

03-09-2025

Deliverable GN5-2 D3.2

Compendium Report

Contractual Date:	30-09-2025
Actual Date:	03-09-2025
Grant Agreement No.:	101194278
Work Package:	WP3
Task Item:	T1
Nature of Deliverable:	R
Dissemination Level:	PU
Lead Partner:	GÉANT
Document ID:	GN5-2-25-2F40E7
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Abstract

The Compendium Report provides a summary of the key developments and emerging trends in European R&E in 2024, identified by the NREN Compendium survey. It is to be read in conjunction with the online version of the Compendium (compendium.geant.org/data) that offers a dataset with which NRENs can explore trends, inform and shape their strategic decisions and understand the status of the collective R&E community, as well as of each individual NREN.

COMPENDIUM OF NATIONAL RESEARCH AND EDUCATION NETWORKS IN EUROPE 2024



Abstract

The GÉANT Compendium provides an authoritative reference source for anyone with an interest in the development of research and education networking in Europe and beyond. Published since 2001, the Compendium provides information on core areas such as NREN budget, staffing, end users, services, and network traffic.



This Report covers key developments in the period January to December 2024 and should be viewed in conjunction with the new GÉANT NREN Compendium website at: www.compendium.geant.org/data.

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ISSN 1569-447X

© GÉANT Association on behalf of the GN5-2 project. The research leading to these results has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement No. 101194278 (GN5-2).

Co-funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. The European Union cannot be held responsible for them.



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COMPENDIUM OF NATIONAL RESEARCH AND EDUCATION NETWORKS IN EUROPE

2024 edition

www.compendium.geant.org



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Introduction

— Jennifer Ross, János Mohácsi, Hank Nussbacher, Daniela Brauner
GÉANT Compendium Advisory Board

Research and Education Networks (RENs) are specialist internet service providers that run communication networks dedicated to supporting the needs of the scientific and academic community. On the scale of countries, they are called National Research and Education Networks (NRENs).

43 European NRENs and RENs are interconnected by the pan-European GÉANT network, the largest and most advanced research and education (R&E) network in the world.

The GÉANT Compendium of National Research and Education Networks in Europe, or simply, the Compendium, is the result of a broad, collective effort based on data from the annual NREN Compendium survey, which has invited Europe’s NRENs to provide detailed information about their network, equipment and users since the year 2000.

The Compendium offers a comprehensive examination of these networks supporting the R&E community in Europe, giving a full picture of what NRENs offer to meet their users’ requirements, the resources they have at their disposal, and the way they are organised.

The most recent survey was open from October to December 2024, and asked respondents about the calendar year 2024¹. The results of the survey were then carefully checked and published in full on the [Compendium website](#)² in February 2025, with every NREN response to every question made available.



This newly improved online version of the Compendium allows users to dig into the data at will, create and download graphs, and explore trends in the European R&E community. It is a dataset with which NRENs can inform and shape their strategic decisions and offers the means to understand the status of the collective as a whole, as well as of each individual NREN.

This year, thanks to the completion of the Compendium data website, the Compendium Report is no longer the primary method of disseminating the survey responses, and in turn, we’ve taken a new and innovative approach to the Compendium Report. This new Report is intended to be a compact, engaging look at the key developments of 2024.

1. Though for a small number of network questions, NRENs were asked to fill in data from the 12 months preceding them completing in the survey.
2. compendium.geant.org/data

THE FINE PRINT

The diversity and complexity of the NREN community, coupled with the voluntary nature of the Compendium, can make comparisons challenging, especially across years. While response rates are very high with 40 out of a possible 43 NRENs responding to the 2024 survey, there are sometimes single-year or multi-year gaps where an NREN did not take part. NRENs are also at liberty to not answer certain questions, so some do not give their budget, for instance, as they deem it commercially sensitive information.

On a more existential level, the question of “what defines an NREN?” must be considered when analysing the Compendium responses and drawing conclusions about the community. As website visitors are reminded, NRENs are free to decide how they define the part of their organisation dedicated to core NREN business when reporting on their budget. Some NRENs focus (or have done so in the past) solely on the operation of the research and education network, while others take a more holistic view, considering the full offering of products, services and support for users as “the NREN”.

The merging of different parts of a large NREN into a single organisation with a single budget can also lead to significant changes between years, as can receiving funding for specific time-bound projects. While not all NRENs have these grey areas to consider, it is a reminder that context should be fully understood before drawing quick conclusions, especially based on a single question.

The Compendium is a community-led resource, created by the NREN community, so this 2024 Report presents spotlights on various European NRENs, allowing the R&E community to tell its own stories and explain emerging trends and notable shifts uncovered by the Compendium survey. NRENs and expert authors were invited to take part based on the analysis of the 2024 data: in some instances, because they were representative of a trend; in others because they were pathfinders, doing something new or innovative.

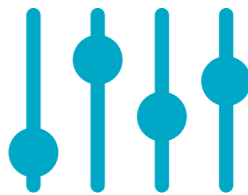
The aim of the Compendium is to deliver insights into the world of GÉANT NRENs; every NREN is unique, with differences in national role and remit, ownership and management, history and culture. It is simultaneously a depiction of the diversity of the NRENs and a reminder that, despite their variations and particularities, the European NRENs are built around delivery of the same interlinked core services. The Compendium website allows for granular insights into individual NRENs; this Report seeks to enlighten through presenting the community as a whole, with spotlights to elucidate key developments and provide context. We hope that this new format is an illuminating development in the evolution of the Compendium.

Even more than ever, this Compendium Report has been made possible thanks to the efforts of the GÉANT community. From CEOs to network engineers, from technical officers to marcomms professionals, the Compendium team extends a big thank you to everyone who took the time to complete the survey and provide their views. A special extra thanks to the writers of our spotlights: the true authors of the GÉANT Compendium Report 2024.

Compendium Advisory Board

The GÉANT Compendium Advisory Board meets regularly to discuss the development and evolution of the Compendium to ensure that it remains relevant and reflects the needs of the community. Chaired by GÉANT sub-task lead on Insights, and member of the Partner Relations team, Jennifer Ross, the two NREN representatives János Mohácsi (Head of International Research and Development, Pro-M/NIIF, Hungary) and Hank Nussbacher (Director of Network, IUCC, Israel) bring a wealth of experience gathered through decades working in the NREN community. GÉANT data specialist Daniela Brauner joined the Board in 2025 to carry out analysis of the collected data and bring her expertise to further improve the quality of data in the future.

The Compendium Advisory Board attempts to strike a balance between consistency (allowing a long-term view of the evolution of the community) and responsiveness (to capture new and emerging trends) when refining the annual Compendium survey. There is a strong desire to ensure that NRENs can make use of the data collected to better know their peers, to learn from one another, and to strengthen mutual understanding within the community. Readers of this report are warmly encouraged to share their feedback and suggestions with the Board, either by reaching out to individuals, or via GÉANT Partner Relations.



1. Organisation

Introduction

The Organisation section opens the Compendium survey, and thus appropriately, this report. It seeks to set out what kind of organisations GÉANT member NRENs are. The budget, income and billing questions help us to understand how large a budget they have, the sources of this funding, and the way they charge their users (if at all) for the services they provide.



The staff and projects questions look at the staffing rates, and where the NRENs sit vis-à-vis both the parent organisations they belong to and the sub-organisations, like CERT teams or HPC centres.

There has been growth across the NREN community, especially since the COVID pandemic; however, this has not been uniform. Some NRENs have experienced cuts to their budgets, and some increases in budgets reflect increasing responsibilities and projects, not always supported by additional headcount.

This chapter has spotlights reminding readers to look at the wider context of EU funding, rather than reading too much into total budget figures – both the impact of the COVID-19 financial recovery package on NREN budgets, and how over a decade of EU membership and support has allowed one NREN to develop.

There are two very different perspectives on the growth in the proportion of subcontracted to permanent staff members of NRENs. Finally, 2024 was an exciting year both for EOSC, maturing from project-based planning to service delivery, and for EuroHPC.



1.1 Budget - Overall

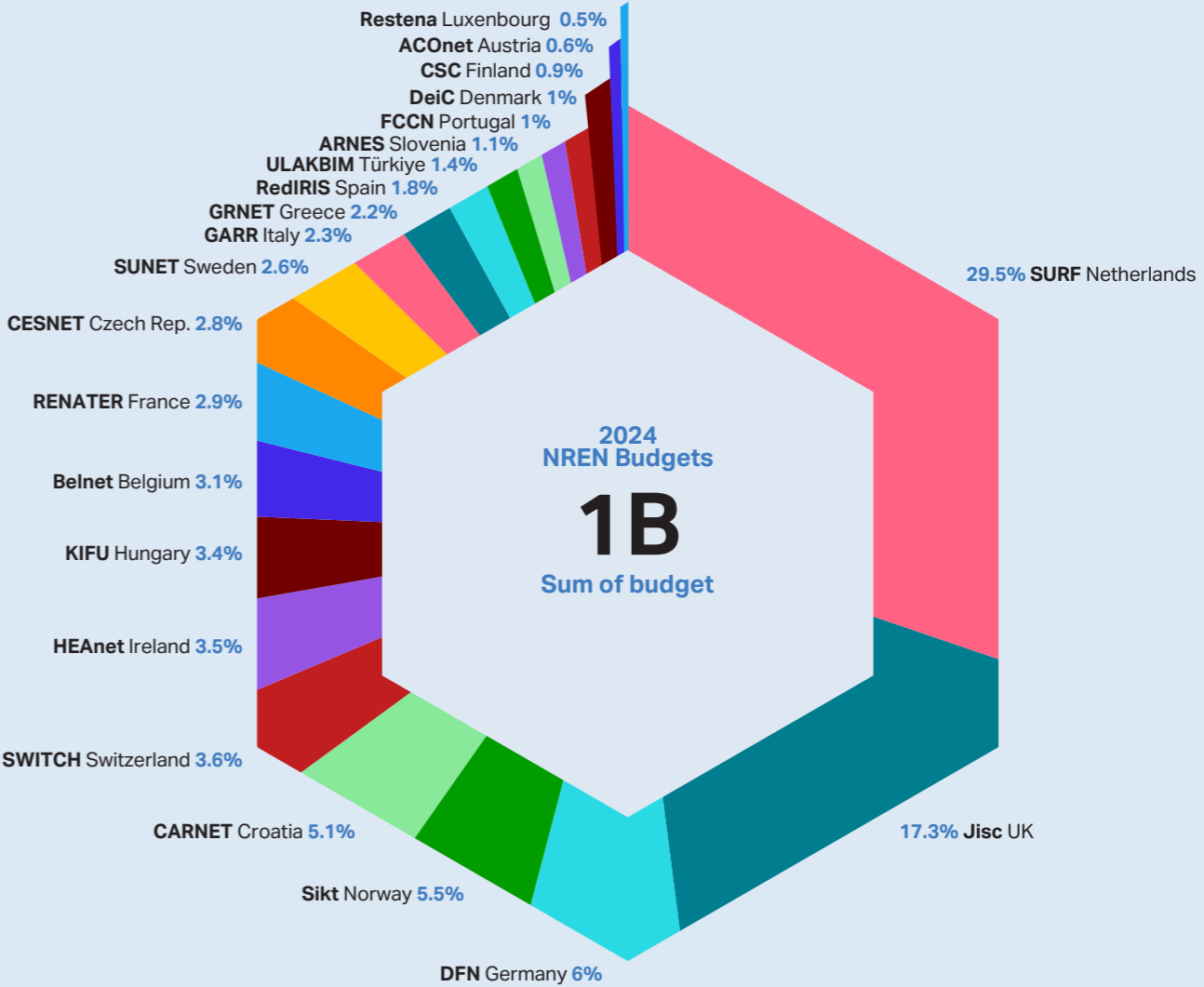
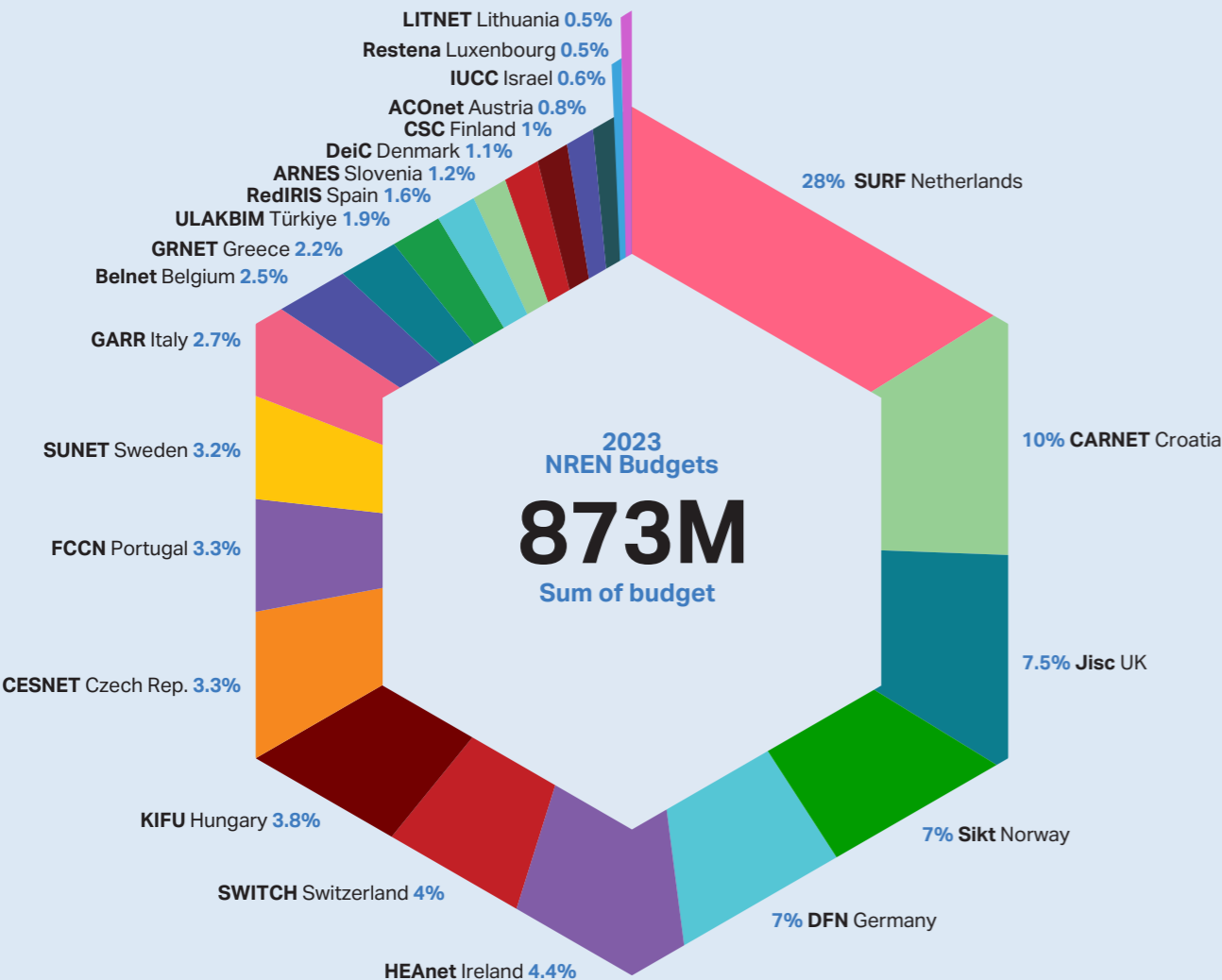


FIGURE 1.1
Please note that we have changed the way we report NREN budgets compared with previous Compendium Reports. This difference in approach may mean that the graphs in this Report are not comparable with previous reports.

Budgets Introduction

For 2024, the combined reported budget across the NREN community is around EUR1 billion, showing general growth and reflecting the increasing importance of digital infrastructure in research and education. However, this figure should be viewed as a conservative estimate.

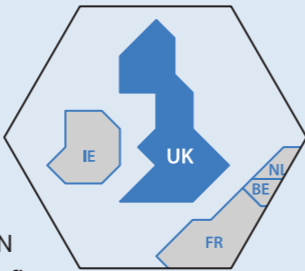


Not all NRENs disclose their full financial picture-some keep budget details internal, and others report only on specific operational units rather than the entire organisation. So, while EUR1 billion serves as a useful reference point, the true scale of investment is likely even higher.

The Real Story Behind Jisc's Budget Increase

— Helen Clare Jisc

Despite what the figures might appear to show, Jisc (UK) hasn't had a huge budget increase between 2023-24 - the NREN has simply changed how its figures are counted, as requested by GÉANT. Jisc has evolved over the years and incorporated many different services as it became more efficient and effective to do so, informed and guided by reviews and sector consulta-



tion. Janet was originally formed in 1984 to provide the core network service and became a subsidiary of Jisc in 2012, then merged into Jisc Services Ltd in 2015. Up until 2023, Jisc's budget figures included only the amount dedicated to providing the Janet network and R&E-related services such as trust and identity, and cybersecurity. The budget figures for 2024 cover the wide range of activities and services provided by Jisc, in addition to the network. This includes services around cloud, data analytics, libraries and learning resources, licensing and procurement, research management, student experience and advice, guidance, and consultancy. Unlike some NRENs where the network is their only service, Jisc provides many services beyond the network and its budget reflects this.

Values below 0.5% are not shown in the graphs

2023
0.0% MREN Montenegro, URAN Ukraine, RENAM Moldova;
0.1% GRENA Georgia, AzScienceNet Azerbaijan, ASNET-AM Armenia, MARnet Macedonia, RASH Albania, CYNET Cyprus, IMCS UL Latvia, EENet Estonia;
0.2% RoEduNet Romania;
0.3% SANET Slovakia, AMRES Serbia, KREN Kosovo*.

2024
0.0% BREN Bulgaria, MREN Monten., URAN Ukraine, RENAM Moldova, MARnet Macedonia, ASNET-AM Armenia;
0.1% GRENA Georgia, CYNET Cyprus, RASH Albania, EENet Estonia, IMCS UL Latvia;
0.2% KREN Kosovo*, SANET Slovakia, RoEduNet Romania; AMRES Serbia, LITNET Lithuania;
0.3% IUCC Israel.

*This designation is without prejudice to positions on status and is in line with UNSCR 1244 and the ICJ opinion on Kosovo Declaration of Independence

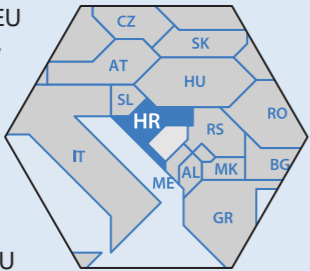
1.2 Funding

FIGURE 1.2
NREN budgets normalised to GDP and population, showing Croatia as a marked leader

CARNET's Story

— Goran Škvarč, Deputy CEO, CARNET

Croatia became the 28th EU Member State on 1 July 2013 after many years of negotiations. This accession opened the door for the Croatian Academic and Research Network – CARNET to utilise EU funds for its development. Planning started as early as 2011 in alignment with then-current and future EU and national operational programs.



One of CARNET's most successful implementations is the strategic and complex e-Schools Programme [A], which provided primary and secondary schools with materials to advance the use of digital technology in teaching, along with support for teaching staff to strengthen their digital professional skills. With the support of three key ministries of the Croatian government, CARNET ensured that each phase of this project was adapted to the challenges faced by the education system and the specific needs of Croatia.

Spanning nine years (2014–2023) with a total value of almost EUR220 million, the e-Schools programme saw

classrooms equipped with digital technologies and created over 70,000 digitally competent teachers able to integrate innovations into their pedagogical practices. Around 85,000 laptops were distributed to public-school teachers and more than 2,400 schools gained high-speed internet access. The programme contributed to boosting the performance of the primary and secondary education systems, preparing students for further education and lifelong learning.

In pursuit of an inclusive and digitally advanced education landscape, CARNET continues to lead the way with transformative projects such as e-Universities [B], BrAIIn [C], and Croatian Quantum Communication Infrastructure (CroQCI) [D].

Building on the success of e-Schools, CARNET's EUR84-million e-Universities project plays a pivotal role in the digital transformation of higher education in Croatia. The project aims to improve digital teaching infrastructure, introduce advanced teaching tools, and enhance academics' digital competencies. e-Universities seeks to foster flexibility and innovation within public higher-education institutions through investments in network infrastructure, cybersecurity, and educational support.

The Application of Artificial Intelligence-Based Digital Technologies in Education – BrAIIn project includes the development of a new curriculum on digital technologies and artificial intelligence for 7th- and 8th-grade primary-

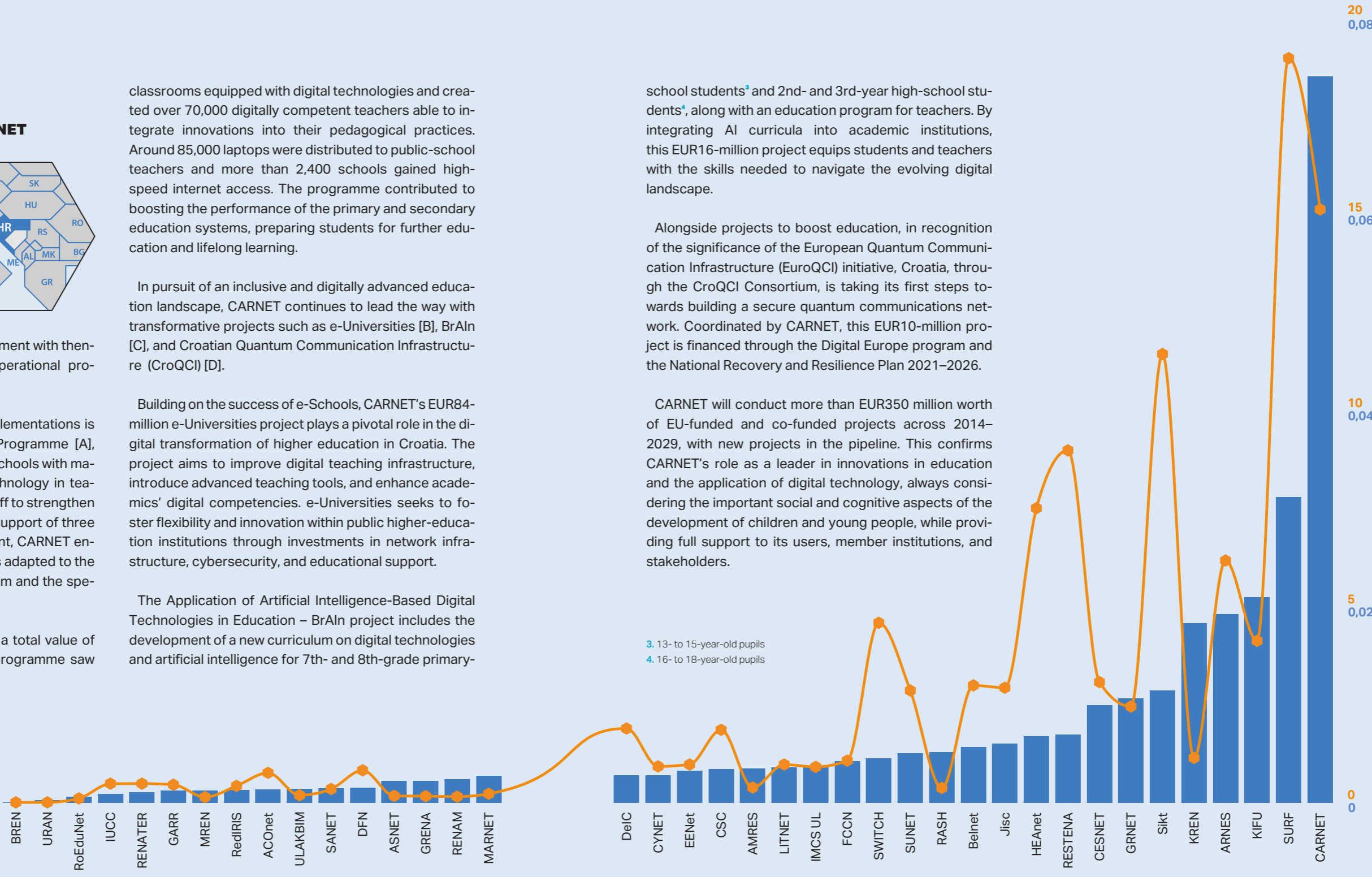
school students³ and 2nd- and 3rd-year high-school students⁴, along with an education program for teachers. By integrating AI curricula into academic institutions, this EUR16-million project equips students and teachers with the skills needed to navigate the evolving digital landscape.

Alongside projects to boost education, in recognition of the significance of the European Quantum Communication Infrastructure (EuroQCI) initiative, Croatia, through the CroQCI Consortium, is taking its first steps towards building a secure quantum communications network. Coordinated by CARNET, this EUR10-million project is financed through the Digital Europe program and the National Recovery and Resilience Plan 2021–2026.

CARNET will conduct more than EUR350 million worth of EU-funded and co-funded projects across 2014–2029, with new projects in the pipeline. This confirms CARNET's role as a leader in innovations in education and the application of digital technology, always considering the important social and cognitive aspects of the development of children and young people, while providing full support to its users, member institutions, and stakeholders.

2024 NREN budget over GDP (x100)
Note: 2023 GDP used due to lack of availability of 2024 figures

2024 NREN budget per capita



NextGenerationEU Funding:
The National Perspective

— Hendrik Ike
GÉANT EU Liaison

As societies and economies struggled to cope with the impacts of the COVID-19 pandemic, a much-needed financial injection was deemed necessary. EU Member States agreed to create a financial recovery package that would support all economies, especially those hardest hit by the outbreak.

The size of the NextGenerationEU (NGEU) fund put together by the Member States is incredible – the grant portion alone is twice the size of the Marshall Plan. It effectively doubled the European budget. It was inevitable, therefore, that some of this funding would be made available to the R&E community, and now is a good time to take stock of what this meant.

20% of all NGEU funding, or one in every five euros spent, was intended for digital transformation (mostly under the Recovery and Resilience Facility and Horizon Europe supplementations). Grants and loan disbursements are the two main mechanisms by which funding is accessed. Currently, the ratio of grants to loans is about 2:1, so the majority of NGEU funding is not repayable.

Close to EUR22 billion worth of grants have been released for digital transformation, compared to EUR13 billion worth of loans. To be eligible for funds, each Member State had to draft its own national recovery plan, and so NRENs’ involvement and interaction with their own ministries and constituencies as a part of these plans varied by country.

5. ec.europa.eu/economy_finance/recovery-and-resilience-scoreboard/disbursements.html?table=finalRecipientByCountry

The reception of NGEU grants has slowed down in 2024 compared to 2022 / 2023* [E]. The reasons for this are threefold: firstly, as the acute effects of the pandemic have decreased, so has the need for emergency funds and support. Secondly, this in turn impacts the level of appetite for loan applications, which are less popular for obvious reasons.

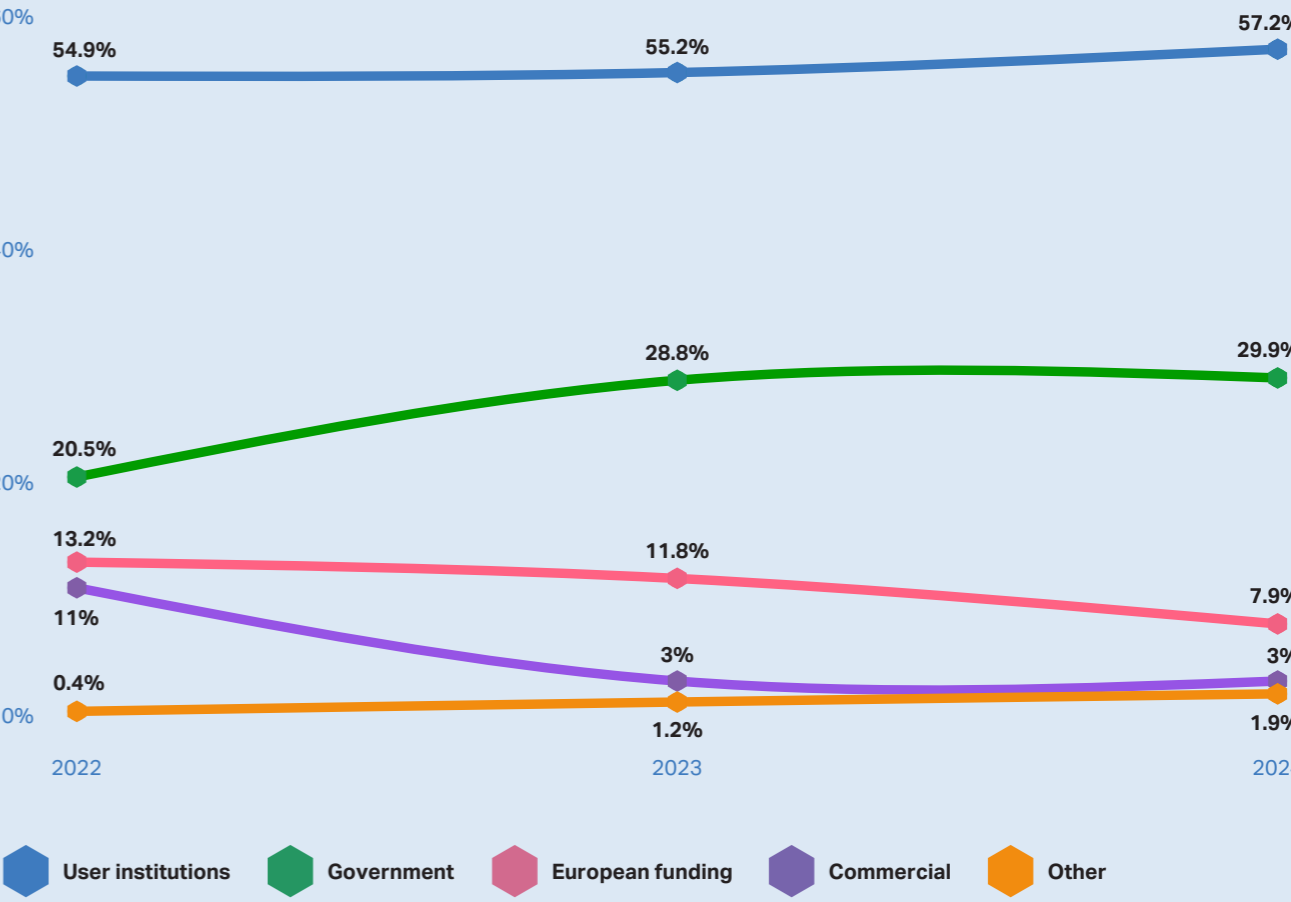


Thirdly, access to European funding is becoming scarcer at the national level – more traditional funds such

as the successor to Horizon Europe (FP10) may be merged with the upcoming competitiveness programme and no longer be ringfenced. Traditional research grants (especially at lower TRL levels) may also be under threat during the next Multiannual Financial Framework (MFF) funding period.

We will, of course, continue to look for success stories that buck these trends and prove that NRENs remain some of the most resilient actors in the digital ecosystem.

FIGURE 1.3
Changes in funding sources for the 32 NRENs that responded across all 3 years. NRENs provided total budget and percentages of income sources. This graph was calculated by applying the % informed on the total budget for each year, and then calculating the totals. In the totals, we calculated the % shares for each income source type.



1.3 Staffing

Staffing Introduction

The Compendium results show a notable increase in staffing levels across GÉANT member NRENs in 2024. A closer regional analysis, however, reveals a more complex picture: in southern European countries, such as Greece and Spain, this growth is from a marked rise in the proportion of subcontracted personnel compared to permanent employees. Here, national restrictions on the new recruitment of civil servants play a significant role.

In other regions of Europe, the increase in staffing appears to be linked to time-limited project funding that necessitates a temporary workforce expansion. To illustrate these differing drivers, spotlights are presented from RedIRIS and SURF.

FIGURE 1.4
Total staff numbers in the European NREN sector (for responding NRENs)

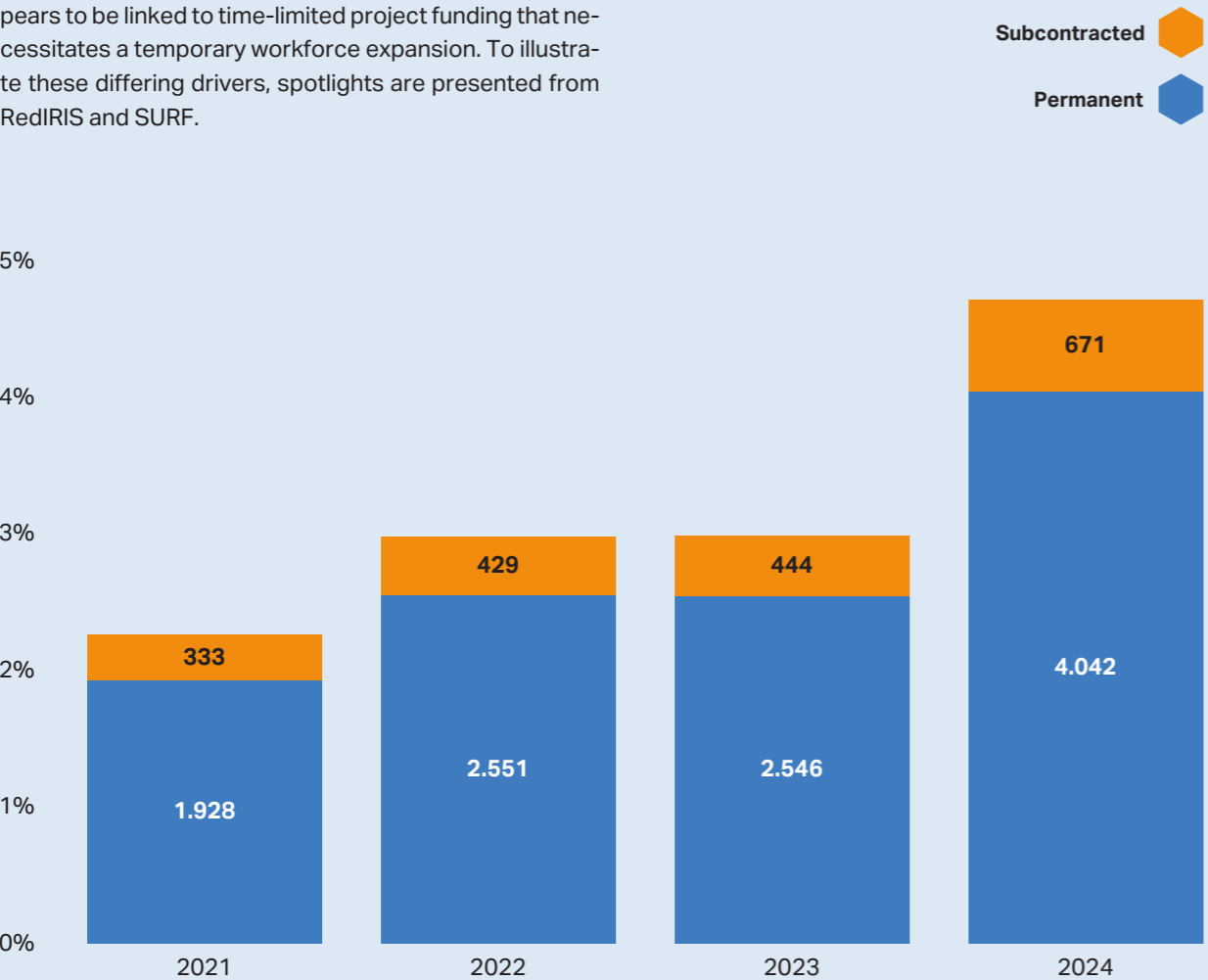
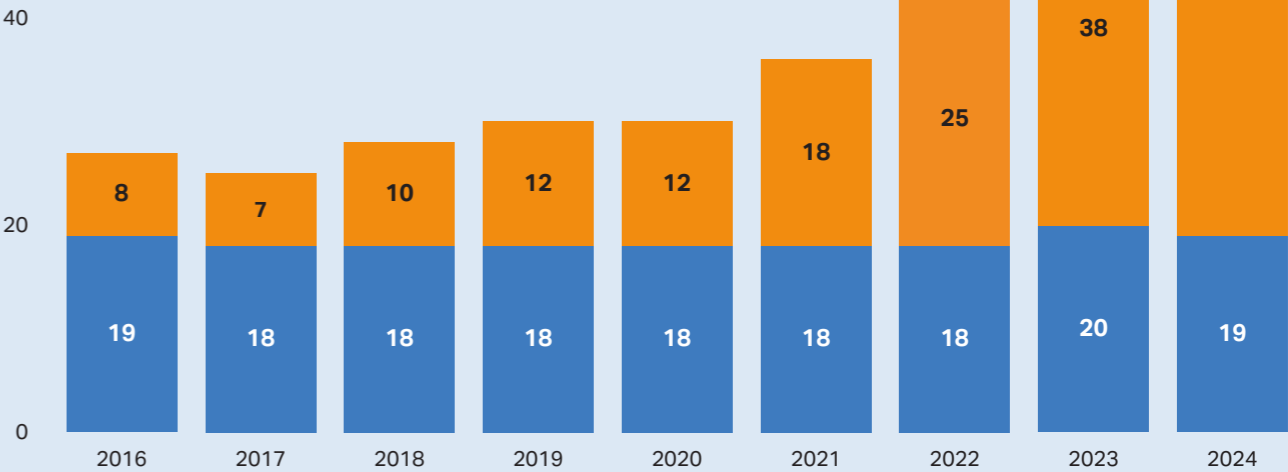
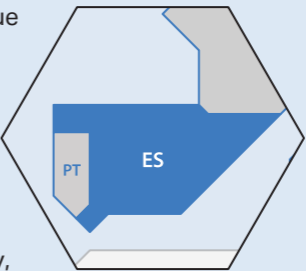


FIGURE 1.5
Full-time equivalent (FTE) count of permanent and subcontracted staff at RedIRIS, 2016–2024



Staffing and Funding Dynamics at RedIRIS

RedIRIS (Spain) is a Unique Scientific-Technical Infrastructure (ICTS) of the Ministry of Science, Innovation, and Universities, managed by Red.es, the Spanish Government's digital transformation agency, since 2004. Being part of the Spanish General State Administration has both disadvantages and advantages for RedIRIS.



The main disadvantage is that personnel hiring is governed by very inflexible rules. For many years, very few new positions have been approved for Red.es, and therefore for RedIRIS. However, RedIRIS's service portfolio has significantly expanded, as have the funds it manages, along with its obligations regarding external certifications. All these new tasks require the hiring of additional staff, ideally permanent employees. As this has not been possible, there has been an increasing reliance on "turnkey" service contracts and outsourcing of personnel.

This bolstering of resources has been crucial for adapting RedIRIS's operations to new needs, although it po-

ses significant challenges (the supervision of so many external personnel by very few permanent staff; drafting tenders for all this subcontracting; high turnover of subcontracted personnel, with the associated knowledge management issues-to name but a few).

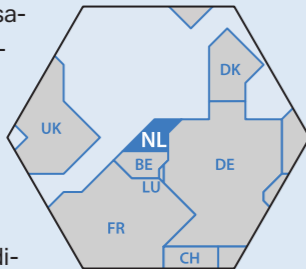
The main advantage of RedIRIS being part of the General State Administration is access to new funding sources. Since 2012, RedIRIS has received from the General State Budget about EUR8 million annually for its operational budget, which became insufficient last year and will be even more so in the future. Red.es is seeking to resolve these funding shortfalls.

However, RedIRIS has also had access to other public funds over the years, allowing it to undertake ambitious projects. Funds were secured from the national Connected Schools project and European Regional Development Fund (ERDF) to renew all of the RedIRIS network, systems and security equipment, mainly between 2021 and 2023. Also in 2021, the NREN was allocated EUR50 million from the Recovery and Resilience Facility (RRF) to extend its fibre-optic footprint and deploy new shared ICT services. RedIRIS has recently been allocated another EUR38 million from RRF funds.

SURF's Increased Staffing for Enhanced Digital Education

— Alexander van den Hil
International Policy & Strategy at SURF

The current SURF organisation (Netherlands) was formed in 2020 by merging three operating companies - SURFmarket, SURFsara, and SURFnet - with the SURF office. This integration brought together diverse cultures, processes, and areas of expertise. Today, SURF is a full-stack IT organisation serving the research and education sector in the Netherlands.



SURF continues to offer traditional NREN services, alongside acting as the national centre of expertise for high-performance computing and data storage for science. SURF also plays a key role in procuring IT-related services for its members and invests heavily in inno-

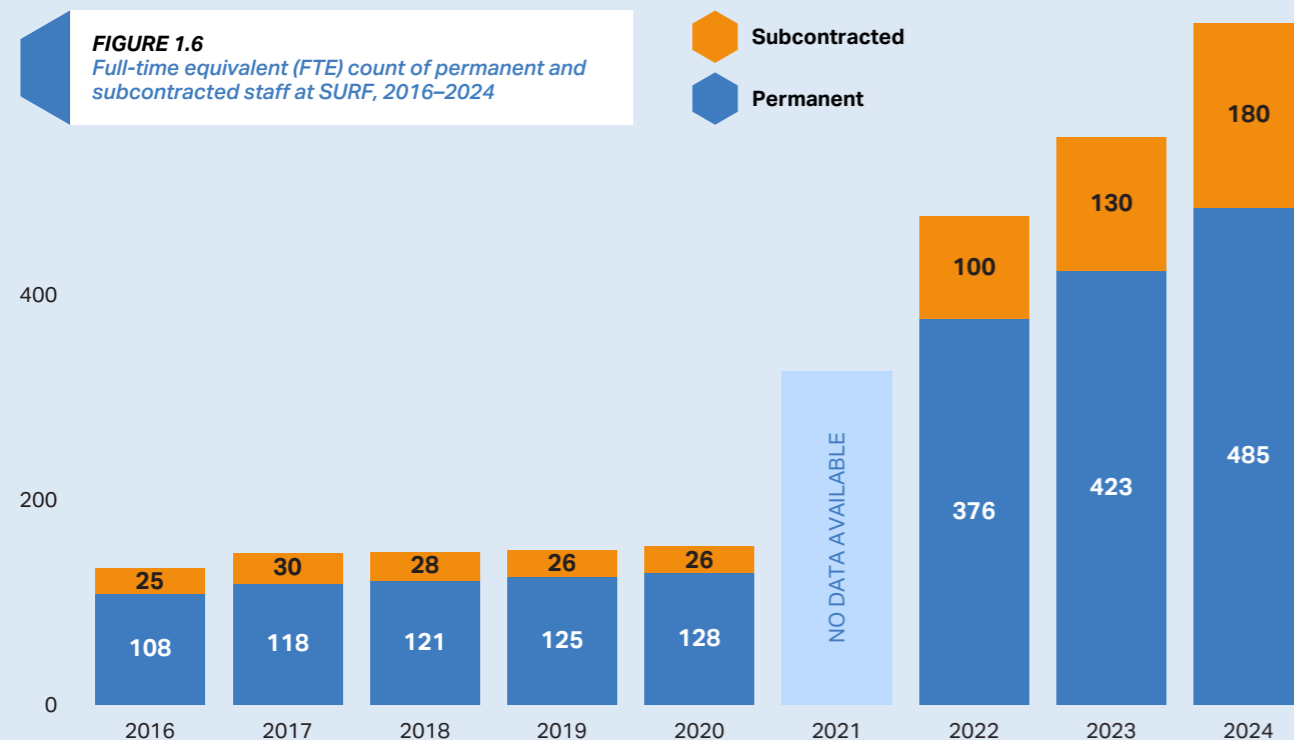
vation. This positions SURF as a valuable partner to its members and the broader Dutch educational and scientific community.

One of SURF's major initiatives, and a game changer for SURF's role in the Netherlands, is the Npuls programme for digital transformation in education. Through Npuls [E], SURF contributes to the development of a high-quality, future-proof education sector. The programme focuses on establishing sector-wide agreements and standards, enabling institutions to respond more quickly to changing educational demands.

Npuls also aims to strengthen digital literacy among learners, aligning their skills more closely with the needs of the labour market and society. The size and scope of Npuls explain some of the recent growth in staffing at the NREN, with 87 SURFers working on the initiative in 2024, alongside 66 staff from other programme members.

By building shared infrastructure, supporting digital education resources, and promoting digital sovereignty and public values, SURF helps enhance both the quality and efficiency of education. With its expertise, digital tools, (inter)national standards, and robust technological infrastructure, SURF continues to drive quality and efficiency in the Dutch education sector.

FIGURE 1.6
Full-time equivalent (FTE) count of permanent and subcontracted staff at SURF, 2016–2024



1.4 EU-Funded Projects

Forging the EOSC Federation

— Cathrin Stöver
Chief Collaboration Officer, GÉANT

2024 saw EOSC mature from project-based planning to service delivery, moving towards federated operations. Already in November 2023, the European Commission announced the winners of the public procurement tender for "Managed Services for the European Open Science Cloud Platform (EOSC)".

The tender was based on three separate but interdependent lots, all of which were supported (and even led) by a subset of Europe's NRENs and key e-infrastructures. This digital ecosystem, including GÉANT, jointly provides the EOSC Access Federation, Identity Hub and EOSC Exchange Infrastructure Proxy.

The public launch of the EOSC EU Node subsequently took place during the EOSC Symposium in Berlin in September 2024. The launch unveiled a gateway through which researchers can now:

- Discover, access and use tens of millions of scientific publications, data and software.
- Find and access services and tools from research infrastructures, technology providers, world-leading scientific clusters and more.
- Use integrated compute and storage as well as interactive collaboration tools, applications and services free at the point of use.
- Create teams and work together putting Open Science principles in practice to access a variety of tools, services, and resources designed to streamline and enhance their research efforts.

The EOSC EU Node is the first European-level node of the emerging EOSC Federation. With its mission to promote and accelerate Open Science, the EOSC Federation is envisioned as a network of interconnected auto-

nomous nodes, all operating under a common framework of standards, policies, and best practices. To this end, the EOSC Tripartite commenced the process to identify Candidate EOSC Nodes in the summer of 2024. A questionnaire was issued to gauge the overall level of interest of relevant parties in joining the EOSC Federation during this build-up phase.

The response was overwhelming, with 121 organisations expressing an initial interest. A shortlist was produced using the maturity and diversity of resources as its selection criteria, along with the inclusivity and representation of research communities. Interviews were then held with the remaining 29 applicants. By early 2025, 13 Candidate Nodes had moved forward into the build-up phase, of which 4 are members of the GÉANT Association [G].

While the establishment of the EOSC EU Node and the subsequent EOSC Federation are key milestones in the delivery of EOSC, the ecosystem also benefitted from a revamp of the EOSC Task Forces and Opportunity Area expert groups in Q2, 2024. Of the 194 volunteers who kick-started activities in mid-2024, 34 came from the GÉANT organisation itself or its direct membership, with an even representation across the four Task Forces.

The GÉANT membership is similarly well represented in the seven Opportunity Areas, which include working groups on Persistent Identifiers to Metadata, Ontologies and Interoperability, FAIR Assessment and Alignment, and Open Scholarly Communication and Research Software.

NRENs and the Future of European Supercomputing

— Annabel Grant
Senior Stakeholder Engagement Manager, **GÉANT**

The European High-Performance Computing Joint Undertaking (EuroHPC JU) is a joint initiative between the EU, European countries and private partners to develop a world-class supercomputing ecosystem in Europe.

- The EuroHPC JU is composed of public and private members. Public members include:
- The European Union (represented by the Commission).
 - Member States and Associated Countries that have chosen to become involved in the Joint Undertaking: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Latvia, Lithuania, Luxembourg, Malta, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Türkiye and the United Kingdom.

Private members include representatives from the three participating private partners, the European Technology Platform for High Performance Computing (ETP4HPC)⁶ [H], the Big Data Value Association (BDVA)⁷ [I], and the European Quantum Industry Consortium (QuIC)⁸ [J].

As a Joint Undertaking, the EuroHPC JU administers its own work plan and distributes funding accordingly. Most recently, a procurement worth EUR20 million was undertaken to federate the ecosystem (which includes a strong AAI component). GÉANT is a key partner in the winning consortium, led by CSC in Finland, to deliver this federation platform [K].

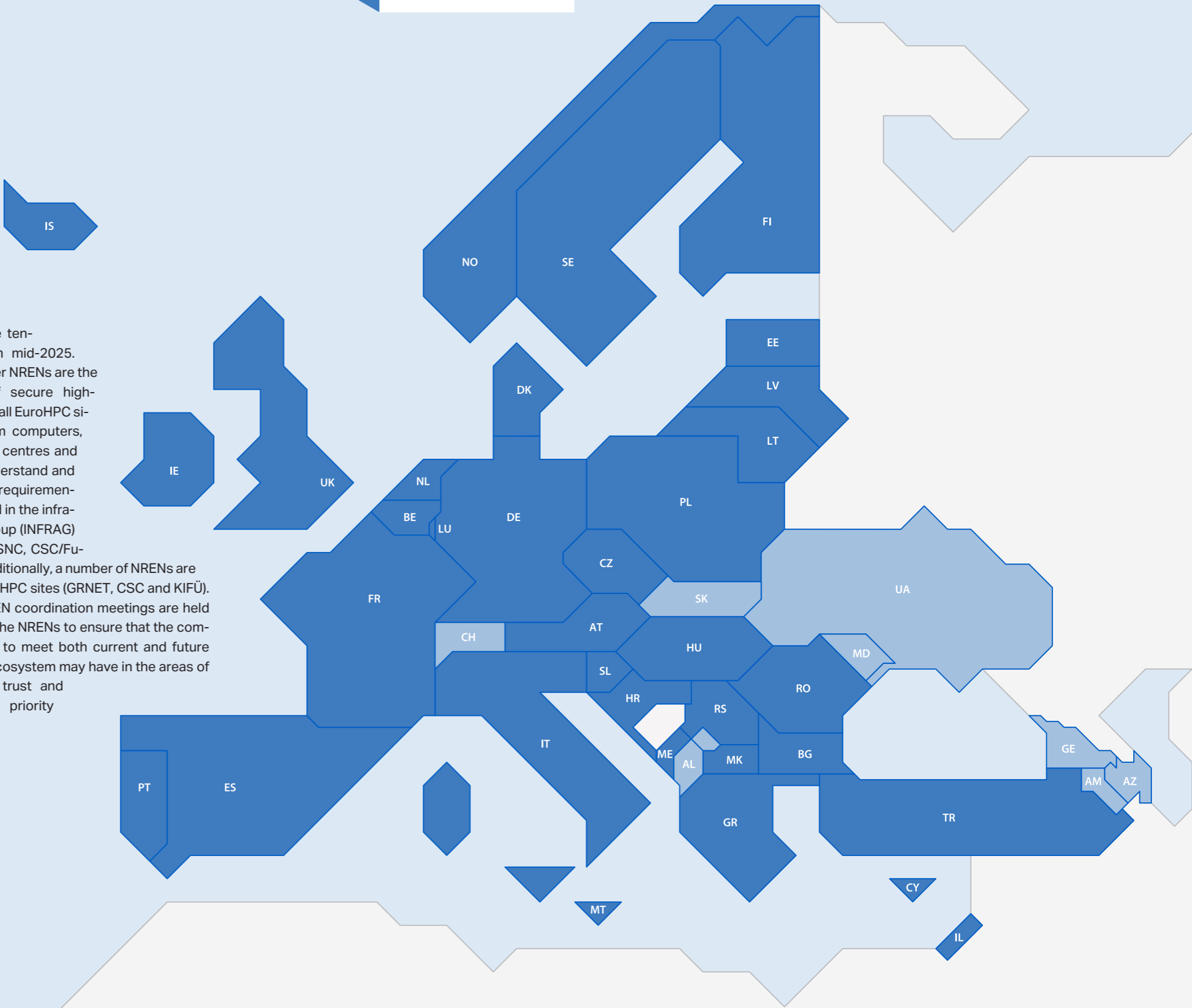
The EuroHPC JU aims to deliver the supercomputing ecosystem for Europe, which includes the objective of hyperconnectivity (terabit connectivity) across all 27 EU Member States. In December 2024, the EuroHPC JU launched an EUR60-million call to build a high-speed, secure network connecting European supercomputers and data centres, creating a hyperconnected and federated HPC and quantum computing ecosystem [L]. The aim of the tender is to create hyperconnectivity and advanced supercomputing network services delivering ultra-fast connections between EuroHPC systems, while

also linking national and regional supercomputing and data centres across Europe that are not part of the EuroHPC network.

The outcome of the tender will be known in mid-2025. GÉANT and its member NRENs are the current providers of secure high-speed connectivity to all EuroHPC sites including quantum computers, AI factories, and data centres and are well placed to understand and respond to changing requirements. NRENs are involved in the infrastructure advisory group (INFRAG) of EuroHPC (SURF, PSNC, CSC/Funet and ULAKBIM); additionally, a number of NRENs are also now running EuroHPC sites (GRNET, CSC and KIFÜ). Regular EuroHPC NREN coordination meetings are held between GÉANT and the NRENs to ensure that the community is well placed to meet both current and future needs that the HPC ecosystem may have in the areas of secure connectivity, trust and identity, and other priority areas.

6. etp4hpc.eu
7. bdva.eu
8. euroquic.org

FIGURE 1.7
NRENs that have chosen to become part of the EuroHPC Joint Undertaking



2. Standards and Policies

Standard and Policies Introduction

The Standards and Policies section is divided into two broad areas. The first, Policy & Portfolio, focuses on the policies of NRENs, both in the senses of setting out the remit and eligible membership of the NRENs, and of written policies. The second area, Standards, is a growing area in the Compendium which explores security subjects including business continuity planning, crisis management, audits and controls.

The Compendium website provides links to the most recent iterations of NREN Acceptable Use Policies, Data Protection Policies, Environmental Policies, Equal Opportunity Policies, Gender Equality Plans, and Privacy Notices. In this chapter, FCCN shines a spotlight on its efforts to put its Environmental Policy into action, Sikt writes about its two-decade history of sourcing high-quality digital tools for their users, and two articles dive into the theme of security, focusing on audits, business continuity planning, and becoming more crisis-prepared.

Championing Sustainability with Environmental Policies

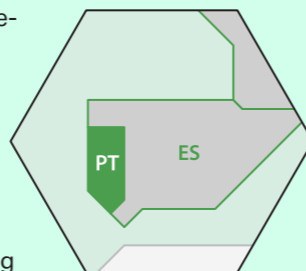
— FCCN Sustainability Team

Well known for its high levels of energy consumption, the ICT sector has a particular duty to reduce its impact on the environment, address climate change and promote sustainability. Among

NRENs, Portugal's FCCN has been actively integrating sustainable policies into its operations.

FCCN wasted no time in becoming an eco leader, establishing the FCCN +Sustainable project to gather data and create innovative environmental policies. The result was 14 policy commitments to help get the NREN into sync with both the UN's Sustainable Development Goals and ECO.AP 2030, the Portuguese government's Resource Efficiency Programme.

Having achieved a 75% reduction in environmental footprint per employee between 2016 and 2022, and compliance with over half of the ECO.AP recommendations (with many more in the works), FCCN decided to deepen its search for novel sustainability initiatives in 2024.



Enhancing Higher Education with Joint Procurement of SaaS

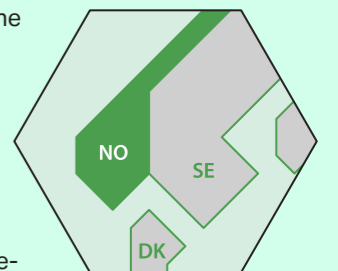
— Lars Skogan, Head of Procurement, Sikt

Sikt (Norway) facilitates the joint procurement of Software-as-a-Service (SaaS)-based solutions for Norway's higher education and research sector. Aggregating demand and securing framework agreements on behalf of institutions ensures cost efficiency, legal compliance, and access to high-quality digital tools that support education, research, and administration.

By coordinating joint procurements and streamlining the process between institutions and vendors, Sikt ensures that software solutions are secure, scalable, and aligned with sector needs. This includes compliance with the GDPR, AI Act, and other relevant regulations, as well as facilitating collaboration on integration platforms, reporting solutions, and data security.

Joint procurement began in 2003 with a framework agreement for routers and switches. This procurement model reduces the administrative burden on individual institutions while fostering collaboration, standardisation, and innovation in digital education. Institutions benefit from streamlined procurement processes and improved interoperability across different systems and services.

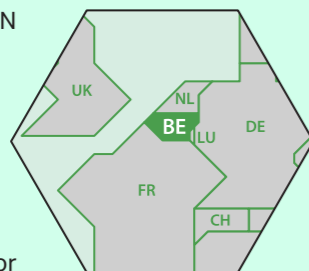
Through these efforts, Sikt strengthens Norway's digital infrastructure, ensuring that universities and colleges can focus on education and research while leveraging cost-effective, compliant, and future-proof software services.



2.1 NREN Community Becoming Increasingly Crisis-Prepared

— Davina Luyten
Communications Officer, **Belnet**

In recent years, the NREN community has made significant strides in conducting and participating in crisis exercises – an essential evolution at a time when NRENs must be more prepared than ever for crises of all kinds.



Belnet (Belgium) has been participating in the annual CLAW workshop for the GÉANT community since the very beginning. This event not only provides an opportunity to practice crisis scenarios with peers but also helps refine crisis management and communication plans. The knowledge and experience gained during CLAW have proven invaluable when dealing with real-life crises.

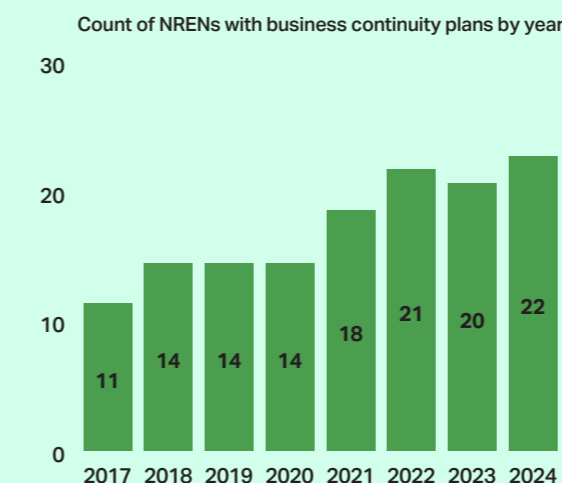
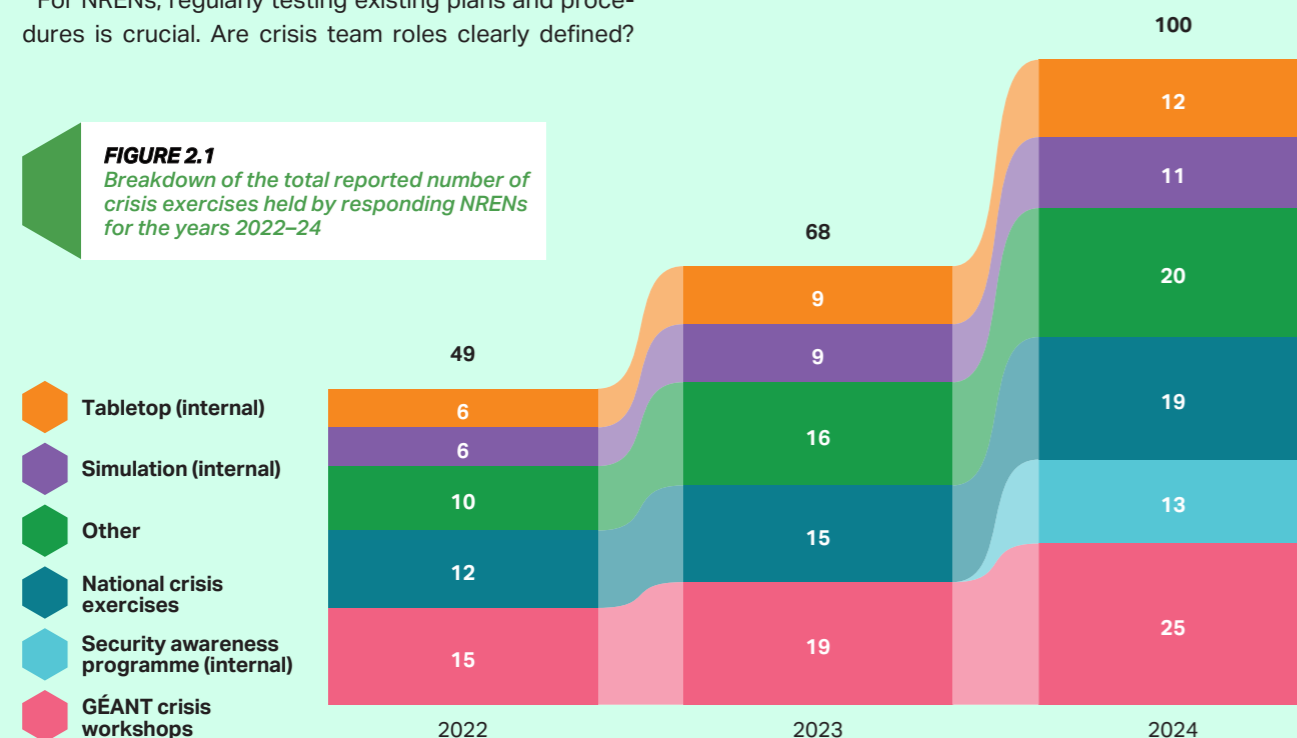
For NRENs, regularly testing existing plans and procedures is crucial. Are crisis team roles clearly defined?

How does escalation to external stakeholders work? And how do you coordinate as a team when communication channels are no longer available?

At Belnet, a tabletop exercise was conducted in 2024 simulating a ransomware attack. This provided the Belnet team with valuable insights into both best practices and areas for improvement. Based on this exercise, the NREN developed an action plan to optimise its processes.

But Belnet has taken things a step further. Within the Belgian R&E community, there was a strong demand for hands-on tools to organise (cyber) crisis exercises. In response, a pilot project was launched at the end of 2023, guiding Belgian universities in setting up and evaluating individual tabletop exercises.

Since then, Belnet has expanded this service to other segments of the Belgian R&E community. This initiative was developed in close collaboration with colleagues at SURF, who already offer a similar service—a great example of how NREN collaboration creates tangible value for our community!



Fortifying European R&E with Cyber Resilience

— Michel Gerdes, DFN-CERT, SIG-ISM Chair
& **GÉANT** Security Bootcamps

The risk of cybersecurity incidents has risen significantly over the past decade, and R&E institutions haven't escaped. NRENs provide connectivity and a range of essential services to their constituents. This relationship makes NRENs an ideal target for attackers seeking to cause damage to them and/or their constituents, especially as these attacks do not just affect the services and data operated by organisations, but also their reputations. Achieving high levels of service uptime and speedy restoration after incidents is only possible with regular training, development and improvement in cyber resilience. Two aspects stand out: first, the implementation of Information Security Management Systems (ISMSs) for continuous improvement of security maturity, and second, the development of structured procedures for effective cyber incident response.

As the [Compendium](https://compendium.geant.org/audits)⁹ results show, a growing number of NRENs within the European R&E community regularly audit their approach to information security [M]. This is a positive development as it demonstrates that management is aware of security risks and provides the resources required to mitigate them. It also highlights, for partners and constituents, that NRENs are committed to improving security over time. Most NRENs are doing so using the international standard ISO 27001, but national standards are also used.



9. compendium.geant.org/audits

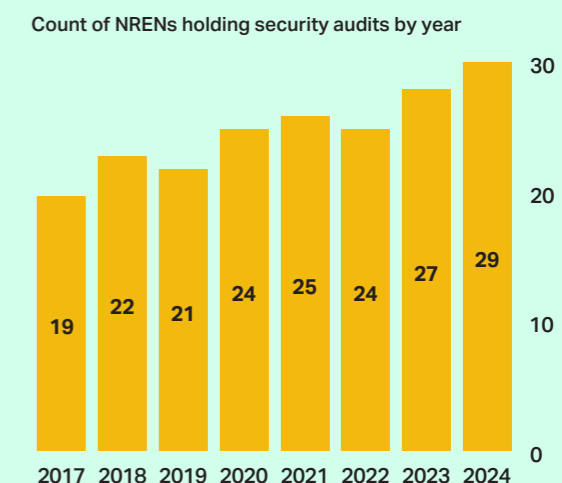


FIGURE 2.2
The growth over the years in the numbers of NRENs developing Business Continuity Plans and holding ISMS audits

Being able to react to severe security incidents in a co-ordinated manner, with plans and constraints (e.g., time, costs) defined in advance, exemplifies an organisation's commitment to continuous service delivery. The number of NRENs implementing and regularly testing their Business Continuity Plans has been slowly growing over recent years, even though only about half of the GÉANT NRENs are currently engaged in this.

Having an ISMS in place does not mean that an appropriate level of security has been implemented to protect the assets of an organisation. It shows that the organisation has a plan to improve over time. Testing Business Continuity Plans regularly shows that cyber risks are taken seriously, and that the organisation is prepared for situations that will hopefully never occur. Demonstrating a high degree of resilience in the face of security incidents ultimately improves NRENs' reputations.

Finally, while work in these areas never ceases, connecting with peers and discussing their respective security implementations facilitates knowledge sharing, leading to a more resilient community. With these ideas in mind, and to foster the adoption of the GÉANT Security Baseline among its members, GÉANT launched the Security Bootcamp training in 2024. The inaugural GÉANT Security Bootcamp took place in March 2024 with the Eastern Partnership NRENs: GRENA (Georgia), ASNET-AM (Armenia), AzScienceNet (Azerbaijan) and RENAM (Moldova). During these interactive workshops, participants gain hands-on experience with the Security Baseline, moving beyond theoretical learning to practical application.

3. Connected Users

Connected Users Introduction

The types of institutions served by NRENs, and in what capacity, is the focus of the third section of the Compendium survey. While the focus of NRENs has traditionally been on connecting universities and research institutions, differences arise regarding their connectivity remits and the percentage market share of the institutions connected. In addition, depending on the country, some NRENs connect primary and secondary schools, libraries, museums, archives, cultural institutions, public hospitals, governmental departments, international research organisations, and in some cases for-profit organisations.

This connectivity remit is especially relevant when considering the types of services an NREN is expected to provide, with, for instance, some NRENs providing centralised web content to prevent school children from encountering inappropriate content.

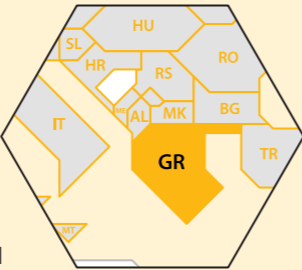
The Connected Users section also contains information on the levels of IP connectivity delivered to different categories of institution served by an NREN, as well as the average and peak loads, and even the NREN's expectations of future connectivity growth.

The NREN spotlight in this chapter focuses on the connectivity of non-university public hospitals. 21 of the 40 NRENs responding to the survey in 2024 connect at least 1 hospital. The 2024 survey revealed a large increase in the number of hospitals connected by GRNET, from 44 to 129, and a corresponding jump in market share from 40% to 90% of the non-university public hospitals in Greece. A light is also shone on the results of TF-EDU's 2024 survey on trends in educational services provided by NRENs, homing in on areas of active development.

GRNET's Advanced Networking Services Transform Greek Public Health

— GRNET

As part of a long-running operational programme on digital convergence, Greece's GRNET provides advanced networking services to support Greek research and clinical activities in medicine and biology via cloud computing.



The public health sector is no exception to this, and GRNET has collaborated for many years with the Greek Ministry of Health to integrate Greece's public hospitals into the GRNET National Academic Network.

Running from 2019–2024, the Machaon project saw GRNET and the Ministry of Health working together to extend advanced networking and cloud-computing services to 129 public health institutions across the country that had not yet benefitted. Machaon aimed to support clinical work, strengthen the research capabilities of medical staff, and improve the competitiveness of the health sector by upgrading its technological infrastructure.

The innovative digital services and infrastructures extended to public hospitals are unique in Greece, offering high-speed Internet (1–10 Gbps) over the GRNET fibre network for data storage, access and exchange, and direct ultra-fast connectivity to research centres across the world.

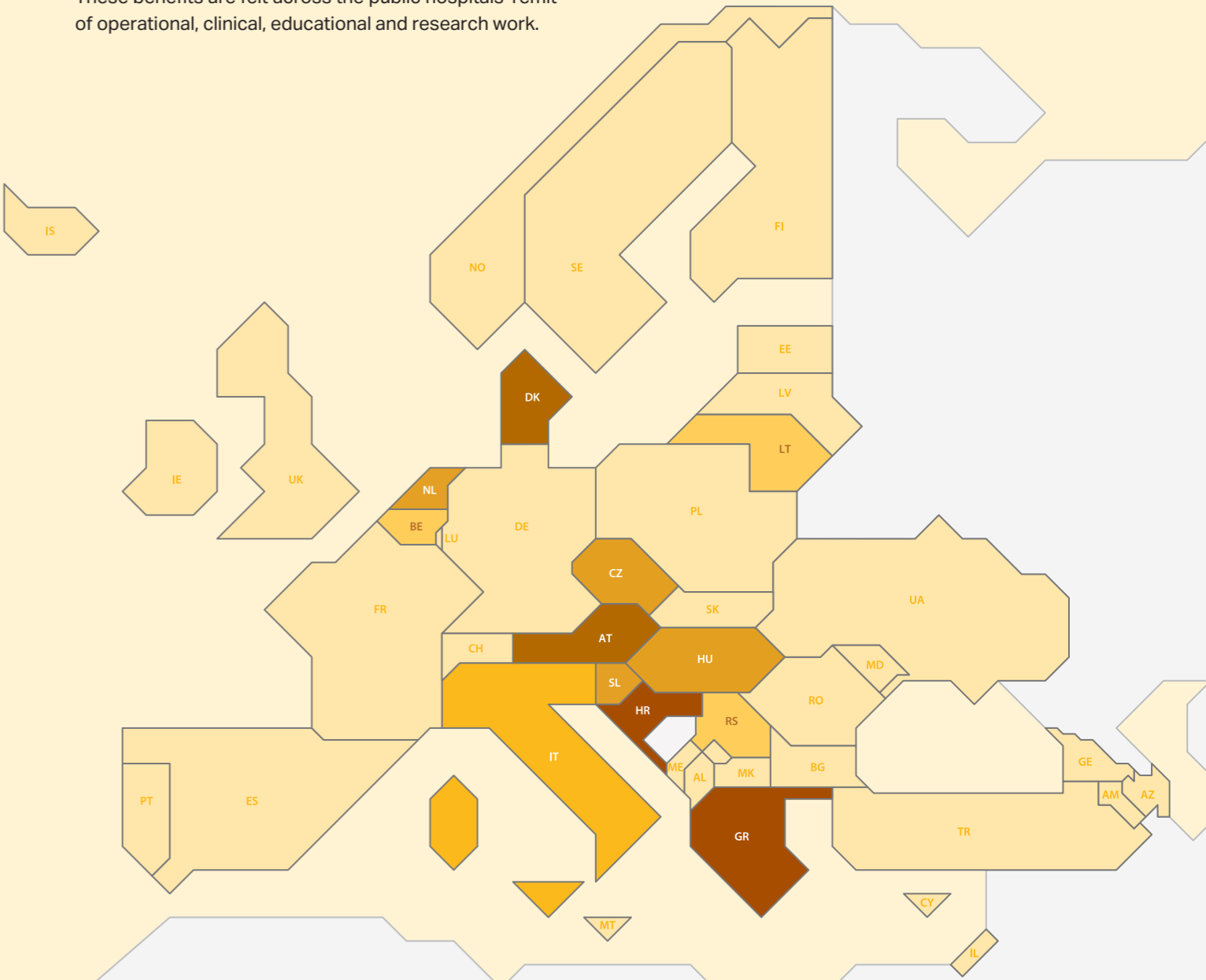
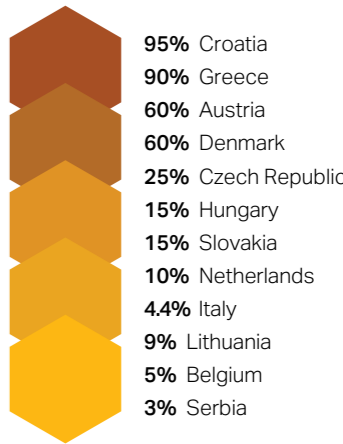
Scientific staff are empowered in their research and medical work by more than 4,500 new wireless access points on hospital premises, along with access to DIADOSIS, an inter-library loan service for medical articles.

FIGURE 3.1
Heatmap showing the percentage of hospitals connected by NRENs in responding countries

And most importantly, patient experience is significantly improved by services such as Harmoni, an archival storage and remote access facility for medical imaging data.

Interconnecting Greece's public hospitals with the GRNET network has delivered the advantages afforded to many other European countries using the same model. These benefits are felt across the public hospitals' remit of operational, clinical, educational and research work.

Percentage values displayed for each country



3.1 Spotlight

FIGURE 3.2
NRENs providing educational services
according to TF-EDU survey

NRENs Stepping Up with Digital Educational Services

— Task Force on Educational Services and Activities (**TF-EDU**),
Gyöngyi Horváth **GÉANT**, Dragana Kupres, **CARNET**

Driven by the EU's push for digitalisation, many NRENs today have expanded their remit beyond the traditional focus on connectivity and now provide digital services that support remote and hybrid learning. Since 2019, TF-EDU's annual surveys of NREN support for education have tracked this broader trend of NRENs evolving into central providers of digital education services.

Although education services are typically provided by national or regional entities (such as Ministries of Education), NRENs' educational service offerings are growing in influence and commitment. The number of NRENs offering services to support education has also been growing steadily for the last few years. While not all NRENs are equally resourced, there is a clear trend of growing involvement in educational infrastructure, calling for continued investment and collaboration within the R&E community.

Looking back at 2024, federated access and identity management took centre stage - with hybrid and remote learning now the norm, services like eduID and eduGAIN were widely in demand to keep everything secure and seamless across platforms. Learning Management Systems (LMS) such as Moodle continued to be the backbone of digital classrooms, with 27 NRENs actively offering digital learning environments and e-content.

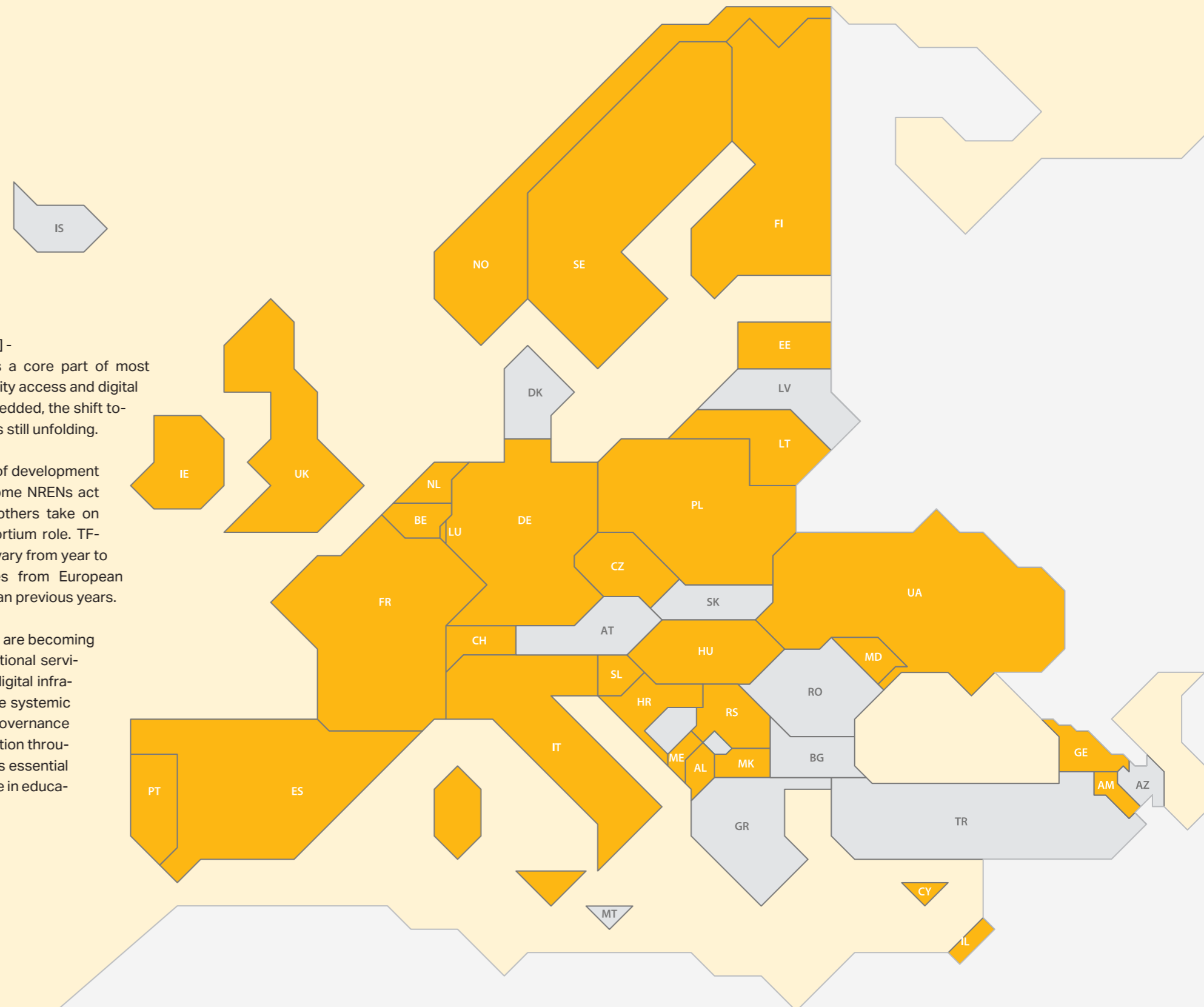
Across the board, NRENs are actively developing new tools and platforms to meet the evolving needs of the education sector. Four areas stand out: digital wallets and AI services are leading the way, each with 13 NRENs working on them. Close behind are learning analytics (12 NRENs) and open badges or digital credentialing (11 NRENs). These developments will shape how learners in-

teract with digital education and how institutions track and validate progress.

While AI was on the radar - especially in projects like BrAIIn [N] - it hadn't yet been integrated as a core part of most NRENs' strategies. So, while identity access and digital learning tools are now firmly embedded, the shift toward AI and newer technologies is still unfolding.

Of course, the pace and scope of development vary from country to country. Some NRENs act as full service providers, while others take on more of a coordinating or consortium role. TF-EDU survey response rates also vary from year to year, with 2024's 43 responses from European NRENs, a higher response rate than previous years.

But the direction is clear: NRENs are becoming increasingly committed to educational service delivery, particularly through digital infrastructure and support, despite the systemic differences, funding gaps, and governance challenges that remain. Collaboration through TF-EDU and similar initiatives is essential to strengthen the global NREN role in education.



4 Network

Network Introduction

The Network section of the Compendium survey contains the most questions of the five sections, and is subdivided into five separate areas: connectivity, performance monitoring & management, alienwave usage, capacity, and software-defined networking (SDN) & network function virtualisation (NFV).

The first area of focus for this chapter is automation, for which data from the SDN & NFV area of the Compendium's Network section sets out the number of NRENs automating their operations processes¹⁰ [O], and the types of network tasks they are using it for¹¹ [P]. GÉANT's path to automation is the subject of a spotlight highlighting the major leap taken in the organisation's automated network management by launching the GÉANT Automation Platform (GAP). This marks a pivotal shift towards fully automated network operations that enhance efficiency, control, and clarity in the management of GÉANT's pan-European network.

Picking up the security theme running through this report, this chapter then shines a spotlight on the certification services used by NRENs, the most common of which is GÉANT's own TCS service.

¹⁰. compendium.geant.org/ops-automation
¹¹. compendium.geant.org/network-automation

FIGURE 4.1
The numbers of NRENs that have automated (or plan to automate) their network operation processes, showing strong growth over the years

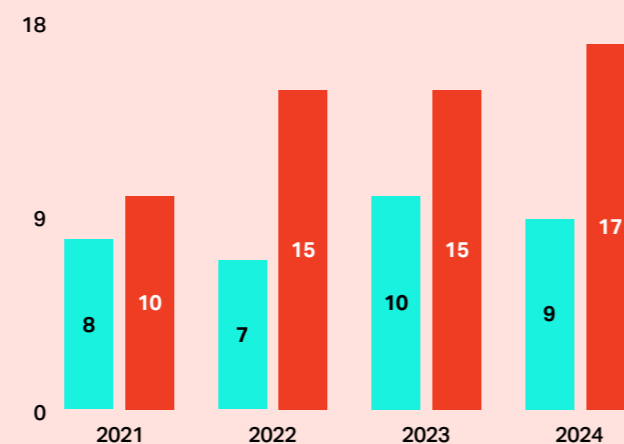
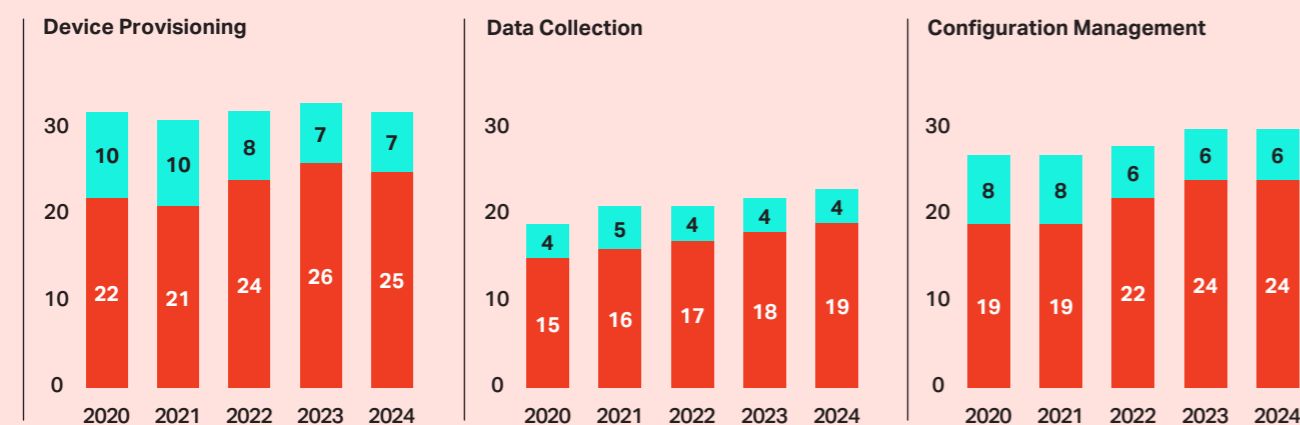


FIGURE 4.2
The network tasks NRENs have automated, or plan to automate. Device provisioning and configuration management are the two main uses for automation, though notable is the steady increase in the number of NRENs using automation for troubleshooting, albeit from a low starting point



A New Era of Automation in Network Management

— Bram Peeters
Chief Network Operations Officer, GÉANT

Looking at the numbers in the 2024 Compendium, it's clear that automation is now a regular part of how NRENs run their networks.

For us, 2024 was a big year in that shift. After tripling the GÉANT network's fibre and spectrum footprint between 2019 and 2023, the next step was to upgrade the entire router platform. That would always be a big job - but switching vendors after 12 years with Juniper and moving to Nokia made it even more challenging. It meant we had to rethink everything: our configuration standards, how we provision services, and much more.

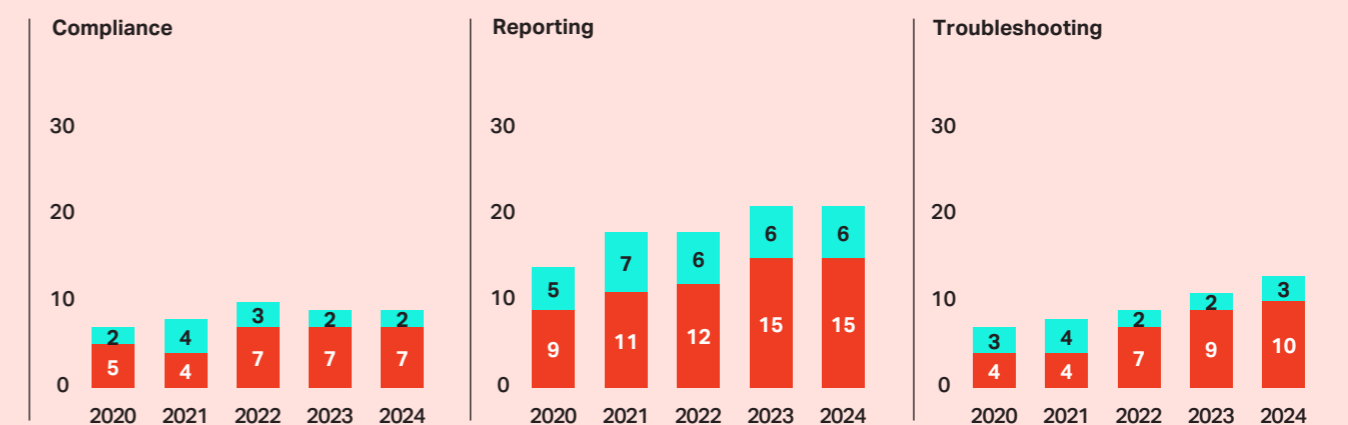
We knew this change was on the horizon, and we had already marked it as the moment to fully commit to automation. So, in the lead-up to the 2025 migration, we started working on GAP – the GÉANT Automation Platform. At the heart of it is Workflow Orchestrator [Q], an open-source tool developed by the community. Around this, we built a few new pieces ourselves – like the Lightweight

Service Orchestrator, which makes it easy to run Ansible playbooks in an automated setup.

All the work we did in 2024 means we're now ready to shift our operations fully to automation. This brings control, clarity, and assurance - crucial benefits when managing a network like GÉANT's. It also makes things more efficient, which is especially important when you're replacing a whole network.

Even though we initially built this for our own needs, we've always been thinking about how others in the community might use it too. Most of us are facing similar problems and have similar network setups and limited time or people to develop everything from scratch. That's where it really makes sense to share, reuse, and build on each other's work.

One nice bonus we've already noticed: once automation is in place, it opens up more room to simplify things and start adding new features more easily. So yes, automation is no longer something to aim for in the future - it's already here, and it's becoming the way we all work. For us, 2024 was a big step in making that real.



4.1 The Future of Certificates

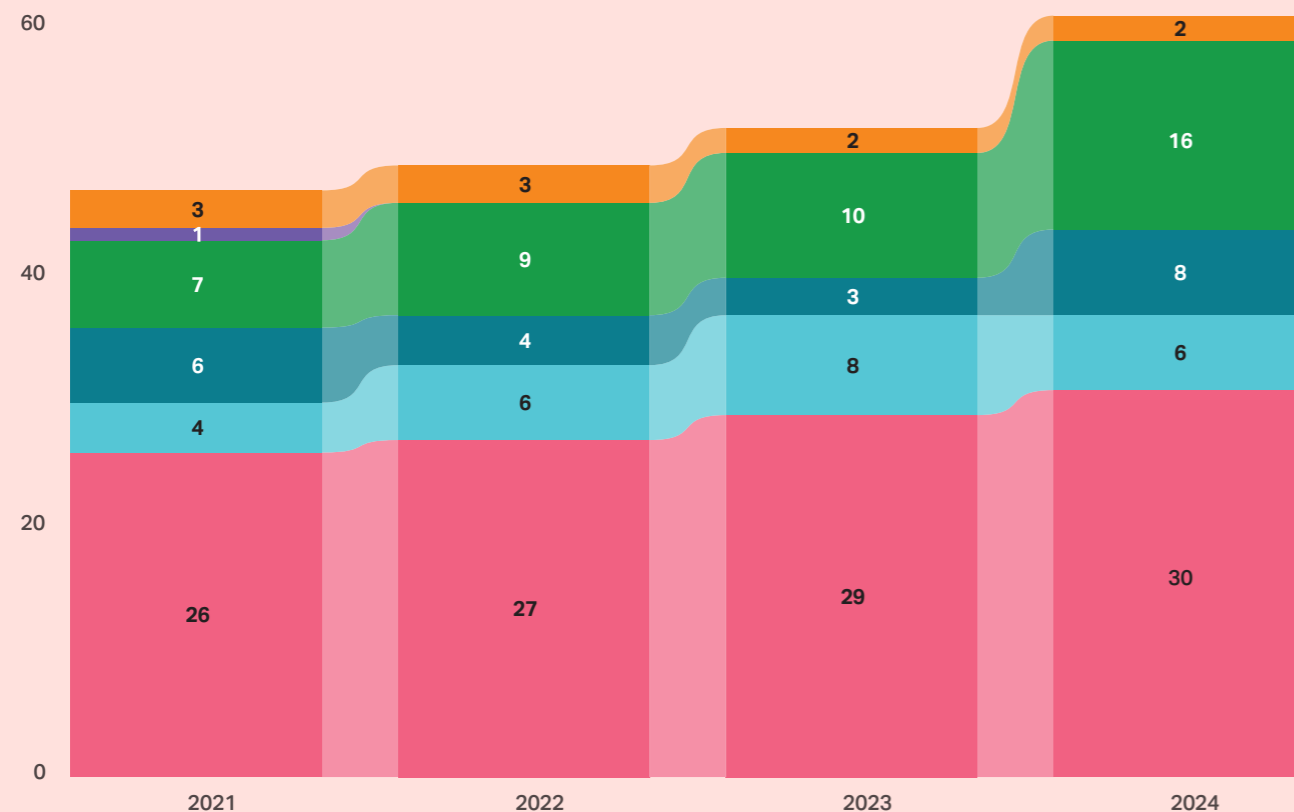


FIGURE 4.3

The numbers of different certificate providers in use at GÉANT NRENs from 2021–24. Note that while Sectigo was the supplier of GÉANT's TCS service through this period, some NRENs chose to purchase certificates directly from Sectigo, hence their inclusion as a separate provider

Insights from GÉANT's TCS

— Nicole Harris

Senior Trust & Security Manager, GÉANT

GÉANT has operated the Trusted Certificate Service (TCS) for its members since 2005. Since its inception, the service has aimed to reduce the barriers to obtaining server and client certificates for organisations that required significant numbers, and to increase the security of our infrastructures by lowering that barrier.

The certificate market has changed significantly in the 20 years that TCS has been in operation, with the most recent period being particularly volatile for the service. The CA/B Forum, which sets the standards for how

certificates should function, has made many changes to its baseline requirements – the most pivotal being the reduction of the duration of certificate validity. Over the next few years, we will see the validity periods of certificates reduce even further¹² [R], meaning that automated processes for renewing certificates will be essential.

Another impact has been the move away from the idea of signalling specific notions of trust to users through the browser, such as the 'green padlock' symbol. Server



¹². github.com/cabforum/servercert/compare/b7-fd69b36171d81930e7758482984ce957a1ce7a..87b4ebb7770e60793d1767c48c295dc7657e596d

certificates have generally come in three types – domain validation, organisational validation and extended validation – with each type nominally offering greater trust. However, the idea that such trust decisions can and should be made by users, and the ability of users to navigate and manage these signals, has been widely discredited. There are few use cases now where anything other than domain validation has real value.

The introduction of services such as Let's Encrypt has been a significant disruptor to the marketplace for certificates. Let's Encrypt offers domain-validated certifica-

tes for free using its automation-only issuance process. Approximately 60% of all websites currently use Let's Encrypt certificates¹³ [S]. However, the technical complexity involved in setting up Let's Encrypt certificates presents barriers to using the service¹⁴ [T] that GÉANT is tracking and reviewing for its membership and that need to be taken into account when considering the future of TCS.

GÉANT continues to monitor and evaluate this changing space, including the impact of legislation¹⁵ [U] on the certificate trust model.



¹³. w3techs.com/technologies/overview/ssl_certificate

¹⁴. wiki.geant.org/display/TCSNT/TCS+2025+FAQ#TCS2025FAQ-WhyNotJustUseLet'sEncrypt? [Federated access required]

¹⁵. connect.geant.org/2023/11/15/what-is-the-true-value-of-trust

5. Services

Services Introduction

The core function of any NREN is to provide services to their users. Most NRENs began with network connectivity services, but the 2024 Compendium survey now covers 58 services spread across 8 different categories. NRENs were asked which of these 58 services they offer, ranging from the standard IP connectivity (offered by all NRENs), to the rather more niche, such as e-portfolio services (offered by 4 NRENs), TV/radio streaming (also offered by 4 NRENs) or operating a PGP key server (something only 3 NRENs do).

There is enormous interest in knowing which services NRENs offer, which services they procure from third parties, and which services they develop in house for the specific needs of their users. Indeed, surveys have shown that one of the key uses of the Compendium is for NRENs to understand which new services are being offered by their peers, and thus which services they may too wish to explore offering.

In the 3 years since the [Compendium service matrix](#) transitioned from a matrix updated on an ad hoc basis, when NRENs added or removed services, to instead being a date-stamped set of “questions” in the survey,

there has been a growth in the number of services offered to users in Europe. The graph below counts the number of services offered by NRENs in each specific category by year.

Some variation across the years can be attributed to NRENs perhaps not contributing to the Compendium in one year; however, the increase in security services is marked.

A deeper dive into the count of NRENs offering specific security services reveals that some of this increase is due to the addition of a “new” service to the survey in

2024, the offering of external security awareness programmes (consisting of training, workshops, toolkits, campaigns, awareness games, etc., aimed at helping member institutions to effectively manage human risk), but also shows general growth across the service category.

The first graph shows the number of services offered by GÉANT NRENs across different service categories, 2022-2024.

The second graph is a detailed breakdown of the “security” category in the previous graph.

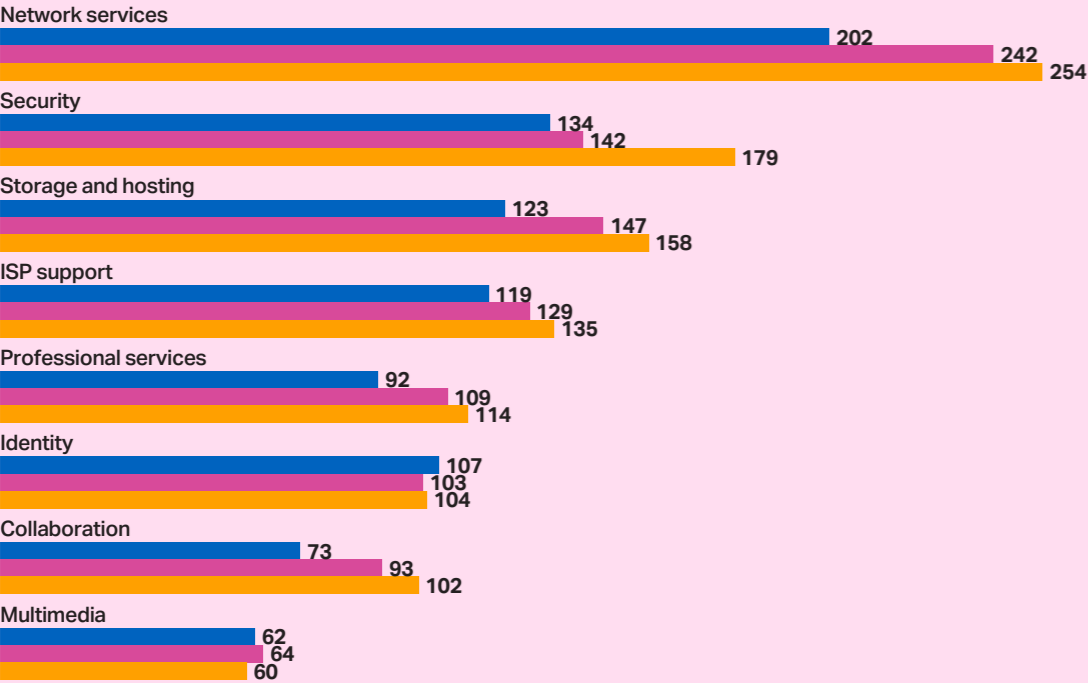
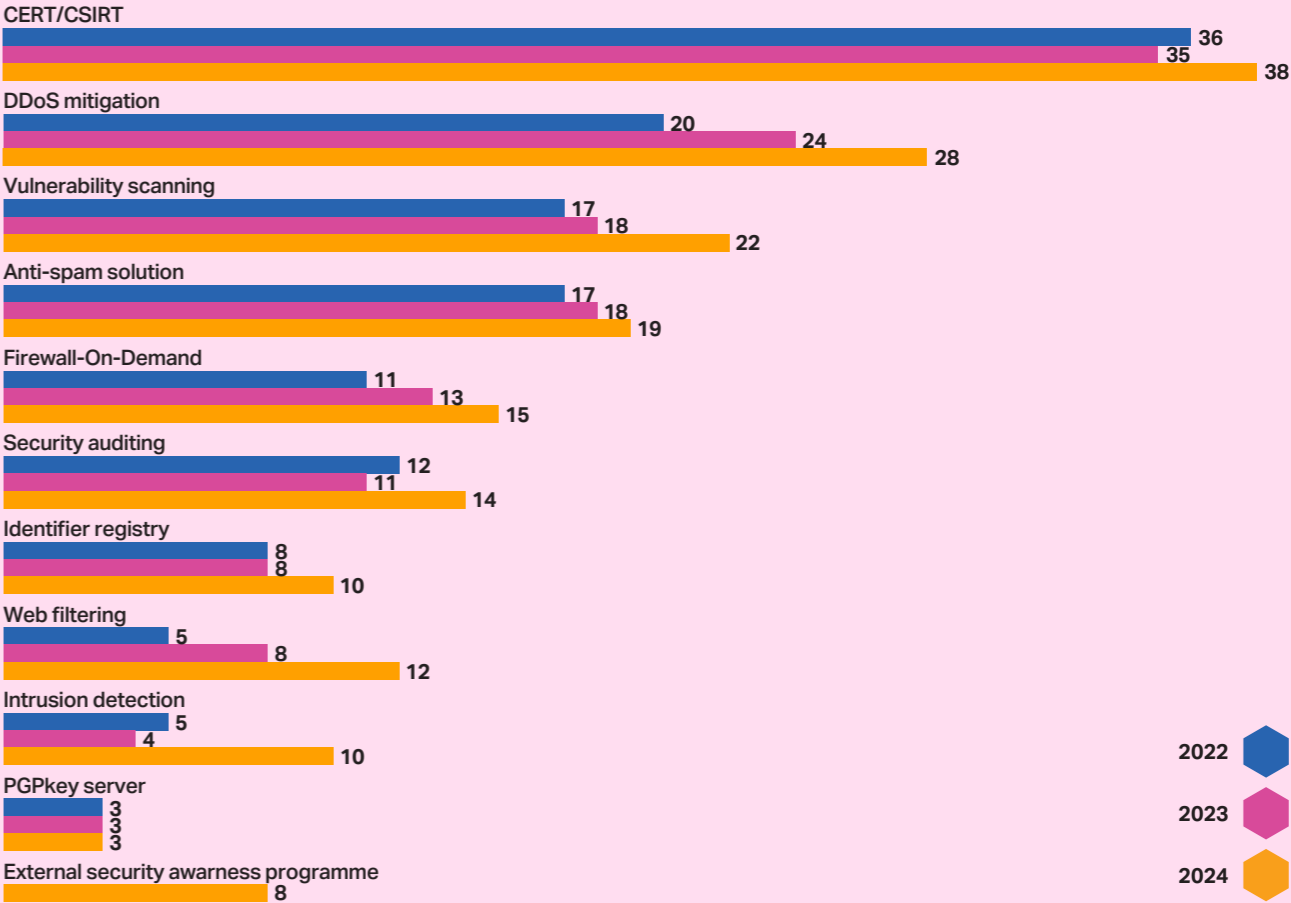


FIGURE 5.1
The number of services offered by GÉANT NRENs across different service categories, 2022–24, with a detailed breakdown of security service offerings

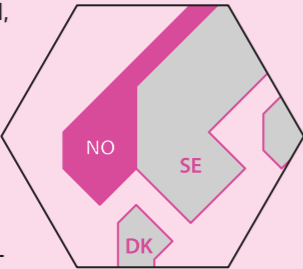


2022
2023
2024

Why Sikt Added CNaaS to Our Service Portfolio

— Vidar Faltinsen
Product Manager CNaaS, Sikt

Sikt, the Norwegian NREN, has been offering Campus Network as a Service (CNaaS) to our customers for over five years. It has proven to be a popular service with 37 paying customers currently onboarded and more in the pipeline.

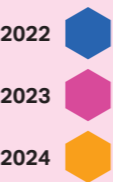
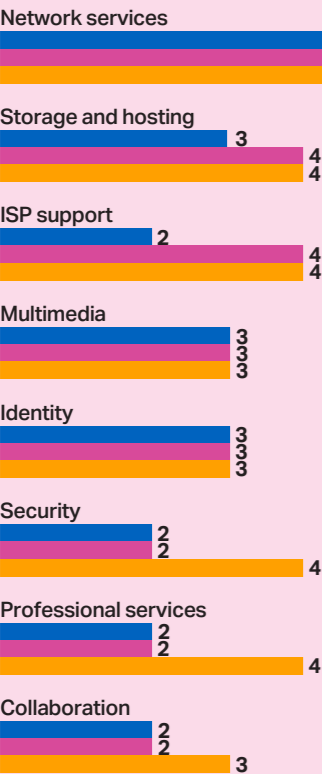


All too often, we see an imbalance between the research network and the campus network in terms of capacity, quality and reliability. CNaaS extends the research network all the way to the student and researcher end users.

With CNaaS, Sikt builds - in an automated fashion - a state-of-the-art campus network according to a standardised blueprint, with 24/7 operational support through our NOC. This typically goes hand in hand with the customers’ ICT strategy: outsourcing basic infrastructure services to a trusted partner, freeing the institution’s ICT staff to more directly support the advanced digital needs of higher education and research.

Sikt’s CNaaS contributes significantly to increasing security, offering network access control, VPNs, firewall functionality, asset management, machine and user tracking, and advanced traffic monitoring.

Count of services offered by Sikt, by service category and year



Total count of services offered by Sikt per year

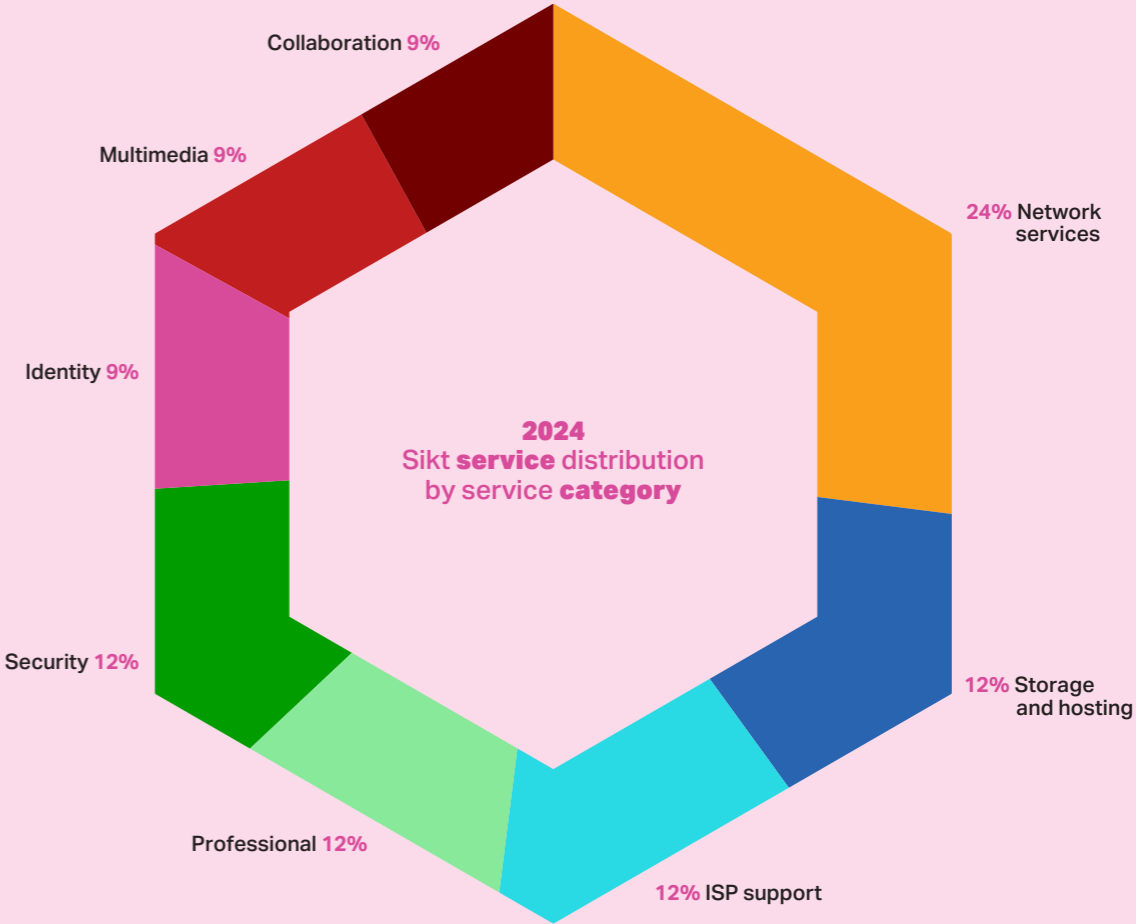


FIGURE 5.2
A breakdown of the distribution of services offered to users by Norwegian NREN, Sikt

We work closely with our colleagues from the eduCyberSecurityCenter to offer a sensible balance between security and the ability to carry out high-end data- and network-driven research, e.g., by implementing science DMZs, a network configuration that prioritises high-speed data transfer while allowing for the segmentation of cybersecurity risk

As the research network develops and new services are offered, CNaaS will advance in lockstep, ensuring that features such as high-precision time services or quantum networking are delivered all the way to re-

search labs. Much like Sikt’s suite of open-source network monitoring tools, such as Argus for NOC alarm management and NAV for monitoring campus networks, CNaaS is uniquely tuned to the needs of the Norwegian higher education and research community and is delivered through Sikt, a long-term trusted partner.

This sets us apart from similar offerings found in the commercial market. We understand the needs of our higher education and research community – and we strive to continuously develop our service to meet these very high expectations.

5.1 Innovation

Innovations and Growth in GÉANT's Above-the-Net Services in 2024

— GN5-1/GN5-2 WP4

Public Infrastructure-Cloud

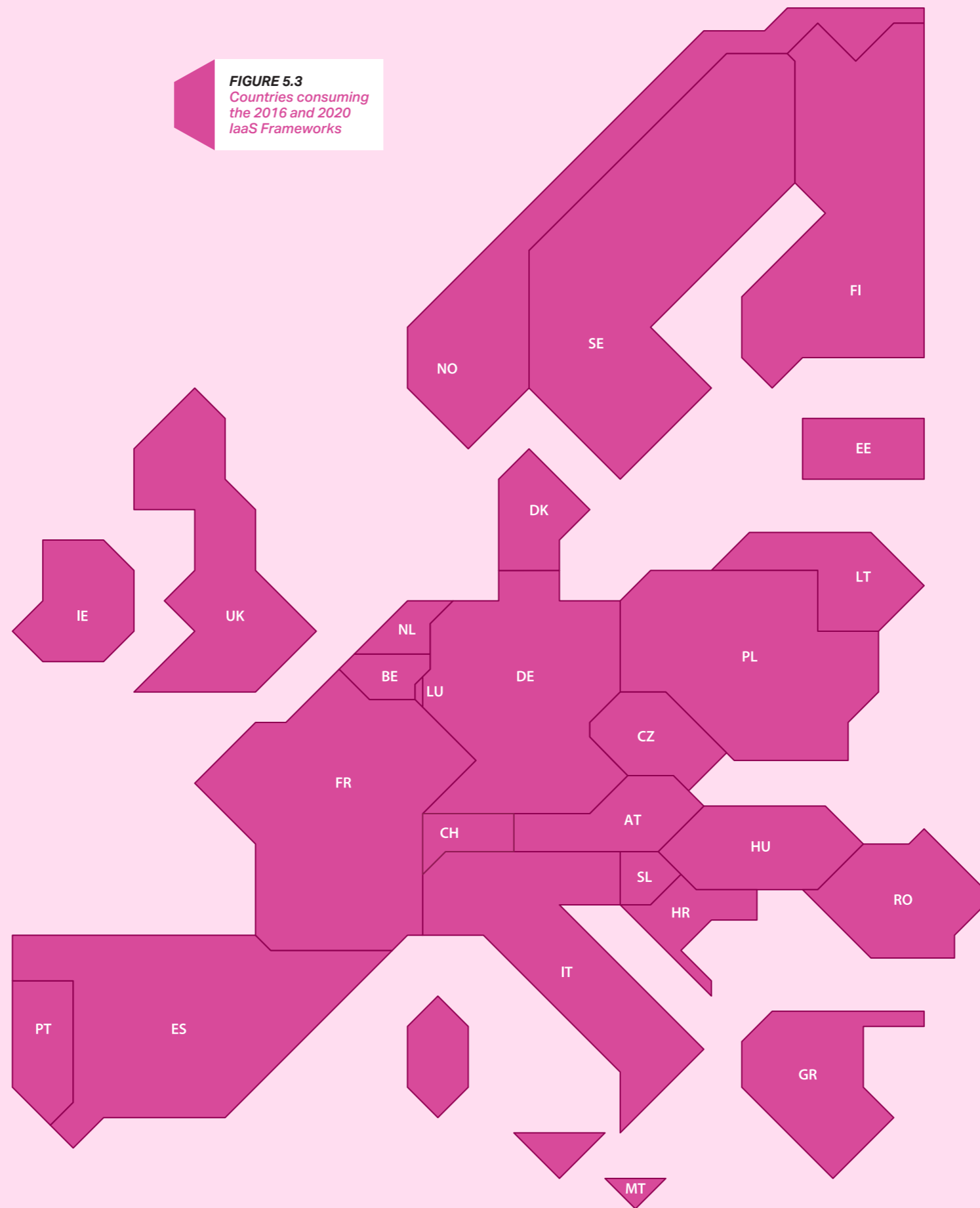
In 2024, Infrastructure-as-a-Service (IaaS) and cloud adoption under the OCRE 2020 framework continued to grow, with ~1,100 institutions and 28 countries eligible¹⁶, reflecting a strong demand for scalable, cost-effective cloud solutions. This growth was driven by demand for enhanced AI-enriched services and managed private instances of leading large language models (LLMs), addressing both operational efficiency and data privacy concerns.

European sovereignty requirements also gained prominence, driving demand for cloud solutions that ensure compliance with regional regulations. Hyperscale providers responded by expanding their 'Sovereign EU Cloud' instances, offering secure, locally governed cloud environments tailored to European research and education needs. The OCRE 2024 tender for renewal of framework agreements was successfully executed by GÉANT and a team of NRENs, securing further unique concessions for the R&E community including near-total waivers of data egress fees and increased discounts on service charges.

Community Service Development

In 2024, service development was driven by infrastructure needs and community collaboration. eduMEET reached a key milestone with version 4, and independent governance efforts secured 80% of eduMEET funding from sources outside the GÉANT project by year-end. The Above-the-Net Incubator pilot shaped future service concepts, fostering collaboration across the GÉANT community. The Incubator also supported projects like the academic ChatGPT 'L.I.S.A.' at ACOMarket and Scalable JupyterHub at Sunet, ensuring alignment with NRENs' and research institutions' needs.

FIGURE 5.3
Countries consuming the 2016 and 2020 IaaS Frameworks



¹⁶ Either EU member states or those sufficiently aligned on procurement legislation, e.g. Norway, the UK, and Switzerland.

€ 127M in 2024 as of 31 December 2024

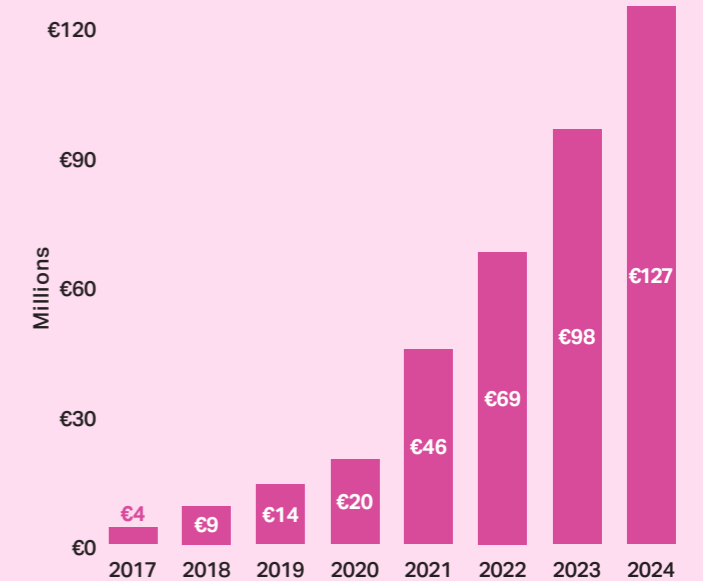


FIGURE 5.4
The growth in consumption of the 2016 and 2020 IaaS Frameworks over the years to 2024

Strategy Recommendations

Strategic discussions throughout the year highlighted the desire to leverage the collective strength of the GÉANT Association even more effectively. One key recommendation was to scale out the existing collective procurement capability, allowing for more efficient acquisition and deployment of solutions that address shared requirements and offer interoperability. A thorough evaluation of service development initiatives underscored the importance of focusing on areas that provide tangible value specific to the NREN community. Where appropriate, service development will be encouraged to follow a 'collective-by-design' approach, ensuring that rollouts occur within a mutually supportive community of practice. These strategic insights were reinforced by engagement in the GÉANT Cloud Strategy Group and the GÉANT Cloud Forum, strengthening alignment between national and European cloud priorities.

CY By integrating procurement, service development, and strategic alignment, the Above-the-Net ecosystem continued to evolve in 2024, supporting the research and education community with robust, scalable, and compliant cloud services.

6. Looking to the Future

The Compendium and Foresight 2030: From Insight to Action

— Charles Hutchings
Head of Market Research and Insight
Jisc/GN5-1 & GN5-2 GÉANT Foresight Project Team

In a world of rapid technological evolution, shifting societal expectations, and growing global challenges, how can GÉANT and the NRENs prepare for the future? That was the question at the heart of the Foresight 2030 study - a collaborative effort led by GÉANT and its partners in 2024 to explore what the next decade might hold for the R&E networking community¹⁷ [V].



Rather than attempting to predict the future, the study embraced uncertainty. It used a structured foresight methodology to explore a range of plausible futures, helping NRENs anticipate change, adapt strategies, and remain resilient. The process involved three key steps: identifying challenges, analysing influencing factors, and developing future scenarios.

The study began by gathering insights from across the NREN community through an expert working group, desk research and a range of interviews with key stakeholders. This collaborative effort surfaced over 50 potential challenges, which were then distilled into six core areas:

1. Interaction with Commercial Actors – Navigating partnerships and competition with commercial service providers.
2. Climate Change and Sustainability – Addressing environmental responsibilities and the impact of climate policies.
3. Employment and Skills – Responding to evolving workforce needs and talent shortages.
4. Technological Advances – Keeping pace with innovation while ensuring interoperability and security.
5. NREN Governance – Adapting governance models to remain agile and effective.
6. Delivering Research and Education at Scale – Meeting the growing demand for digital infrastructure and services.

From these challenges, the team identified key factors that could shape the future, ranging from funding models and regulatory environments to cybersecurity threats and user behaviours. These were mapped across multiple axes of uncertainty to build a multidimensional view of possible futures.

The result? Three compelling scenarios:

- **Playing the Fair Game:** A collaborative, innovation-driven future where NRENs thrive by partnering with commercial actors and adapting to user needs. It's a landscape defined by shared value and strategic agility.
- **Rough Seas:** A turbulent scenario marked by fragmented governance, funding instability, and external pressures. NRENs must fight to stay relevant amid uncertainty and competition.
- **The Beaten Track:** A conservative future where change is minimal. While stability is maintained, it comes at the cost of missed opportunities and growing irrelevance.

Each scenario is not a prediction, but a tool - a way to test strategies, spark discussion, and prepare for a range of outcomes. Across all the future scenarios explored in this study, three core factors consistently shape the potential evolution of NRENs and the GÉANT community:

- The evolving emphasis on skills needed to ensure the NREN community remains resilient and future-ready.
- The dynamic relationship with commercial actors, including the various roles NRENs assume in these interactions.
- Cybersecurity, particularly its intersection with skills development and emerging technologies like AI, and the role NRENs play in this space.

These enduring influences are complemented by context-specific factors whose impact varies depending on national circumstances, including regulatory frameworks, funding environments, national approaches to R&E data management, and each NREN's own development strategy.

But it's not all about the challenges the future may hold - rather, the opportunities it presents. Our findings certainly resonate with those of the Compendium, brought to life in the preceding chapters: the interconnection between NREN activities and climate change, our role(s) in cyber security, the shape and composition of our workforce, and our ability to continue to deliver infrastructure to support science and education.

The study concludes with practical recommendations for NRENs, some of which are already evidenced in practice in the 2024 Compendium survey: embrace collaboration, invest in skills, stay alert to emerging trends, and use foresight as an ongoing practice.

Ultimately, Foresight 2030 is a call to action. It encourages the NREN community to think boldly, plan flexibly, and lead confidently into an uncertain but opportunity-rich future.

¹⁷ resources.geant.org/wp-content/uploads/2024/11/Foresight-Study-v02-ONLINE.pdf

Appendix

Contact List

The following table lists the NRENs that responded to the 2024 Compendium survey and contains links to their respective websites.

NREN	COUNTRY	WEBSITE
ACOnet	Austria	www.aco.net
AMRES	Serbia	www.amres.ac.rs
ARNES	Slovenia	www.arnes.si
ASNET-AM	Armenia	www.asnet.am
Belnet	Belgium	www.belnet.be
BREN	Bulgaria	www.bren.bg
CARNET	Croatia	www.carnet.hr
CESNET	Czechia	www.ces.net
CSC	Finland	www.csc.fi
CYNET	Cyprus	www.cynet.ac.cy
DeiC	Denmark	www.deic.dk/en/front
DFN	Germany	www.dfn.de
EENet	Estonia	www.eenet.ee
FCCN/FCT	Portugal	www.fct.pt
GARR	Italy	www.garr.it
GRENA	Georgia	www.grena.ge
GRNET	Greece	www.grnet.gr
HEAnet	Ireland	www.heanet.ie
IUCC	Israel	www.iucc.ac.il
Jisc	United Kingdom	www.jisc.ac.uk
KIFÜ <i>Pro-M/NIIF from 1/1/2025</i>	Hungary	www.kifu.gov.hu/main-page www.pro-m.hu

NREN	COUNTRY	WEBSITE
KREN	Kosovo*	www.kren-ks.eu
IMCS UL	Latvia	www.lumii.lv
LITNET	Lithuania	www.litnet.lt
MARnet	North Macedonia	www.marnet.mk
MREN	Montenegro	www.mren.ac.me
PSNC	Poland	www.man.poznan.pl
RASH	Albania	www.rash.al
RedIRIS	Spain	www.rediris.es
RENAM	Moldova	www.renam.md
RENATER	France	www.renater.fr
Restena	Luxembourg	www.restena.lu
RoEduNet	Romania	www.nren.ro
SANET	Slovakia	www.sanet.sk
Sikt	Norway	www.sikt.no/en/home
Sunet	Sweden	www.sunet.se/en/about-sunet
SURF	Netherlands	www.surf.nl
SWITCH	Switzerland	www.switch.ch
ULAKBIM	Türkiye	www.ulakbim.gov.tr
URAN	Ukraine	www.uran.net.ua

*This designation is without prejudice to positions on status and is in line with UNSCR 1244 and the ICJ opinion on Kosovo Declaration of Independence

Glossary

AI	Artificial Intelligence
BDVA	Big Data Value Association
CA/B Forum	Certificate Authority Browser Forum
CLAW	Crisis Management Workshop for the GÉANT Community
CNaas	Campus Network as a Service
CroQCI	Croatian Quantum Communication Infrastructure project
DMZ	Demilitarized Zone
EOSC	European Open Science Cloud Platform
ERDF	European Regional Development Fund
ETP4HPC	European Technology Platform for High Performance Computing
EuroHPC JU	European High-Performance Computing Joint Undertaking
EuroQCI	European Quantum Communication Infrastructure
FAIR	Findable, Accessible, Interoperable, and Reusable (data principles)
FTE	Full-Time Equivalent
GAP	GÉANT Automation Platform
GDRP	General Data Protection Regulation
IaaS	Infrastructure as a Service
ISMS	Information Security Management System
INFRAG	Infrastructure Advisory Group
LLM	Large Language Model
MFF	Multiannual Financial Framework
NGEU	NextGenerationEU
NREN	National Research and Education Network
OCRE	Open Clouds for Research Environments
QuIC	European Quantum Industry Consortium
R&E	Research and Education
RFF	Recovery and Resilience Facility
SaaS	Software as a Service
SDG	UN Sustainable Development Goals

References

[A] e-Schools Programme – Croatia
<https://digital-skills-jobs.europa.eu/en/inspiration/good-practices/e-schools-programme-croatia>

[B] CARNET: e-Universities
<https://www.carnet.hr/en/projekt/e-universities/>

[C] CARNET: Application of Artificial Intelligence-Based Digital Technologies in Education – BrAI
<https://www.carnet.hr/en/projekt/brain/>

[D] EU Funding & Tenders Portal – CroQCI
<https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/how-to-participate/org-details/999655326/project/101091513/program/43152860/details>

[E] EC RRF Disbursements
https://ec.europa.eu/economy_finance/recovery-and-resilience-scoreboard/disbursements.html?table=finalRecipientByCountry

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<https://npuls.nl/>

[G] EOSC News: EOSC’s build-up phase to begin with March kick-off
<https://eosc.eu/news/2025/02/eoscs-build-up-phase-to-begin-with-march-kick-off/>

[H] European Technology Platform for High-Performance Computing
<http://www.etp4hpc.eu/>

[I] Big Data Value Association
<https://www.bdva.eu/>

[J] European Quantum Industry Consortium
<http://www.euroquic.org/>

[K] CSC News: CSC-led consortium to deliver the EuroHPC Federation Platform
<https://csc.fi/en/news/csc-led-consortium-to-deliver-the-eurohpc-federation-platform/>

[L] EU Funding & Tenders Portal – Acquisition of Hyperconnectivity Services for HPC systems
<https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/tender-details/94401ced-caf1-4786-92da-bd3dd0d8dcbe-CN>

[M] GÉANT Compendium Data: External and Internal Audits of Information Security Management Systems
<https://compendium.geant.org/audits>

[N] See [C]

[O] GÉANT Compendium Data: NREN Automation of Operational Processes
<https://compendium.geant.org/ops-automation>

[P] GÉANT Compendium Data: Network Tasks for which NRENs Use Automation
<https://compendium.geant.org/network-automation>

[Q] Workflow Orchestrator programme
<https://workfloworchestrator.org/>

[R] GitHub Repository for the CA/Browser Forum Server Certificate Chartered Working Group
<https://github.com/cabforum/servercert/compare/b7fd69b36171d81930e7758482984ce957a1ce7a...87b4ebb7770e60793d1767c48c295dc7657e596d>

[S] Usage statistics and market shares of SSL certificate authorities for websites
https://w3techs.com/technologies/overview/ssl_certificate

[T] GÉANT Wiki – Why not just use Let’s Encrypt? [Federated access required]
<https://wiki.geant.org/display/TCSNT/TCS+2025+FAQ#TCS2025FAQ-WhyNotJustUseLet'sEncrypt?>

[U] CONNECT: What Is The True Value of Trust?
<https://connect.geant.org/2023/11/15/what-is-the-true-value-of-trust>

[V] Foresight 2030: Navigating Change
<https://resources.geant.org/wp-content/uploads/2024/11/Foresight-Study-v02-ONLINE.pdf>

Notes

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GÉANT Compendium Report of National Research and Education Networks in Europe 2024 Edition

The GÉANT Compendium provides an authoritative reference source for anyone with an interest in the development of research and education networking in Europe. Published since 2001, the Compendium provides information on key areas such as NREN users, services, traffic, budgets and staffing.

The GÉANT NREN Compendium may be found online at compendium.geant.org.

© GÉANT Association on behalf of the GN5-2 project. The research leading to these results has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement No. 101194278 (GN5-2).

Co-funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.



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