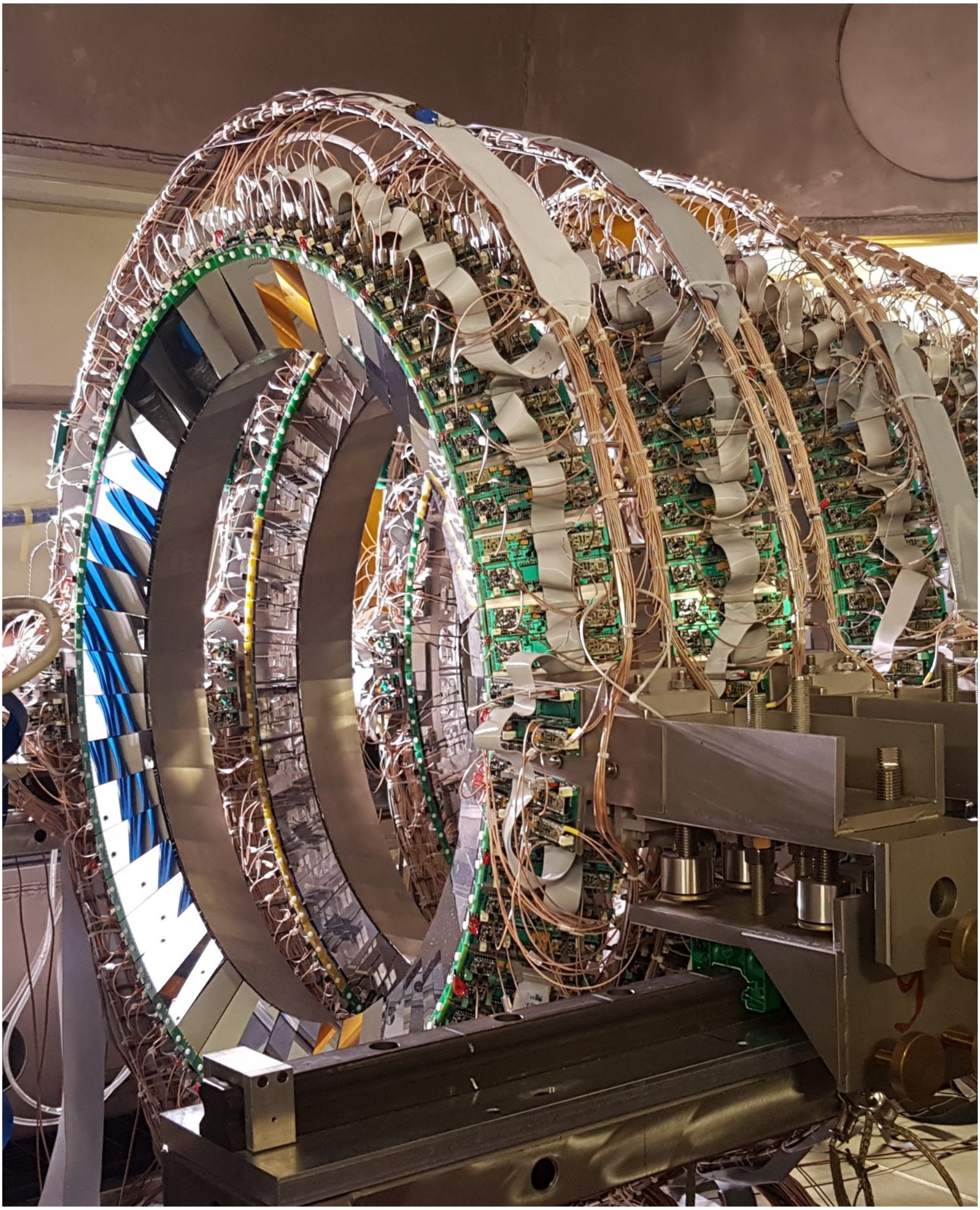

Figure 37. CHIFAR experiment at the LNS.

6. WASTE MANAGEMENT

The KPI focuses on the management of waste generated within the research laboratories and the National Center in Bologna, analyzing both the types of waste produced and the methods implemented for its disposal and recycling.

6.1. METHODOLOGY

To evaluate the effectiveness of environmental policies and monitor progress toward sustainability within the laboratories and the national center, specific indicators have been identified to assess both waste production and its management practices.

Regarding waste generation, two principal indicators have been established:

- **Non-Hazardous Waste**: the total annual volume (measured in tons) of non-hazardous waste produced within the facilities.
- **Hazardous Waste**: the total annual tonnage of hazardous waste generated.

For waste management, two additional key indicators have been defined:

- **Waste Recovery:** This indicator evaluates both the total quantity of waste recovered and the percentage of waste recovered relative to the total waste generated, highlighting the efficiency of recycling and reuse practices. Waste is collected and delivered to specialized companies that manage its recovery through certified processes.
- **Waste Disposal:** This indicator tracks the proportion of waste sent for disposal—such as landfilling, incineration, or other authorized methods—relative to the total waste produced. Disposal activities are carried out by licensed contractors in accordance with applicable regulations.

The data collection has been based on the annual declaration that organizations must submit to provide detailed information on the waste produced and managed. The waste register data includes the quantity of waste produced, specified by type (hazardous and non-hazardous), waste management methods (recovery, recycling, reuse, and disposal in landfills, incineration, etc.), and the origin of the waste (industrial, domestic, etc.). For the analysis, waste characterized by code R was included in the recovery indicator, while code D was associated with disposal.

6.2. RESULTS

The analysis of waste production data for the period 2021-2024 reveals a highly variable trend, with a significant peak in 2023 followed by a marked reduction in 2024 (Figure 38).

In 2024, the total waste production amounted to 546 237 kg, representing a significant decrease compared to previous years. This value marks a return to levels similar to those of 2021, after two years—2022 and 2023—characterized by exceptionally high volumes due to the decommissioning operations of the Borexino experiment at LNGS.

Table 36. Waste production [kg].

	2021*		2022*		2023*		2024	
Non-hazardous waste	694 789	79%	926 420	44%	3 423 869	98%	453 578	83%
Hazardous waste	179 277	21%	1 194 912	56%	56 407	2%	92 659	17%
TOTAL	**874 066**		**2 121 332**		**3 480 276**		**546 237**	

* Updated data following a revision of the data collection procedures at the LNS.

The waste composition in 2024 shows a predominance of non-hazardous waste, accounting for 83% of the total, while hazardous waste constitutes the remaining 17% (Figure 33). Although the quantity of hazardous waste is relatively low in relation to the total, it remains higher than the amount recorded in 2023, when only 56 407 kg of hazardous waste were produced.

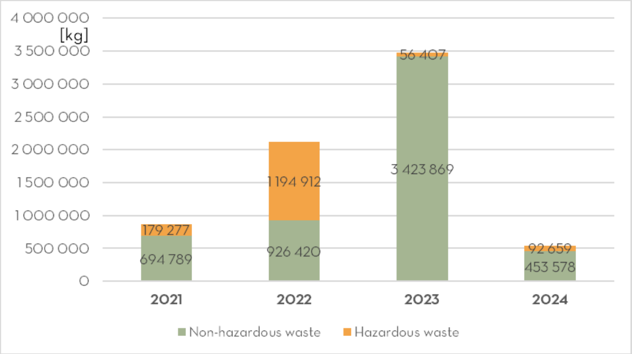

Figure 38. Total amount of waste generated [kg].

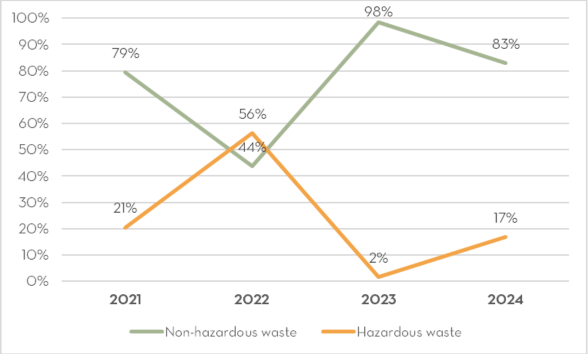

Figure 39. Percentage of waste produced to total.

Table 37 shows the annual quantities of waste sent to end-of-life treatment. In 2024, waste management reflects a more restrained profile compared to previous years, with a significantly lower total production and a distribution between recycling and disposal that, although not optimal, approaches the levels observed in 2021.

Specifically, 71% of the waste was sent for disposal (equivalent to 387 169 kg), while 29% was sent for recycling (159 068 kg). Although these figures indicate a predominance of disposal, they represent an improvement compared to 2023, an exceptional year when recycling was nearly negligible (3%) and 97% of the waste was disposed of. When compared to 2021, it is evident that both years show contained volumes and a similar distribution between the two management methods, albeit with differences in absolute values.

Table 37. Waste management (end-of-waste) [kg]

	2021*		2022*		2023*		2024	
Recycling	258 569	30%	1 378 095	65%	116 183	3%	159 068	29%
Disposal	615 547	70%	743 477	35%	3 364 092	97%	387 169	71%
TOTAL	**874 116**		**2 121 572**		**3 480 275**		**546 237**	

***** Updated data following a revision of the data collection procedures at the LNS.

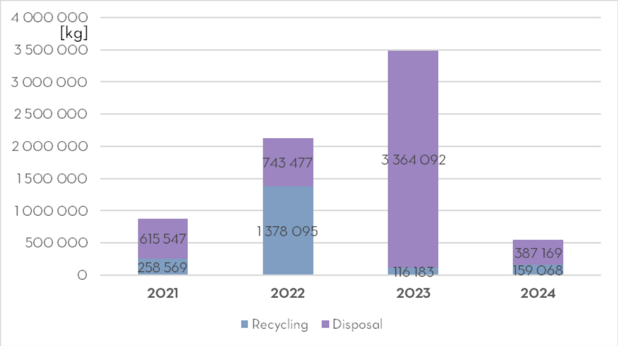

Figure 40. Total amount of waste treated [kg].

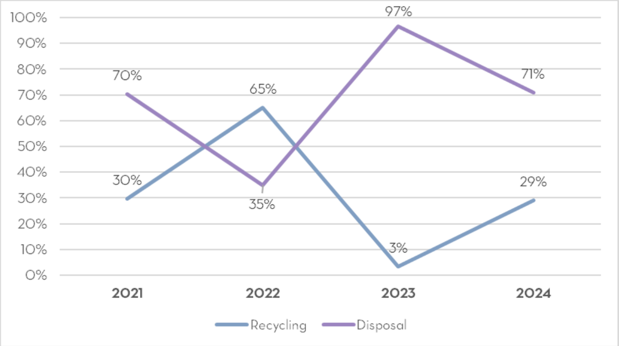

Figure 41. Percentage of waste treated to total.

6.2.1. Insights by site

- **LNF**

At the LNF, the waste production trend shows a substantial improvement in the last year, both in quantitative and qualitative terms. In 2024, a significant reduction in total waste production is recorded, with a total of 39 605 kg, marking a sharp decline compared to previous years.

A particularly noteworthy figure is the continuous decrease in non-hazardous waste, which in 2024 amounts to 38 090 kg, representing approximately 96% of the total. Hazardous waste also shows a notable reduction, with only 1 515 kg produced, accounting for 4% of the total. This result is especially significant when compared to 2023, when the production of hazardous waste reached its highest value during the period, at 4 880 kg.

Table 38. Waste production by LNF [kg].

	2021		2022		2023		2024	
Non-hazardous waste	48 290	96%	44 000	93%	44 056	90%	38 090	96%
Hazardous waste	1 985	4%	3 305	7%	4 880	10%	1 515	4%
TOTAL	**50 275**		**47 305**		**48 936**		**39 605**	

Table 39. Waste management (end-of-waste) by LNF [kg].

	2021		2022		2023		2024	
Recycling	49 245	98%	44 440	93%	48 226	99%	39 415	99%
Disposal	1 080	2%	3 105	7%	710	1%	190	1%
TOTAL	**50 325**		**47 545**		**48 936**		**39 605**	

Regarding waste management, the overall trend observed over the four-year period is stable, with a clear predominance of waste sent for recycling compared to that intended for landfill disposal. Specifically, the amount of recycled waste remains high, fluctuating between approximately 44 000 and 49 000 kg annually, confirming the laboratory's ongoing commitment to sustainable management practices. In contrast, the share of non-recyclable waste sent for disposal is notably low, with a peak of 3 105 kg in 2022, followed by a significant reduction in the subsequent years. In 2024, the waste sent to landfill amounts to only 190 kg, representing less than 1% of the total waste produced.

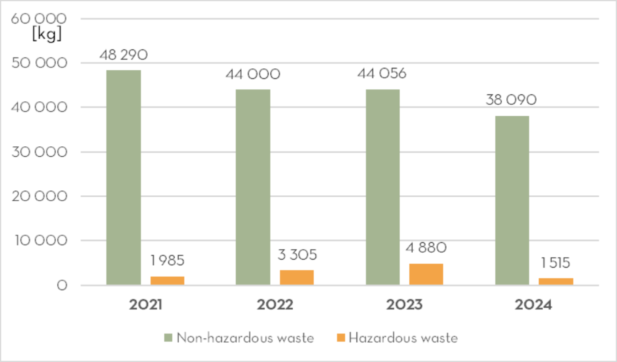

Figure 42. Total amount of waste generated by LNF [kg].

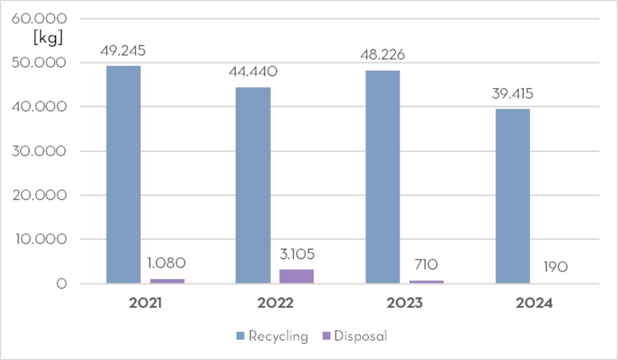

Figure 43. Total amount of waste treated by LNF [kg].

• LNGS

In 2024, the total waste production at the LNGS reached 348 578 kg, marking a return to normal levels after two years characterized by significant fluctuations. This value is largely aligned with that recorded in 2021, which was 523 097 kg, and reflects a substantial reduction compared to the extraordinary peak in 2023, when total waste production exceeded 3.2 million kg. This increase was primarily due to the completion of the decommissioning operations of the Borexino experiment, which involved managing exceptionally high volumes of waste. Regarding the type of waste, in 2024, non-hazardous waste amounted to 307 084 kg, representing the largest share of the total waste produced (Table 40).

The 2024 data can be seen as a year of normalization in waste production, where volumes have returned to reflect the standard and regular activities of the laboratory, after two years marked by extraordinary operations and significant interventions. Additionally, there was an overall reduction of 33% in the total volume of waste produced compared to the 2021.

Table 40. Waste production by LNGS [kg].

	2021		2022		2023		2024	
Non-hazardous waste	424 145	81%	607 696	35%	3 237 842	100%	307 084	88%
Hazardous waste	98 952	19%	1 143 614	65%	14 899	0%	41 494	12%
TOTAL	**523 097**		**1 751 310**		**3 252 741**		**348 578**	

From a management perspective, most of the waste is sent to landfills, while 29% is destinated for recycling (Table 41).

Table 41. Waste management (end-of-waste) by LNGS [kg].

	2021		2022		2023		2024	
Recycling	136 125	26%	1 170 016	67%	39 226	1%	100 994	29%
Disposal	386 972	74%	581 294	33%	3 213 514	99%	247 584	71%
TOTAL	**523 097**		**1 751 310**		**3 252 740**		**348 578**	

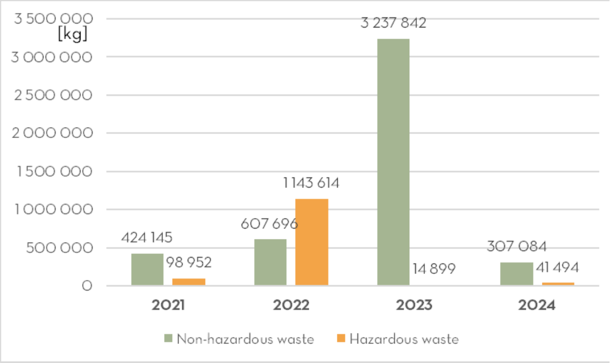

Figure 44. Total amount of waste generated by LNGS [kg].

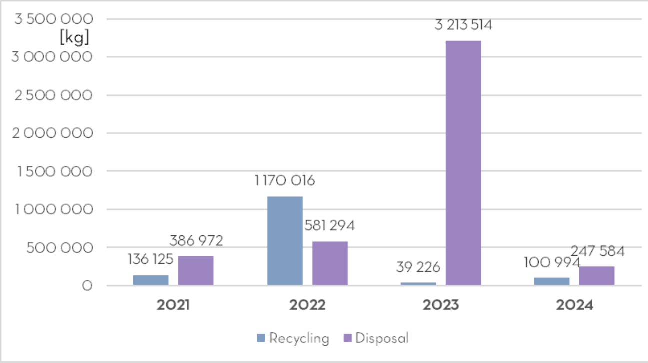

Figure 45. Total amount of waste treated by LNGS [kg].

• LNL

The total waste production at LNL reached 153 594 kg in 2024, confirming the downward trend already observed in the previous year (Table 42). Specifically, after the significant peak in 2022, the total waste volume experienced a considerable decrease in 2023, with a reduction of 42.6%, followed by a further decline of 13.5% in 2024 compared to the previous year. Regarding the type of waste, non-hazardous waste continued the negative trend that began in 2023, registering a 26% reduction compared to the previous year, totalling 104 334 kg.

On the other hand, hazardous waste showed an inversion of the trend, with an increase of 34.49% compared to 2023. This rise brought the total volume of hazardous waste to 49 260 kg, thus interrupting the gradual decrease observed since 2021.

Table 42. Waste production by LNL [kg].

	2021		2022		2023		2024	
Non-hazardous waste	199 334	72%	261 654	85%	140 991	79%	104 334	68%
Hazardous waste	78 000	28%	47 618	15%	36 628	21%	49 260	32%
TOTAL	**277 334**		**309 272**		**177 619**		**153 594**	

Analyzing waste management (Table 43), disposal continues to be the predominant waste management method, with a total of 138 855 kg of waste directed to this destination. Although this figure represents a slight decrease compared to the previous year (-7.3%), its percentage share of total waste produced has increased significantly due to the sharp decline in the volume allocated to recycling (a 47% reduction compared to the previous year).

Table 43. Waste management (end-of-waste) by LNL [kg].

	2021		2022		2023		2024	
Recycling	49 859	18%	150 194	49%	27 751	16%	14 739	10%
Disposal	227 475	82%	159 078	51%	149 868	84%	138 855	90%
TOTAL	**277 334**		**309 272**		**177 619**		**153 594**	

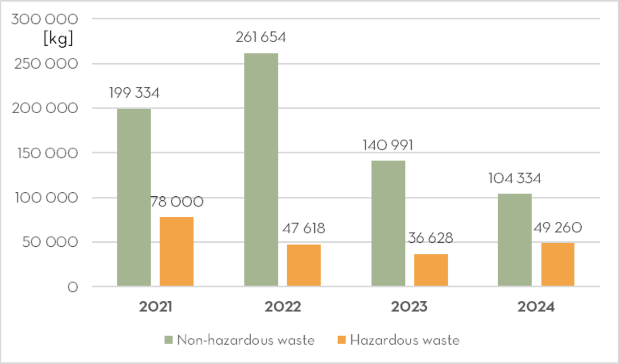

Figure 46. Total amount of waste generated by LNL [kg].

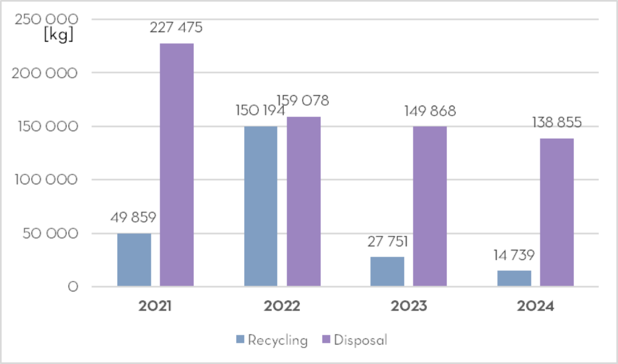

Figure 47. Total amount of waste treated by LNL [kg].

- **LNS**

In 2024, LNS recorded a total waste production of 1 340 kg, comprising 1 020 kg of non-hazardous waste and 320 kg of hazardous waste. This marks a slight recovery compared to the previous year, during which the total waste produced was 980 kg, with no hazardous waste generated (Table 44).

A review of the data over the past four years reveals a consistent downward trend in waste production, with a particularly notable reduction between 2021 and 2023. This decline followed the decommissioning of the cyclotron, which had led to the generation of 21 490 kg of waste in 2021. Subsequently, waste production levels returned to normal operational levels.

It should be noted that the data presented in Table 44 and Table 45 have been updated in comparison to the previous report, following a revision of the waste collection and classification procedures which affected earlier years. This revision has resulted in a more accurate representation of waste flows, thereby enhancing the consistency and reliability of the historical analysis.

Table 44. Waste production by LNS [kg].

	2021		2022		2023		2024	
Non-hazardous waste	21 150	98%	5 670	94%	980	100%	1 020	76%
Hazardous waste	340	2%	375	6%	0	0%	320	24%
TOTAL	**21 490**		**6 045**		**980**		**1 340**	

Table 45. Waste management (end-of-waste) by LNS [kg].

	2021		2022		2023		2024	
Recycling	21 470	100%	6 045	100%	980	100%	800	60%
Disposal	20	0%	0	0%	0	0%	540	40%
TOTAL	**21 490**		**6 045**		**980**		**1 340**	

With regard to end-of-life waste treatment, in 2024 the waste generated at the LNS was managed primarily through recovery and recycling processes, which accounted for approximately 60% of the total. The remaining portion was handled through disposal operations. This represents a slight shift in waste management practices compared to previous years, during which nearly all waste produced was directed towards recovery and recycling (Table 45).

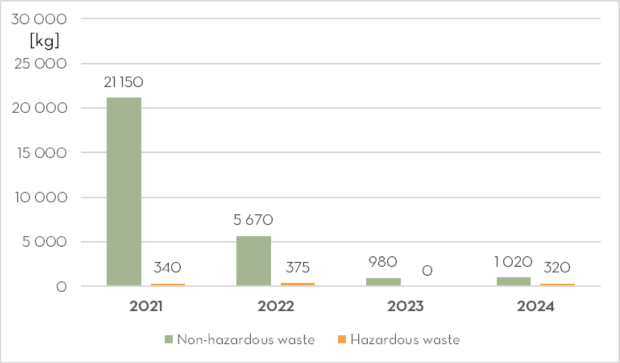

Figure 48. Total amount of waste generated by LNS [kg].

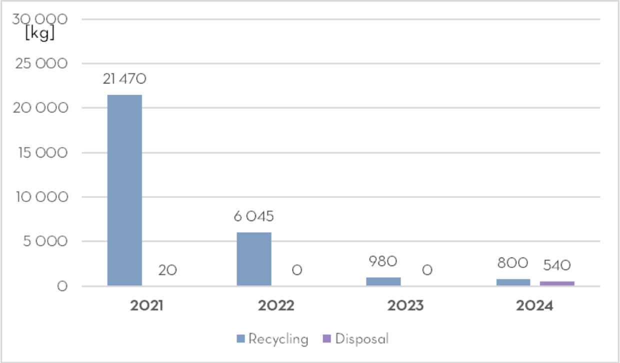

Figure 49. Total amount of waste treated by LNS [kg].

• **CNAF**

Table 46 presents the waste quantities recorded by the CNAF in recent years. In 2024, the total waste production amounted to 3 120 kg, a decrease compared to 7 400 kg in 2022. This represents a 57.8% reduction compared to the previous year monitored, marking a return to more contained levels, although still higher than the 1 870 kg recorded in 2021. The main component consists of non-hazardous waste, totalling 3 050 kg, showing a reduction of 58.8% compared to 2022.

Table 46. Waste production by CNAF [kg].

	2021		2022		2023		2024	
Non-hazardous waste	1 870	100%	7 400	100%	0	0%	3 050	98%
Hazardous waste	0	0%	0	0%	0	0%	70	2%
TOTAL	**1 870**		**7 400**		**0**		**3 120**	

The Table 47 reveals that all waste produced was delivered to specialized centres for raw material recovery and recycling, and no waste was sent for disposal.

Table 47. Waste management (end-of-waste) by CNAF [kg].

	2021		2022		2023		2024	
Recycling	1 870	100%	7 400	100%	0	0%	3 120	100%
Disposal	0	0%	0	0%	0	0%	0	0%
TOTAL	**1 870**		**7 400**		**0**		**3 120**	

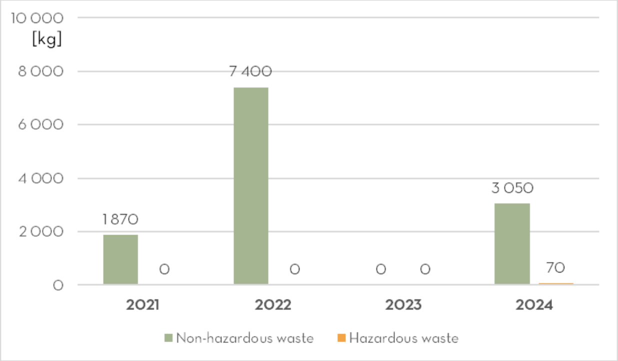

Figure 50. Total amount of waste generated by CNAF [kg].

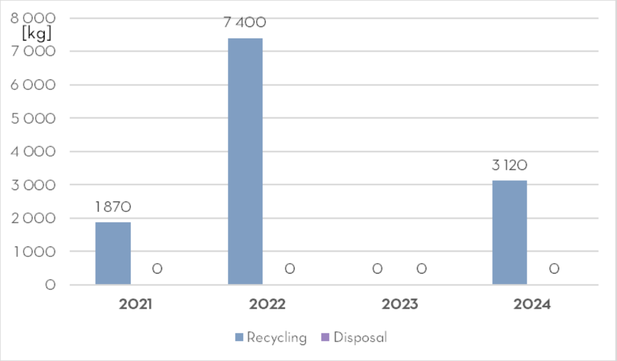

Figure 51. Total amount of waste treated by CNAF [kg].

Figure 52. Tier1 computing centre at CNAF.

7. IONISING RADIATION

The indicator assesses the environmental impact of ionizing radiation emissions, taking into account the nature of the institute's scientific activities and the public interest, particularly among residents living near the laboratories.

7.1. METHODOLOGY

For the evaluation of environmental impacts related to ionizing radiation emissions, data obtained from the periodic monitoring of laboratories for radioprotection risk assessment were used. Annually, the laboratories undergo dose measurements, expressed in mSv, detected by dosimeters placed along the perimeter. Data are available only for laboratories where particle accelerator-based research was conducted, specifically LNF and LNL. No evaluations of ionizing radiation were carried out at the other sites because it is not applicable at LNGS, the particle accelerators at LNS are not operational, and there are no particle accelerators at CNAF

The evaluation of the emissions involved analysing the difference between the measured value and the exposure from natural background radiation. The natural background radiation consists of terrestrial radiation (produced by primordial nuclides or cosmogenic nuclides in radioactive decay) and cosmic radiation (extraterrestrial). A fundamental component of terrestrial radiation is Radon (Rn-222), a naturally occurring radioactive gas produced during the radioactive decay chain of Uranium-238. It disperses everywhere, and its concentration varies from place to place.

7.2. RESULTS

Table 57 reports the ionizing radiation emissions recorded at INFN laboratories between 2021 and 2024. The data analysis reveals an overall stable and well-controlled situation, with emissions remaining extremely low and well below regulatory and safety thresholds.

Table 48. Ionising radiation.

	UM	2021	2022	2023	2024
LNF	mSv	0.03	0.00	0.07	0.05
LNGS	mSv	-	-	-	-
LNL	mSv	0.00	0.00	0.00	0.00
LNS	mSv	-	-	-	-
CNAF	mSv	-	-	-	-

At LNF, the only INFN site among those analysed to report non-zero values, a modest variation in ionizing radiation emissions was observed over the four-year period. The dose recorded was null in 2022, rose to a peak of 0.07 mSv in 2023, and then decreased to 0.05 mSv in 2024. These fluctuations are consistent with the intensification of experimental activities and the increased operation of the particle accelerator during 2023. Despite this increase, the measured values remain significantly below the average annual dose from natural background radiation in Italy, which is approximately 3.5 mSv. Furthermore, the estimated annual exposure for individuals residing near the laboratories or visiting the site is estimated to be less than 0.01 mSv per year (it is about 330 times less than the natural background radiation in Italy and 1000 times less than a dose by an abdominal CT).

At LNL, radiation levels remained consistently at zero throughout the entire period under review. Monitoring was carried out using eight perimeter detectors, with the data aggregated over a ten-year statistical baseline. The absence of detectable emissions confirms the effectiveness of the containment strategies and radiological safety measures implemented at the site.

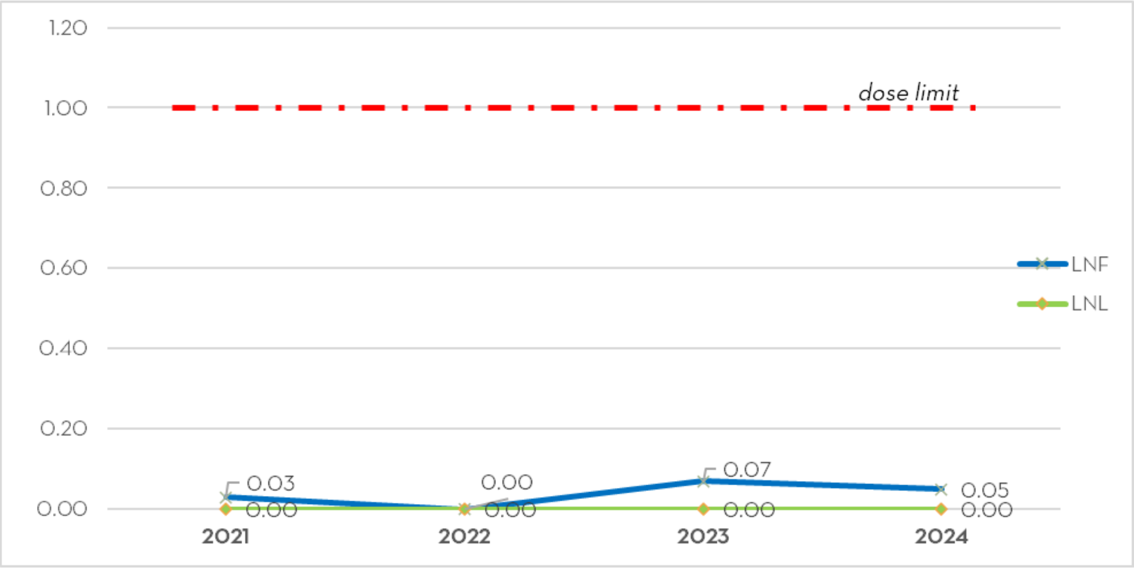

Figure 53. Emissions of ionising radiation [mSv].

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APPENDIX

This appendix presents the environmental inventory data used to calculate the organization's energy consumption and carbon footprint. The information provided forms the quantitative foundation of the analyses carried out in the report and includes key energy inputs, sources of direct and indirect greenhouse gas emissions, as well as data related to water usage and waste generation.

A. ENERGY DATA INVENTORY

The following data were collected for the evaluation of energy consumption, categorized by type and usage. The data were extracted from the analysis of monthly energy bills, meters installed in the laboratories, and the organization's management systems.

Fuel

Table 49 and Table 50 respectively present the consumption of methane and diesel in fixed equipment within the analysed INFN facilities.

Table 49. Methane consumption.

Fuel	UM	2021	2022	2023	2024
LNF	smc	85 883	40 635	38 329	41 871
LNGS	smc	199 482	207 685	237 578	211 849
LNL	smc	334 709	264 606	213 999	227 380
LNS	smc	56 670	53 517	46 076	62 313
CNAF	smc	0	0	0	0
TOTAL	smc	**676 744**	**566 443**	**535 982**	**543 413**

Table 50. Diesel oil consumption.

Fuel	UM	2021	2022	2023	2024
LNF	lt	0	0	0	0
LNGS	lt	0	0	0	0
LNL	lt	0	564	1 430	2 045
LNS	lt	500	500	500	0
CNAF	lt	9 545	1 210	2.437	450
TOTAL	lt	**10 045**	**2 274**	**4 367**	**2 495**

Table 51 shows the fuel consumption of owned vehicles with an indication of the anti-pollution class and the type of fuel used.

Table 51. Fuel consumption for laboratories-owned cars.

Lab	Type	EURO	Fuel	UM	2021	2022	2023	2024
LNF	FIAT TIPO	6	Diesel oil	lt	560	430	525	826
	FIAT DUCATO	6	Diesel oil	lt	507	994	1 046	955
	FIAT ULISSE	6	Diesel oil	lt	-	-	-	381
	OPEL MERIVA	6	LPG	lt	921	929	-	-
			Gasoline	lt	323	326	-	-

	KIA SPORTAGE	6	Diesel oil	lt	617	787	100	-
	JEEP COMPASS	6	Gasoline / Electric	lt	-	-	1 848	2 200
LNGS	FIAT PANDA	6	Gasoline	lt	700	700	700	583
	FIAT PANDA	6	Gasoline	lt	700	700	700	583
	FIAT PANDA	6	Gasoline	lt	700	700	700	584
LNL	PSA BOXER	4	Diesel oil	lt	609	438	221	88
	FIAT FIORINO	6D	Diesel oil	lt	300	392	359	233
	FIAT 500L	6D	Diesel oil	lt	67	442	463	335
	OPEL COMBO	6D	Diesel oil	lt	-	-	50	710
LNS	FURGONE	6D	Diesel oil	lt	359	359	359	359*
CNAF	FIAT DUCATO	6D	Diesel oil	lt	-	-	143	509
	FORD TRANSIT	6	Diesel oil	lt	-	-	184	-
	PSA BOXER	6	Diesel oil	lt	372	778	-	-

* Estimated data (in the absence of available data, consumption is assumed to be consistent with previous years).

Electricity

Below are tables of electricity consumption in the analysed INFN facilities.

Table 52. Electricity consumption of LNF.

Electricity	UM	2021	2022	2023	2024
High voltage electricity	kWh	21 742 976	15 238 950	20 857 711	18 452 296
Medium voltage electricity	kWh	0	0	0	0
Low voltage electricity	kWh	0	0	0	0
Renewable electricity	kWh	0	0	0	0
TOTAL	kWh	**21 742 976**	**15 238 950**	**20 857 711**	**18 452 296**

Table 53. Electricity consumption of LNGS.

Electricity	UM	2021	2022	2023	2024
High voltage electricity	kWh	0	0	0	0
Medium voltage electricity	kWh	9 647 969	9 409 311	9 710 585	9 312 448
Low voltage electricity	kWh	0	0	326	128
Renewable electricity	kWh	0	0	0	0
TOTAL	kWh	**9 647 969**	**9 409 311**	**9 710 911**	**9 312 576**

Table 54. Electricity consumption of LNL.

Electricity	UM	2021	2022	2023	2024
High voltage electricity	kWh	10 041 315	13 681 611	16 553 430	16 747 236
Medium voltage electricity	kWh	381 276	5 097	125 331	67 714
Low voltage electricity	kWh	0	0	0	0
Renewable electricity	kWh	0	0	0	0
TOTAL	kWh	**10 422 591**	**13 686 708**	**16 678 761**	**16.814.950**

Table 55. Electricity consumption of LNS.

Electricity	UM	2021	2022	2023	2024
High voltage electricity	kWh	0	0	0	0
Medium voltage electricity	kWh	5 679 211	3 617 761	3 851 501	4 153 090
Low voltage electricity	kWh	32 625	36 531	74 924	98 590
Renewable electricity	kWh	0	0	0	0
TOTAL	kWh	**5 711 836**	**3 654 292**	**3 926 425**	**4 251 680**

Table 56. Electricity consumption of CNAF.

Electricity	UM	2021	2022	2023	2024
High voltage electricity	kWh	0	0	0	0
Medium voltage electricity	kWh	7 593 555	8 012 994	8 219 869	7 132 271
Low voltage electricity	kWh	0	0	0	0
Renewable electricity	kWh	0	0	0	0
TOTAL	kWh	**7 593 555**	**8 012 994**	**8 219 869**	**7 132 271**

B. GHG EMISSION DATA INVENTORY

Below are the activity data, which characterize the operations that generate greenhouse gas emissions, used for the carbon footprint analysis.

Scope 1 – Direct GHG emissions

Regarding direct emissions from stationary sources, the activity data pertains to the annual consumption of methane and diesel oil for heating and laboratory activities. For the data, refer to Table 49 and Table 50. Regarding direct emissions from mobile sources, the activity data has been extracted from the fuel consumption of the different vehicles that are under the control of the different laboratories. For the data, refer to Table 51. Table 57 shows the distances driven by owned cars.

Table 57. Distance travelled by owned cars.

Lab	Type	EURO	Fuel	UM	2021	2022	2023	2024
LNF	FIAT TIPO	6	Diesel oil	km	8 125	6 237	7 624	11 982
	FIAT DUCATO	6	Diesel oil	km	5 330	10 440	10 989	10 032
	FIAT ULISSE		Diesel oil	km	-	-	-	4 772
	OPEL MERIVA	6	LPG	km	11 105	11 205	-	-
			Gasoline	km			-	-
	KIA SPORTAGE	6	Diesel oil	km	8 846	17 488	1 386	-
	JEEP COMPASS	6	Gasoline / Electric	km	-	-	26 015	30 970
LNGS	FIAT PANDA	6	Gasoline	km	10 000	10 000	10 000	8 333
	FIAT PANDA	6	Gasoline	km	10 000	10 000	10 000	8 333
	FIAT PANDA	6	Gasoline	km	10 000	10 000	10 000	8 334
LNL	PSA BOXER	4	Diesel oil	km	6 091	4 384	2 206	884
	FIAT FIORINO	6D	Diesel oil	km	5 003	6 530	5 977	3 879
	FIAT 500L	6D	Diesel oil	km	1 119	7 369	7 722	5 579
	OPEL COMBO	6D	Diesel oil	km	-	-	762	10 929
LNS*	FURGONE	6D	Diesel oil	km	3 589	3 589	3 589	3 589*
CNAF	FIAT DUCATO	6D	Diesel oil	km	-	-	1 429	5 091
	FORD TRANSIT	6	Diesel oil	km	-	-	2 039	-
	PSA BOXER	6	Diesel oil	km	3 716	7 775	-	-

***** Estimated data (in the absence of available data, consumption is assumed to be consistent with previous years).

Finally, the data related to fugitive emissions have been derived from both the annual gas purchases for experiments and the maintenance and refilling operations of refrigerant gas within the cooling systems. Below is a detailed breakdown of the activity data for each laboratory.

Table 58. Activity data related to the LNF's fugitive emissions

System	Gas	UM	2021	2022	2023	2024
Firefighting system	R-227ea	kg	0.00	0.00	0.00	0.00
CDZ _ DAφNE RC	R407	kg	83.00	0.00	0.00	0.00
Chiller Emicon	R407	kg	6.00	0.00	0.00	0.00
Cooling systems _a	R410a	kg	0.00	0.00	0.00	6.2
Cooling systems _b	R32	kg	0.00	0.00	0.00	2.8
Cooling systems _c	R407c	kg	0.00	0.00	0.00	16.6
Gas mixtures used for experiments						
Exp. CYGNO	CF_4	kg	38.00	38.00	38.00	0.00
Exp. CMS	CF_4	kg	7.00	7.00	7.00	0.00

Lab. DDG ed.8	CF_4	kg	13.50	13.50	13.50	0.00
Lab. DDG ed.8	$C_2H_2F_4$	kg	33.00	33.00	33.00	0.00
Exp. CMS	SF_6	kg	13.00	13.00	13.00	0.00

Table 59. Activity data related to the LNGS's fugitive emissions

System	Gas	UM	2021	2022	2023	2024
EMERSON LIEBERT	R-407C	kg	12.00	0.00	0.00	0.00
HIROSS	R-448A	kg	18.00	0.00	0.00	0.00
MCQUAY	R-448A	kg	15.00	0.00	0.00	0.00
RC GROUP	R-407C	kg	13.00	0.00	0.00	0.00
CLIVET	R-407C	kg	10.40	0.00	0.00	0.00
Gas mixtures used for experiments						
-	SF_6	kg	0.00	0.00	0.00	0.00
-	CF_4	kg	0.00	0.00	0.00	0.00

Table 60. Activity data related to the LNL's fugitive emissions

System	Gas	UM	2021	2022	2023	2024
Cooling systems _a	R134a	kg	0.00	35.00	0.00	62.00
Cooling systems _b	R407c	kg	3.00	3.00	4.00	0.00
Cooling systems _c	R410a	kg	31.00	12.00	0.00	0.00
Gas mixtures used for experiments						
Electrostatic particle accelerator restoration	SF_6	kg	520.00	2 080.00	2 360.00	442.00
Tetrafluoromethane	CF_4	lt	0.00	40.00	0.00	40.00
Hydrostar (gas mixture)	95% Ar + 3% CF_4 + 2% C_4H_{10}	lt	200.00	400.00	0.00	0.00
Gas mixture	90% Ar + 10% C_4H_{10}	lt	0.00	0.00	80.00	0.00
Gas mixture	95% Ar + 5% C_4H_{10}	lt	0.00	160.00	0.00	0.00
Carbon dioxide-nitrogen mixture (for CN and AN2000)	70% N2 + 30% CO_2	lt	1 000.00	1 280.00	0.00	640.00
Gas mixture	90% Ar + 10% CO_2	lt	14.00	0.00	0.00	0.00
Carbon dioxide	CO_2	lt	0.00	56.00	28.00	40.00
Methane	CH_4	lt	0.00	20.00	0.00	40.00

Table 61. Activity data related to the LNS's fugitive emissions

System	Gas	UM	2021	2022	2023	2024
Firefighting system	IG-541 (40% Ar + 52% N + 8% CO_2)	kg	0.00	0.00	0.00	0.00
DAIKIN- Capacity tot kg 110	R-134a	kg	0.00	0.00	0.00	0.00
DAIKIN- Capacity tot kg 38	R-134a	kg	0.00	0.00	0.00	0.00
DAIKIN- Capacity tot kg 38	R-134a	kg	0.00	0.00	0.00	0.00
DAIKIN- Capacity tot kg 110	R-134a	kg	0.00	0.00	0.00	0.00
DAIKIN- Capacity tot kg 110	R-134a	kg	0.00	0.00	0.00	0.00
DAIKIN- Capacity tot kg 110	R-134a	kg	0.00	0.00	0.00	0.00
CLINT- Capacity tot kg 19	R-410A	kg	0.00	0.00	0.00	0.00
DAIKIN- Capacity tot kg 312	R-134a	kg	0.00	0.00	0.00	0.00
DAIKIN- Capacity tot kg 312	R-134a	kg	0.00	0.00	0.00	0.00

YORK- Capacity tot kg 11,4	R-407C	kg	0.00	11.40	0.00	0.00
CLIMAVENETA- Capacity tot kg 13.2	R-410A	kg	0.00	13.20	0.00	0.00
CLINT- Capacity tot kg 19	R-425B	kg	0.00	0.00	0.00	0.00
CLIMAVENETA- Capacity tot kg 74	R-410A	kg	0.00	0.00	0.00	0.00
RHOSS- Capacity tot kg 48	R-410A	kg	0.00	0.00	0.00	0.00
Gas mixtures used for experiments						
Electrostatic particle accelerator restoration	SF_6	mc	27.0	50.0	45.0	65.0
Lab. Numen	Isobutane	kg	11.00	11.00	11.00	11.00
Lab. Radiobiologia	CO2	kg	120.00	120.00	120.00	120.00

Table 62. Activity data related to the CNAF's fugitive emissions

System	Capacity	Gas	UM	2021	2022	2023	2024
CDZ Uffici - FUJITSU	14	R410a	kg	0.00	0.00	0.00	0.00
CDZ Stanza 45 -EMERSON HPSE06	7,7	R407c	kg	0.00	0.00	0.00	0.00
CDZ sala trafo -LIEBERT M470A	60	R407c	kg	0.00	0.00	0.00	0.00
Chiller - EMERSON SRH032	432	R407c	kg	0.00	0.00	0.00	0.00
Firefighting system	1393,6	R-227ea	kg	696.80	0.00	0.00	0.00

Scope 2 – Electricity indirect GHG emissions

The activity data related to indirect emissions from imported energy refer to the electricity consumption in the facilities. The consumption data were extracted from management systems and corporate accounts and are based on the quantities billed by the supplier. For the data refer to Table 52 and following.

Scope 3 – Indirect GHG emissions

The following are the activity data related to the different emission categories considered in the estimation of indirect emissions.

The estimation of indirect emissions arising from the purchase of goods and services was carried out using the spend-based approach, which is based on the analysis of budget data related to the annual expenditures incurred by the organization. Although this methodology has some inherent limitations and varying levels of uncertainty, it provides an indicative assessment of the emissions associated with this category, while also offering a useful basis for identifying areas with higher environmental impact. The activity data used for quantifying emissions in this category are presented in the Table 63.

Table 63. Activity data related to the purchase of goods and services (2024).

	UM	LNF	LNGS	LNL	LNS	CNAF
Catering Service	€	474 795	166 136	244 532	0	0
Security Service	€	615 352	1 239 550	337 990	353 310	1 516
Cleaning Service	€	677 478	255 750	570 165	263 108	11 309
Green Area Maintenance	€	84 842	22 152	31 639	55 281	0
Building Maintenance	€	972 419	175 247	958 439	268 881	4 453
Plant/System Maintenance	€	143 054	1 500 127	0	0	0
Equipment Maintenance	€	494 505	259 187	554 279	491 653	786 762

Purchase of Consumables	€	251 405	24 821	74 683	961 451	0
Purchase of Scientific Equipment	€	2 615 802	2 047 099	1 564 603	5 017 129	9 272 501
Capital expenditure for facility systems	€	4 870 530	3 682 057	1 609 456	511 441	0

Regarding the category of indirect emissions associated with the extraction of fuels and energy production, reference was made to the data presented in the tables of Appendix A. These data serve as the foundation for estimating emissions arising from upstream processes in the energy supply chain. Similarly, the activity data used for quantifying emissions related to waste management were extracted in the tables of paragraph 6.2.

Table 64. Activity data related to the purchase of business travel (2024).

	UM	LNF	LNGS	LNL	LNS	CNAF
Hotel Stays	n° night	8 684	2 488	2 489	3 551	830
Air Travel	€	362 754	99 177	114 840	255 563	29 755
Train Travel	€	112 620	26 240	36 156	9 867	24 058
Bus Travel	€	5 433	7 139	7 765	5 520	751
Ship Travel	€	6 759	1 646	529	7 534	2 149
Taxi Travel	€	30 948	2 289	10 191	13 456	1 164
Car Travel (Rental)	€	13 289	17 212	4 716	17 024	104
Car Travel (Private Vehicle)	km	220 004	92 100	88 453	123 755	7 814

With respect to emissions from business travel, only the trips made by employees directly paid by INFN were considered, i.e., those for which the Institute exercises direct control and operational supervision. The same approach was applied for estimating emissions from commuting, limiting the analysis to the employed staff. Emissions attributed to visitors, whose access to laboratories occurs intermittently and for varying durations, were excluded, as their quantification in a reliable and consistent manner is complex.

Table 65. Activity data related to the purchase of employee commuting (2024).

	UM	LNF	LNGS	LNL	LNS	CNAF
Bicycle Travel	10^3 km	398	81	149	54	138
Electric Car Travel	10^3 km	111	0	0	0	0
Hybrid Car Travel	10^3 km	111	0	20	67	0
Average Car Travel	10^3 km	3 547	818	1 071	688	168
Motorcycle Travel	10^3 km	259	0	30	81	6
Bus Travel	10^3 km	462	157	59	27	60
Train Travel	10^3 km	462	0	59	0	150
Intermodal Travel	10^3 km	5 349	65	41	65	0
Remote working	hour	117 936	21 341	12 730	28 829	20 592

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