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March 2026

Assessment of the socio-economic benefits of CERN activities

Main Report

Technopolis and CSIL

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1 Introduction to the study

1.1 CERN

The European Organization for Nuclear Research (**CERN**) is an international organisation that operates the world's largest physics laboratory, located on the Franco-Swiss border. CERN's core mission is basic research in particle physics, a branch of physics that investigates the fundamental constituents of matter (smallest detectable particles) such as quarks and leptons; and the fundamental interactions necessary to explain their behaviour.

CERN is home to the Large Hadron Collider (LHC): with its 27km circumference, it is the world's largest and most powerful particle accelerator. Beyond the LHC, the CERN complex boasts a unique range of particle accelerator facilities that enable research at the forefront of human knowledge, covering a broad range of subjects – ranging from nuclear to high-energy physics, and from studies of antimatter to the possible effects of cosmic rays on clouds.

CERN's research activities also unite people from all over the world to push the frontiers of science and technology. The Organization's mission also includes training new generations of experts, including physicists, engineers and technicians, and engaging citizens in research and in the value of science.

CERN is committed, through its Convention, to identifying and making available opportunities for the dissemination and societal use of its results. The notion of "results" has, over time, come to include not only scientific findings, but also the know-how and technologies developed by CERN in the construction of the accelerator, detector and computing infrastructure required for its research.

1.2 This Report

The report presents a comprehensive summary of the principal findings from a study examining the socio-economic benefits of CERN's activities over the past two decades. It integrates and synthesises a wide range of materials developed during the course of the study, including:

- A rapid assessment of existing literature relating to the impact assessment of large research infrastructures (including CERN), to identify conceptual approaches and methodologies, as well as results and evidence, that could inform and support the study.
- Seven detailed workstream papers, each addressing a distinct area of benefit. These papers offer in-depth methodological insights, literature reviews, expanded descriptions of CERN's operations, elaborated findings, and recommendations for future studies.
- Nine case studies, illustrating the benefits of CERN through, for example, the broader application of CERN technologies.

This report consolidates this extensive body of evidence, with particular emphasis on the most significant socio-economic benefits identified.

1.3 Study Objectives and Scope

The study objectives were to produce a coherent picture of CERN's socio-economic benefits, and provide guidance for future / follow-up tracking and evaluation activities.

The key features and added value of the study are that it:

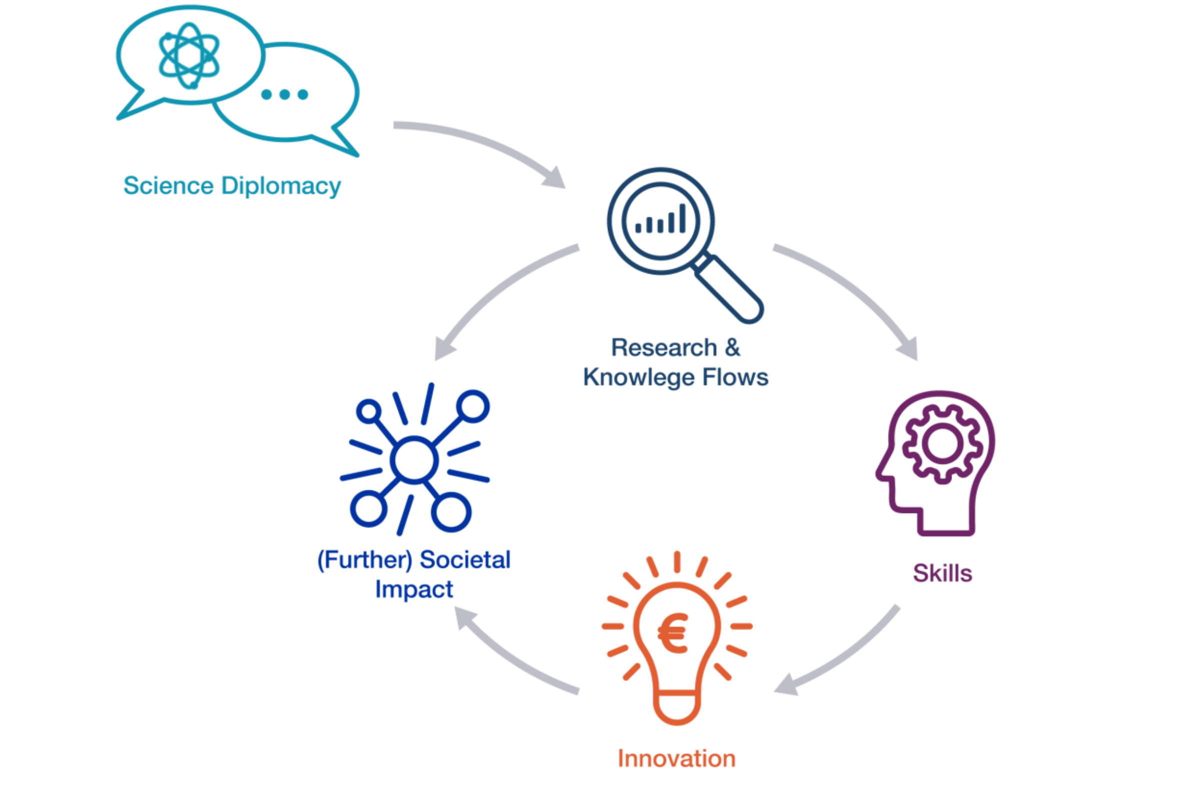
- Looks at **CERN 'as a whole' (all activities)** and beyond just specific projects, programmes, or experiments, considering it is a research infrastructure serving as a hub for various forms of engagement with the wider science and innovation community.
- **Covers the past ~20-30 years, when possible** (based on available data), complementing past and ongoing studies relating to the Future Circular Collider that are largely forward-looking.
- Looks at **CERN's socio-economic benefits in a holistic way** by capturing evidence on different pathways and focusing on the most compelling evidence.

- **Capitalises on the existing literature and evidence**, and brings together different data sources in one place, including evidence collected through CERN's own dispersed monitoring efforts and exercises (e.g. surveys).
- **Provides exercises and analysis that are a first of their kind,** e.g. examining knowledge production and the flows of knowledge within and beyond academia, or examining the effects on suppliers and innovation, using innovative methodological approaches.
- **Combines historical data and statistics**, with a wider narrative and deep dive case studies to exemplify benefits.
- **Presents relevant quantitative indicators** (including monetised estimates) where possible.
- Provides a **strong basis for further study**, and includes learnings and recommendations for future exercises.

1.4 Conceptual Framework

The study is structured around a **comprehensive conceptual framework that identifies five principal areas in which CERN generates socio-economic benefits** (Figure 1). These areas are interconnected, with outcomes often emerging in non-linear and sometimes unforeseen ways. For example, CERN's research activities not only advance knowledge and skills but also promote technological development and innovation, frequently through an extensive collaborative network that brings additional resources and expertise. Similarly, fulfilling CERN's research infrastructure requirements can stimulate further technological progress and innovation. The resulting advancements and associated competencies may subsequently find applications beyond CERN itself. Once disseminated, these initial impacts can lead to broader societal benefits by driving knowledge and innovation across diverse sectors, including the environment, public health, and economic activity. Consequently, such benefits may require several years to fully materialise and typically result from collaborative efforts, even when their origin is attributable to CERN.

Figure 1 Conceptual Framework



2 Research and Knowledge Flows

2.1 Pathways to Benefits

The core mission of CERN is to perform "world-class research in fundamental physics", with a particular focus on both theoretical and experimental aspects of high-energy physics. Its research activities are diversified and fit into an internationalised web of scientific collaborations. As such, CERN research is a major channel to create worldwide benefits beyond high-energy physics.

Excluding considerations of scientific quality or excellence, four interrelated pathways can be identified by which research activities produce socio-economic benefits:

- **Production of scientific and technical outputs**: CERN's research activities (undertaken at / and / or by CERN) produce new knowledge, which is disseminated through various scientific outputs such as publications, conference proceedings, and datasets. This work is referenced, utilised and further developed by the wider community, thereby advancing the understanding of pertinent research questions and facilitating both incremental progress and significant breakthroughs within particle physics and related disciplines.
- **Facilitating the development of scientific networks and communities:** CERN's research initiatives involve thousands of researchers globally, fostering a unique and dynamic environment for scientific collaboration.
- **Providing curated data resources:** CERN facilities, experiments, and collaborations offer external researchers access to distinctive, high-quality datasets, complete with detailed documentation and metadata to support independent research.
- **Advancing new research methodologies:** Leveraging its substantial critical mass, CERN plays a pivotal role in shaping research practices and the dissemination of scientific results.

These different benefit pathways are interrelated and thus influence each other. For instance, the provision of curated datasets can serve the production of further publications and citations.

2.2 Approach

Building upon and complementing previous work (see **key literature** in Appendix A), the study provides a comprehensive, long-term perspective of the scientific and technical outputs produced at and by CERN, tracking its use through citations and mapping the collaboration networks it has enabled. At the core is a **bibliometric analysis** on CERN's scientific and technical production from 1989 to 2024, with particular focus on the last 20 years. The analysis examined two levels of publications to capture the different stages of the benefit pathway:

- **P0 Publications**, produced by authors directly affiliated to CERN and/or authors affiliated to other Institutions and who are directly involved in the Organization's research activities.
- **P1 Publications**, that cite at least one P0 publication and thus build (at least partially) on the evidence developed at CERN/by CERN-affiliated authors.

The analysis relied primarily on the CERN Document Server (CDS)[1] with support from the CERN Scientific Information Service and IT teams, as well as a dedicated Steering Committee group. This was complemented with information on citations gathered from LENS[2].

[1] Accessed via API in June–July 2025, complemented by an additional extraction in October 2025.

[2] LENS is a free online database of patents and scholarly literature. It includes more than 272 million scholarly works and 155 million patent records. 30% of CERN P0 Publications were matched through LENS (via DOI) and were used as a subsample to analyse citations.

2.3 Key Findings

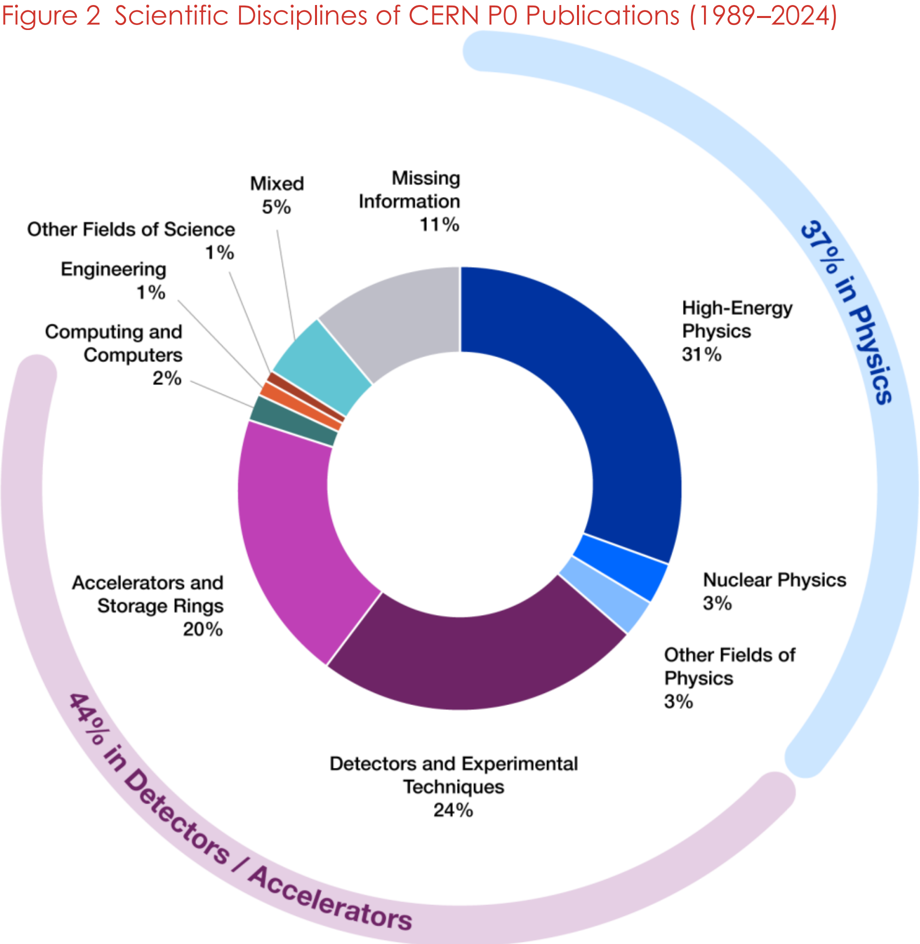
CERN's research activities produce a significant body of scientific and technical outputs, underscoring its contribution to advancement of fundamental knowledge.

From 1989 to 2024, CERN's research activities generated 160,860 scientific and technical outputs (P0 publications), averaging approximately 4,468 per year. These outputs encompass a diverse range of document types — scientific articles, conference papers and proceedings, reports, as well as slides, theses and books — highlighting the extensive scope and impact of CERN's research across various audiences and scientific communities.

CERN's research outputs are closely aligned with structured programmes, with both lifecycle stages and major discoveries influencing their volume and distribution. Publications have been tagged according to the CERN Grey book, the official database of research programmes and activities at CERN. Publications stemming from the Large Hadron Collider (LHC) research programme represent the primary contributor, accounting for 44.7% of total P0 publications. Other major contributors are the research programmes related to the Large Electron-Positron Collider (LEP, 7.6%), Proton Synchrotron (PS, 7.1%), and Super Proton Synchrotron (SPS, 5.1%).

The majority of research done at CERN advances knowledge in multiple areas of physics and related scientific domains such as accelerators and detectors (83% of P0 publications), in line with the Organization's core mission. Computing and computers are the main subject of 2% of publications, followed by Engineering (besides accelerators/detectors) at 1%. There is also meaningful activity in other disciplines, such as social sciences and medicine, albeit representing a smaller proportion of total outputs (0.46% and 0.43% respectively) (Figure 2).

Figure 2 Scientific Disciplines of CERN P0 Publications (1989–2024)

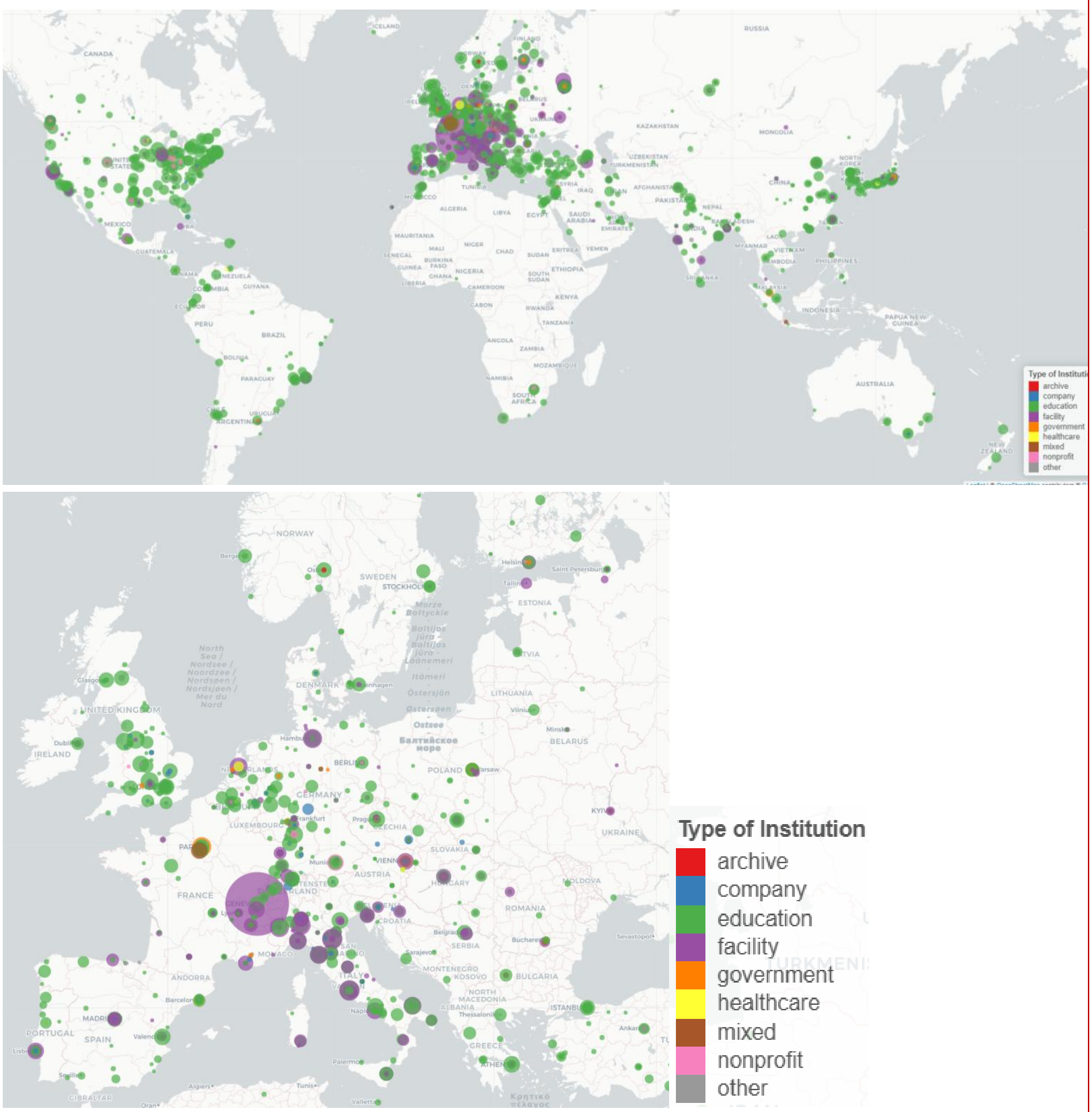


Source: Study team elaboration based on 160,860 records corresponding to CERN P0 publications collected for 1989–2024.

CERN's mission to foster and develop scientific networks serves as a critical driver for achieving impactful outcomes. The Organization's collaborative scope is substantial, encompassing 4,654 unique institutions across 128 countries between 1989 and 2024.

These patterns confirm the important internationalisation of research done at CERN and its key role in the scientific community related to particle physics. CERN collaborates with various key players in this field, including other facilities (e.g., accelerators), universities, and companies. This is clear from the distribution of collaborating institutions shown in Figure 3 below.

Figure 3 Map of key institutions involved in the production of P0 Publications (1989–2024)

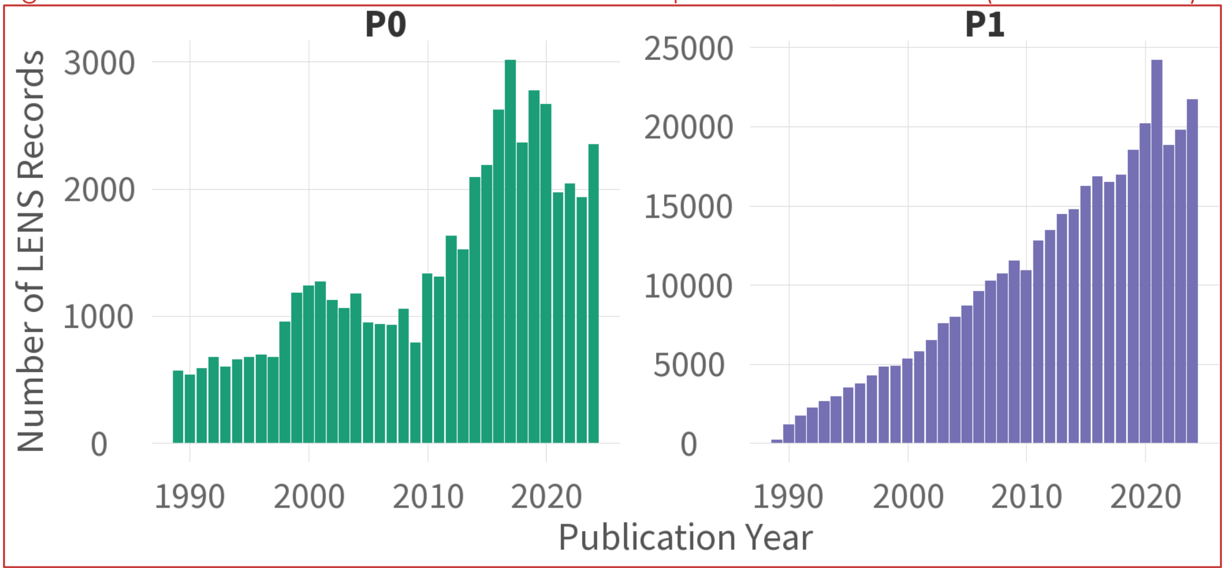


Source: Study team elaboration based on 119,737 CDS records corresponding to CERN P0 Publications with at least one attributable affiliation collected for 1989–2024. Institutions with 10 or more publications shown. The size of circles relates to the number of publications, and the colours to the types of institutions.

Research activities at CERN exert significant impact beyond the immediate scientific community. The majority of scientific and technical outputs (P0 publications) are openly accessible, facilitating researchers worldwide to build upon these findings and further advance scientific knowledge. From 1989 to 2024, CERN P0 journal articles garnered an average of 38.8 citations, notably exceeding the Nuclear and High-Energy Physics field average of 22.4 during the same period (according to LENS data). This consistently high citation rate underscores the substantial scientific influence of CERN's research programmes.

Through its research, CERN continuously contributes to the generation and dissemination of new knowledge by enabling subsequent scientific work. An analysis based on LENS data indicates that 50,194 P0 publications resulted in 372,547 secondary publications (P1) that cited at least one of these primary P0 outputs. This demonstrates CERN's role as a catalyst for further exploration and innovation across multiple disciplines. The annual number of new P1 publications shows a sustained increase over time (see Figure 4), evidencing the lasting and expanding influence of CERN's research, affirming its critical role in fostering global scientific advancement and the diffusion of knowledge.

Figure 4 Number of LENS Records of new P0 and P1 publications, 1989–2024 (not cumulative)



Source: Study team elaboration based on 50,194 CERN P0 publications retrieved from LENS for 1989–2024 and the corresponding 372,547 P1 publications that cite at least one of these P0 publications. Note that scales differ depending on the panel. Columns show the total number of new publications each year.

CERN's research activities also enjoy significant visibility and prestige. Some research in particle physics can indeed only be done at CERN. Its collaborations have contributed directly to at least five Nobel Prizes in Physics, including those awarded to Carlo Rubbia and Simon van der Meer (1984), Georges Charpak (1992), and François Englert and Peter Higgs (2013).

2.4 Case Studies (Research & Knowledge Flow Benefits)

The cases below highlight CERN-developed open-access tools and platforms that can be used by the wider research community and beyond

Zenodo is an open-access research data repository created at CERN through the European OpenAIRE programme. It builds on the Invenio digital library framework (also developed at CERN). It acts as a digital library where anyone around the world can upload and search for research outputs for free. All items uploaded on the platform have a digital object identifier (DOI) which makes them easily searchable, identifiable, and citable by users.

- It supports 300,000+ researchers in 7,500 research organisations across the world. It is recommended by the European Commission for Horizon Europe projects (where open science is mandatory). Zenodo powers the EU Open Research repository, containing 146K records from 13K EU-funded projects.
- Since its inception in 2004, and up to 2021, Zenodo had accumulated over 45 million unique views and over 55 million unique downloads across all records.
- In 2021, Zenodo hosted 1 Petabyte of data, equivalent to 500 billion pages of standard printed text which makes it the world's largest general purpose research repository. A similar platform called Dryad, which is free to access, but "pay to deposit", costs €129 per record with size up to 5GB, ,€155 for a record with size between 5GB and 10GB, and €670 per record with size between 10GB and 50GB.

Indico: an open-source event management and conference platform. It provides free tools for managing and archiving conferences, workshops and meetings, covering the entire lifecycle, from event registration to post-event communication.

- Indico tools are used by 400,000 users through 300 active servers in 52 different countries.
- Up to March 2023, over 1 million events have been organised on the CERN Indico platform.
- A Willingness to Pay (WTP) of €568 per event was estimated in a recent paper[3]. The WTP was calculated using a choice experiment method and a survey-based approach of 2,100 individuals.
- Beyond CERN, there are also now over 100,000 events per year managed via additional deployments of the Indico platform.

[3] Crespo Garrido, Gutleber, Loureiro Garcia in "The economics of Big Science 2.0"

The following cases exemplify the use of CERN facilities to support wider research and innovation

CERN-MEDICIS is a facility that produces high-purity non-conventional radionuclides for biomedical research. These are provided to biomedical labs, hospitals, and, more recently, the pharmaceuticals industry for research activities in medical imaging and therapy. The research programme is driven by the MEDICIS international collaboration.

Key tangible benefits include:

- It has expanded the range of radionuclides available for biomedical research, including through the EU-funded project PRISMAP[4].
- It has contributed to the development of high-efficiency separation techniques, resulting in improvements to purity levels that make them safer, more effective, and more predictable in clinical and research use. These techniques are also relevant for future accelerator-based radionuclides production facilities.
- CERN-MEDICIS radionuclides have been used for pre-clinical studies, demonstrating their future potential use for cancer diagnostic and treatment methods for human patients.

CHARM (High Energy Accelerator Mixed field) is a unique irradiation facility for testing of electronics, systems and detector components in a simulated mixed-radiation environment, replicating conditions in space or in particle accelerators.

It supports both fundamental physics research and industrial R&D projects:

- In the last 10 years, around 300 system-level tests have been carried out at CHARM (172 in 2024 alone).
- First ground irradiation test of a satellite model (CELESTA CubeSat) in a fully representative mixed-field radiation environment took place here. Many other space systems have been tested, from on-board computers to optical cameras and transmission devices.
- As part of the EU-funded project HEARTS[5], CHARM will be a leading facility in Europe for high-penetration testing of space electronics using high-energy heavy ions. In the 2024–25 pilot runs, more than 20 space users (industry & academia) accessed CERN facilities through HEARTS.

CLEAR was built to satisfy demand for test facilities capable of providing high-energy electron beams. It provides a unique environment for particle physics as well as space, healthcare, and other application areas.

The facility is supporting research and applications for the CERN community and beyond:

- CERN & particle physics community. CLEAR is used to conduct beam instrumentation R&D studies; test and refine beam diagnostic tools.
- Space applications. VESPER (Very energetic Electron facility for Space Planetary Exploration missions in harsh Radiative environments), part of CLEAR, has supported space missions, e.g. ESA JUICE mission to Jupiter, by providing a unique radiation environment to test on the ground the effects of extremely energetic electrons on sensitive electronic parts. There is no other facility on Earth capable of reproducing the most extreme phenomena of Jupiter's harsh radiative environment.
- Medical applications. CLEAR offers testing capability for new radiation therapy modalities using Very High Energy Electron (VHEE) beams, e.g. for FLASH radiotherapy.

[4] PRISMAP has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101008571.

[5] The HEARTS project is funded by the European Union under Grant Agreement No. 101082402.

3 Suppliers and Innovation

3.1 Pathways to Benefits

CERN sources goods and services from a diverse global network of suppliers. Its procurement acts as a strategic driver for technological advancement and economic benefit, fostered through close collaboration with high-tech partner firms. As documented in the literature, these effects unfold through four interconnected pathways (see Figure 5).

Figure 5 Benefit pathways relating to suppliers and innovation

Learning and skills growth

Working with CERN pushes suppliers to tackle advanced technologies, helping them learn new skills and improve their overall abilities

Innovation impacts and spillovers

Suppliers often create new products or improve existing ones, and some breakthroughs find uses beyond CERN, boosting broader industry innovation

Market and economic performance enhancement

CERN contracts enhance a supplier's reputation, and, combined with innovation activities, helps them win new clients, enter new markets, and grow

Supply chains and wider ecosystem effects

Impact extends beyond direct suppliers, spreading benefits across local economies and supply chains, contributing to jobs and regional growth

These pathways may operate independently or in succession, illustrating the cumulative progression that develops over time. The initial phase often consists of learning and skill growth, which empowers suppliers to innovate and then improve their economic performance.

3.2 Approach

This pathway was explored using the following approach:

- **A literature review** to acknowledge existing studies and findings and identify evidence gaps (see summary of key literature in Appendix A).
- **Descriptive statistics** of all orders (incl. supplies and services) placed by CERN between 1999 and 2024 to provide a comprehensive, long-term perspective on all CERN activities with suppliers (note this has a different rationale and scope than CERN Procurement Reports).
- Analysis of results of a **2024 survey** conducted by the CERN Procurement group[6] (502 responses), merged with procurement and Orbis balance sheet data[7] and enhanced by an **econometric analysis** to identify the factors that shape the likelihood/intensity of impacts.
- A **counterfactual analysis** estimating the Average Treatment Effect on the Treated (ATET), which compares outcomes realised by firms that supplied good or services to CERN (the so-called treatment group)[8] with the counterfactual outcome those same firms would have experienced had they not been CERN suppliers. A matched control group of comparable non-supplier firms is used to approximate this counterfactual[9]. Using balance sheet data, the analysis assesses how suppliers' innovation activities and economic performance have changed as a direct causal consequence of participation in CERN activities.

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[6] The survey targeted suppliers who had received payments exceeding 50,000 CHF during the years 2022 and 2023. Invitations were sent to 1,569 suppliers, representing a broad and diverse group of CERN's business partners. 502 completed questionnaires were collected, corresponding to a response rate of approximately 32%. Full results are available here: https://procurement.web.cern.ch/system/files/document/supplier-impact-survey-report.pdf

[7] Orbis is a global business database that provides detailed information (e.g. on financial performance, ownership structures, and mergers and acquisitions) on over 400 million companies worldwide.

[8] A subset of 815 suppliers was used (those that received their first order in the period 2016–2024, with at least one order above 10,000 CHF, and where balance sheet information was available).

[9] Matched based on country, NACE 4 digit, size in the year before the first CERN order, and type of entity.

- Results of an **input-output analysis** of the global value chains associated with CERN procurement.

The purpose of the analysis was to systematically map and describe the mechanisms and benefits that result directly from CERN's role as a research infrastructure through its procurement, encompassing both routine operations and scientific activities. The analysis:

- Includes all supplies and services orders placed through the CERN procurement service over the last 25 years, regardless of funding source (including both CERN and team accounts), plus in-kind contributions for projects coordinated by CERN (excluding in-kind contributions specific to experiments).
- Is not directly comparable to that presented in the CERN Procurement Reports.
- Is not directly comparable to earlier studies conducted for specific projects or activities, such as LHC or High Luminosity LHC (HL-LHC).

3.3 Key Findings

From 1999 to 2024, CERN sustained a competitive and geographically diversified procurement ecosystem. During this period, more than 1.3 million orders for supplies and services were placed, amounting to a total expenditure of 14 billion CHF across over 30,000 suppliers in 92 countries (average expenditure of 543 million CHF per year and 1,000 new suppliers each year).

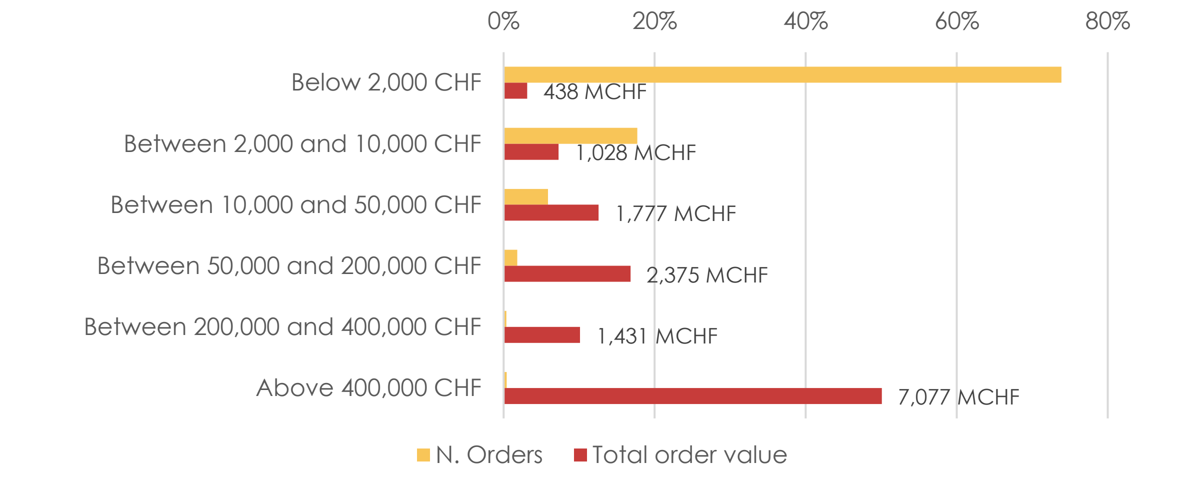
Procurement activities reflected CERN's project cycles (see Figure 6), with significant peaks noted in 2004 during the construction of the LHC and again in 2018 at the commencement of Long Shutdown 2 (for the LHC injector upgrade, plus other modifications, consolidation and maintenance). Periods of external disruption, such as the COVID-19 pandemic in 2020, resulted in temporary reductions in activity.

Figure 6 Cumulated value of supplies & services orders at order creation year

Source: Study team elaboration, based on CERN procurement data.

The procurement landscape has also become increasingly bi-modal (see Figure 7), with the majority of orders under 10,000 CHF (e.g., store purchases) contributing minimally to overall expenditure, while a small number of high-value contracts exceeding 400,000 CHF — primarily for high-tech components — account for most of the total spend. As shown in Figure 7, the order volumes (n. order) and total order values by CERN threshold are inversely distributed.

Figure 7 Supplies and services order value distribution across thresholds



Source: Study team elaboration, based on CERN procurement data. Note that the graph also includes financial valuations of in-kind contributions managed by CERN; the numbers therefore are not aligned with those in CERN procurement reports.

High-value service contracts operate alongside numerous component-based contracts and purchase orders. The range of orders absorbing the majority of expenditures covers a broad spectrum of sectors, including electrical services at CERN, civil engineering, utilities, as well as advanced technological activities such as magnets and cryogenics. A significant proportion of CERN's spending on supplies and service orders is allocated to on-site services, which encompass site management, heating, temporary staffing, and administrative functions.

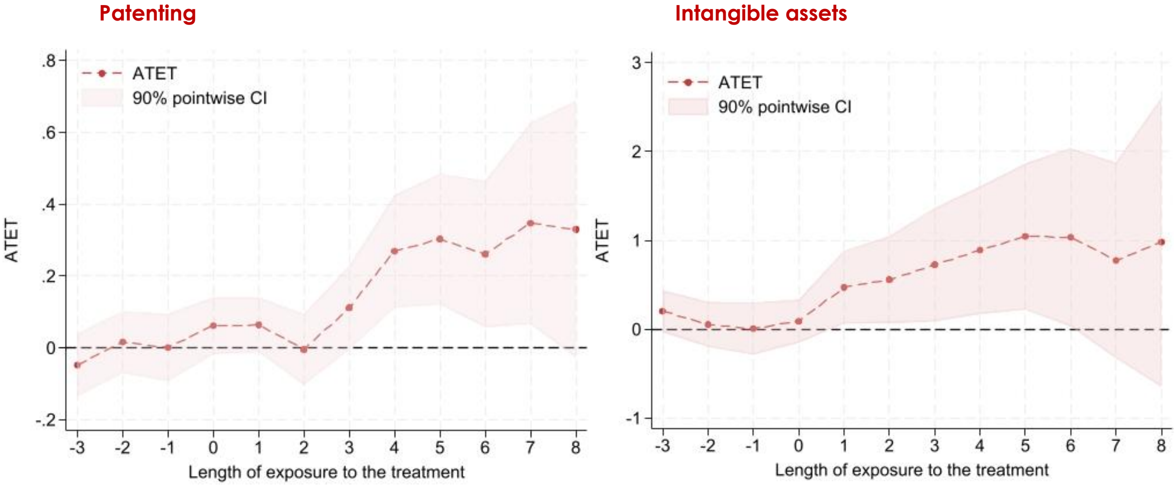
CERN is recognised among suppliers as a highly valued and sought-after client. Its procurement activities facilitate ongoing and significant learning, promoting the advancement of both technical and organisational competencies within its supplier network. Approximately 72% of surveyed CERN suppliers reported improvements in their technical expertise. These learning outcomes are particularly prevalent among SMEs and high-tech suppliers, highlighting the more substantial benefit that collaboration with CERN has on their capabilities. Engagements with CERN not only initiate immediate learning benefits but also sustain these effects through continued collaboration, with greater intensity observed in more complex projects.

CERN's procurement activities serve as a catalyst for innovation, resulting in substantial product and process enhancements across various industrial sectors, as demonstrated by both subjective assessments and empirical analysis.

Approximately 66% of suppliers surveyed by CERN reported improvements in their products or services, while 48% indicated the development of new products stemming from their collaboration with CERN. The most pronounced effects are observed within high-precision engineering and core research infrastructures, including particle and photon detectors, vacuum and cryogenic systems, transport and handling equipment, electronics, and radiofrequency technologies. Notably, small and medium-sized enterprises (SMEs) exhibit a greater likelihood of fostering innovation compared to larger organisations.

Furthermore, repeated contractual engagements contribute to cumulative innovation, albeit with diminishing returns following initial collaborations. The causal impact of participation in CERN procurement activities on firms' innovation performance is assessed through a counterfactual analysis estimating the Average Treatment Effect on the Treated (ATET), i.e., difference in outcomes due to the exposure to CERN activities. Based on a sample of 815 companies receiving their first CERN order between 2016 and 2024, the analysis showed that CERN suppliers experienced an additional 15% increase in patent stock and a 63% growth in intangible assets (beyond that achieved by a control group of comparable firms). Figure 8 shows these ATET estimates as a function of the length of exposure to CERN activities, illustrating when they materialise and for how long they last.[10] The results point to a two-stage dynamic: there is an immediate enhancement of R&D and knowledge resources within one year, followed by increases in patent activity after approximately four years, thereby promoting sustained innovation and long-term competitiveness.

Figure 8 Impact on innovation outcomes: duration of exposure ATET (Average Treatment Effect on the Treated)



Source: Study team computations based on CERN procurement data

CERN's procurement activities contribute to enhancing the market position and economic outcomes of its suppliers. Notably, approximately 54% of CERN suppliers indicated in the 2024 survey that they had accessed new markets following their collaboration with CERN. This effect is particularly pronounced among suppliers involved in particle and photon detectors, mechanical engineering, raw materials, and site-specific services at CERN.

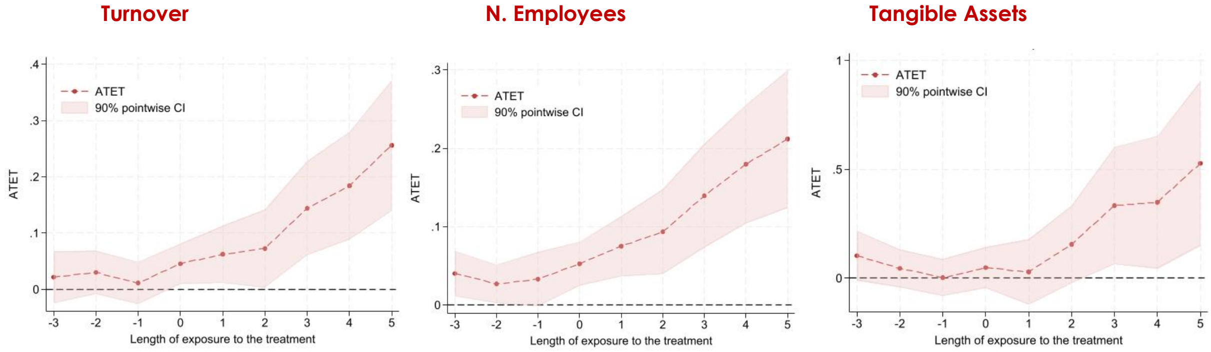
In contrast to outcomes related to learning and innovation, market penetration is driven predominantly by the prestige and visibility associated with CERN cooperation, which serves as a "powerful reference" and "mark of excellence." In addition to these reputational and market expansion benefits, CERN suppliers commonly report improvements in economic performance, including increased sales (73% of respondents) and personnel growth (26%).

The counterfactual analysis corroborates these observations by estimating the Average Treatment Effect on the Treated (ATET) for key economic outcomes. In this setting, ATET measures the average causal effect of being a CERN supplier on firms' turnover, employment, and tangible assets, relative to the counterfactual scenario in which the same firms did not receive a CERN order. Firms receiving their first CERN order between 2016 and 2024 experienced, on average, a 14% increase in turnover, a 13% rise in employment, and a 27% increase in tangible assets within five years after their first order. Figure 9 reports the estimated ATET as a function of the length of exposure to CERN procurement, illustrating how these economic effects evolve over time following initial participation. The results indicate a gradual

[10] Note that ATET estimates are different from zero when their confidence intervals do not cross the horizontal line.

strengthening of economic performance with continued exposure, with effects becoming statistically distinguishable from zero as confidence intervals no longer overlap the zero line.

Figure 9 Impact on economic outcomes: duration of exposure ATET (Average Treatment Effect on the Treated)



Source: Study team computations based on CERN procurement data

The impact of CERN procurement varies according to supplier characteristics, with SMEs deriving the greatest benefits owing to their flexibility and proportionate share of contracts.

Learning effects and investments in intangible assets tend to occur promptly, whereas innovation-related outcomes typically emerge after an average delay of four years. These effects may be cumulative: capability development and learning can facilitate innovation, which may subsequently lead to market expansion and improved economic performance. Suppliers that enhance their technical expertise are most likely to achieve product innovations, access new markets, and secure sustainable competitive advantages. Notably, market expansion may also result solely from reputational improvements.

CERN procurement has positive impacts at the national level as well. A study conducted in 2025[11] identified the global value chains associated with CERN procurement and analysed the changes caused by deepening global integration on:

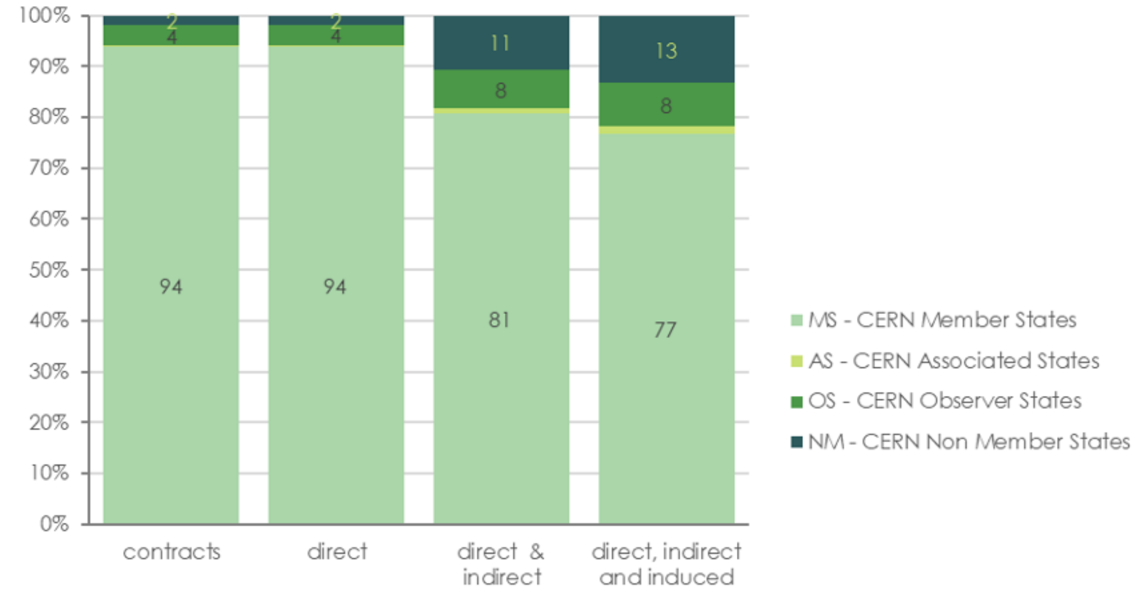
- Direct effects, linked to the supply of goods and services
- Indirect effects, created by intermediate inputs (e.g. upstream materials and services)
- Induced effects, linked to the economic activities of the suppliers' employees

Results of the study indicate that the costs associated with research infrastructure such as CERN are linked to measurable economic benefits, including value added and employment. These effects extend not only to staff and scientists but also to suppliers and their workforce.

On average, CERN's procurement activities for goods and services generate approximately CHF 680 million in direct, indirect, and induced economic value added annually. These effects are associated with investments in new infrastructure, equipment, taxes and social contributions, and regional household spending. The results also show that the connection between annual contributions to CERN, direct contracts and indirect benefits is not always clear-cut, crucially depending on the position of a region in the global value chain: countries that are not CERN Member States are awarded only approximately 2–3% of orders on average, but value-added effects reach about 13% (see Figure 10).

[11] Conducted by the Austrian Institute of Economic Research (WIFO), using the same data set as the current study. It employed a multi-regional Input-Output model (a time-series variant of ADAGIO), which depicts inter-industry relationships, showing how output from one industrial sector may become an input to another industrial sector.

Figure 10 Average share of contract volumes and economic effects (as of 2025)



Source: WIFO computations based on CERN procurement data

3.4 Case Studies (Suppliers and Innovation Benefits)

Case studies developed for this study help to illustrate Innovation-related benefits through examples of CERN suppliers. The key benefits reported in each case are summarized in Table 1 below.

Table 1 CERN Supplier Case Studies: Summary of benefits

Supplier	Product / Service	Benefits of being a CERN supplier
B&S International (France)	• On-site electro-mechanical technical services • CERN supplier since 1978	• Growth in revenue, workforce and expertise • CERN experience helped securing new clients (CEA, ITER, ESS)
2M Kablo (Turkey)	• Low-voltage cables • CERN supplier since 2019	• Enhanced technical expertise and quality standards • Having CERN as a reference gave credibility with other potential clients internationally
Advafab (Finland)	• Radiation detection sensors and detector modules assembly • CERN supplier since 2016	• Optimization of processes and increased technical capabilities • Global reputation established and new clients (DESI, ESS) secured, resulting in 270% revenue growth in a decade
ETM Professional Control (Austria)	• Supervisory Control and Data Acquisition (SCADA) systems • CERN supplier since 1980's	• Tangible product enhancements from addressing the requirements of a demanding environment • CERN deployment regularly used to potential scalability to other potential clients
CAEN (Italy)	• Advanced electronics and power supplies • CERN supplier since 1980's	• Additional innovation and growth • Validation of products and global credibility • Positioning as a leading supplier of specialised electronics for particle physics

4 Technology Development and Innovation

4.1 Pathways to Benefits

CERN's scientific advancements frequently facilitate technological progress, both directly and indirectly, and the transfer of CERN technologies and expertise to wider society is a core aspect of the Organization's efforts, offering innovative solutions across various domains.

There are two principal mechanisms through which these benefits are achieved:

- **Knowledge flows:** CERN's research is systematically documented in publications and technical reports, with knowledge then flowing by the uptake of those outputs in academia (citations) (covered in Section 2), and in patents and by society at large (see below). This dissemination spans multiple fields and industries beyond high-energy physics.
- **CERN knowledge transfer activities:** While CERN's primary objective remains the pursuit of fundamental knowledge in high-energy physics, the Organization also serves an essential function in ensuring that the technologies, expertise, and innovations generated are effectively transferred to society for broader benefit through dedicated knowledge transfer initiatives.

4.2 Approach

The study has built upon some limited **past literature** (see summary of key papers in Appendix A) and the existing evidence base, and added value by:

- Collating up-to-date and historical **statistics** on knowledge transfer activities.
- Analysing evidence from a **2024 pilot survey of CERN's innovation partners** (completed by 36 out of 40 selected partners approached, including companies, research institutes and hospitals, who had been accessing CERN technology and know-how in different ways)[12] and a **2025 survey of CERN-related start-ups** (21 responses received at the time of analysis).
- Estimating business generation from the **licensing** of CERN technology.
- Conducting a new analysis of **funding raised by CERN start-ups** using Crunchbase[13].
- Providing a new analysis of the **flow of knowledge from CERN publications to: patents** (using LENS[14]), **policy related literature** (using Overton[15]), **and wider audiences** (using Wikipedia).
- Developing in-depth **case studies** exploring particular CERN technologies that have found wider application and benefits across multiple industries.

[12] https://report2024-kt.web.cern.ch/knowledge-transfer-impact/

[13] Crunchbase is a platform tracking business information and funding events

[14] https://www.lens.org/. Lens is the world's largest open and free data platform of the global patents and scholarly articles.

[15] Overton provides the world's largest policy and grey literature database, linked to publications https://www.overton.io/

4.3 Key Findings

Overview of CERN knowledge transfer activities

CERN's technological ecosystem, which is centred on accelerators, detectors, and advanced computing systems, is supported by a diverse array of specialised expertise, including superconducting magnet technology, microelectronics, cryogenics, radiation monitoring, and data processing. These competencies have demonstrated significant relevance and applicability in various sectors such as healthcare, aerospace engineering, environmental applications, heritage conservation, and digital infrastructure.

CERN engages in a variety of knowledge transfer activities (Figure 11) with innovation partners in academia, industry, and public institutions, enabling applications beyond particle physics

Figure 11 CERN's knowledge transfer ecosystem

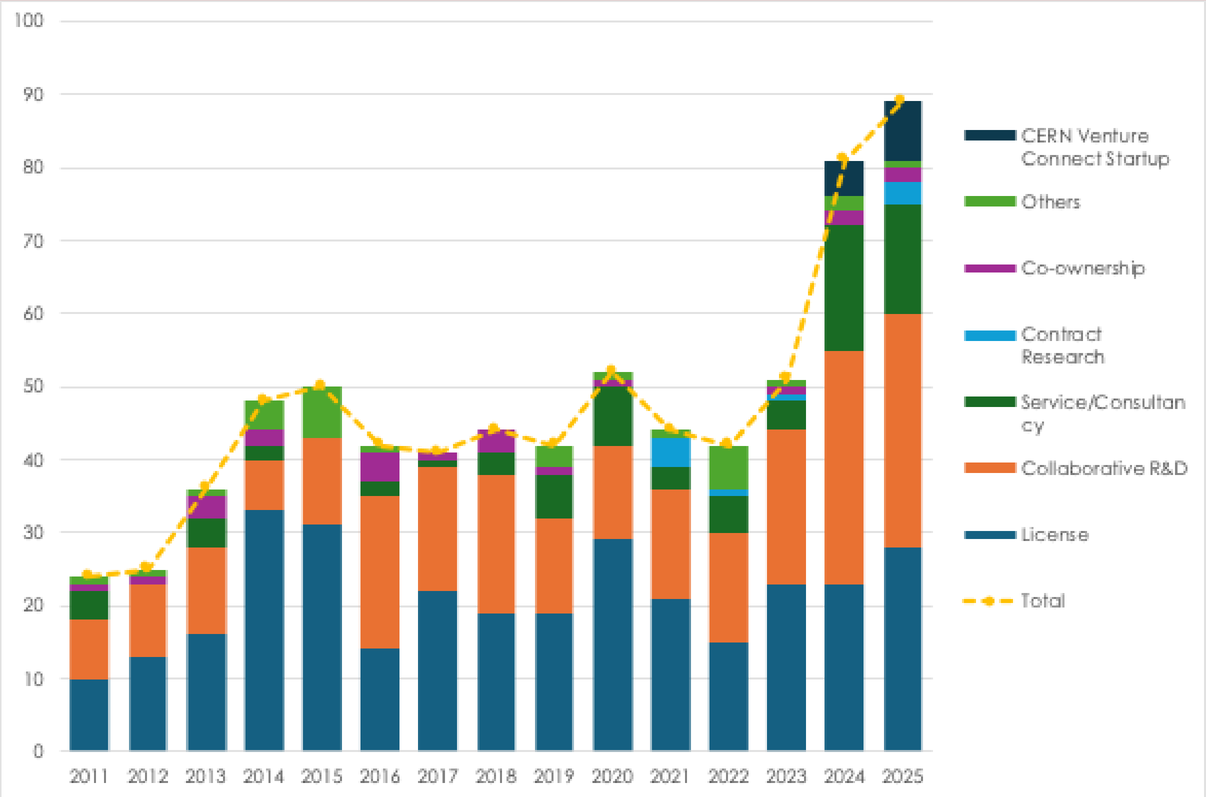
Overview of CERN knowledge transfer agreements

Since 2011, CERN has signed over 700 contracts to support knowledge transfer[16]. The most prominent categories are licences (316 contracts) and collaborative R&D agreements (247).

Figure 12 below illustrates a clear evolution over the 2011–2025 period:

- **Steady growth**: The number of contracts signed each year has increased significantly over time, from 24 in 2011 to over 80 in each of the latest two years.
- **Diversification**: There is a notable expansion in the types of mechanisms used, and a significant increase in the numbers of both collaborative R&D agreements (demonstrating increased adoption of co-creation in domains of common interest) and service / consultancy agreements (in part enabled by fast-track access to facilities for space tests).

Figure 12 CERN's knowledge transfer agreements over the years



Note: 'Others' includes e.g. Assignment IP agreements.

Licensing

CERN issues licences to both commercial and academic partners for the utilisation of its technologies (see overview of technology portfolio areas in Figure 13). These licences may originate from collaborative research initiatives or be granted independently, and can encompass proprietary and open-source arrangements.

[16] These are the figures officially reported to the CERN Finance Committee. However, other types of agreement have also been signed during this period. For instance, there have been over 160 Non-Disclosure Agreements and Mutual Transfer Agreements since 2019 (figures for earlier periods are not available). CVC Partner agreements were also introduced in 2023 (contracts entered into by partners to participate in the CERN Venture Connect program), with 58 signed in the past 3 years.

Figure 13 CERN Technology portfolio

Accelerators | Beam Component & Systems | Cooling & Ventilation | Cryogenics | Detectors | Electronics | High & Ultra-High Vacuums | Industrial Controls & Simulations | Information & Communication Technology (ICT) | Magnets | Manufacturing & Mechanical Processes | Materials | Mechanics | Metrology | Microelectronics | Particle Tracking & Radiation Monitoring | Radiation Protection | Radio Frequency Technology | Superconductivity | Testing Facilities

From 2007 to 2024, CERN's income from the commercialisation of intellectual property (IP) and co-ownership agreements ranged from CHF 613,000 to CHF 3.2 million annually. Over this period, CERN received a total of CHF 26.1 million, equating to an average annual income of CHF 1.5 million, consistent with previous analyses (Nilsen and Anelli, 2016).

Although details of individual agreements are unavailable, assuming that this income generally aligns with the royalty fees stipulated in the CVC programme (2% of CERN technology-related revenue, applicable after exceeding CHF 1 million in annual sales), it can be estimated that over the past 18 years, companies have collectively generated an average of at least CHF 72.5 million per year in revenue from CERN technology.

Knowledge Transfer Partners

Companies, research institutes, and other organisations that form innovation partnerships with CERN gain both direct and indirect advantages from these collaborations.

In 2024, CERN administered a pilot survey aimed at assessing its impact through technological innovation, specifically as reflected in formal innovation partnerships. Although the sample size was limited (n=37), the survey yielded valuable insights and results, summarised in Figure 14 .

Figure 14 Key results from pilot survey of CERN knowledge transfer partners

Response	Benefit
8 out of 10	Increased knowledge and enhanced technological problem-solving
Over 75%	Improved skills of their personnel
Over 85%	Strengthened research activities
80%	Strengthened product development
Over 70%	Developed new instrumentation, methodologies, or processes for product development
40%	Reduced costs of development and production
65%	Increased sales and/or obtained additional funding thanks to CERN collaboration

Source: 2024 CERN pilot survey of formal knowledge-transfer partners

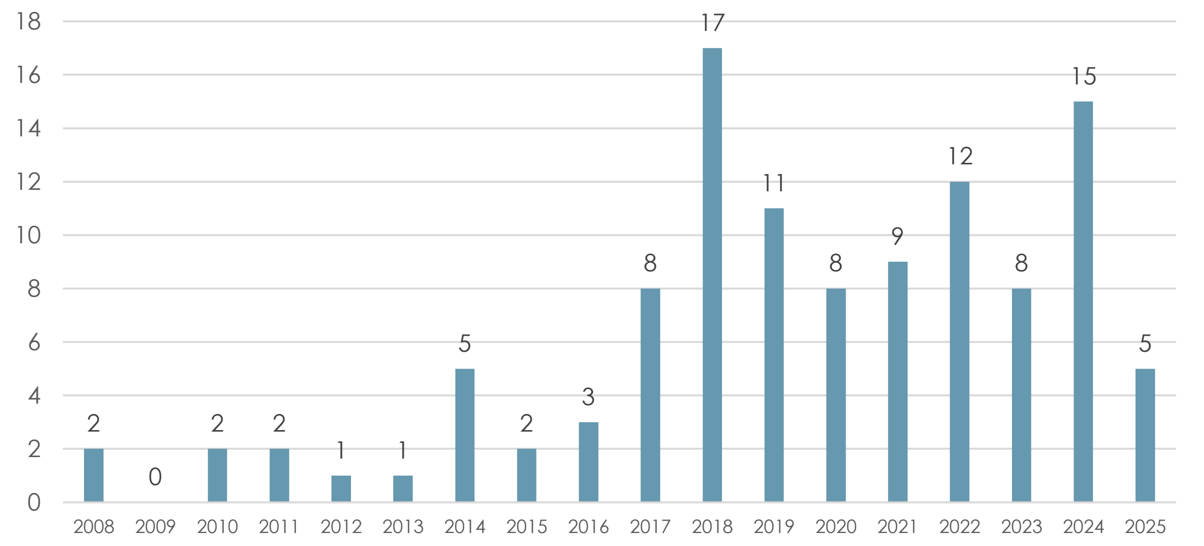
CERN-related start-ups

CERN is actively engaged in entrepreneurship support and is building a database to track CERN-related start-ups. This database covers about 100 companies – founded by CERN alumni, using CERN technology or otherwise linked to CERN. This number likely underestimates the true number, as indicated by the ~60 further self-reported startups from a CERN alumni survey.

According to data collected in 2025 from a survey and interviews with 21 start-ups, over 70% reported utilising CERN technology or knowhow in the foundation of their companies. The survey also requested that start-ups estimate the value-added contribution of CERN technology to their businesses. In response, 10% estimated this at 75% or greater, while 19% assessed it between 25-50%.

Furthermore, an analysis of the achievements of CERN start-ups and spin-offs (using Crunchbase) revealed 111 investment deals completed by 27 companies from 2008 to 2025 (see Figure 15), averaging four per company. Based on this data, these companies have attracted between $10,000 and $2.5 billion each, or $3.8 billion in investments in total[17], through various channels, including venture capital, debt financing, and corporate rounds. In 2025, start-ups in the CERN Venture Connect programme raised 6 million Euros in funding.

Figure 15 Number of funding / investment deals announced, by year



Flow of Knowledge from Publications to Patents

Patent filing provides a useful method to estimate industrial uptake of knowledge generated by CERN, noting that some companies may use that knowledge without patenting.

Due to its emphasis on fundamental research, only a small proportion of CERN's P0 publications[18] are referenced in patents. Nonetheless, their influence can be substantial. Data

[17] Note: Results are dominated by one large ($2.5 billion) post-IPO debt raised by Novartis in 2024 (Novartis acquired the CERN spin-off Advanced Accelerator Applications in 2017 for $3.9 billion)

[18] P0 Publications, produced by authors directly affiliated to CERN and/or authors affiliated to other Institutions and who are directly involved in the Organization's research activities

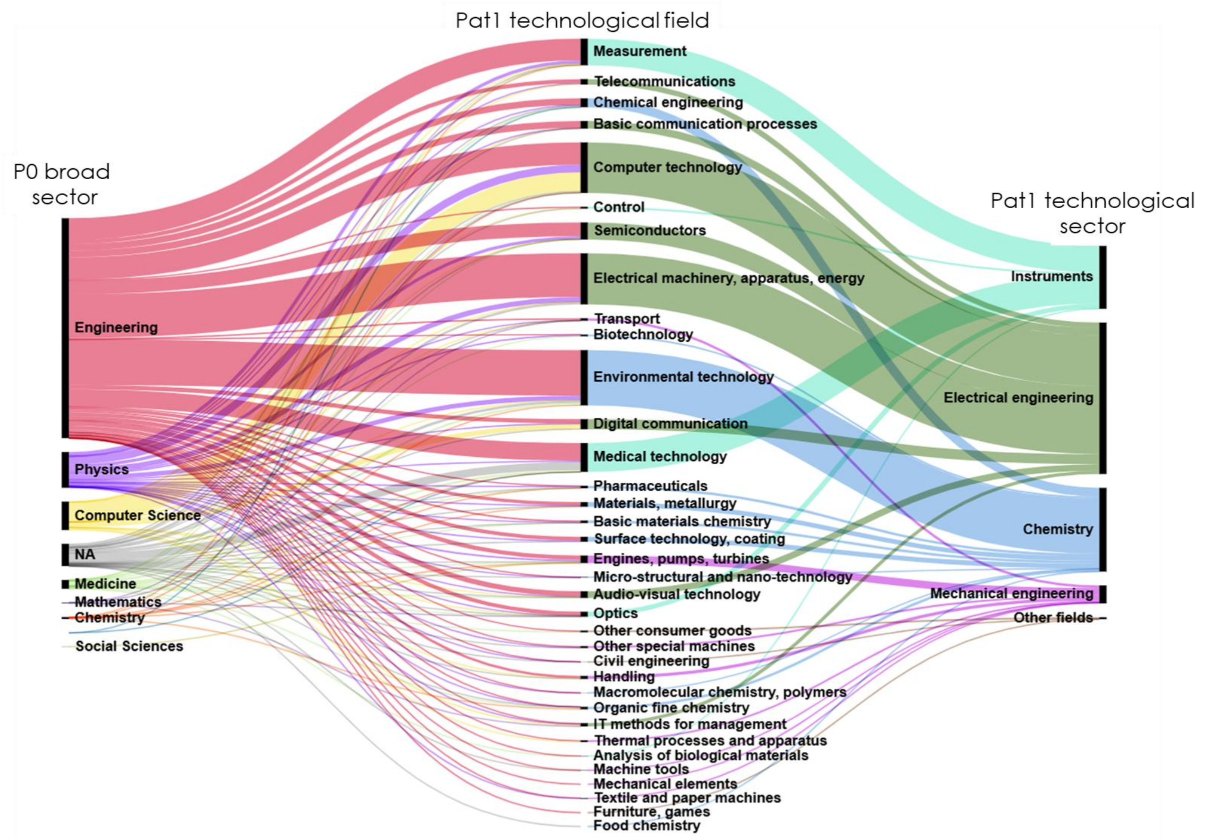
indicate that 648 CERN publications (1.3% of 50,194) have been cited in 1,302 patent applications, which correspond to 1,007 distinct patent families[19].

CERN's publications primarily contribute to innovation through applied research fields with direct technological relevance. An examination of the cited publications (left-hand side of Figure 16) shows that the majority pertain to Engineering (67.1%), particularly within the "Detectors and Experimental Techniques" discipline. This is unsurprising, as patents typically build on concrete engineering advances (e.g. sensor technologies, accelerator components, or data acquisition systems) that can be directly adapted for industrial or medical applications.

Collaboration plays a pivotal role in these innovative contributions. Most frequently cited CERN publications list multiple authors, with author counts ranging from 1 to 3,162. Authors affiliated with CERN contributed directly to 438 of the cited publications (67.6% of 648), while the remaining 210 were authored by individuals associated with different institutions but linked to various CERN-related projects or experiments.

The majority of patents are concentrated in the technological sectors of electrical engineering and chemistry (right-hand side of Figure 16), while a smaller proportion pertain to fields such as mechanical engineering. Within the electrical engineering and chemistry domains, computer technology, electrical machinery, apparatus, energy, and environmental technology represent the principal areas of innovation, followed by advancements in medical technology.

Figure 16 Citing patents: from research programme to technological fields



[19] A patent family is defined as a group of patent applications that cover the same or similar technical subject matter

From right to left, the Figure shows the connections between the technological sector and technological field of patents, and the broad sector of the CERN publications cited in these patents.

Finally, analysis indicates that the process of patenting requires a considerable period to materialise. The interval between the release of a publication and its initial citation in a patent document varies notably across different technological disciplines. For CERN publications, this time lag may range from immediate citation to a delay of up to thirty years, depending on the specific scientific field referenced.

Flow of Knowledge from Publications to Wider Society

Linking research outputs to Wikipedia pages provides a signal of the dissemination of knowledge to wider audiences. We used a similar approach as with patents, tracing the extent to which CERN P0 publications are cited, and found that:

- 952 Wikipedia entries cite at least one CERN publication. That includes entries in 96 languages (although English is the predominant language).
- There are 1,800 CERN publications cited by Wikipedia. There are 150 thousand CERN publications in total, meaning that less than 1% of CERN publications are cited, which is not surprising since Wikipedia is geared towards providing general, rather than highly specialised knowledge.
- In the past year alone, those entries have had a total of 51.4 million views, showcasing the powerful reach of even a relatively small number of publications.

We also tested the extent to which CERN publications are cited in **policy related literature** and are consequently helping to inform public debates policy makers**.** Using Overton, we found that between 1998 and 2025, 295 reports cited CERN P0 publications, 184 of which have been published by governmental organisations. The 'footprint' of those documents is wide, with many being cited in EU documents or by Intergovernmental Organisations (IGO), as well as in European countries and in the USA. Those policy documents cover a variety of topics, not only related to science and technology, but also the economy, the environment, education and health, supporting societal benefits (see Table 2).

Table 2 Policy documents citing CERN publications: thematic classification

Classifications	**Number of policy documents**	**Classifications**	**Number of policy documents**
Science and Technology	290	Arts, Culture and Entertainment	8
Economy, Business and Finance	193	Conflicts, War and Peace	6
Environment	58	Labour	6
Education	55	Lifestyle and Leisure	5
Health	50	Crime, Law and Justice	4
Politics	24	Disaster, Accident and Emergency incident	3
Society	21	Sport	1
Weather	16		

4.4 Case Studies (Technology Development & Innovation Benefits)

The cases below exemplify technologies and innovations created to address CERN's needs that have found wider use across multiple industries

Medipix is a family of read-out chips for particle imaging and detection (capturing high-resolution, high-contrast, noise-free images via photon counting / analysis). Originally created for particle tracking in the LHC, and further developed over three decades, with each generation providing a more sophisticated chip, with new features e.g. time-stamping.

Routes to collaboration and dissemination / access:

- A formal collaboration was established 3 decades ago to promote adoption and development of the technology, including applications beyond particle physics. Over time the initiative has engaged ~40 different research institutes and universities.
- Currently, around 30 commercial licenses are active, generating royalties exceeding 5 million CHF over the past decade (and contributing to an estimated industry revenue of more than 100 million CHF). The royalties are reinvested into research and development, supporting a financially sustainable model. Licensees comprise providers of solutions for life sciences, manufacturers of laboratory instruments, and medical imaging companies.
- CERN-authored publications have achieved an average of 32.5 citations each and have supported the development of 73 patents by companies such as Philips, ASML, and Siemens. The technology has driven advancements across diverse sectors, including medicine (e.g., treatment of brain tumours, thyroid diagnostics, CT scans), aerospace (e.g., radiation monitoring on the ISS), nuclear energy (e.g., radiation monitoring during decommissioning), and cultural heritage (e.g., artifact analysis, artwork verification).
- Interest in the technology has been recently growing, with 40% of all licences signed within the past three years, and with half of all sales involving Medipix or Timepix technology in the last 15 years occurring during this recent period.

Hadron therapy is an advanced form of cancer therapy. Unlike radiotherapy, hadrons such as protons and light ions deposit most of their energy at the tumour site, reducing radiation exposure to nearby organs and enabling treatment of deep-seated, radio-resistant tumours.

Over three decades, CERN has served as a key contributor to the advancement of carbon-ion therapy technologies across Europe, fulfilling technological, scientific, educational, and organisational roles. CERN's accelerator expertise and its collaboration with Med-AUSTRON, Onkologie-2000, and the TERA Foundation (via the 1996–2000 Proton-Ion Medical Machine Study, PIMMS), established the groundwork for two major hadron-therapy initiatives: CNAO (Italy), primarily supported by INFN, and MedAustron (Austria). Collectively, these centres have treated nearly 9,000 patients since commencing operations in 2011 and 2016, respectively. This number reflects treatments for rare and difficult-to-treat cancers rather than common conditions, underscoring the specialised focus of these therapies.

Two key enabling factors proved decisive in this successful process.

- The entrepreneurial spirit and dedication of individual scientists proved indispensable. Key figures functioned as technical experts, project architects, coalition builders, and persistent advocates. They mobilised resources often in the absence of formal funding, maintaining project viability in early stages.
- CERN's culture and structure provided an essential environment for visionary ideas to develop and flourish. Its collaborative ethos successfully united governments, research labs, and industry, a capability enhanced by CERN's international credibility. Moreover, institutional autonomy and decision-making flexibility enabled an entrepreneurial approach that permitted pursuit of ambitions beyond core research programmes.

Together, these created the unique conditions necessary for translating particle physics expertise into a life-saving medical technology that not only extends patients' survival, but also enhances quality of life by minimising side effects and shortening treatment periods.

White Rabbit is an open-source technology (hardware, software, firmware & gateware) to synchronise time and frequency in devices connected through a fibre optic network. It was developed at CERN, with other institutes and companies, for the accelerator complex.

White Rabbit (WR) technology distinguishes itself through several key attributes:

- As a pioneering solution, WR delivers breakthrough performance with sub-nanosecond accuracy and picosecond-level precision.
- It provides enhanced reliability, functioning as a terrestrial time distribution technology that avoids the vulnerabilities and inconsistencies of satellite-based systems.
- Integration into established global industry standards ensures that WR is straightforward to deploy, scalable, and equipped for future advancements.

The technology has yielded significant spillover benefits

- WR networks facilitate research initiatives across Europe, with adoption in fields such as high-energy physics, astronomy, and metrology. National-scale implementations are in progress in countries including France, Italy, Belgium, Czechia, and the Netherlands.
- The development of CERN's Open Hardware Licence was initiated in collaboration between CERN's Knowledge Transfer group and the WR technical team; this licence now serves a wide user base and achieved OSI certification from the Open Science Initiative in 2021.
- The financial sector quickly embraced WR for facilitating reliable high-frequency trading and timestamping applications by regulated national exchanges.
- Additional industries — including telecommunications and power grids — are actively exploring WR deployment, as evidenced by Orange Polska's adaptation efforts within telecom networks.
- WR has been identified as a promising emerging technology in the European Commission's 2023 European Radio Navigation Plan, underscoring its significance in position, navigation, and timing (PNT) and the resilience of essential infrastructure.
- The European Space Agency is utilising WR to connect its timing laboratory to the Dutch National Metrology Institute. Furthermore, WR is synchronizing developing quantum networks and has featured in proof-of-concept trials for next-generation terrestrial navigation systems.

ROOT is an open-source software framework developed at CERN since 1995 for the effective management, storage, visualization, and analysis of large scientific datasets. Advanced computer-aided sifting techniques such as those integrated in ROOT are used to identify anomalies in substantial particle collision datasets.

Applications in the Financial Sector:

- Market manipulation imposes considerable financial, legal, and systemic risks on individuals, organisations, and the broader economy.
- Through the HighLO collaborative initiative with the Commodity Risk Management Expertise Centre (CORMEC) and Wageningen University — established in 2019 — CERN leveraged the ROOT infrastructure to co-develop analytical tools and models aimed at supporting national regulators and regulated exchanges in detecting market manipulation in high-frequency electronic trading (HFT) data. This technology has been utilised by trading exchanges such as Deutsche Börse.
- HighLO has also introduced the Market Surveillance Analytics Lab (MSA Lab), a sophisticated surveillance software that enables regulators and exchanges to visualise market manipulation within their proprietary data. The MSA Lab's demonstration garnered interest from trading venues including Eurex, which are currently collaborating with HighLO to integrate and analyse their data using this tool. Furthermore, MSA Lab is presently instrumental in ongoing market manipulation court litigations in Germany.

The following case studies highlight some of CERN's contributions to Fast Machine Learning, Edge AI and Federated Learning

Collaboration with Zenseact, where CERN supported the Volvo-owned company in developing techniques to reduce the computational cost of running fast and accurate **AI algorithms in automotive applications,** while preserving accuracy, based on its experience of deploying algorithms on custom trigger electronics for the particle detectors' data pipelines.

Edge SpAIce[20], an ongoing EU-funded project, involving CERN and a consortium of companies and laboratories, which aims to support the deployment of **edge AI systems in space,** by reducing the size of deep neural networks, while maintaining processing accuracy. One of the key applications is the monitoring of marine plastic pollution from orbit.

Collaboration with CEVA, a leader in digital signal processing technology, which involved the adaptation, compression and optimisation of neural networks for data processing on low-bit hardware, with good accuracy but low power consumption. It drew on CERN's experience in compressing computationally expensive neural networks to make them run more efficiently, and applying this to **smart consumer devices,** where battery life is key.

CEVA has subsequently incorporated algorithms from the project into their product offering, which is licensed to large clients like LG, Samsung, Sony, Nokia and Intel, and potentially is saving power consumption in thousands of electronic consumer products.

The CAFEIN federated learning platform, developed by CERN for **medical applications**, based originally on an AI fault-detection model used internally for CERN's cryogenic systems.

CERN used its knowledge of distributed computing to develop a federated learning platform i.e. a system that allows entities such as hospitals to train their local version of the algorithm with their own data, and then send the inference model (the trained algorithm minus the patient data) to a central hub (in this case, CERN) for integration with other local versions and then redistribution of the updated model. This platform is particularly appealing for healthcare applications, as it allows hospitals to learn collectively and improve patient outcomes without sharing sensitive data.

CERN is adapting CAFEIN for **stroke treatment**. This is done in the framework of two EU-funded projects; TRUSTroke[21], which focuses on post-hospitalisation, and UMBRELLA[22], which expands to include the greater treatment and prevention value chain. These projects involve several medical sites, and their buy-in is largely attributable to the federated learning system and its management by CERN, which is seen as a trusted provider.

[20] Edge SpAIce receives funding from the European Union's Horizon Europe research and innovation programme under grant agreement no. 101135358.

[21] Trustroke receives funding from the European Union's call Horizon-hlth-2022-stayhlth-01-two-stage under grant agreement No.101080564.

[22] UMBRELLA is supported by the Innovative Health Initiative Joint Undertaking (IHI JU) under grant agreement No 101172825. The JU receives support from the European Union's Horizon Europe research and innovation programme and COCIR, EFPIA, Europa Bío, MedTech Europe, and Vaccines Europe.

5 Skills (Education, Training & Experience)

5.1 Pathways to Benefits

As one of the world's leading scientific institutes and a centre for excellence, CERN engages with many individuals and organisations each year. It provides an inspiring training ground for the current and future STEM workforce, and stakeholders acquire skills during their engagement with CERN, especially due to the expertise available, the scale of projects, the interdisciplinary nature of work and the exposure to tools and techniques at the technological frontier.

The benefits are transmitted via a variety of mechanisms:

- Increasing skills and capabilities among users, including early-career researchers who have the opportunity to gain new skills and expand their network in a highly prestigious and challenging workplace.
- Providing suppliers to the facility with the opportunity to enhance their technical capabilities and knowledge through close collaboration and the demands of frontier science.
- Training new generations of experts, including physicists, engineers, computer scientists and technicians, through study programmes and hands-on research opportunities at CERN.
- Engaging with schools and teachers, in person, online and through the development of materials, to cultivate scientific curiosity and build foundational skills, including in STEM.

The study explored how skills are developed across different stakeholders engaging with CERN, and how this is carried across to other organisations and industries.

5.2 Approach

Various prior exercises have investigated the effect of CERN on skills (see summary of **key literature** in Appendix A). The study has built upon this prior evidence by:

- Collating up-to-date and historical **statistics** on CERN's education and training activities and their uptake / reach.
- Analysing new evidence from a **2025 survey of CERN alumni**[23] (982 responses) and a **2024 survey of CERN suppliers**[24] (502 responses).
- Calculating the **wage premia** for CERN alumni, to complement prior narrower studies (e.g. focused on the LHC or a particular career stage).
- Bringing together a description of skills-related activities, descriptive statistics and quantitative and qualitative evidence of benefits into a single and coherent story.

[23] Sent to 10,394 Alumni Network members through an e-mail campaign in July 2025.

[24] The survey targeted suppliers who had received payments exceeding 50,000 CHF during the years 2022 and 2023. Invitations were sent to 1,569 suppliers, representing a broad and diverse group of CERN's business partners. 502 completed questionnaires were collected, corresponding to a response rate of approximately 32%. Full results are available here: https://procurement.web.cern.ch/system/files/document/supplier-impact-survey-report.pdf

5.3 CERN Community

CERN maintains an extensive and expanding community consisting of employed staff, trainees, students, and a broad network of external users such as collaborators and visiting scientists (see Figure 17). In 2024, the number of CERN staff and registered users totalled nearly 18,000 individuals; on-site presence of users ranges from occasional visits to more than 50% of the time.

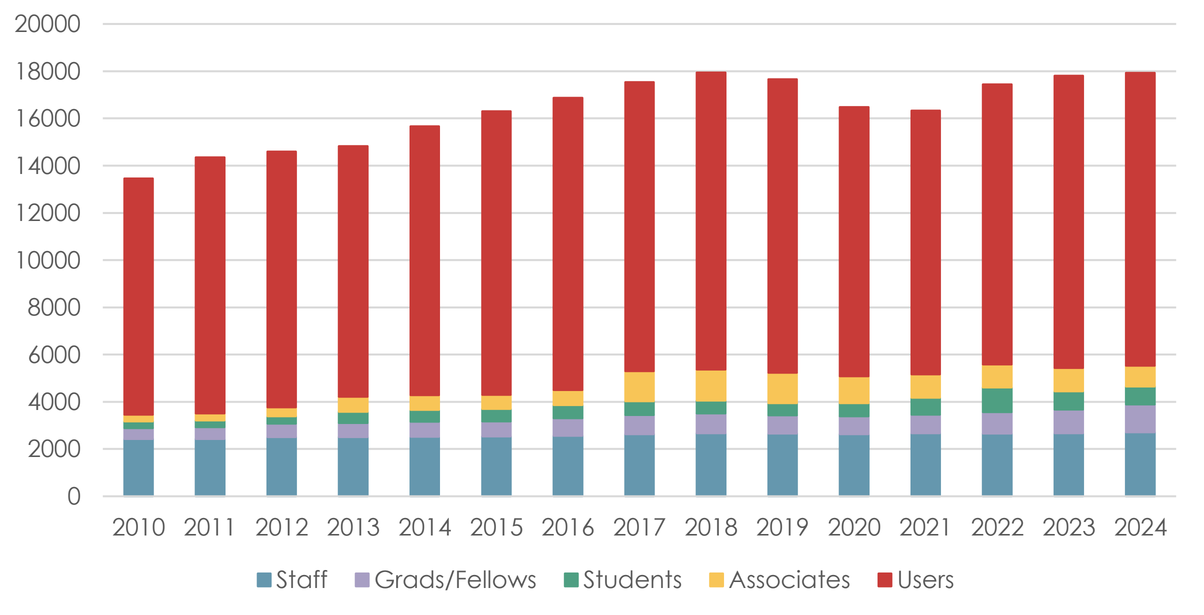
In 2024, **the Organization directly employed around 2,700 staff members plus 1,000 graduates and fellows**, who are involved in the operation of the facilities, the construction of new accelerators and detectors, and in experimental data collection, analysis, and interpretation.

A significant proportion of this workforce supports CERN research efforts directly: more than 75% of staff work in engineering and technical roles which require training and expertise. Around 150 new employees are onboarded each year and interest in joining CERN remains high: almost 19,000 people applied for positions in 2024, with 167 candidates eventually hired.

Approximately 13,000 individuals use CERN's facilities each year, as part of the research programme at CERN. These scientific users — researchers, technicians, students and engineers — come from 950 institutions in more than 80 countries and represent 100+ nationalities. They include approximately 70% of the world's particle physicists, along with large numbers of nuclear physicists, astrophysicists and others. Through their involvement, users gain access to infrastructure, advanced training, and exposure to CERN's research environment to enhance their scientific and technical skills.

Participation at CERN has been shown to confer benefits upon users, with previous studies indicating that prolonged engagement correlates with increased advantages. CERN employees and researchers build skills and knowledge 'on the job', and in informal exchange with team members. The acquired knowledge and skills, gained through different forms of interaction with CERN, can relate to various domains, e.g. technical, scientific, digital, project management, multi-lateral and international team working, cultural awareness, problem solving, process improvements, etc.

Figure 17 Members of Personnel and registered users of CERN

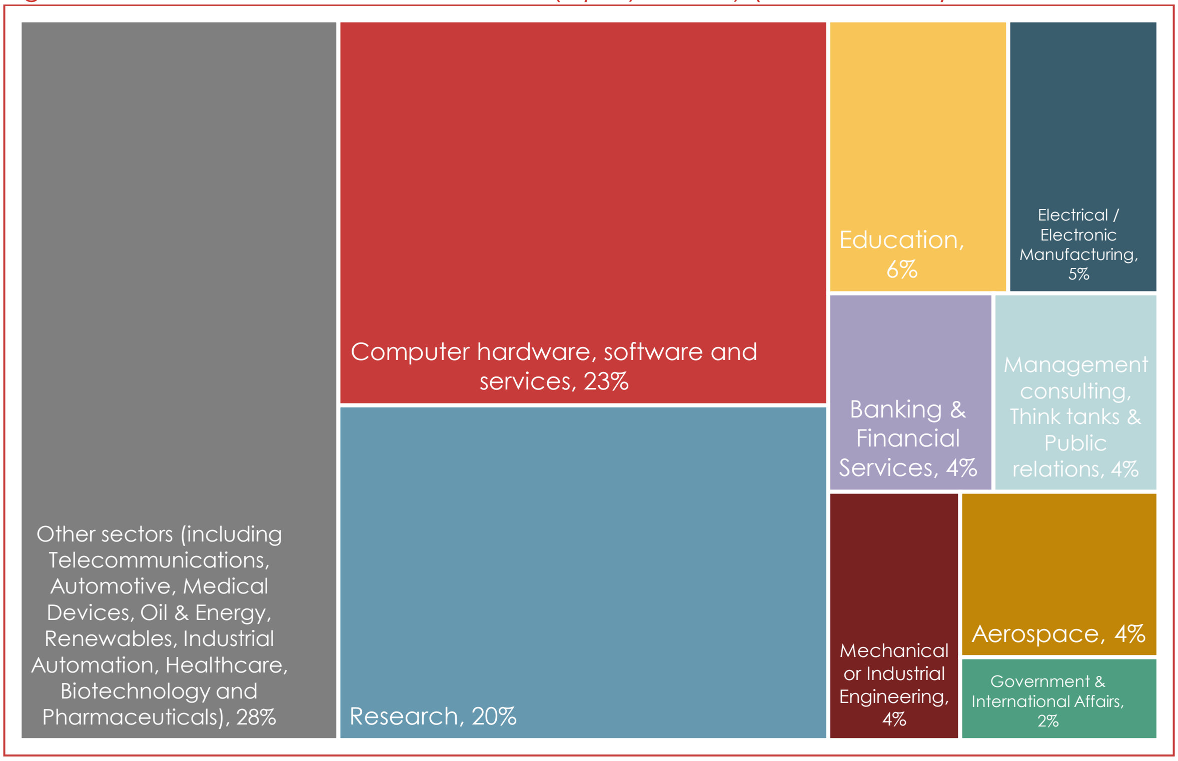


5.4 Skills Benefits via Alumni

When departing from CERN, former members of personnel (including, students, fellows, graduates, staff, users and associates) leave with a comprehensive foundation of scientific knowledge, valuable transferable skills, and substantial experience in international collaboration. **The transition of talent from CERN to the wider economy therefore facilitates significant spillover effects, contributing to broader societal and economic benefits.**

As of 2024, the CERN Alumni Network comprised over 10,000 members, with more than 7,800 individuals having moved on from the Organization. Members of this network are currently employed across a wide range of sectors (see Figure 18). While 26% remain engaged in education or research (including a notable minority who are still affiliated with CERN), many alumni pursue careers in other industries such as Computer Hardware, Software & Services (23%), Electrical & Electronic Manufacturing (5%), Banking & Financial Services (4%), and Mechanical & Industrial Engineering (4%) (see Figure 18).

Figure 18 Distribution of CERN Alumni (%), by industry (October 2025)

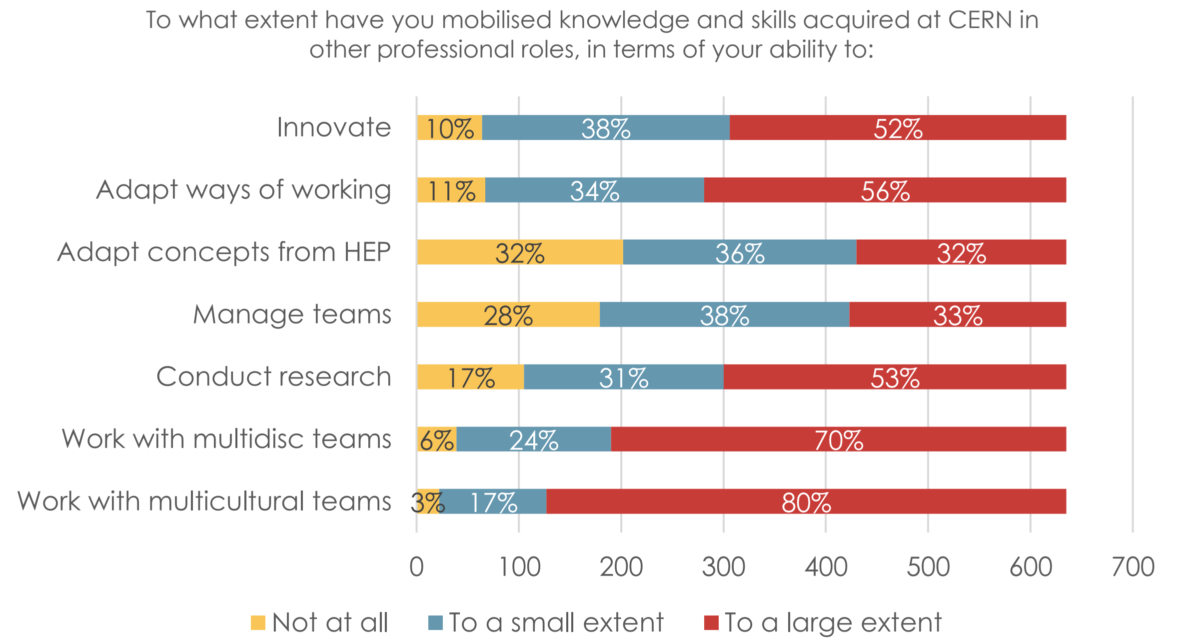


Source: CERN Alumni Network database statistics, October 2025. Includes past and current members of personnel.

According to the 2025 alumni survey, 95% of respondents reported that their experiences and interactions with CERN were beneficial to their career advancement. Notably, 42% indicated that CERN had a significant or fundamental influence on their professional trajectory. Similarly, a previous 2019 survey conducted at CERN among experimental physicists working outside high-energy physics revealed that 70% perceived their time at CERN as having a highly positive impact on securing their current positions (Giacomelli, 2019).

Employment at CERN enabled alumni to acquire knowledge and skills transferable to various professional roles (see Figure 19).

Figure 19 Survey responses showing CERN's positive impact on knowledge and skills



Source: CERN Alumni Career Survey (2025). 982 responses.

The 2025 Alumni Survey included questions regarding **wage premia**. Participants were asked to "assess their current and anticipated long-term salaries in comparison to peers with similar educational backgrounds but without CERN experience".

Responses were selected from a range of categorical options, ranging from lower earnings (e.g. "it is lower") to higher earnings (e.g. "it is more than 11–20% higher"). Each response category was quantified by assigning three different values: lower, average, and upper bound.

Table 3 presents the average current and future wage premia for all respondents, and shows how it changes across age, gender, location, and nature of last engagement with CERN. Overall, respondents reported an **average wage premium of 4%** and ranging from 2–6% on their current earnings. In the long-term, they expect the **future wage premia to increase to 5%, on average,** and ranging from 4–7%.

Although these figures are self-reported, they align with previous studies, which have found wage premia between 5% and 13%, thereby reaffirming the positive influence of CERN experience. In particular, Delugas et al (2025) conducted novel research, applying the methods of the applied microeconomic literature of the human capital theory, to estimate the effect of training at CERN early career researchers' (ECR) wages. They find that training in a research project at CERN yields a significant 7% increase in ECR's yearly wages in the baseline estimation. These average effect of 7% is attained at an average 3.4 years of training at CERN. The authors also conclude that wage returns arise because new or improved skills enhance the ECRs' existing human capital, making them more productive in the workplace due to the additional capabilities generated. This would indicate that productivity-related effects outweigh the prestige and reputational mechanisms that CERN affiliation might signal in the labour market.

Table 3 Current and future wage premia of CERN alumni

Category	Current Wage Premia (%)				Future Wage Premia (%)			
	N	Low	Average	High	N	Low	Average	High
All respondents	437	**2%**	**4%**	**6%**	414	**4%**	**5%**	**7%**
Age: Below 40 yrs	30	1%	3%	5%	35	1%	2%	4%
Age: Above 40 yrs	17	3%	5%	7%	13	1%	2%	3%
Men	32	2%	5%	7%	31	2%	3%	5%
Women	12	1%	2%	3%	14	-1%	0%	2%
Location: EU	40	0%	2%	4%	39	0%	1%	3%
Location: Others	8	10%	13%	16%	9	5%	7%	9%

Source: 2025 Alumni Survey

We calculated the *value* of this wage premia based on the estimates provided via survey in terms of current wage premia and salary.

Respondents were invited to provide their current salaries in bands (e.g. EUR81–90k). Using the lower and upper bound estimates of both salary and wage premia, the average value of the wage premia is estimated at EUR 3,700 to EUR 7,800, consistent with earlier assessments. This figure represents an average across all levels of seniority and fields of expertise.

Table 4 Calculation of CERN Alumni average annual wage premia

	Lower bound (wage premia)	Upper bound (wage premia)
Average value of annual wage premia (for all respondents to the survey)	EUR 3.7k	EUR 7.8k

5.5 Skills Benefits for Industry and Suppliers

CERN maintains a collaborative relationship with a diverse network of suppliers and industry partners. Although the procurement process itself is transactional, the broader implications of engaging with CERN extend well beyond the mere provision of goods and services.

A key advantage for CERN's **suppliers** lies in the enhancement of technical capabilities. The demanding environment at CERN enables participating industry members to rigorously assess their products and engage in co-development activities. CERN offers substantial input and constructive feedback on innovative, non-standard products and emerging technologies, thereby contributing significantly to product development processes.

Skill development is further demonstrated by an increase in technical knowledge. According to the CERN Procurement Survey (2024), 70% of suppliers reported heightened expertise in their respective domains following collaboration with CERN, with the most notable gains observed among those operating in particle and photon detection, transport and handling, as well as health, safety, and environmental technologies.

This advancement facilitates the development of new products. Nearly 50% of CERN suppliers surveyed in 2024 indicated that collaboration with CERN led to the creation of new products, a proportion that rises to 75% within specialised areas such as vacuum and low temperature technologies, optics and photonic instruments, and detector systems.

Furthermore, 65% of suppliers noted improvements in their products or services directly resulting from engagement with CERN. This was especially prominent in sectors including information technology, particle and photon detectors, and transport and handling equipment.

"Through our collaboration, we were given the opportunity to acquire know-how and state-of-the-art equipment". [CERN's Supplier Survey, 2025]

CERN's knowledge transfer activities (which are covered in more detail in Section 4) encompass a wide range of mechanisms that can also play a key role in spreading CERN's knowledge and expertise.

For example, **CERN openlab**, managed by the IT Department, is a public–private partnership that accelerates the development of advanced ICT solutions for the CERN community and broader scientific research. Its collaborations with leading ICT firms — such as Intel, Oracle, Siemens, Micron, NVIDIA, and Google — often generate mutual benefits. The partners work together to accelerate development of cutting-edge computing technology that is of relevance and importance to CERN (addressing its computing requirements and the needs of the research community), but also to the wider business interests of its partners (who get to demonstrate, test, develop and optimise technologies that have wider application).

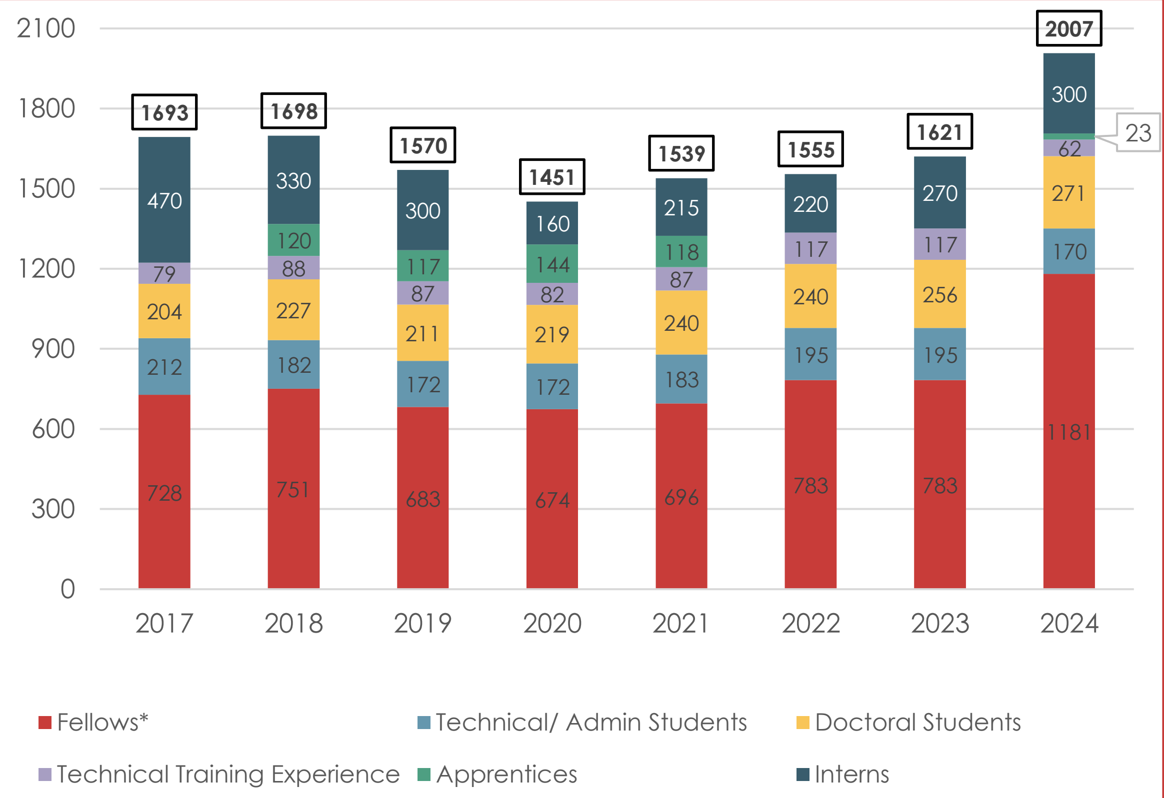
CERN openlab is entering in its 23rd year, and Phase VIII was launched in March 2024. There are 19 ongoing projects, with current areas of focus being: Sustainable infrastructures (heterogenous computing, platforms and HPC systems, computing architectures and software engineering, advanced storage, data management and networks, and infrastructures and techniques for AI) and Emerging Technologies (digital twins, and new materials for long-term digital storage). Members gain access to a unique ecosystem characterised by unparalleled computing challenges, ground-breaking scientific endeavours, and pioneering minds.

5.6 Skills Benefits via Education and Training Programmes

CERN provides a range of educational programmes with the aim of fostering interest in science and equipping participants with essential skills. The programmes include short and long academic on-site courses, online courses, internships, competitions, and research opportunities.

CERN offers **university students** a rich learning environment through academic programmes and hands-on research opportunities. Students gain technical skills as well as soft skills through exposure to international collaborations, which make them highly qualified for business and industry. The opportunities are in applied physics, engineering and computing and to train in fields at the cutting edge of technology. Between 2017 and 2024, CERN trained and supported over 13,000 university students through various programmes (Figure 20 below).

Figure 20 Students trained at CERN from 2017 onwards



CERN offers many educational opportunities for **school students and their teachers**, from primary to high school, designed to cultivate scientific curiosity and build foundational skills in STEM and other subjects. The programmes introduce participants to particle physics, research and CERN technologies or related concepts, but also foster scientific, research and other skills.

To broaden access, CERN has developed several online learning programmes for high-school students. In 2024, CERN piloted an online particle physics course that reached 3,841 high-school students, with 608 completing all modules. Students who completed the course received certificates, validating their learning and participation. This initiative aims at helping students develop conceptual understanding in a structured, self-paced format.

Students and teachers visiting CERN can participate in the short hands-on experimental sessions in its dedicated educational labs. Working in small groups of 2–4, participants manipulate authentic equipment to explore scientific phenomena connected to CERN's research and technologies. They make predictions, observe their experiments, and discuss their results. For example, between 2017 and 2022, over 22,000 students participated in lab workshops at the education lab "S'Cool Lab". Between their inauguration in October 2023 and December 2025 almost 60,000 participants joined one of the workshops at the new education labs at CERN Science Gateway. More generally, the Science Gateway welcomed half a million visitors in total within its first 16 months of being open to the public[25].

For schools unable to visit CERN, the Timepix@school initiative will bring particle physics into classrooms. Building on the Medipix collaboration, it will allow students to be part of a national collaboration of students, teachers and academics, and to analyse data obtained from

[25] https://visits.web.cern.ch/node/19015

detectors based on the ground and in space. The programme plans to source Timepix detectors and use these to support engagement with 20,000 students by 2030. This active learning approach created by Timepix@school will enable students to develop a range of skills, including research design, critical and independent thinking and the ability to analyse results critically.

CERN's school-level programmes deliver more than knowledge; they are designed to inspire, motivate, and develop key competencies. A significant portion of these initiatives involve direct engagement with CERN scientists and engineers. According to findings from the broader literature, such interactions:

- Enhance students' aspirations for careers in STEM fields.
- Positively shape students' perceptions of scientists.
- Serve as strong predictors of various educational outcomes, including increased interest, curiosity, enjoyment, self-efficacy in physics, and perceived cognitive activation.

CERN's **teacher training** programmes are designed to bring teachers up-to-date with the latest developments in particle physics and related areas, and experience a dynamic, international research environment. While national programmes are held in one of the national languages of CERN Member States, they are also open to teachers from other countries who speak the same language. International teacher programmes are delivered entirely in English and are open to in-service science teachers from around the world. Since its inception, teacher training programmes have been attended by 15,508 teachers from 112 countries or territories (CERN Annual Report, 2024).

CERN also provides educational materials for teachers to use in all schools via the internet (whether they have visited or not). These materials range from presentation slides to videos and from simple word documents to interactive tours. All are aimed at allowing teachers to provide excellent classes to students, increasing their knowledge and encouraging them into science.

CERN offers an online database of educational resources that teachers can access for free. This database contains a wide variety of materials such as explainer videos, interactive lessons, hands-on activities, or multimedia content from CERN's education and outreach activities. The resources aim to support classroom teaching and student engagement with physics and related scientific topics, and they can be used whether or not teachers have visited CERN.

Education activities at CERN are also supported by a team of **physics education researchers**, who ensure the evidence-based development of educational materials and activities, as well as their empirical evaluation.

6 Science Diplomacy

6.1 Pathways to Benefits

Herwig Schopper (2009), former Director General of CERN, noted that the Organization was established with two primary objectives: advancing scientific research and fostering international unity. Regarding the latter, he emphasised two principal areas of CERN's influence: Science for Peace and The CERN Model.

Science for Peace: CERN has played a significant role in enhancing mutual understanding and promoting peace among nations by facilitating collaboration between scientists from diverse countries and cultures, and by influencing broader political engagement both directly and indirectly.

- During the cold war CERN signed a contract with the Institute of High Energy Physics in the USSR, which became a model for a similar contract between the USA and the USSR, which in turn created sufficient trust for an agreement signed by the presidents Ford and Brezhnev.
- When the disarmament meeting between President Reagan and Gorbachev was prepared in 1985 the official discussions got into a bottleneck and CERN was asked if it could provide the environment for a private discussion to unlock the deadlock, and indeed an invitation to dinner at CERN, a neutral environment respecting both negotiating partners, unblocked the situation.
- For many decades (the first scientific exchanges began in 1960) the cooperation between CERN and the Joint Institute of Nuclear Research JINR at Dubna (USSR), a kind of CERN for the Warsaw Pact States, provided a unique link for scientific and personal contacts between West and East (the only possibility for contacts between the two Germanys).
- Scientists from the Peoples Republic of China and Taiwan worked together for the first time in international collaborations at CERN, particularly in the later stages of LEP (1990's).

The CERN Model: The Organization has pioneered a distinctive approach to global cooperation, offering a paradigm that may inform solutions to international challenges.

Schopper (2009) suggests that "at CERN a new style of global cooperation has been developed, partly voluntarily, partly pushed by necessity". It explains the gradual evolution from small group experiments financed by CERN, through to the establishment of large scale experiments running as independent international organisations and requiring new management structures and principles. These experiments have no legal entity, all partners are 'equal' and objectives are defined bottom-up, yet these are world-wide projects, with hundreds or thousands of participants, costing hundreds of millions of Euros.

The paper concludes that "the CERN model, exemplified by LHC and its experiments, may provide a new paradigm for future large projects to be realised on a global level, perhaps even for industrial or other international projects", and that "in a world where the complexity of global actions increases continuously, the exploration of new ways of managing new challenges has a considerable social value independent of CERN's scientific success."

CERN maintains a constitutionally-defined commitment to openness and provides an impartial environment for worldwide collaboration. It serves as a key platform for international dialogue, leadership, and strategic direction, actively promoting research and establishing partnerships with countries across the world, thereby encouraging cooperation among scientists and policymakers.

6.2 Key Findings

The 1954 Convention establishing CERN set forth its mission to organise and sponsor international cooperation in research, foster contacts among scientists, and facilitate exchanges with other laboratories and institutes. Consequently, CERN was founded with a dual mandate: to advance scientific excellence and to promote unity among nations.

Although international diplomacy is not expressly within CERN's mandate, the Organization consistently practices openness and transparency in all its undertakings. Successive Directors-General and numerous scientists have demonstrated a strong commitment to broader international collaboration.

In recognition of its significant contributions to bringing nations together through science, CERN was granted **observer status at the UN General Assembly** in December 2012. Both CERN and the United Nations actively disseminate knowledge in science and technology through open science policies, particularly to support development initiatives. Through its collaborative projects, which unite scientists from across the globe, CERN facilitates inter-nation dialogue and serves as an exemplary model for international cooperation.

CERN was established as one of Europe's earliest collaborative ventures, originally founded by 12 member states. At present, it comprises 25 Member States, 10 associate members, and 4 observers, in addition to international cooperation agreements with 46 countries and scientific collaborations extending to a further 21 nations.

Over the years, CERN has built bridges between peoples in many ways. Smith (2017) lists a series of points where CERN has been instrumental. For example:

- It was the first intergovernmental organisation that Germany joined after the war; the first post-war meetings between German and Israeli scientists took place at CERN.
- During the Cold War, the scientific collaboration between CERN and Russian institutes provided a model for later USA-Russia collaboration.
- In the 1970s, scientific contacts between Europe and China were pioneered at DESY and later at CERN, in collaborations led by Nobel Laureate Sam Ting (MIT), with the backing of Deng Xiaoping.
- In 1985, when USSR-USA arms negotiations in Geneva were stalled, the US delegation asked the DG of CERN to arrange a dinner at CERN for Russian and US advisors, which facilitated a breakthrough.
- CERN had an open-door policy for Eastern European scientists during the cold war, allowing them to quickly join CERN (an expression of their European identity) following the fall of the Berlin wall.

More recently (2024-2026), CERN has hosted the pilot phase of the Open Quantum Institute, a multilateral governance initiative that promotes global and inclusive access to quantum computing and the development of applications for the benefit of humanity. As a novel science diplomacy instrument, it offers a neutral platform for international collaboration between research, diplomacy, private sector and philanthropy stakeholders.

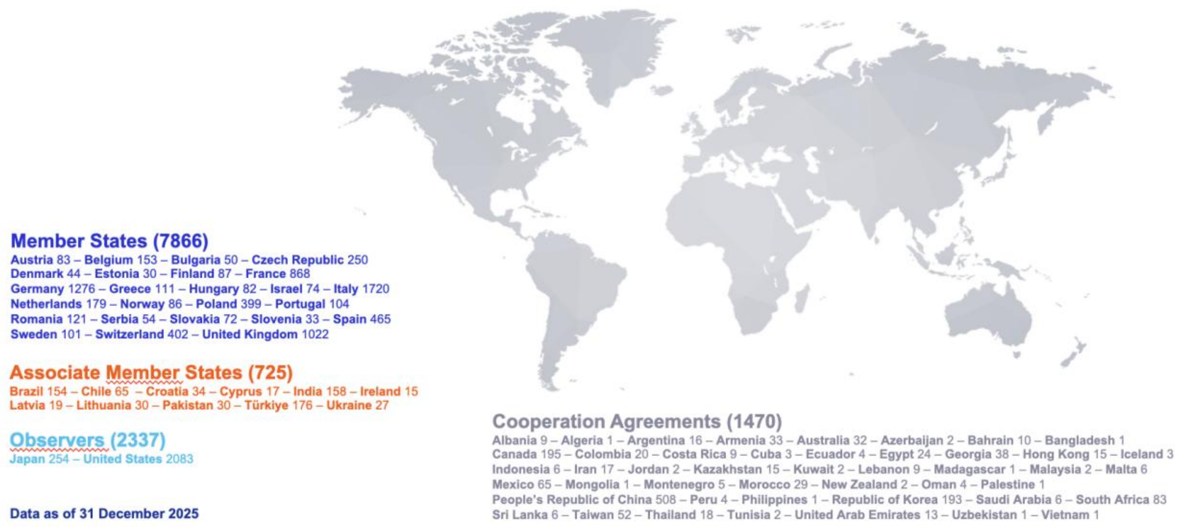
The Organization is also serving as a blueprint for others. The case study in Section 6.3 already mentioned that the convention and organisational design of the European Space Agency (ESA) mirrored CERN's constitution, commitment to civil science, and integration of facilities and science. In recent years there have also been calls for a "CERN for AI", a pan-European initiative that would create a distributed network of AI research centers, with a central hub serving as a focal point for collaboration, innovation, and ethical AI development.

CERN **supports a substantial and continually expanding community** that includes employed staff, trainees, students, and an extensive network of external users. In 2024, the combined number of staff and active users approached 18,000 individuals.

Scientific users at CERN, encompassing researchers, students, technicians, and engineers, are affiliated with 950 institutions across more than 80 countries (see Figure 21) and collectively represent over 100 nationalities.

Also, the bibliometric analysis conducted for this study (presented in Section 4) examined collaborations in publications produced at or by CERN in the period 1989–2024. **Overall, it estimates that these CERN Publications involved 4,654 distinct institutions from 128 countries worldwide**, with a notable predominance of European countries.

Figure 21 Distribution of all CERN users by location of home institute, December 2025[26]



[26] Most updated statistics available as of March 2026.

6.3 Case Studies

The following case uses the example of ESA to demonstrate CERN's role in international science diplomacy and collaboration

CERN inspired the creation & establishment of ESA in two main ways:

- **Advocating the case for the Agency**: Edoardo Amaldi (Secretary General of the provisional CERN, 1952–54), championed the creation of a (CERN-like) European collaborative effort for civil space, arguing that space exploration was beyond the capacity of individual nations.
- **Setting up the organisational footprint**: When ESA was established in 1975, its convention and organisational design mirrored CERN's constitution, commitment to civil science, and integration of facilities and science.

Over the past decade, CERN and ESA have started collaborating in a structured way in technological and scientific areas of mutual benefit.

Examples include cosmology and planetary exploration, Earth observation and spaceflight, supporting new space-tech ventures and developing electronic systems, radiation-monitoring instruments and irradiation facilities.

Additionally, ESA centres and their contractors access CERN's state-of-the-art infrastructures and technologies, to test and qualify space technologies and enhance mission implementation

Collaboration has led to exciting technological developments. Realised in partnership with the University of Montpellier, CELESTA was a successful educational project and CERN's first CubeSat, an in-space technology demonstrator used to validate the performances of the SpaceRadMon (miniaturized instrument for radiation effects on electronics developed at CERN) and the capability of CHARM facility to reproduce a radiation environment comparable to Low Earth Orbit.

In 2022, thanks to the cooperation with ESA, it was launched in an ideal orbit to demonstrate the potential of CERN's radiation monitoring technologies for space sustainability. More than 30 students contributed to the mission development (platform and payload).

Example of CERN-ESA collaboration

CERN has been collaborating with the Euclid Consortium (a network of more than 200 institutes in charge of the payload) in the development of ESA's Euclid mission since 2015 (contributing to conceptual development of the ground segment, preparatory work / testing, data processing and scientific research).

- Access to CERN's software tools and expertise: CERN's virtual-machine file system (VM-FS) is integrated into Euclid's ground computing infrastructure and is essential for processing the vast data Euclid is collecting.
- Contributions to fundamental research: Cosmologists at CERN are developing theoretical frameworks to predict galaxy density fluctuations, which will be compared with Euclid's data to test beyond-standard-model theories.
- Access to CERN data processing expertise: CERN helped develop Euclid's data processing pipeline, which will produce calibrated images and catalogues for scientific analysis.

The Euclid telescope was launched in 2023 and began observations in 2024. It is designed to explore and map the composition and evolution of the dark Universe. The first piece of the map was released in 2024, showing millions of stars and galaxies.

With tens of petabytes expected in its final data set, it will generate more data than any other ESA mission.

Appendix A **Summary of the existing literature**

A.1. Research and Knowledge Flows

Existing literature on CERN's research benefits typically concentrates on describing the type of knowledge produced and the way it propagates in the scientific and professional communities. It does so through the analysis of publications, citations, and collaborations, and it is often restricted to specific experiments (e.g., the LHC), time periods, or countries (e.g., the UK).

- Six studies have specifically addressed this topic, pursuing diverse objectives: describing publication trends and tracking research building on CERN outputs (Carrazza, Ferrara & Salini, 2016); assessing national benefits (Brown et al., 2020); projecting the socio-economic benefits of future infrastructures (CERN, 2025); estimating the monetary value of publications (Giffoni et al., 2025); and exploring collaborative dimensions, such as international researcher linkages (Krause et al., 2007).
- Collectively, these studies suggest that research done at CERN generates substantial scientific and socio-economic returns, both directly through publications and indirectly via wider spillovers.
- Some studies have examined CERN's provision of datasets and the changes in research practices enabled by open science, but generally only at a preliminary or narrow scope, focusing on data volume (5 publications) or academic reuse (6 publications), typically for specific experiments or runs. As a result, these pathways remain understudied, despite their central role in the CERN research model.
- Existing reports document the scale of CERN's open-data initiatives, which now encompass multiple experiments, including CMS, ATLAS, ALICE and LHCb (Lassil-Perini et al., 2021; Albornoz & Isabel, 2024; Basaglia et al., 2023).
- Beyond data volume, there is evidence of substantial academic reuse, with numerous peer-reviewed studies and case studies demonstrating rapid uptake and citation of these datasets (Larkoski et al., 2017; Komiske et al., 2019; De Lellis et al., 2020; Agafonova et al., 2021).

A.2. Suppliers and Innovation

Existing literature highlights the significant benefits of CERN's procurement activities among its suppliers, including:

- **Learning and skill growth.** Amaldi 2012, Autio et al., 2003; Nielsen and Anelli, 2016 showed that companies working with CERN often gain new skills and improve their internal knowledge through hands-on experience and close collaboration.
- **Innovation boost:** Using different approaches and data, Florio et al., 2018; Castelnovo et al., 2018; Bastianin and Castelnovo, 2022, Bastianin et al., 2025 found that **CERN suppliers (especially high-tech)** developed new products, increased their **R&D investment**, and sometimes generated **patents** following CERN collaboration.
- **Productivity and market benefits:** Autio et al., 2003; Florio et al., 2018; and Castelnovo et al., 2018 demonstrated that by fostering innovation, CERN procurement improves firms' **productivity, competitiveness, and profitability**, while prestigious references help **attract new clients and enter international market.**

- **Supply chains and wider ecosystem effects:** Knowledge and technology spread beyond direct suppliers, strengthening local industries, regional innovation, and cross-sector benefits (Sirtori et al., 2019).

A.3. Technology Development and Innovation

CERN Knowledge transfer activities were documented in Nilsen and Anelli (2016) which provides a useful overview of the different modes CERN uses and provides examples and evidence from different studies on the benefits being created, including on licensing, service and consultancy agreements, open source software and hardware and spin-offs.

- On **open source software,** the paper highlights that efforts to track the dissemination and benefits of the large portfolio at CERN are very limited. However, it points to ROOT (a framework for storing and analysing data) as a good example of positive impact, as it is now used by telecom companies, in the aerospace industry, by finance institutions and by insurance companies. The paper highlights the work of Florio et al., (2015) who quantified the benefits to society of ROOT and GEANT4 (a software for simulating the passage of particles through matter) at €5.4bn. Elsewhere, Crespo et al (2023) estimated the benefit of the Zenodo open source repository at CHF 2.8 billion over 29 years, while Crespo et. al. (2024) estimated the benefit of Indico event organisation tool at CHF 3.1 billion.
- On **open hardware**, the paper again notes the significant challenges in tracking and measuring dissemination and impact. However, an overview made at the end of 2014 showed that of the eight CERN open hardware designs commercially available, more than 1200 units were produced for almost 100 different users, indicating that open hardware can lead to the creation of commercially successful products. Wareham et al (2014) examined the CERN-derived open-source hardware White Rabbit, and found that it had improved time synchronization for particle accelerators, and seen commercial adoption in telecommunications and financial services.
- On **spin-offs**, the paper found that very few companies had so far been actively spun-off from CERN, but that significant efforts had been put in place more recently, both internally (via policies and training) and externally (through CERN business incubation centres) to facilitate process. These very recent efforts had led to a slight increase in start-up activity, although only two spin-off agreements had been established in 2014.

A.4. Skills

Various prior exercises have investigated the effect of CERN on skills:

- Brown et al. (2020) found 90%+ of **scientists & engineers reported a positive impact from involvement with CERN in all nine skills & capabilities tested**: subject knowledge, working in international environments, experimental skills, analytical skills, problem solving, communication, computing, team-working & project management.
- The same study found **formal training at CERN would have a significant market value** if obtained commercially. UK involvement alone in CERN's student, doctoral and technical programmes over a decade was valued at £4.9m.
- Bianchin et al (2019) found the **CERN experience positively impacts career trajectories**, including in diverse fields such as IT, finance & academia.
- Bruzzi and Anelli (2014) found **evidence of a continued scientific 'fertilisation effect'** from activities such as the CERN's Fellowships, which contributes to the creation of high-skilled and professionalised human resources to the benefit of industry.

- Multiple papers suggest a **wage premia (of 5–13%) for early-career researchers** who spent time at CERN, reflecting the added value of skills / capabilities gained. (Catalano et al., 2015; Camporesi et al., 2017; Catalano et al., 2018; Brown et al., 2020; Catalano et al., 2021; Delugas et al., 2025).
- Autio, et al. (2003) find evidence of **skills and learning effects among suppliers,** including enhanced technological learning (44%), market learning (36%), and improved credibility due to CERN's marketing reference.
- Other studies have focused on the benefits of CERN's school-level programme. They find that the direct engagement with CERN scientists and engineers enhance student's aspirations for careers in STEM fields (Fadigan & Hammrich, 2004; Mills & Katzman, 2015) and positively shape students' perceptions of scientists (Houseal et al., 2014; Woods-Townsend et al., 2016). Participation also serves as a strong predictor of various educational outcomes, including increased interest, curiosity, enjoyment, self-beliefs in physics, and perceived cognitive activation (Woithe et al., 2022).

A.5. Science Diplomacy

CERN itself has not conducted any formal evaluation of its role in science diplomacy, but this aspect of CERN's activities has been documented in various sources. In particular:

- Schopper (2016) notes that "CERN was founded with two tasks — promote science and bring nations together — and no way has yet been developed to assess in economic terms success for the second objective ". It goes on to highlight two additional areas of CERN's positive impact that should be considered:
  - **Science for peace:** Fostering understanding and peace between nations, by bringing scientists from different countries and cultures together, and by "irradiating in many direct and indirect ways into politics").
  - **The CERN Model:** Establishing a new style of global international cooperation which can provide a new paradigm for addressing challenges on a global level.
- Smith (2017) also reflects on how CERN has built bridges between people, highlighting examples such as being the first intergovernmental organisation that Germany joined after the war; the host for the first post-war meetings between German and Israeli scientists; a pioneer of scientific contact between Europe and China in the 1970's; and open to Eastern European scientists after the fall of the Berlin wall.
- Brown et al. (2020), focusing on the UK's involvement in CERN, concluded that it provides its members with an important platform for international engagement, leadership and agenda-setting, as well for engagement in global initiatives and international networks. CERN is highly visible and well regarded internationally, which spills over to favourable perceptions of its members and greater engagement (in science, technology and beyond).

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- Rachel Bray (International Relations Sector representative)
- Johannes Gutleber (Future Circular Collider representative)
- Chris Hartley, Giovanni Anelli (Industry, Procurement and Knowledge Transfer representative and chair, and alternate)
- Katarina Sigerud (Accelerator and Technology Sector representative)

- Manuela Cirilli (Knowledge Transfer, project coordinator)

Bibliometrics working group: Etiennette Auffray Hillemanns, Manuela Cirilli, Maria Girone, José Benito Gonzalez Lopez, Johannes Gutleber. Katarina Sigerud, Pippa Wells.

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