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Deliverable D1.1: ACHIEVE master's programme: Market analysis and curriculum design

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Abstract

This deliverable aims at providing an overview of the results of the market analysis in the area of Cloud and Network Infrastructures and High Performance Computing, and a description of its curriculum. The first part of the Market analysis and curriculum design document gives an overview of the technology market size and technology drivers of high-performance computing and cloud and network infrastructures. It is followed by a job market analysis and the discussion of expected knowledge and skills. The study is supported by a job market analysis survey performed by the project.

The second part of the document focuses on the design of the master's programme curriculum, and how it is implemented in the universities of the consortium. The general framework for the design of the curriculum is described, as well as the local implementations of the first and second years in the universities of the ACHIEVE consortium. Finally, admission requirements are described.

Versioning and contribution history

Date	Version	Contributor	Notes
05/06/2025	0.1	Viktoria Fodor (KTH), Selcuk Bilmis (TUBITAK), Gianluca Palermo (POLIMI), Fabrizio Granelli (UNITN)	First version of D1.1, including the market analysis and programme draft
15/07/2025	0.2	Viktoria Fodor (KTH), Selcuk Bilmis (TUBITAK), Gianluca Palermo (POLIMI), Fabrizio Granelli (UNITN)	First revision, including the job market analysis
30/7/2025	0.3	Viktoria Fodor (KTH), Selcuk Bilmis (TUBITAK), Gianluca Palermo (POLIMI), Fabrizio Granelli (UNITN)	Complete draft of technology and job market analysis, without the survey results
22/08/2025	0.4	Viktoria Fodor (KTH), Selcuk Bilmis (TUBITAK), Gianluca Palermo (POLIMI), Fabrizio Granelli (UNITN)	Revised version with complete reference list.
04/9/2025	0.5	Viktoria Fodor (KTH), Selcuk Bilmis (TUBITAK), Gianluca Palermo (POLIMI), Fabrizio Granelli (UNITN)	Integrated version with the Master Programme and detailed implementation
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13/10/2025	0.9	Selcuk Bilmis (TUBITAK), Viktoria Fodor (KTH)	Integration of survey results.
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17/10/2025	1.1	Fabrizio Granelli (UNITN), Viktoria Fodor (KTH)	Updated version ready for the internal review process
22/10/2025	1.1	Alvaro Pina Stranger (UR), Amir Aghaei (UR)	Full review and resolution of comments. Proposition of overall suggestions for improvement.
29/10/2025	1.2	Fabrizio Granelli (UNITN), Viktoria Fodor (KTH)	Implementation of review comments.
30/10/2025	1.3	Fabrizio Granelli (UNITN), Viktoria Fodor (KTH), Vilma Djala (EITD)	Minor editing and corrections.

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Project Abstract

Advanced Cloud and High-Performance Infrastructure for European Education (ACHIEVE) aims to train the next generation of specialists and innovators in Cloud Computing, Networking Infrastructure (CNI), and High-Performance Computing (HPC) in Europe. ACHIEVE will reach this goal by designing and delivering a double-degree master's programme (ISCED Level 7, 120 ECTS) with a major in Cloud and Networking Infrastructure and a minor in Innovation and Entrepreneurship. The master's programme is designed and created by 8 higher education institutions from 6 different countries, together with leading research centres in HPC and EIT Digital, a pan-European organisation with long-standing expertise in delivering education programmes in advanced digital skills across Europe. ACHIEVE will foster strong interactions and mobility between academia and business, strengthen knowledge-triangle integration, promote entrepreneurship, foster inclusiveness, and boost the growth of the existing EIT Digital ecosystem, one of the largest digital ecosystems in Europe. In addition to the master's programme, ACHIEVE partners will develop and deploy self-standing learning modules on Cloud, Networking, and HPC topics. These modules will result in certifications in advanced digital skills released by participating higher education institutions and EIT Digital, targeting a wide audience of students and professionals. In line with the goals of the Digital Compass and the New European Innovation Agenda, ACHIEVE will train more than 1000 participants across four years and contribute to reducing the gap in advanced digital skills in Europe while increasing Europe's competitiveness in key digital technology domains such as Cloud, Networking, and HPC. Finally, it is important to highlight the added value of this project: while training opportunities in HPC, Cloud Computing or Networking exist in Europe, ACHIEVE is the 1st European double-degree master's programme that systematically integrates Cloud, Networking Infrastructure, and HPC with Innovation and Entrepreneurship, thereby addressing a crucial need for Europe's digital transformation.

Executive Summary

This document summarizes the results of the activities performed in WP1 of the ACHIEVE Project. The objective of the ACHIEVE project is to strengthen the European competence and innovation in the areas of HPC, cloud computing, and advanced networking, by implementing a double-degree master's program and self-standing modules for life-long learning, as well as enforcing academia-business interactions and entrepreneurship skills.

As such, this document presents the labour market needs analysis related to HPC, Cloud Computing, and Advanced Networking, carried out by the consortium, and it describes the final curriculum of the ACHIEVE Master's programme, which has been refined and improved based on the results of the analysis.

HPC, cloud computing, and advanced networking form the backbone of Europe's digital future. HPC refers to the use of powerful supercomputers and parallel processing techniques to solve complex, data-intensive problems – from simulating climate patterns to running AI models. Cloud computing and the emerging edge computing deliver scalable computing resources (servers, storage, software) over the internet and mobile networks, enabling businesses and research to access vast computing power on-demand. Networking ties these elements together, providing the high-speed data transfer and connectivity required to link users to cloud and edge computing services and to interconnect supercomputing centres across Europe. These domains are increasingly interdependent: for example, modern scientific research might use an HPC cluster accessed via cloud interfaces, with distributed teams collaborating over high-speed networks. The convergence of these technologies is essential for processing and analyzing the exponentially growing volume of data – projected to reach 181 zettabytes globally in 2025 (High Performance Computing, Shaping Europe's digital future [1]) and translating it into societal and economic benefits.

The consortium carried out a market study, combining a questionnaire survey with an analysis of EU reports, industry publications, and academic studies. This document constitutes an overview of the technology and job markets of HPC, cloud computing, and advanced networking, including the technology drivers and the knowledge and skills requirements of the industry and the academia. The survey performed collected ca. 190 responses from companies, research centres, and professionals, covering sectors such as AI and Data Science (23%), Biotechnology (11%) and Healthcare and Pharmaceuticals (11%) Among the respondents, 32% came from large enterprises (>250 employees), 27% represented medium-size companies and 41% small enterprises and start-ups.

The technology and job market analysis together with the survey results highlighted:

- Typical master level curricula in EU lack deep HPC exposure
- Programs provide insufficient hands-on or system level training
- Programs are fragmented and do not cover the strongly connected areas of computing, cloud and networking
- There is a lack of cross-cutting competencies
- There is a lack of integrated content spanning HPC, cloud, and networking for upskilling of working professionals or for life-long learners.

Building on these results, the ACHIEVE Master's programme has been co-designed by partner universities, UNITN, POLIMI, KTH, AALTO, METU, UBB, UR, AALTO, UNS FTN, together with EIT Digital, industry members and research partners. The curriculum provides graduates with both a strong technical foundation and the innovation and entrepreneurship skills necessary to translate technology into business and societal impact.

The programme follows the EIT Digital Master School model:

- Students study one year at an "entry" university and one year at an "exit" university, ensuring cross-border mobility.

- The first year provides foundational training in HPC, Cloud, and Networking, combined with core Innovation and Entrepreneurship courses.
- The second year offers specialisations, including modules on HPC and cloud applications and software technology, networked AI, cloud and edge computing, security for cloud and HPC, wireless networks and 5G/6G, and sustainable ICT. The second year is completed with graduation project.
- The graduation project includes an internship at a company or research institute, culminating in a Master's thesis with a strong innovation and entrepreneurship dimension.
- Between the first and second year, students participate in an EIT Digital two-week Summer School focused on business opportunities within a socially relevant theme.
- Graduates receive double degrees from the two universities they attend, as well as a certificate on entrepreneurial studies from the European Institute of Innovation and Technology (EIT).

In parallel, ACHIEVE partners will develop and deploy self-standing learning modules on HPC, Cloud, and Networking topics. These will result in certifications released by the participating higher education institutions and EIT Digital, extending the project's impact to lifelong learners and professionals.

ACHIEVE will train more than 1000 participants over four years, strengthening Europe's competence and innovation capacity in key digital technologies. By integrating three critical and interdependent domains into a single European Master's programme, ACHIEVE addresses a unique gap in advanced digital education and contributes directly to the goals of the Digital Compass and the New European Innovation Agenda.

The partners of the ACHIEVE project are listed in the table below.

Short name	Full name	Country
EITD	EIT Digital	Belgium
EITD-ES	EIT Digital Spain	Spain

UNITN	Universita Degli Studi Di Trento	Italy
METU	Middle East Technical University	Turkey
UR	Universite De Rennes	France
KTH	Kungliga tekniska högskolan	Sweden
UBB	Universitate Babes Bolyai	Romania
AALTO	Aalto Korkeakoulusaatio Sr	Finland
POLIMI	Politecnico di Milano	Italy
UNS	University of Novi Sad	Serbia
EA	Evolutionary Archetypes Consulting SL	Spain
TECHVALLEY	Tech Valley Management	Spain
RISE	Research Institutes of Sweden (Associate)	Sweden
INFINEON	Infineon	Austria
ODTUTEK	ODTU Teknokent	Turkey
TUBITAK	Scientific and Technological Research Council of Turkey	Turkey

Table 1: ACHIEVE Project Partners

1 Technology Market

We start our study with analysing the technology market for computing, cloud and networking. The objective of this analysis is to see what technology areas emerged in the last decade, so that we see how these affect the job market itself and the skill requirements of new graduates. The technology review is based on EU reports, scientific articles, web resources and own studies of emerging technologies and patent trends. The results of the review are also strengthened by the survey the project performed, which investigated what are the main technologies used by the companies, and the possible barriers to introduce new technologies.

1.1 Market Size and Growth Trends

The global market of High-Performance Computing (HPC), cloud and networking is rapidly expanding driven by the digitalization of the industry, by the rise of Artificial Intelligence (AI) and Machine Learning (ML), and by the increasing need for real-time data processing and scalability. While these three areas are often assessed independently in market reports, they are deeply intertwined and represent the computational backbone of modern digital transformation across all sectors.

Cloud computing, advanced networking and high-performance computing are technologies that emerged during the second decade of the millennium, with these characteristic periods:

2010–2015: Cloud foundations; HPC fragmented

Enterprises begin cloud adoption; on-premise HPC remains national and domain-specific. EU's network connectivity improves but is uneven.

2016–2019: Scale & sovereignty

Hyperscalers are built in more EU regions, the market share consolidates around AWS, Microsoft, and Google. EU launches the **EuroHPC Joint Undertaking (JU)** to pool funds and coordinate world-class supercomputers (LUMI, Leonardo, MareNostrum 5). Policy seeds for data sovereignty (GAIA-X) appear.

2020–2022: Pandemic acceleration

Remote operations and supply-chain shocks push workloads to the cloud; industrial computer aided engineering and design as well as emerging digital twins boost HPC usage in SMEs and OEMs. The EuroHPC systems enter global top rankings.

2023–2025: AI wave + connectivity push

Cloud: 45.2% of EU enterprises buy cloud; the use of higher-value cloud services grows. Hyperscalers hold ~70% of the EU market; EU providers ~15% (steady since 2022). Specialized AI clouds expand in Europe (e.g., GPU-centric builds).

HPC: EuroHPC delivers **JUPITER** (first European exascale) and keeps multiple systems in the global top-10/Green500, cementing regional capability for training large AI models, advanced simulation, and climate/health workloads.

Networking: EU reports ~94% 5G household coverage by end-2024 and continued FTTH expansion; however, quality (standalone 5G, latency) and rural gigabit remain patchy.

Below we detail the status of the technology market today, in these three segments.

1.1.1 HPC Market

The HPC market is experiencing robust growth, driven by the demand for faster data processing in various sectors such as scientific research, engineering simulations, weather forecasting, and AI/ML workloads. In 2023, the global HPC market was valued at approximately $50 billion and is expected to more than double by 2032, reaching $109.99 billion, with a compound annual growth rate (CAGR) of 9.2% [2] [3]. In the global scenario, North America leads the market with more than 40% of the global share, while Europe accounts for 28%, and around 21% by Asia Pacific [4].

Key segments of this market include servers, storage, networking equipment, software, services (such as installation, maintenance, and support) and cloud computing, with cloud-based HPC emerging as one of the most dynamic and fastest growing segments. This is in response to increasing demands for elasticity, scalability and cost-effectiveness from both large enterprises and SMEs [5] [3].

On the IT infrastructure side, while servers and modern accelerators such as GPUs and specialized AI chips drive the core computational power of HPC systems, networking and storage infrastructure play a critical role in enabling large-scale distributed processing and efficient data movement. This makes the IT infrastructure part (servers, network, storage) accounting for approximately 60% of the global HPC market [6].

Not explicitly in the HPC market, but now considered an internal branch, it is also starting to make sense to consider the quantum computing market alone. Although still in its early stages, it is emerging as a strategic frontier in advanced computing. In 2023, it has been valued at approximately $928 million, and it is expected to grow to over $6.5 billion by 2030, at a CAGR of over 32% [7] [8]. This rapid expansion is being driven by growing interest from sectors such as finance, pharmaceuticals, and cybersecurity, as well as significant R&D investment from governments and technology giants worldwide. As quantum technology matures, it is expected to place new demands on data centre networking and HPC infrastructures. It is important to note that mid- to long-term forecasts for the quantum computing market are subject to significant uncertainty, largely due to the rapid pace of technological innovation, evolving use cases, and the still-emerging commercial viability of quantum systems. Breakthroughs in hardware scalability, error correction, or algorithm development could dramatically accelerate or delay adoption timelines, making current forecasts inherently volatile and highly sensitive to scientific and engineering progress.

1.1.2 Cloud Computing Market

The cloud computing market significantly outperforms the HPC one in terms of size, but also overlaps with it, especially in hybrid and cloud-native HPC applications [9]. In 2023, the global cloud market has been measured at the value of $587.78 billion and is expected to grow to a substantial value of $2,291.59 billion by 2032, which represents a CAGR of 16.5%. Currently, North America dominates the global cloud computing market, accounting for more than half of the total market share in 2023. Europe and Asia-Pacific will almost split the remaining market share, with Europe holding around 28% of the global market, but China and Japan showing a CAGR of well over 20%.
The fastest growing cloud model is composed of the public cloud infrastructures, with Software as a Service (SaaS) dominating, although Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) are also growing in terms of market. The cloud is now essential to the delivery of digital services, enabling start-ups and various enterprise types to innovate quickly and deploy globally [9].

The role of cloud computing for HPC workloads is expanding, particularly with the growing need for burst capacity and accessibility for SMEs and academia, leading to a CAGR of 16.6%. The integration of HPC with cloud infrastructure (cloudification of HPC) is expected to facilitate more democratized access to computing resources, particularly through services such as AWS ParallelCluster, Azure CycleCloud and Google Cloud's HPC offerings [10].

1.1.3 Networking Market

Although the networking market is often treated separately from HPC and cloud, it is fundamental to both, especially if distributed computing, edge processing, AI/ML workloads and 5G continue to grow.

The communication networks market includes a wide range of technologies and services that enable the exchange of various types of data. In general, the market includes wireless and mobile networks, broadband, optical fibres, and, with increasing importance, satellite systems. The global market size is estimated to be USD 1.2 Trillion and is expected to grow with a CAGR of 8.9%. While telecommunication is not a new technology area, the growth of the communication network market is fuelled by the increasing demand for high-speed internet, e.g. for streaming services, mobile connectivity through smart devices, IoT applications, and access to cloud computing services. The emerging AI/ML applications are expected to demand further growth of communication capacity and coverage [11].

The global data centre networking market, which provides the critical backbone for both HPC and cloud computing, was valued at USD 34.22 billion in 2023. It is expected to grow to USD 91.1 billion by 2030, at a compound annual growth rate (CAGR) of 15.2% over the forecast period [12]. The global data centre networking market is witnessing robust growth in all major regions. North America leads the market with an estimated share of 39% in 2023, driven by the presence of hyperscale cloud providers and ongoing investments in next-generation networking technologies. Among the other segments analysed, Europe and Asia-Pacific follow with around 27% of the market, with the latter having the highest projected growth rate compared to the other regions.

1.2 Industry Breakdown

The following technology sectors have the highest demand for HPC, supported by cloud and networking [1]:

- In finance, HPC and cloud are used for complex risk modelling, high-frequency trading, and real-time fraud detection, demanding secure and high-performance infrastructure.
- Healthcare and biosciences leverage these technologies for drug discovery, genomic analysis, molecular modelling, and managing vast, sensitive patient datasets.
- The automotive industry relies heavily on HPC and cloud for vehicle simulations (e.g., crash tests, aerodynamics) and the development of

autonomous driving systems, requiring massive data processing and AI model training capabilities.
- Manufacturing utilizes HPC for complex simulations (e.g., computational fluid dynamics), digital twins, and product development, while cloud enables predictive maintenance and smart factory integration.
- Energy and green tech apply these tools for climate modelling, optimizing renewable energy grids, and researching new energy sources like fusion.
- Research and academia remain core users for fundamental scientific simulations and large-scale data analysis across diverse disciplines.

Considering the industry segments where HPC has high investments, the most prominent segment is, without doubts government and defence, having around 30% of the market share. However, education and research, healthcare and life sciences, and manufacturing each represent more than 10% of the market [2]. Within manufacturing the most important application areas seem to be automotive, aerospace and energy [13].

Focusing on HPC in research, in the EGI annual report from 2023 [5] we can find these main application areas, with percentage in terms of users: structural biology (44%), bioinformatics (23%), high energy physics (14%), and areas below 10%: other physics, engineering and technology, earth and environmental sciences, astronomy and astrophysics, other life sciences.

The main industry segments for cloud computing differ slightly from HPC, since HPC is only one of the many possible application areas of cloud, with its storage and computing possibilities. The most relevant segment for cloud computing is finance and banking, IT and telecom (including public cloud), other relevant segments are retail and manufacturing [9].

1.3 Enterprise Types

Because of high needs of investment and long-term product development, the HPC market is dominated by large enterprises, both in terms of providing HPC components like chips and servers, and in terms of utilizing HPC services. The key actors are for example HPE (largest market share of HPC servers), Dell, Lenovo and IBM [14].

The main players in the cloud computing market, providing storage and computation services are, not surprisingly, also large enterprises, including cloud and software providers as Amazon, Oracle, IBM, Alibaba, Microsoft, VMware, Google [9].

Networking equipment vendors and network operators are also key players in the emerging computing-communication continuum. While network operators and service providers are country specific, the main vendors are the traditional ones, including Huawei, Nokia, Ericsson and Cisco [15].

Considering the use of HPC and cloud technologies, the demand patterns vary across the different types of enterprises and organizations [16]. Considering Europe:

- Large enterprises: Exhibit high cloud adoption rates (77.6% in 2023) and are significant users of HPC for R&D and complex operations.
- Small and medium-sized enterprises (SMEs): Represent a major growth area for HPC and cloud adoption. While adoption rates are lower than large enterprises (e.g., 41.7% of small businesses used cloud in 2023), digital transformation is driving demand for HPC-based cloud services. SMEs face specific challenges including lack of awareness, budget constraints, and skills gaps. Initiatives like the EuroHPC National Competence Centres (NCCs) aim to support SME uptake.
- Startups: Particularly in AI, fintech, and deep tech, startups heavily rely on cloud scalability and often require access to HPC resources for computationally intensive tasks like AI model training [17].

1.4 Government and Research Institutions Investing in HPC Infrastructure

Government and publicly funded research organizations are a fundamental pillar (and key driver) of the HPC ecosystem. They play a central role in advancing computing capabilities, fostering innovation, and supporting both scientific discovery and strategic technologies. They often take the lead in long-term infrastructure development, especially, in the establishment and operation of national and regional supercomputing centres, which form the backbone of publicly accessible HPC resources across the globe. To this end, we provide a brief overview of strategies and scenarios across major geographic regions.

1.4.1 Europe

In Europe, the EuroHPC Joint Undertaking (JU) is the main framework for coordinating pan-European investment in supercomputing. Through this public-private partnership, the European Commission, Member States, and industry stakeholders are jointly investing in the development of an interconnected network of national and regional supercomputing centres. These centres aim to position Europe at the cutting edge of global computing power, while ensuring strategic independence from foreign technologies.

The ACHIEVE project, financed through the EU Advanced Digital Skills framework, contributes substantially to this European ecosystem for HPC, through educating and upskilling professionals in the interrelated areas of HPC, cloud and networking, through a two-year master program, independent modules, and innovation and entrepreneurship education.

Prior to the launch of the EuroHPC JU, European HPC efforts were largely coordinated through the Partnership for Advanced Computing in Europe (PRACE). Established in 2010, PRACE created a valuable pan-European platform by enabling researchers from all member countries to access Tier-0 systems hosted at leading centers. PRACE has been instrumental in consolidating Europe's fragmented HPC landscape, promoting shared use policies and ensuring open access to computational resources for excellence-driven science. However, despite its achievements, PRACE had its limitations. It operated primarily as a coordination and access mechanism, without a centralized strategy for infrastructure funding, procurement, or technology development.

The need for a more strategically integrated and financially empowered entity led to the creation of the EuroHPC JU in 2018. Unlike PRACE, the EuroHPC JU is a legal and financial entity with the mission to (i) develop a world-class supercomputing infrastructure in Europe, including the acquisition of pre-exascale and exascale systems, (ii) support research and innovation in HPC technologies, software and applications, (iii) promote the development of HPC skills and industrial uptake, especially among SMEs.

The EuroHPC Joint Undertaking brings together the European Commission, participating EU countries and private partners to combine their resources and co-invest in a unified European HPC strategy.

Major HPC centres across Europe, hosting some of the EuroHPC infrastructures, include:

- CINECA (Italy): One of the largest supercomputing centres in Europe, CINECA is hosting Leonardo, a EuroHPC pre-exascale system ranked among the top 10 most powerful supercomputers globally. Leonardo supports both academic research and industrial applications, with a strong focus on data analytics, AI, and simulation.
- CSC – IT Centre for Science (Finland): Hosting the LUMI supercomputer, the most powerful European HPC system, CSC plays a leading role in both research computing and green data centre innovation. LUMI is part of the EuroHPC JU initiative and supports pan-European research in fields such as climate modelling, bioinformatics, and material science.
- Jülich Supercomputing Centre (Germany): Known for its leadership in quantum-HPC convergence, it houses JUWELS and it is preparing for JUPITER, the first near-future European exascale system. It also actively participates in European collaborations on modular HPC and neuromorphic computing.
- Barcelona Supercomputing Centre – BSC (Spain): It hosts MareNostrum 5, BSC is not only a top-tier HPC centre but also a hub for cutting-edge research in AI, bioinformatics, and energy efficiency in computing. BSC plays a strategic role in the European Processor Initiative.

Other national centres exist around Europe, including a set hosting EuroHPC Petascale systems, such as IZUM-VEGA (Slovenia), LuxProvide-Meluxina (Luxemburg), IT4Innovation-Karolina (Czech Republic), Sofia TechPark-Discoverer (Bulgaria), MAAC-Deucalion (Portugal), GRNET-Daedalus (Greece).

All these centres often serve both national and EU-wide projects, providing computing access to academic institutions, industrial collaborators, and cross-border research initiatives. In addition to providing raw compute power, these facilities are also key players in training the HPC workforce.

1.4.2 United States

The United States maintains its leadership in HPC through a robust federal investment ecosystem, driven primarily by the Department of Energy (DOE), and supported by agencies such as NSF and DARPA. The DOE operates a network of national laboratories that house some of the world's most advanced HPC systems. Key centres include:

- Oak Ridge National Laboratory (ORNL): Host of Frontier, the world's first publicly confirmed exascale supercomputer as of 2023. ORNL leads research in energy, materials, and climate science. OakRidge was also previously hosting Summit, remained for several months on the first spot of the top500 list.
- Lawrence Livermore National Laboratory (LLNL) and Argonne National Laboratory (ANL): These institutions operated systems like Sierra and Polaris, and now host Aurora and EL Capitan, respectively, supporting applications in national security, advanced simulations, and quantum computing.
- Lawrence Berkeley National Laboratory (LBNL): Through its NERSC center, LBNL runs Perlmutter, a cutting-edge pre-exascale system designed to support a wide range of DOE Office of Science missions. Perlmutter combines traditional HPC with accelerated AI capabilities, particularly for materials design, astrophysics, and energy simulations.
- National Center for Supercomputing Applications (NCSA) at the University of Illinois, Texas Advanced Computing Center (TACC), and the San Diego Supercomputer Center (SDSC) further complement the federal HPC landscape, supporting academic research and open science.

Despite the US HPC ecosystem is strongly rooted in flagship facilities at Department of Energy (DOE) national laboratories, such as ORNL, ANL, LLNL, and LBNL, it also includes a rich network of additional federal centres, including smaller HPC resources at agencies such as NASA, NOAA, NSF-funded centres (e.g., NCSA, TACC and SDSC), and DOD labs, forming a decentralized yet robust infrastructure. The US approach combines long-term national interests, such as climate modelling, nuclear simulation and drug discovery - with shorter-term innovation pipelines for industry, facilitated by public-private partnerships with cloud and chip manufacturers. In recent years, the diversification strategy introduced by the US has been clearly visible, with funding to supercomputers mainly equipped with different technologies from different national suppliers (i.e. NVIDIA, AMD, Intel).

1.4.3 China

China has been rapidly rising in the HPC world over the past decade, largely driven by national strategic priorities of technological independence and data sovereignty. Through national programs, China has built several petascale and exascale-class systems, including Sunway TaihuLight (Wuxi) and Tianhe-2A (Guangzhou), former TOP500 leaders that were developed using largely self/in-house developed processors and interconnects. Unlike the previous systems, Sunway OceanLight is reported to be the first exascale-class system in operation, although it has not been officially benchmarked (and is therefore not listed in the TOP500). The presence of several high-performance systems in China that are either unlisted or not publicly benchmarked reflects a deliberate strategy of hiding detailed performance data, emphasizing the country's focus on technological self-reliance, national security, and competitive secrecy. This approach is consistent with China's broader policy of securing strategic capabilities in frontier technologies, including HPC, quantum computing and AI, while investing aggressively to lead global computing power rankings.

China's HPC efforts are closely linked to AI development, cryptographic research and national security priorities, making the sector more centralized and mission-driven than many counterparts in the rest of the world.

1.4.4 Japan

Japan has long been a leader in HPC, particularly in architectural innovation and energy efficiency. The RIKEN Centre for Computational Science, in collaboration with Fujitsu, is responsible for the development of Fugaku, the world's fastest supercomputer from 2020 to 2022. Based on ARM architecture, Fugaku is designed for broad societal applications, including pandemic modelling, personalised medicine and disaster prevention.

Japanese HPC efforts are focused on integrating AI with traditional HPC workflows, promoting software portability, and transitioning to post-exascale paradigms.

1.5 Key Innovations

High Performance Computing is entering in a transformative era, with the potential to reshape scientific discovery, industrial operations, and digital innovation across all sectors. In an increasingly data-driven world, HPC is no longer just about raw computing power - it is about intelligent, adaptive and interconnected infrastructures ranging from edge devices to exascale supercomputers. The HPC environments of today are merging with artificial intelligence, cloud ecosystems, quantum technologies, and real-time simulation to unlock unprecedented capabilities. Innovations such as quantum-HPC integration, AI-enabled simulation, urgent computing and the rise of the computing continuum are redefining how companies model, predict and respond to complex challenges. Meanwhile, shifts in architecture (from custom accelerators, energy-efficient systems, to federated multi-cloud infrastructures) are opening new frontiers for sustainability and flexibility. Businesses and research institutions that capitalize on these innovations are positioning themselves to lead in different application areas, ranging from climate resilience and digital health to autonomous systems and fundamental AI models. As HPC evolves into a truly dynamic and distributed ecosystem, recognizing these trends is essential to remaining competitive.

To better illustrate the concept, the following innovations highlight the most impactful developments expected to shape the HPC landscape over the next decade:

- Quantum Computing: Emerging quantum processors promise exponential speed-ups for specific problem classes, especially in cryptography, chemistry, and optimization
- Quantum–HPC Integration: Hybrid quantum-classical architectures will become critical, leveraging quantum accelerators alongside classical HPC for real-world workflows like materials design and machine learning.

- Exascale and Beyond: The transition to exascale computing marks a leap in simulation fidelity and scalability, enabling breakthroughs in weather prediction, genomics, and nuclear research.
- Post-Exascale Architectures: Energy-efficient computing paradigms, such as neuromorphic, analog, or photonic architectures, are being explored to address exascale's power and thermal limitations.
- Urgent and Real-Time Computing: Urgent computing capabilities will become essential for crisis response scenarios (e.g. pandemics, wildfires, earthquakes), requiring on-demand access to HPC.
- Multi-Cloud and Federated HPC Environments: Integration of HPC resources across multiple cloud providers and data centres will enhance flexibility, resilience, and global collaboration.
- The Computing Continuum (Edge–Fog–Cloud–HPC): Seamless orchestration across edge devices, fog nodes, and centralized HPC/cloud systems will support complex applications like autonomous systems and digital twins.
- AI-Enhanced Simulation and Surrogate Modelling: Machine learning will increasingly augment traditional simulations, enabling faster approximations and model tuning in fields like fluid dynamics and drug discovery.
- HPC for AI and Large-Scale Foundation Models: Training of massive generative AI models (e.g., LLMs) will rely heavily on HPC infrastructure, driving co-design of hardware, memory, and interconnects.
- High-Speed Interconnects and Smart Networking: Next-gen interconnects (e.g., NVLink, EFA, Quantum networks) and in-network computing will reduce bottlenecks in data movement at exascale scale.
- Advanced Cooling and Green HPC: Innovations in liquid cooling, immersion, and energy reuse will be necessary to manage power consumption and reduce the carbon footprint of HPC centres.
- Custom and Open-Source Hardware Architectures: RISC-V and domain-specific accelerators will challenge traditional x86/GPU dominance, promoting hardware sovereignty and modular co-design.
- Software-Defined Infrastructure and HPC-as-a-Service: The rise of composable and containerized HPC will enable dynamic resource

provisioning, user-defined workflows, and cloud-native HPC-as-a-Service models.

- Digital Twins at the Extreme Scale: Real-time digital replicas of physical systems, powered by HPC, is expected to revolutionize domains such as aerospace, smart manufacturing, and urban planning. Extreme digital twins such as the one promised by Destination Earth, will change the way to take decisions at all levels.
- Secure and Trusted HPC Infrastructures: Enhanced focus on cybersecurity, zero-trust architectures, and secure enclaves will be essential as sensitive workloads expand across shared infrastructures.

2 Job Market Needs

In this section we detail the job market needs in HPC, cloud and networking. First, in Section 2.1 we analyse the labour market trends in these areas. Then, in Section 2.2 we discuss what knowledge and skills are expected by the industry, and what is offered by today's educational programs. In Section 2.3 we define the gaps in the educational offering, with this defining the areas the ACHIEVE master program needs to address. In Section 2.4 we discuss the requirements and gaps in professional education and life-long learning offerings.

2.1 Labour Market Trends and Workforce Needs in Digital Infrastructure

The economic scale and rapid growth of High-Performance Computing (HPC), Cloud Infrastructure, and Networking technologies in Europe highlight an urgent and increasing demand for specialized talents. These sectors are not only vital to scientific advancement and industrial competitiveness but also form the backbone of the EU's digital and green transitions. As demand for computational power and data-driven solutions rises, so does the need for professionals capable of developing, managing, and applying these complex systems across domains. The EU's Digital Decade policy targets 20 million employed ICT specialists by 2030, nearly double the ~9.8 million recorded in 2023 [18, 19].

2.1.1 High-Performance Computing (HPC) Workforce Demand

High-Performance Computing is experiencing robust growth in demand across Europe, driven by both technological advancement and increasing demand from research and industry. On the technology side, major investments are being made under the EuroHPC Joint Undertaking, which is spearheading Europe's efforts to establish global leadership in supercomputing. Also, as discussed above, eight leading-edge supercomputing centres have been deployed or are under development across Europe, including JUPITER, Europe's first exascale supercomputer [20]. These systems represent a significant leap in computing capacity and call for a highly skilled workforce to design, operate, and optimise next-generation HPC systems.

On the demand side, HPC has become critical for scientific discovery, public policy, and industrial innovation. It plays a central role in addressing societal challenges such as climate change, energy transition, and global health. As the European Investment Bank has noted, supercomputing is "making a difference in the everyday life of citizens" by enabling breakthroughs in fields like drug discovery, personalized medicine, and natural disaster prediction [21]. Key industries, like pharmaceuticals, biomedical research, automotive engineering (e.g., crash and aerodynamic simulations), finance (e.g., risk modelling), and renewable energy, are increasingly reliant on HPC for research and product development [21]. As a result, there is strong and growing demand for specialists in HPC systems engineering, parallel programming, performance optimization, and data-intensive computing.

The demand for professionals with HPC skills is growing faster than the supply. The EU Digital Skills and Jobs Platform highlights a "growing demand for skilled HPC professionals across Europe" in response to expanding HPC adoption across sectors. As more industries adopt HPC and big data analytics, this demand is expected to increase even further. From a labour market perspective, job postings for roles like HPC system administrator, parallel computing specialist, or HPC application engineer are becoming more common – not only at supercomputing centres and universities but also in industry (e.g. large manufacturing firms and consultancies). Moreover, many organizations report difficulties in filling these positions. In interviews with STEM hiring managers, over half of them indicated that their company would offer higher salaries to candidates with HPC experience, reflecting how scarce and valued such skills are [22].

The EuroHPC Joint Undertaking has explicitly acknowledged a “critical skills gap” in the field and launched dedicated pan-European master’s programme to address it [23]. These efforts are part of the EU’s broader digital skills agenda, as outlined in the Digital Decade 2030 strategy. The European Commission aims to employ 20 million ICT specialists by 2030, and HPC is viewed as a key capability supporting digital transformation in areas such as climate modelling, drug discovery, and AI research [19].

At the national level, the EuroCC initiative has funded the creation of HPC Competence Centres across Europe. These centres act as bridges between HPC infrastructure and industry, particularly small and medium-sized enterprises (SMEs). They generate additional demand for HPC-trained personnel who can guide industrial users in applying HPC to their workflows, further expanding the job market in this field [24].

European policy initiatives and investments also reflect the growing demand for HPC-related skills and jobs. The EuroHPC Joint Undertaking is not only investing in supercomputing infrastructure, but also prioritizing human capital development. A core part of its mission is to “support the development of key HPC skills for European science and industry” [25].

To that end, new projects, such as the EuroHPC Virtual Training Academy [26] and dedicated education-focused calls aim to train thousands of students and professionals in the coming years. The Horizon Europe programme, EU’s flagship research funding initiative, has also allocated significant support to HPC-related efforts. This includes funding for Centres of Excellence in HPC applications [27] and research on energy-efficient HPC technologies [28].

These projects typically create employment opportunities for researchers, engineers, and technical staff with HPC expertise. At national level, many European countries have also established HPC Competence Centres, often through the EuroCC initiative. These centres aim to help businesses, especially small and medium-sized enterprises (SMEs), adopt HPC technologies. As a result, they are actively hiring professionals who can connect technical know-how with real-world industrial needs, further expanding the job market for HPC-skilled personnel.

It is also important to highlight the mismatch between Europe's HPC demand and its current computing capacity, a gap that further reflects workforce needs. Although European industry and researchers account for roughly one-third of global demand for HPC, only about 5% of the world's HPC capacity is located in Europe [21]. While this is partly due to infrastructure limitations, a significant factor is the shortage of skilled professionals able to fully exploit existing and emerging systems.

As Europe rapidly expands its supercomputing infrastructure, including progress toward exascale computing, the need for a local, highly skilled workforce is becoming even more pressing. If these systems are to be used effectively across scientific domains and small-to-medium-sized enterprises (SMEs), thousands of new HPC professionals will be required across the EU. In-demand roles include HPC system administrators (who ensure optimal system operation), computational scientists (who write scalable code for HPC architectures), and data analysts (who apply HPC to AI, machine learning, and big data challenges).

In summary, the European labour market for HPC professionals is strong and growing rapidly. The shortage of qualified personnel is evident in the European industry [22], therefore, HPC is in the explicit focus of EU-level initiatives on workforce development. For any Master's programme covering HPC, this signals excellent career prospects for graduates and provides a compelling case for training more specialists in this high-demand field.

2.1.2 Cloud infrastructure skills and employment trends

Alongside the rise of HPC, Europe is also witnessing sustained and growing demand for cloud computing professionals. Over the past decade, cloud services have evolved from a niche IT solution to a fundamental component of business operations and public services. By 2023, nearly half of all European enterprises were using cloud services for tasks ranging from email hosting and data storage to application deployment and analytics [29]. Europe's rapid shift to cloud computing has triggered an unprecedented demand for skilled professionals. Roles such as Cloud Engineer, DevOps Engineer, Cloud Architect, and Cloud Security Specialist are among the most sought-after, reflecting a tight labor market for cloud expertise. LinkedIn data shows a 55% increase in demand for cloud skills within job listings over the past two years, while nearly two-thirds of EU enterprises trying to recruit ICT specialists in 2021 reported difficulties in filling vacancies [30]. This talent scarcity coincides with the adoption of hybrid and multi-cloud strategies, now the norm for most organizations, as they seek reliability, scalability, and vendor independence. To keep pace, Europe will need a significant expansion of its tech workforce.

Cloud investment trends further reinforce this demand. European public cloud spending rose to an estimated $150 billion in 2023, up from $110 billion in 2022 [31]. As businesses increase their reliance on cloud services, they must also optimize their cloud architectures to reduce waste and ensure efficiency, a concern echoed by the European Commission's emphasis on the need for energy-efficient data processing capacities [32]. Cloud architects play a key role in this process. Significant cloud spending is often wasted on underutilized resources, frequently stemming from the overprovisioning of capacity [33]. Organizations adopting FinOps (Financial Operations) practices to address such inefficiencies can realize consistent cost reduction of around 20% [34], and specialised AI-driven optimization models have demonstrated potential server cost reductions of as much as 45% by minimizing resource underutilization [35]. Furthermore, 'dark data', information that is collected, processed, and stored but never subsequently used for any meaningful purpose, can constitute as much as 55% of an organization's stored data, and this contributes significantly to resource drain and unnecessary expenditure [36]. As a result, cloud cost management and architecture optimization skills are increasingly valuable in the labour market.

Europe's policy and investment landscape also supports cloud job growth. Initiatives like GAIA- X (a federated European cloud project) aim to create a sovereign cloud infrastructure in Europe [37]. If successful, GAIA-X could accelerate the development of cloud services in Europe and stimulate job creation in cloud engineering and operations. Meanwhile, the Digital Europe Programme and the Recovery and Resilience Facility (RRF) include funding not only for infrastructure but also for cloud-focused training and reskilling programmes, recognizing that technology adoption must be matched by a skilled workforce [38, 39]. Furthermore, the synergy between cloud and other priority areas like AI and cybersecurity amplifies demand: cloud experts who also have AI knowledge, or who can implement secure cloud architectures, are particularly sought after.

Another critical dimension is the geographical distribution of cloud-related opportunities. While tech hubs like Dublin, Amsterdam, Berlin or Paris host many cloud data centres and companies, cloud adoption is everywhere, meaning every country needs cloud-savvy IT professionals. The normalization of remote work and cloud-based infrastructure management, accelerated by the pandemic, has enabled companies to hire across borders. However, this also means European firms increasingly compete with global companies (especially in North America) for top cloud talent. This international competition contributes to rising salaries and talent retention challenges, reinforcing the need for continuous investment in training and upskilling initiatives.

In summary, the European labour market for cloud infrastructure and services is vibrant, growing, and under pressure. Cloud-related roles consistently rank among the fastest-growing IT jobs, and skill shortages are reported particularly in areas like cloud security and Kubernetes administration. For a Master's programme focused on digital infrastructure, this presents a promising opportunity: graduates with cloud expertise, certifications, and project experience will be highly employable across a range of sectors, from technology and consulting to finance, manufacturing, and scientific research.

2.1.3 Networking and connectivity professions in the digital economy

While often less visible than other digital domains, computer networking remains a foundational pillar of the digital economy. It is now experiencing renewed demand for professionals who understand the networking requirements of HPC and cloud computing environments. As Europe continues to expand its digital infrastructure, the need for a qualified network engineering workforce grows in parallel. Network specialists ensure the seamless and secure flow of data between data centres, supercomputers, and cloud platforms, making them indispensable to both operational continuity and performance optimization.

A clear example of this priority is the EuroHPC Joint Undertaking's recent initiative to develop a high-speed, secure, pan-European network interconnecting HPC and quantum computing facilities. In late 2024, EuroHPC launched a call for proposals to build what it described as a "hyper-connected and federated HPC and quantum computing ecosystem", often referred to as the EuroHPC Network or Hyperconnect initiative [40]. This network will require specialized expertise in ultra-fast optical connections, software-defined networking (SDN), and potentially terabit-scale technologies. Professionals with advanced knowledge of HPC interconnects, as well as those skilled in cybersecurity for networked infrastructure, will be essential to implementing and securing this architecture. EU investment in dedicated HPC networking infrastructure underscores an important insight: the success of distributed supercomputing and cross-border scientific collaboration depends on low-latency, high-bandwidth networks.

Beyond HPC-specific networks, Europe's broader push to expand its digital connectivity, including the deployment of 5G, the research and early piloting of 6G networks, and the widespread integration of Internet of Things (IoT) devices, generates strong demand for skilled networking and telecommunications engineers. Companies across the telecommunications, network hardware, and smart infrastructure sectors are actively recruiting professionals who can support next-generation connectivity.

In enterprise IT, the widespread shift to cloud computing and remote work has further elevated the demand for network architects who can design hybrid networks, securely connecting on-premises systems with cloud-based infrastructure. At the same time, growing cybersecurity threats, particularly to critical infrastructure and data-intensive systems, have made network security specialists increasingly indispensable. These trends together continue to drive a steady and persistent demand for skilled networking professionals across sectors.

According to labour market trends, job titles such as Network Architect, Network Reliability Engineer, and Cloud Network Engineer are now regularly featured alongside postings for cloud and HPC-related roles. Employers increasingly seek individuals with expertise in software-defined networking (SDN), network automation, and cloud networking, requiring proficiency with Azure and AWS networking services, VPNs, and virtual network design. Crucially, the demand extends beyond maintaining legacy systems; organizations are also looking to innovate next-generation network architectures. This includes implementing advanced protocols and designs capable of managing the massive data throughput generated by HPC simulations, AI models, and large-scale IoT sensor grids.

One notable challenge is that networking is sometimes perceived as a more “traditional” IT field, which leads to fewer young professionals choosing it over trendier areas like software development, data science, or AI. As a result, some organizations face an aging networking workforce, with a growing number of experienced engineers approaching retirement. To maintain and expand Europe’s digital infrastructure, companies and public institutions will need a new generation of professionals who possess both strong foundational knowledge in networking and familiarity with modern technologies and tools.

The planned Master’s programme can help address this gap by teaching networking not as an isolated skill, but as a core enabler of HPC, cloud, and data-driven systems. For example, graduates should learn how to build and optimize networks that support HPC clusters, manage hybrid cloud connectivity, and secure data flow in real-time IoT applications. Integrating networking education with broader digital infrastructure themes will ensure that students are equipped to design, troubleshoot, and optimize performance in complex, multi-domain environments.

In summary, while HPC and cloud roles often capture more attention, networking professionals remain essential to Europe’s digital transformation. Initiatives such as EuroHPC’s federated network, the rollout of 5G and 6G, and the rise of edge and IoT systems all underscore the growing need for advanced networking expertise. Graduates who combine core networking skills with knowledge of HPC and cloud computing will be particularly valuable. These interdisciplinary capabilities position them to bridge critical gaps between computing and communications domains, supporting both innovation and infrastructure resilience across Europe.

2.1.4 Sectoral drivers and investments shaping demand

It is important to highlight why these trends are happening by looking at a few key sectors and EU investments:

- **Artificial Intelligence & Big Data:** The AI boom is a major driver of demand for HPC and cloud skills. Training AI models, especially large ones (like GPT-style neural networks), requires massive computing power often delivered via HPC clusters or cloud compute instances. Europe's push for leadership in AI research and adoption creates many roles at this intersection (AI engineers who need HPC, or HPC specialists working in AI labs). A recent survey found that a majority of European decision-makers see AI/ML skills shortages as a pressing issue [41]. By training people in HPC/cloud, we indirectly fill AI skill gaps too, since AI workloads run on those platforms. By coordinating AI, data, and robotics programmes under Horizon Europe, the European Commission funds projects that require HPC and cloud-computing expertise for data-intensive research: such projects are indeed a "job incubator" for these skills.
- **Pharmaceuticals & Healthcare:** Pharma companies use HPC for drug simulations (e.g. protein folding, genomics). During the COVID-19 pandemic, for example, European supercomputers were used to screen compounds and model virus spread. This has led to pharma companies seeking in-house HPC experts or collaborating with HPC centres. Either way, skilled personnel are needed to run those computations. Personalised medicine and genomics also generate huge datasets requiring both HPC analysis and cloud-based sharing among research hospitals. The healthcare sector's digital transformation (like hospital cloud data systems, health analytics) creates demand for cloud and data centre experts, while cutting-edge biomedical research creates demand for HPC programmers and bioinformaticians with HPC skills.
- **Energy & Climate:** The EU's energy sector (from oil & gas to renewable energy) has long used HPC for exploration simulations, grid modelling, and climate predictions. With the Green Deal, there is increased emphasis on renewable energy optimization and climate science, both of these are heavy users of HPC. Meteorological services (like ECMWF,

national weather centres) are building the next generation of climate models on supercomputers and require specialists to maintain these HPC codes and systems. Energy companies are also adopting cloud solutions for IoT sensor data and smart grid management, creating a clear need for cloud architects and data pipeline engineers. Moreover, green computing is a concern: data canters and HPC labs are investing in efficiency (as discussed, EuroHPC is funding R&D into energy-efficient HPC software and management [25]. This spurs demand for experts who can both implement performance and also minimize energy usage, a new kind of dual engineering competence.

- **Finance & Manufacturing:** The finance sector uses HPC for risk analysis and real-time trading analytics, and increasingly uses cloud for its flexibility. Banks in Europe have been hiring cloud engineers to migrate legacy systems to the cloud while also employing HPC specialists in areas like portfolio risk modelling or cryptography. Manufacturing (including automotive and aerospace) heavily uses HPC for simulation (computer-aided engineering). For example, carmakers run crash simulations and aerodynamics in HPC clusters. These companies are now exploring the use of cloud bursting, using cloud instances when HPC centres are full. This trend requires professionals who understand HPC workloads and how to offload or extend them to cloud environments. The convergence of HPC and cloud in such industrial applications is creating hybrid roles and thus a need for broad skill sets.
- **Public sector & Academia:** European universities and research institutes are major employers of HPC specialists, as they run large supercomputers for scientific research. National labs (e.g. nuclear research, weather forecasting, computational chemistry) all need a pipeline of skilled HPC system managers and application experts. Meanwhile, public administrations are moving services to the cloud (e-government services, open data platforms) requiring cloud IT specialists. EU institutions themselves (like the European Centre for Medium-Range Weather Forecasts, CERN for particle physics, or the EuroHPC sites) hire internationally for these skills, and often face competition to attract talents.

Significant EU and national-level investments are being made to expand HPC and cloud infrastructure across Europe. Programmes such as EuroHPC JU, Horizon Europe, and the Digital Europe Programme are co-funding new supercomputing facilities, exascale systems, and skills development initiatives. These investments not only address existing capacity gaps but are expected to further increase demand for skilled professionals capable of operating and utilizing these technologies effectively.

In conclusion, the labour market analysis clearly demonstrates a robust and growing demand for professionals in HPC, cloud infrastructure, and networking technologies across Europe. Driven by accelerated digitalisation, and strategic infrastructure buildouts, this demand significantly exceeds current supply. A new Master's programme focused on these fields is not only timely but essential.

2.2 Required job skills for HPC, cloud and networking roles

The convergence of HPC, cloud, and advanced networking in modern computing means that employers are looking for multidisciplinary skill sets. A graduate of the proposed Master's should ideally be a "Swiss army knife" in computing – capable of configuring a supercomputing cluster, deploying applications on the cloud, automating workflows, and optimizing performance and energy use. Based on job postings and industry surveys, the following job-ready skills are most frequently sought by employers in these fields:

- **Computer and data scientist basic skills:** including computer architecture, operating systems, and algorithms, data analytics, machine learning or statistical modelling with a strong understanding of big data technologies such as Hadoop/MapReduce and NoSQL databases [42].
- **HPC systems operation and management:** Employers seek professionals who can effectively operate and manage HPC clusters. This includes proficiency with job schedulers like Slurm, system monitoring, and workload management in multi-user environments. Strong Linux administration skills are essential, as most HPC systems run on Linux. Scripting in Bash or Python is often required to automate job submissions and maintenance tasks. A well-rounded HPC specialist

should be capable of managing compute nodes, storage, and troubleshooting jobs, while also optimizing scheduler configurations and resource usage to improve system throughput [43].

- **Parallel programming and software development:** HPC professionals are expected to have strong programming abilities, specifically in parallel and high-performance contexts. Knowledge of MPI (Message Passing Interface) is often a must for HPC developer roles, as MPI is the standard for distributed-memory parallelism across cluster nodes. Likewise, expertise in OpenMP (for shared-memory parallelism on multi-core processors) is valuable. Modern HPC also increasingly involves GPU programming (using CUDA or OpenCL, or frameworks like GPU-accelerated libraries and OpenACC directives) since GPUs power many top supercomputers. Employers look for experience in languages commonly used in HPC: C/C++, Fortran (which still underpins a lot of scientific code), and increasingly Python (with optimization techniques or use of HPC libraries). A successful candidate should be able to profile and optimize code, understanding concepts like vectorization, memory hierarchy, and communication overhead [22, 44].
- **Cloud architecture and services:** Employers value professionals who can design reliable, scalable, and secure cloud architectures. This requires a solid understanding of cloud service models (IaaS, PaaS, SaaS), virtualization, and workload distribution across cloud environments. While experience with platforms such as AWS, Azure, or Google Cloud is frequently requested, the most in-demand skills relate to architectural thinking: cost-efficiency, autoscaling, security best practices, and resource provisioning. Familiarity with identity and access management, network isolation, and encrypted storage is especially relevant for roles requiring secure deployments. Knowledge of open-source cloud frameworks like OpenStack is a plus for organizations using private or hybrid clouds. Overall, candidates are expected to combine technical proficiency with an understanding of how to align cloud infrastructure with operational and business needs [45].
- **Containerisation and orchestration:** Containers have revolutionized software deployment in both cloud and HPC (via containerized

workflows for portability). Employers therefore seek skills in container technologies, primarily Docker for creating and managing containers, and Kubernetes for container orchestration at scale. Skills in packaging applications with their dependencies, managing container registries, and configuring deployments using tools like Helm are widely valued. As container orchestration services are offered by all major cloud platforms, these competencies enable flexibility across environments. In HPC, tools such as Singularity or Apptainer are gaining traction to support portable, reproducible workflows on supercomputers. The ability to manage containerized applications efficiently is considered a key differentiator in modern infrastructure roles.

- **Infrastructure as code (IaC) and automation:** Automation is central to modern cloud and HPC operations, and employers value professionals who can manage infrastructure programmatically. Skills in Infrastructure as Code, particularly using tools like Terraform, are highly sought after for deploying and maintaining complex cloud environments consistently and at scale. Configuration management tools such as Ansible, Puppet, or Chef, along with CI/CD systems like Jenkins, GitLab CI, or GitHub Actions, are also in demand. These tools support automated software testing, building, and deployment, key components of DevOps workflows. In HPC, similar automation practices are emerging for scientific code integration and containerized pipeline management. The ability to script repeatable infrastructure or build pipelines that trigger tests and deployments automatically is considered a critical efficiency skill in both cloud and HPC roles.
- **DevOps and site reliability engineering (SRE) mindset:** Beyond specific tools, companies are looking for the mindset and practices of DevOps, that is, the ability to work across development and operations to ensure systems are delivered quickly and run reliably. This includes familiarity with version control (Git), agile collaboration, and practices like infrastructure monitoring and observability (using tools like Prometheus, Grafana, ELK stack, etc.). A candidate for a cloud/HPC role who can not only deploy systems but also set up logging, monitoring, and alerting will stand out. Job descriptions for DevOps Engineer or

Cloud SRE typically require experience with microservices architecture, container orchestration, CI/CD, and maybe programming skills to develop automation tools (often in Python or Go). In HPC centres, roles similar to SRE are emerging to ensure high uptime and performance. These roles require skills in systematic troubleshooting, performance monitoring (using telemetry from HPC jobs), and automating routine maintenance tasks.

- **Networking and security skills:** Networking knowledge is essential across HPC, cloud, and hybrid environments. Employers look for familiarity with core network protocols (e.g., TCP/IP, HTTP, DNS), configuration of physical and virtual networks, and concepts like Software-Defined Networking (SDN). In cloud settings, skills in setting up VPCs, VPNs, load balancers, and firewall rules are commonly requested. For HPC, understanding high-speed interconnects such as InfiniBand or tuned Ethernet, as well as topologies (e.g., fat-tree, dragonfly), latency, and bandwidth optimization, is particularly valuable. Security is equally critical, since candidates are expected to know how to protect data in transit and at rest, implement authentication and authorization, and follow best practices for securing systems (e.g., managing cloud access controls or user environments on HPC clusters). Strong networking and security fundamentals are often embedded even in roles not explicitly labelled as such, especially in multidisciplinary cloud and HPC engineering positions.
- **Green computing and efficiency optimization:** An emerging skill set that is especially relevant in Europe with its strong sustainability agenda is energy-efficient computing. This can mean several things: writing software that is optimized to use less energy (for instance, optimizing code so it runs faster and thus uses less CPU time), managing power settings on servers (like using power capping or CPU frequency scaling on HPC nodes), or designing data centre layouts for cooling efficiency. While few job postings explicitly list "green computing" yet, companies and research labs increasingly value this expertise as energy costs rise and carbon reduction commitments firm up. The EuroHPC initiative explicitly calls for energy-aware resource management solutions [25] so

having skills or knowledge in this area could set candidates apart. This might involve familiarity with tools for monitoring power consumption of jobs, or methods to schedule workloads in ways that reduce peak power draw. It also overlaps with hardware knowledge, for example, with the understanding of the differences between CPU architectures in terms of energy use, or how using GPUs might save energy for certain workloads.

- **Soft skills and interdisciplinary work:** While technical expertise is essential, employers consistently emphasize the importance of soft skills and domain-specific awareness in cloud and HPC roles. These technologies are typically deployed in collaborative, interdisciplinary settings, where effective communication, teamwork, and project coordination are critical. For example, an HPC and cloud support engineer must often work closely with scientists or researchers who may lack deep technical expertise, requiring the ability to translate user needs into technical solutions and offer guidance in an accessible manner. In their supporting role engineers need to manage risks, including technology being delayed, not meeting performance assumptions, or the consequences of selecting wrong hardware options, architecture or configurations [46]. They need to understand the total cost of various solutions, including cost of ownership, and be able to assess value-risk-cost tradeoffs [46].
- **Business acumen and strategic thinking:** Similarly, cloud architects are expected to liaise with business or operational stakeholders, aligning infrastructure strategies with organizational goals. This calls for a blend of technical insight and business acumen, along with skills in negotiation and strategic thinking.
- **Domain knowledge:** In more senior or leadership-oriented roles, such as managing DevOps or user support teams, mentorship, conflict resolution, and team leadership capabilities become increasingly relevant. Additionally, domain knowledge is a strong differentiator. Since HPC and cloud technologies are used across specialized fields like engineering, life sciences, finance, and climate modeling, a candidate's effectiveness and employability can be significantly enhanced thanks to

the familiarity with domain-specific tools, data formats, or workflows (e.g., simulation software, statistical packages, or genomics pipelines). Professionals who can bridge computational infrastructure with scientific or business domain needs are particularly valued in both academic and industrial settings.

- **Cross-functional capabilities:** Employers in the HPC, cloud, and networking sectors are seeking well-rounded, hands-on professionals who can demonstrate practical experience with current tools, platforms, and operational practices. It is no longer sufficient to possess theoretical knowledge alone; job postings routinely specify skills such as administering Linux-based HPC clusters with Slurm, or proficiency in Docker, Kubernetes, and CI/CD workflows, reflecting the real-world expectations for technical roles. Beyond tool familiarity, the ability to work collaboratively, communicate across disciplines, and adapt to domain-specific challenges is increasingly valued. Professionals who bring together technical depth, applied experience, and cross-functional capabilities are best positioned to meet the evolving demands of this fast-paced and highly integrated field.

2.3 Skill and Knowledge Gaps in Current Educational Programmes

Despite the clear demand for HPC, cloud, and networking expertise, most traditional educational pathways in computer science and IT do not sufficiently cover these areas, especially not in an integrated, hands-on manner. This has led to a skills gap where graduates often lack the practical abilities needed by employers.

Limited HPC exposure in typical curricula

- One major gap is the limited exposure to high-performance computing in standard university programmes [47]. In many undergraduate CS degrees, students might learn the basics of parallel algorithms or concurrency on a single machine, but they seldom get to run code on an actual cluster or learn the specifics of supercomputing environments.

Key HPC concepts, like distributed memory vs shared memory programming, message passing (MPI), accelerator programming, or even simply using a scheduler in a multi-user system, are often absent unless a student takes a niche elective or pursues postgraduate study in a related field.

- Furthermore, HPC often lies at the intersection of computer science and applied domain science, which traditional programmes do not bridge well. A physics or engineering student may use HPC applications but not learn how to develop or maintain them, while a CS student might learn theoretical parallel computing but not how to apply it to, for example, a climate model or a bioinformatics pipeline. This siloed approach leaves a gap for interdisciplinary HPC training.
- The typical CS graduate is proficient in writing code for a single computer, but if handed a problem that requires utilizing 1000 cores on a supercomputer, they would be at a loss. As one HPC hiring manager commented, "any experience in parallel computing… is a real asset" because it is so rare that graduates have it [22]. Some universities have started to address this by introducing HPC modules or specialisations. However, these are not widespread. Often, learning HPC is something done at the postgraduate level or via extracurricular training (like PRACE [48] or EuroHPC training activities [49], which only reach a limited audience). This means a systemic gap: even as HPC becomes fundamental to research and industry, one cannot assume a new STEM graduate has any HPC familiarity.

Insufficient Hands-On and System-Level Training

- Another critical gap is the lack of hands-on, systems-level training in many computing programmes. Traditional curricula often emphasise theory and software development on personal computers, but not the operational side of running large systems or the DevOps practices required in modern IT. For instance, a student might graduate knowing multiple programming languages and algorithms, but never have configured a server rack, deployed a service on a cloud platform, or optimized a database query across distributed nodes. This is problematic because employers heavily value practical experience. Some examples of courses and master level programs with significant hands-on content are the Stanford High Performance Computing Center's introductory HPC course [50], or the HPC master at University of Edinburgh [51], and the EUMaster4HPC program implemented across Europe [23].

- When it comes to cloud computing education, similar gaps exist. Many universities have only recently begun to include cloud computing in their curricula. There might be a course on cloud basics or perhaps content about distributed systems, but students may not get to use commercial cloud platforms in any depth due to cost or complexity. As a result, they lack familiarity with AWS/Azure/GCP environments, which puts them at a disadvantage in job interviews where they might be asked if they have set up a cloud service or used Docker/Kubernetes. Some institutions are addressing this by using free cloud credits from providers or teaching with open-source tools like OpenStack for a private cloud experience. Yet, comprehensive cloud curriculum that covers architecture, services, DevOps, etc. is not mainstream. Additionally, DevOps culture (CI/CD, automation, etc.) is still not deeply ingrained in most academic programmes, which often compartmentalize software development and system administration topics.
- Networking education also tends to be quite theoretical (protocol design, network algorithms) or limited to Cisco certification training in vocational contexts. There is often a disconnection between classic computer networking courses and the realities of networking in cloud/HPC contexts (like virtual networking, software-defined networks, high-performance interconnects). Thus, a graduate might know how TCP congestion control works in theory, but not how to configure a virtual private cloud network or tune an InfiniBand fabric on a cluster.

Fragmentation and Lack of Integration

- Another observed gap is that the three areas – HPC, cloud, and networking – are usually taught separately, if at all. A student might specialise in one (for example, HPC or data science) but then not learn about cloud computing which is considered a different track, or vice versa. Current programmes rarely integrate these disciplines, which is increasingly necessary in the real world where HPC and cloud are converging (e.g. HPC centres offering cloud-like interfaces, or cloud providers offering high-performance computing instances). For example, a data science master's might teach cloud big data tools but not the HPC aspects of training very large models on a supercomputer; an HPC course might teach MPI on clusters but not containerization which is common in cloud deployments.

- The result is a talent pool that is siloed. Industry, however, is looking for hybrid skills: someone who understands HPC and cloud, or someone who can optimize low-level performance and utilize high-level cloud services. The lack of holistic programmes that cover the spectrum is a shortfall. There is an opportunity to bridge these domains, producing graduates who can navigate the full stack from hardware to application.
- Feedback from industry also suggests that soft skills and real-world project experience are lacking. Employers sometimes find that new graduates, while intelligent, are not accustomed to working on large collaborative projects or using industry tools/workflows. Academic projects are often smaller scale or solo endeavours.
- Some programmes, such as those at Stanford [50], EPCC [51], or within the EUMaster4HPC initiative [23], aim to close this gap through hands-on projects and industry collaboration—but these remain limited in number. Moreover, no existing programme fully aligns with the breadth (HPC+Cloud+Networking) that is envisioned, which means graduates currently often need to acquire the remaining competencies through on-the-job training. Indeed, companies frequently run their own training or rely on on-the-job upskilling to bring new hires up to speed with HPC systems or cloud platforms. The Commission notes that universities need to improve their education offering to satisfy the needs of the industry [47].
- In summary, current educational programmes have several gaps: limited HPC content, insufficient practical training in both HPC and cloud systems, fragmented coverage of related disciplines, and a lack of emphasis on operational skills and cross-cutting competencies.

2.4 Lifelong Learning Needs in the HPC, Cloud and Networking Sectors

Rapid technological evolution in high-performance computing (HPC), cloud, and networking has made continuous upskilling a critical priority. The half-life of technical knowledge is shrinking, meaning skills can become outdated within just a few years. Working professionals who cannot pause their careers for full-time degrees rely instead on flexible, practical learning pathways to stay current. Industry certifications and micro-credentials have thus risen in importance as targeted upskilling tools. Vendor credentials (e.g., AWS, Azure, Cisco) validate specific cloud and networking competencies, while online micro-credential programs on platforms like Coursera and edX offer bite-sized courses suited for busy schedules. These alternatives are increasingly seen as a direct response to workforce upskilling needs, providing a quick and affordable path to build new skills without the time and cost of another degree. Not only do such certifications and short courses impart practical skills, but evidence shows they can yield career benefits: an IDC study found that earning IT certifications measurably improves professionals' performance and promotion prospects [52].

In practice, on-the-job learning and online training have become the most common avenues for acquiring cloud and digital infrastructure skills. Employers favour on-the-job training as a cost-effective way to ensure new skills are immediately relevant to business needs [52] and many firms now embed continuous learning into employees' roles. At the same time, self-paced online courses and MOOCs have surged in popularity, eclipsing traditional classroom courses. Globally, millions of learners are turning to platforms like Coursera and edX for on-demand learning. Coursera alone registered over 20 million new learners in 2021 [52]. Employers have also adjusted their expectations accordingly, 94% of business leaders now expect their staff to pick up new digital skills on the job, a significant increase from 65% just a few years prior [53].

This underscores that continuous, work-integrated learning and easily accessible online education are now central to professional development in these sectors. Despite the growth in offerings, there remains a lack of sufficient integrated content spanning HPC, cloud, and networking, leaving many lifelong learning needs unmet. Current training resources are often siloed by domain. For example, a few MOOCs cover HPC basics or cloud architecture, but it is rare to find coordinated curricula blending all three areas in context. This gap presents an opportunity to develop modular, targeted content (for instance, via a platform like Moodle) aligned with real-world job requirements and lifelong learning goals. While some online courses and MOOCs exist today, more tailored, domain-integrated and industry-validated programs are needed. Such offerings should connect directly to real-world skill demands across HPC, cloud, and networking, providing working professionals with stackable learning modules that collectively keep their skillsets in sync with the cutting edge of the industry.

3 THE ACHIEVE JOB MARKET SURVEY

3.1 Survey Design

The ACHIEVE project conducted a Europe-wide survey between August and October 2025, with the goal to understand the current status of High-Performance Computing (HPC) and Cloud Computing adoption in industry and academia. The questionnaire combined multiple-choice and open-ended questions targeting both academic and industrial stakeholders. The questionnaire was distributed through ACHIEVE consortium partners and relevant professional networks, targeting both academic institutions and industrial organizations active in computing, data science, and digital innovation.

The survey aimed to:

- Identify the skills and competencies most in demand.
- Understand workforce composition in HPC and cloud domains.
- Capture the challenges that organizations face in recruitment and training.
- Provide evidence for shaping industry-oriented MOOCs and master's-level curricula.

A total of 188 valid responses were collected from organizations from 21 European countries, ensuring broad geographical and sectoral coverage. The survey responses by country are shown on Figure 3.1.

The survey reveals a broad representation of industries and organizational types across Europe (see Figure 1). Among respondents, AI & Data Science (23%), Biotechnology (11%), and Healthcare & Pharmaceuticals (11%) stand out as the leading sectors, reflecting the increasing integration of advanced computing in data-intensive research and innovation.

In terms of organization size, participation is well-balanced: 32% of respondents come from small enterprises (10–49 employees), 32% from large enterprises (250+ employees), and 27% from medium-sized companies (50–249 employees), with 9% representing micro-enterprises.

A more detailed technical report, that includes the full questionnaire and visualized results, will be published separately as a dedicated ACHIEVE survey deliverable. The present section therefore provides only an overview and interpretation of the key trends and implications for curriculum design.

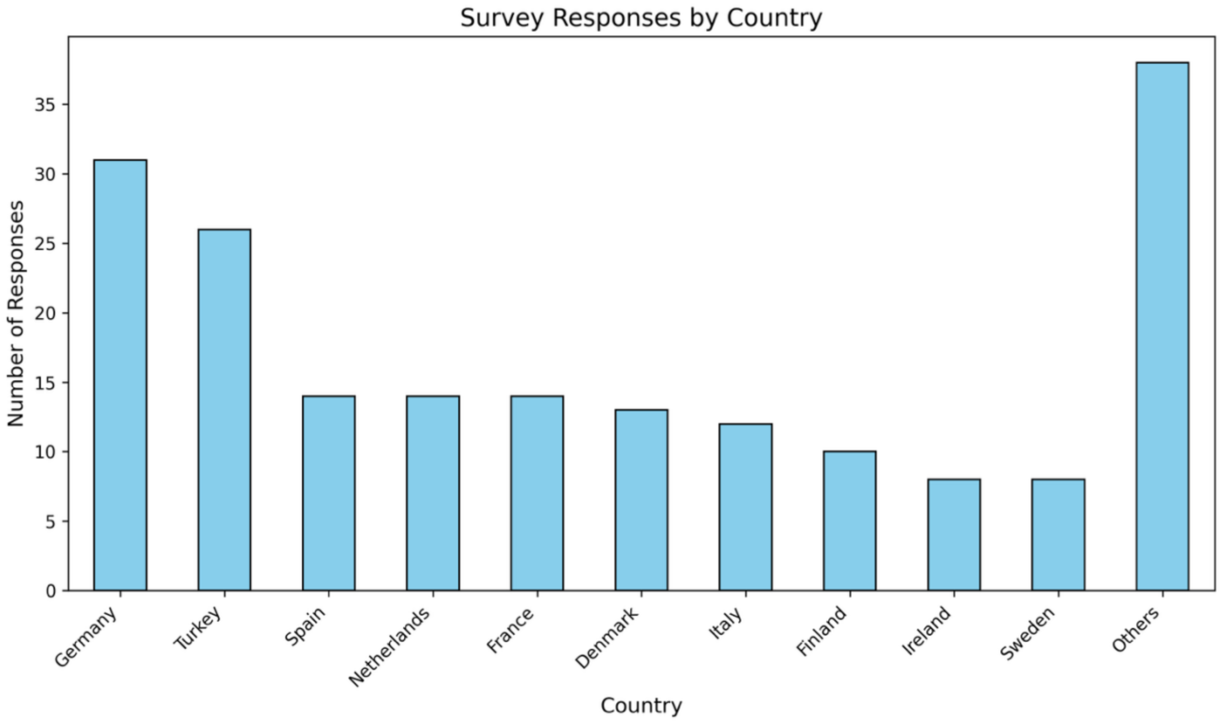

Figure 1: ACHIEVE job market survey responses by country.

3.2 Results and Findings

The survey results confirm that European industries and research organizations face a critical shortage of professionals skilled in HPC and Cloud technologies. This shortage is not merely quantitative but qualitative: employers struggle to find candidates with the right blend of theoretical understanding and hands-on experience required for managing hybrid, data-intensive computing environments. The survey also revealed that most organizations now rely on both HPC and Cloud infrastructures (65%), reflecting the rapid convergence between the two domains. Traditional engineering programs cannot by themselves meet this need; new curricula that combine academic rigor with practical, hybrid-computing skills are required.

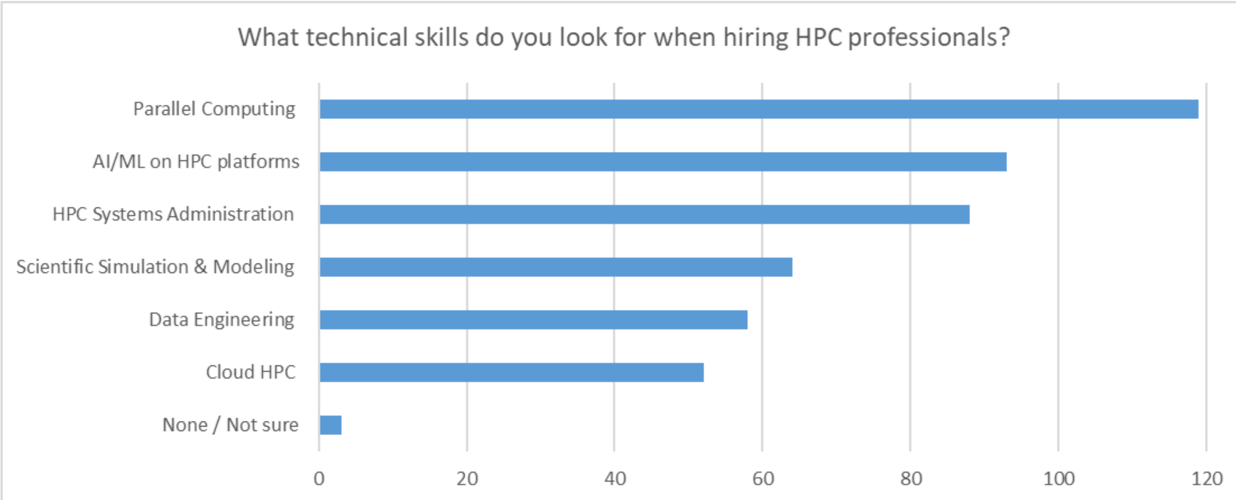

Figure 2: Most important technical skills for HPC professionals, according to the ACHIEVE survey.

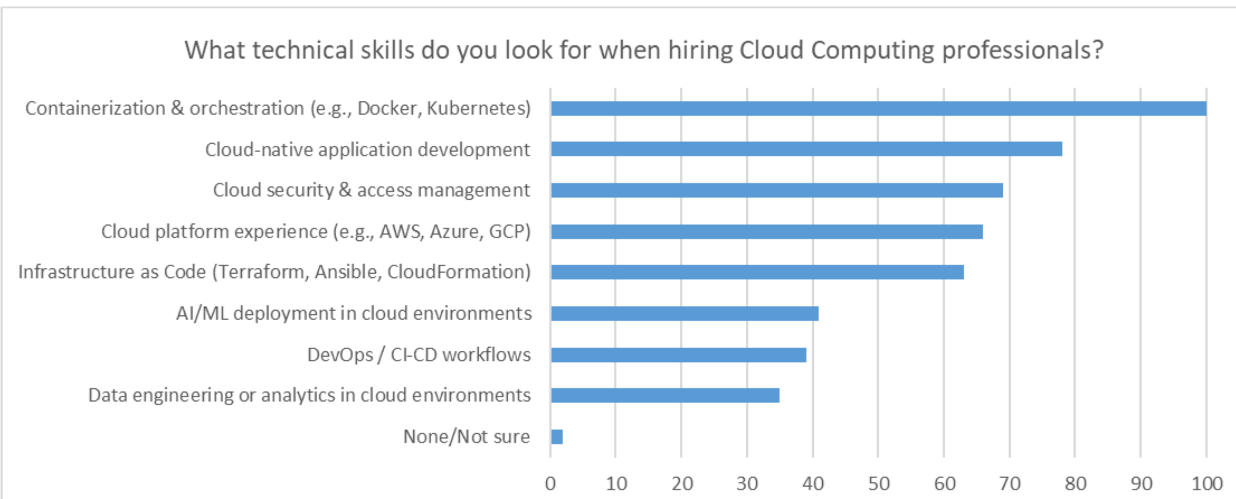

Figure 3: Most important technical skills for cloud professionals, according to the ACHIEVE survey.

Respondents consistently emphasized that traditional Computer Science and Engineering programs provide good theoretical foundations but insufficient practical exposure to the tools, platforms, and interdisciplinary workflows used in modern research and industry. As shown in Figures 3.2 and 3.3, they identified parallel programming, GPU acceleration, HPC-Cloud interoperability, and DevOps for scientific computing, cloud orchestration and application developement as the most pressing areas for new training. The answers show that students should be trained to operate across both HPC and Cloud ecosystems, mastering not only the technologies but also related aspects such as data governance, security compliance, and cost-efficient resource management.

The survey highlighted also that HPC adoption is driven by both traditional scientific workloads and emerging data-intensive applications. Core application areas include machine learning and deep learning, big-data analytics, and classic engineering simulations, complemented by specific research-driven uses like drug discovery and climate modelling. This mix indicates that future HPC education must address both legacy simulation workflows and new AI-driven paradigms.

The need for skilled professionals, and the promising setup of the ACHIEVE master program are reflected also in the answers to the open-ended responses on collaboration with academia: 45 % expressed willingness to co-design courses, 49 % to act as advisory partners, and 56 % to host interns or apprentices, with 37 % willing to do so even without financial support.

A major theme across responses was the importance of flexible, modular learning pathways. Many organizations indicated that MOOCs and professional certifications will be vital complements to formal degrees, particularly for upskilling existing staff and supporting lifelong learning.

Employers expressed preference for certified competencies (e.g., in Kubernetes, Slurm, AWS, or GPU computing) as recognizable proof of practical capability. The survey therefore validates ACHIEVE's strategy to integrate stackable online courses and certification modules alongside traditional master's education, ensuring both accessibility and labour-market relevance.

By grounding its program design in these findings, ACHIEVE can build a master's program that responds directly to sectoral needs, complements existing engineering education with specialized hybrid-computing skills, and offers flexible learning formats that reach both students and working professionals. Such a program will help close the talent gap, support innovation in strategic industries, and position Europe at the forefront of advanced, data-intensive computing.

3.3 The Impact of the Survey on the Curriculum Design

While the initial curriculum framework of the ACHIEVE master's programme was defined prior to the survey, these findings serve as an evidence base for the refinement of the actual course content, and for the definition of the self-standing learning modules in Work Packages 3 and 4.

Based on the insights collected, ACHIEVE will further strengthen modules on Parallel Programming and GPU Acceleration, Cloud-Oriented DevOps, and Hybrid HPC–Cloud Orchestration. The results will also inform the development of MOOCs and certification pathways to ensure that the program remains aligned with evolving industry demands.

In conclusion, the survey results form a solid empirical basis for the continuous refinement of ACHIEVE's educational framework, ensuring its alignment with Europe's long-term ambitions in advanced digital and hybrid computing.

4 Structure and Contents of the Master Programme

4.1 Outcome of the Market Analysis and Impact on the Programme

4.1.1 General Remarks

The market analysis outlined the needs for professionals operating in the areas of Cloud and Network Infrastructures (CNI) and High-Performance Computing (HPC).

Roles such as Cloud Engineer, DevOps Engineer, Cloud Architect, and Cloud Security Specialist are among the most sought-after, reflecting a tight labour market for cloud expertise. As Europe continues to expand its digital infrastructure, the need for a qualified network engineering workforce grows in parallel. Network specialists ensure the seamless and secure flow of data between data centres, supercomputers, and cloud platforms — making them indispensable to both operational continuity and performance optimization.

Moreover, with the advent of 5G/6G mobile networks and progressive softwarization of the communication infrastructures, cloud technologies are penetrating and being integrated in the network infrastructure, with emerging paradigms such as IoT and edge computing.

On the HPC side, the EuroHPC Network or Hyperconnect initiative will require specialized expertise in ultra-fast optical connections, software-defined networking (SDN), and potentially terabit-scale technologies. Professionals with advanced knowledge of HPC interconnects, as well as those skilled in cybersecurity for networked infrastructure, will be essential to implementing and securing this architecture.

4.1.2 Labour Market Trends

According to labour market trends, job titles such as Network Architect, Network Reliability Engineer, and Cloud Network Engineer are now regularly featured alongside postings for cloud and HPC-related roles. Employers increasingly seek individuals with expertise in software-defined networking (SDN), network automation, and cloud networking — including proficiency with Azure and AWS networking services, VPNs, and virtual network design. Crucially, the demand extends beyond maintaining legacy systems; organizations are also looking to innovate next-generation network architectures. This includes implementing advanced protocols and designs capable of managing the massive data throughput generated by HPC simulations, AI models, and large-scale IoT sensor grids.

The planned Master's programme can help address this identified gap by teaching networking not as an isolated skill, but as a core enabler of HPC, cloud, and data-driven systems. For example, graduates should learn how to build and optimize networks that support HPC clusters, manage hybrid cloud connectivity, and secure data flow in real-time IoT applications. Integrating networking education with broader digital infrastructure themes will ensure students are equipped to design, troubleshoot, and optimize performance in complex, multi-domain environments.

In summary, while HPC and cloud roles often capture more attention, networking professionals remain essential to Europe's digital transformation. Initiatives such as EuroHPC's federated network, the rollout of 5G and 6G, and the rise of edge and IoT systems all underscore the growing need for advanced networking expertise. Graduates who combine core networking skills with knowledge of HPC and cloud computing — such as configuring interconnects for distributed compute nodes or resolving bottlenecks in multi-cloud environments — will be particularly valuable. These interdisciplinary capabilities position them to bridge critical gaps between computing and communications domains, supporting both innovation and infrastructure resilience across Europe.

As a result, the following job skills for HPC, cloud and networking roles are emerging:

- Computer and data scientist basic skills
- HPC systems operation and management
- Parallel programming and software development

- Cloud architecture and services
- Containerisation and orchestration
- Infrastructure as code and automation
- DevOps and site reliability engineering mindset
- Networking and security skills
- Green computing and efficiency optimization
- Soft skills and domain knowledge
- Business acumen and strategic thinking
- Cross-functional capabilities

The following gaps in the current educational programmes were identified:

- Limited HPC exposure in typical curricula
- Insufficient hands-on and system-level training
- Fragmentation and lack of integration

Respondents to the survey consistently emphasized that traditional Computer Science and Engineering programs provide good theoretical foundations but insufficient practical exposure to the tools, platforms, and interdisciplinary workflows used in modern research and industry. They identified parallel programming, GPU acceleration, HPC-Cloud interoperability, and DevOps for scientific computing as the most pressing areas for new training. The answers show that students should be trained to operate across both HPC and Cloud ecosystems, mastering not only the technologies but also related aspects such as data governance, security compliance, and cost-efficient resource management.

4.1.3 Market Impact on the Programme

A major theme across responses was the importance of flexible, modular learning pathways.

It is not possible to design a single, monolithic master's programme that provides all these skills at the same level of detail for every student. Therefore, ACHIEVE partners studied the best way to strike a balance between broad coverage of general topics and focused, vertical specialization in selected areas. The previous experience by several consortium members within the EIT Digital consortium was useful in order to drive the decision about constraints and degrees of freedom in the programme, including also the need for satisfying local regulations in each of the corresponding countries.

M.Sc. degrees in Information Engineering and Computer Science (or in general in the field of ICT) were used as blueprints in order to structure the program, while integrating Innovation & Entrepreneurship subjects and facilitating mobility between the First Year (mostly focused on basic topic and broad technical knowledge) and the Second Year (characterized by vertical specialization and relevant exposure to the industrial environment).

The next sub-section provides a detailed description of the selected Programme Structure.

4.2 General Programme Concept and Structure

The master's programme will be developed in parallel building on the already existing structure of the EIT Digital Master School programmes. Figure 4.1 provides an overview of the programme structure developed in ACHIEVE.

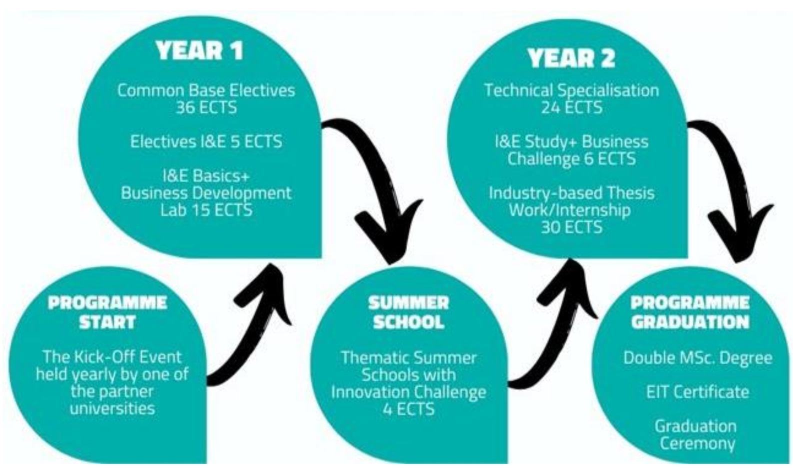

Figure 4: Structure of ACHIEVE Master's programme, including the I&E minor.

The key characteristics of the programme are the following:

- **Common technical knowledge**: The first year of the programme will offer a set of courses providing to all students with the same foundational knowledge, enabling them to select any second-year university for their specialization. Due to the variety of possible specializations, ACHIEVE partners decided to require at least one basic course in networking and one basic course in HPC basics.
- **Mobility**: Students will study each year in a different higher education institution in a different country, with the higher education institutions awarding a double degree to students. The two higher education institutions will be denoted hereafter as Entry University (where a student studies during the first year) and Exit University (where a student studies during the second year).
- **Specialisation**: Every higher education institution acting as Exit University will offer students a technical specialisation (24 ECTS) in the scientific area(s) of excellence of their researchers. A detailed list of the available specializations is provided later in the text.

- **Minor in Innovation and Entrepreneurship (I&E)** for a total of 30 ECTS. This minor includes 24 ECTS to be completed in the first year, including:
  a. a mandatory course on I&E Basics and a Business Development Lab course (15 ECTS in total),
  b. an elective I&E course (5 ECTS) which can be chosen by students based on the options made available by each partner institution,
  c. 4 ECTS awarded via an EIT Digital Summer School course on how to turn innovative digital technologies into business.

The summer courses on topics around digital technologies applications will be developed by EITD in the context of the EIT Digital Master School with separate resources. The remaining 6 ECTS of the I&E minor will be completed by students in the second year of their studies through an I&E study with Business Challenges. The business challenges will be provided by the SMEs in ACHIEVE consortium and by other SMEs in the network of EMAI4EU partners.

- **Internship**: An internship during the second year of studies will be mandatory for all students. ACHIEVE partners will define an effective mechanism to collect internship opportunities from corporates and SMEs across Europe, mainly leveraging on the local networks of every ACHIEVE partner. The Internship programme will be built on the already existing EIT Digital Internship Programme and will assist students in identifying relevant research and business internship opportunities in their country or abroad.
- **Cooperation with companies**: The courses taught in the master's programme by each higher education institution will include several guest lecturers/seminars from other ACHIEVE partners, including other higher education institutions, industry partners such as INFINEON, EA, TECHVALLEY and research centres such as ODTU TEKNOKENT and TUBITAK
- **Double degree:** the students completing the programme will be awarded two degrees, one from the entry university and one from the exit university.
- The provision of guest lecturers will be facilitated through the implementation of mechanisms for inclusion of guest lectures (in online or face-to-face format). Guest lectures, together with the internship programme, and the I&E minor will allow students to benefit from the knowledge and experience from people not only from higher education institutions, but also from actors from all sides of the knowledge integration triangle. Thanks to the internship programme and other initiatives, ACHIEVE will establish extensive industry connections and collaborations that extend beyond the consortium partners.

The higher education institutions in the ACHIEVE consortium are involved in the master's programme either as Entry or Exit University according to the map in Table 4.1. The Master's programme in Cloud and Network Infrastructures and HPC offers students the possibility of studying at **8 Entry Universities from 7 different countries and 7 Exit Universities from 7 different countries**. Whenever involved as Entry or Exit university, a partner will contribute to awarding the double-degree title to students who successfully complete the master's programme.

Academic partners	UNITN	METU	UR	KTH	UBB	AALTO	POLIMI	UNS
Entry year	X	X	X	X	X	X	X	X
Exit year	X	X	X	X	X	X		X

Table 2: Entry and Exit year institutions

General Program Structure in short:

- First year (CNI+HPC basics):
  - At least 5 ECTS course on networking
  - At least 5 ECTS course on HPC
  - Around 24 ECTS in I&E
- Second year (technical specialization):
  - 6 ECTS in I&E
  - 30 ECTS Final thesis in a company (including internship)

The following partner universities offer an entry year:

Polytechnic University of Milan (POLIMI)
University of Trento (UNITN)
University of Rennes (UR)
KTH Royal Institute of Technology (KTH)
AALTO University (AALTO)
Babes Bolyai University (UBB)
Middle East Technical University (METU)
University of Novi Sad Faculty of Technical Sciences (UNS FTN)

Table 3: Entry Universities

And, below, these partner universities offer an exit year (with the list of their specialisations):

University of Trento (UNITN)	(1) 5G and Beyond, (2) HPC architectures
University of Rennes (UR)	Smart City services
KTH Royal Institute of Technology (KTH)	Networked intelligence
AALTO University (AALTO)	(1) 5G and Beyond, (2) Cloud computing and networking, and (3) Sustainable ICT
Babes Bolyai University (UBB)	Cloud and Network infrastructure with High Performance Computing
Middle East Technical University (METU)	HPC for Data Science
University of Novi Sad Faculty of Technical Sciences (UNS FTN)	High Performance Computing and Artificial Intelligence

Table 4: Exit Universities

4.3 Curriculum Integration Challenges

Combining multiple M.Sc. degrees into a single M.Sc. programme focused on "Cloud and Network Infrastructures and HPC" presents several significant challenges. One primary hurdle is **curriculum design**. Each individual M.Sc. program typically has a specialized and in-depth curriculum and integrating them requires a careful balancing act to ensure students gain sufficient expertise in all three areas—cloud, networking, and high-performance computing—without sacrificing depth. The ACHIEVE Consortium decided to define a standardized curriculum in the entry points (first year universities) and a more specific and deep specialization in the exit points (second year universities). In this way, the ACHIEVE Consortium aimed to provide additional added value by providing the students with the specific areas of excellence of each of the involved partners, while striking the right balance between common competences and site-specific excellence.

A related challenge is the **course and academic calendar synchronization**. Different universities, particularly in an international consortium, may have varying academic calendars, credit systems, and teaching methodologies, making it difficult to align course schedules and student mobility between institutions.

Another major challenge is **faculty and resource allocation**. An international programme requires a consortium of universities, and each institution must contribute not only faculty expertise but also specialized resources like data centres, high-performance computing clusters, and networking labs. Coordinating these resources across different countries and institutional budgets is complex. Accreditation and quality assurance also pose a significant obstacle. Each country has its own accreditation bodies and standards for higher education. Ensuring the integrated degree meets the requirements of all participating countries and is recognized globally is a lengthy and bureaucratic process. This involves harmonizing learning outcomes, assessment methods, and quality benchmarks. Moreover, it requires time, and it is characterized by different schedules in each of the involved countries.

Finally, **student management and support** represent a unique set of difficulties. Students in such a programme will likely be moving between different countries and academic cultures. They will need comprehensive support for visa applications, housing, language barriers, and adapting to new learning environments. Providing a consistent and high-quality student experience across different institutions is crucial for the programme's success. Additionally, ensuring that the job market recognizes the value of such a unique, integrated degree is vital. While the interdisciplinary nature is a strength, it must be clearly marketed to employers so they understand the unique skill set of graduates who are competent in cloud computing, network infrastructure, and HPC.

4.4 Intended Learning Outcomes

The Study Course in CNI&HPC is aimed at training graduates who possess an adequate knowledge of general scientific methods and concepts in the field of computer science, information technology and applied mathematics.

In particular, the programme aims to train experts able to address problems related to the design of parallel applications based on mathematical/ statistical models, the analysis of complex data in the field of supercomputing, and the development of algorithms and solutions in the emerging domain of quantum computing.

At the end of the Study Course, CNI&HPC graduates will have acquired:

- an adequate knowledge of the scientific method and data analysis that will allow them to analyse problems and systems in any field of computer engineering;
- a solid knowledge of the methodological-operational aspects, of the theoretical and applicative foundations of the various domains of computer engineering;
- a solid knowledge of the core concepts, the structural organization and the use of information processing systems to best seize all the opportunities enabled by high performance computing;
- a solid knowledge of the fundamental concepts, techniques and methodologies for the design, implementation and management of information systems and computer networks enabling them to conceive, plan, design and manage complex computing systems;
- the ability to communicate thoughts in a rational and consequential way, in order to make them clear and convincing by developing a positive attitude to study and lifelong learning mindset;
- the ability to understand the industrial context, the functions and processes in which they operate to address problems and opportunities.

Those outcomes of the major are combined with the I&E minor to enable graduated students to create or get involved in start-up companies, and lead innovation in existing companies developing cloud and network infrastructures, HPC architectures and services, and monetize them.

These learning outcomes have been closely aligned with the overarching learning outcomes as identified in the EIT Handbook for Planning, Labelling and Reviewing EIT-labelled Master and Doctoral Programs.

The following table 5 provides a picture of the courses providing common Learning Objectives to the students of the ACHIEVE programme, independently from the specific choice of entry and exit points:

Course Title / Topic	ECTS	Learning Objectives
Basics of Computing	At least 5	Students will acquire a foundational understanding of computer hardware components, software principles, and the logic of structured programming.
Basic of HPC / Parallel Computing	At least 5	Students will learn the core concepts, architectures, and programming models necessary to utilize high-performance computing systems and develop parallel algorithms for faster problem-solving.
Innovation and Enterpreneurship (I&E) Basics	5-8	Students will be able to understand fundamental concepts, models, and processes related to innovation management and entrepreneurial venture creation.
Business Development Lab	6-9	Students will gain hands-on experience in applying theoretical knowledge to develop and test a viable business model and go-to-

		market strategy for a new idea or product.
ICT Innovation	6-9	The course aims for students to analyze the drivers, technologies, and challenges specific to innovation within the Information and Communication Technology sector.
I&E Minor Thesis	5-6	Students will apply advanced analytical and critical thinking skills to investigate a specific topic within innovation and entrepreneurship and present their findings in a structured thesis.
Thesis + internship	30	Students will integrate academic research and practical work experience by conducting an in-depth thesis project that addresses a real-world business challenge identified during their professional internship.

Table 5: Common Learning Objectives

4.5 Employment Profile

Several companies take advantage of the benefits that cloud networking and High-Performance Computing (HPC) can provide, and the demand for cloud, network, and HPC professionals is booming. According to a study conducted by Deloitte for the EU in 2016, 1.6 million jobs could be created and the formation of 303,000 new businesses, in particular SMEs, is expected. Graduates qualify for jobs in international and local organizations in both technical and business roles. Typical titles are:

- Network designers
- Network planners
- ICT managers
- Cloud CTO
- HPC System Administrator
- Cloud Software Engineer
- Lead Software Developer
- Cloud Service Broker
- Cloud Alliance Manager
- Cloud Infrastructure Architect
- HPC Application Specialist
- Business developer
- Product manager
- Consultant

Through their multidisciplinary attitude, graduates are valuable in open innovation settings where different aspects (market, users, social aspects, media technologies) come together. They easily find jobs within companies that provide value-added products and services, such as telecom companies, e-commerce providers, e-learning, web developers, cloud operators, and organizations specializing in large-scale data analysis and scientific computing. An alternative path would be to establish their own companies to provide product or technology development, media content, business development, or consultancy services. They will be able to

- manage and contribute to (open) innovation and entrepreneurship projects and
- evolve later towards managerial positions, as they are experts having a global understanding of complex ICT and HPC systems, including their impact on businesses.

Also, they can start their own company to provide products and services, whether they relate to cloud computing infrastructures, HPC solutions, or to application domains based on them. They can also offer business development and consultancy services.

Students also qualify for a research and academic career through a follow-up doctoral project.

4.6 Local Implementation of the Program

The ACHIEVE programme is built upon successful existing M.Sc. degrees that provide diversity and customization to each student's study pathway.

The following subsections provide a brief description on how the programme is implemented in each of the involved academic institutions. More details are provided in Appendix A.

4.6.1 UNITN

Participation in the program: Entry point & exit point
Exit point specialization(s): (i) 5G and Beyond, and (ii) HPC architectures
Local degree awarded: M.Sc. in Information Engineering

First Year - Mandatory Courses	
Course Name	**ECTS**
Networking	12
HPC for Data Science	6
Next Generation Networks	6
Advanced Computing Architectures	6
Fog and Cloud Computing, or GPU Computing	6
I&E Basics	*6*
Business Development Lab	*9*
ICT Innovation	*9*

Second Year - Mandatory Courses	
Course Name	**ECTS**
Project Course on 5G and Beyond or HPC	6
I&E Studies in ICT	6
Internship + Thesis	30

Second Year - Electives	
Course Name	**ECTS**
GPU Computing	6
Network Security	6

Communication Systems	6
Distributed Systems	6
Fog and Cloud Computing	6
Machine Learning	6
Advanced Computing Architectures	6
Embedded Systems	6
Wireless Networking and Localisation	6
HPC for Data Science	6
Next Generation Networks	6
Project Course	6
Recognition Systems	12

4.6.2 AALTO

Participation in the program: Entry point & exit point
Exit point specialization(s): (1) 5G and Beyond, (2) cloud computing and networking, and (3) sustainable ICT
Local degree awarded: MSc. (Tech)

First Year - Mandatory Courses	
Course Name	**ECTS**
Introduction Course for Master's Students: Academic Skills	1
Language course: Compulsory degree requirement, both oral and written requirements	3
Networking at Scale and Advanced Applications	5
Advanced Networking	5
Programming Parallel Computers	5

First Year - Electives	
Course Name	**ECTS**
Numerous options	5 (each)

Second Year - Mandatory Courses	
Course Name	**ECTS**
Introduction Course for Master's Students: Career and Working Life Skills	1

Language course: Compulsory degree requirement, both oral and written requirements*	3
A selection of 5 courses	10-20

Second Year - Electives	
Course Name	**ECTS**
Numerous options	5 (each)

4.6.3 KTH

Participation in the program: Entry point & exit point
Exit point specialization: Networked intelligence
Local degree awarded: Master of Science in Computer Science and Engineering

First Year - Mandatory Courses	
Course Name	**ECTS**
Advanced Internetworking	7.5
Data-intensive Computing	7.5
Applied GPU programming	7.5
Research Methodology and Scientific Writing	7.5
Entrepreneurship for Engineers	6
Business Development Lab of Entrepreneurship Engineers	*9*

First Year - Electives	
Course Name	**ECTS**
Wireless Networks	7.5
Queuing Theory and Tele Traffic Systems	7.5
Distributed Systems, Advanced Course	7.5
Data Mining, Basic Course	7.5
Network Systems with Edge or Cloud Datacenters	7.5
Networked Systems for Machine Learning	7.5
Methods in High Performance Computing	7.5
Internet Marketing	7.5
Technology-based Entrepreneurship	7.5

Second Year - Mandatory Courses	
Course Name	**ECTS**
Research Methodology and Scientific Writing	7.5
ICT Innovation Study Project	6
Degree Project in Computer Science and Engineering	30

Second Year - Electives	
Course Name	**ECTS**
Network Analytics	7.5
Networked Systems Security	7.5
Internet Security and Privacy	7.5
Seminars in Information and Network Engineering	3
Modern Methods in Software Engineering	7.5
Distributed Artificial Intelligence and Intelligent Agents	7.5
Data Mining	7.5
Scalable Machine Learning and Deep Learning	7.5
Quantum Computing for Computer Scientists	7.5
Applied GPU Programming	7.5
Project Course in High-Performance Computing	7.5

4.6.4 METU

Participation in the program: Entry point & exit point
Exit point specialization(s): HPC for Data Science
Local degree awarded: M.Sc. in Information Systems and High Performance Computing

First Year - Mandatory Courses	
Course Name	**ECTS**
Introduction to HPC, Parallel and Distributed Systems	6
Computer Networking for HPC and Cloud	6
Software Architecture for HPC	6
Cloud Computing: Technology and Business	6
Research Methods and Ethics	5
Graduate Seminar	1

First Year - Electives	
Course Name	**ECTS**
Numerical Methods	3
Programming and Operating Systems	3
Advanced Parallel Programming	6
Performance Analysis and Optimisation	3
Compilers and Optimisations	3
Computer Architecture for HPC	6
Quantum Computing	3
Applied Parallel Programming on GPU	6
Web Services and Service Oriented Architecture	6
Devops Essentials	6

Second Year - Electives	
Course Name	**ECTS**
Foundations of Deep Learning	6
Spatio-Temporal Data Mining	6
Transformers and Attention-based Deep Networks	6
Reinforcement Learning	6
Machine Learning Systems Design and Deployment	6
Deep Learning: Methods and Applications	6
Generative Models for Multimedia	6
Introduction to Data Informatics	6
Knowledge, Discovery, and Mining	6
Social Media Analytics	6
Social Network Analysis	6
Big Data	6
Deep Learning for Text Analytics	6
Artificial Intelligence for Cognitive Science	6
Machine Learning Design and Application for Cyber Security	6
Statistical Learning for Bioinformatics	6

4.6.5 POLIMI

Participation in the program: Entry point

Local degree awarded: Laurea Magistrale (Equivalent To Master Of Science) in High Performance Computing Engineering

First Year - Mandatory Courses	
Course Name	**ECTS**
Parallel Computing	5
Numerical Linear Algebra	5
Quantum Computing	5
Computing Infrastructures	5
Advance Computer Architectures	6
Digital Business Lab	10
Software Product Management for HPC	5
Summer School	4

First Year - Electives	
Course Name	**ECTS**
Advanced Methods for Scientific Computing Or Numerical Methods for PDE Or Applied Statistics	5
Distributed Systems Or Quantum Communication Or Network Computing	5
Hig-tech Startups: Creating and Scaling Up Or High-tech Entrepreneurship Or Digital Business	5

Politecnico di Milano is an ENTRY University only, thus only the first year is included.

4.6.6 UBB

Participation in the program: Entry point & exit point
Exit point specialization(s): Could and Network Infrastructure with High-performance Computing
Local degree awarded: Master's degree

First Year - Mandatory Courses	
Course Name	**ECTS**
Network virtualization	7

Computer Ethics and Academic Integrity	4
Digital Economy Principles	8
Cloud databases	6
Grid, Cluster and Cloud Computing	7
Models in parallel programming	6
Algorithms, models, and concepts in distributed systems	6
Innovation Management	7
Thematic Project with Innovation Challenge	4

First Year - Electives	
Course Name	**ECTS**
Process Automation	5
Business Forecasting and Predictive Modelling	5

Second Year - Mandatory Courses	
Course Name	**ECTS**
Multimedia Communications in IP Networks	8
Operating systems for parallel and distributed architectures	8
Cloud Application and Infrastructure Security	8
Entrepreneurship in IT	6
Internship in specialization	20
Project in network infrastructure and cloud	6
Elaboration of the dissertation thesis	4

Second Year - Electives	
Course Name	**ECTS**
N/A	N/A

4.6.7 UNS FTN

Participation in the program: Entry point & exit point
Exit point specialization(s): High Performance Computing and Artificial Intelligence
Local degree awarded: Master of Science in Information Technologies

First Year - Mandatory Courses	
Course Name	**ECTS**
Parallel and Distributed Programming	6

Distributed Systems and Blockchain	6
High Performance Computer Systems	6
Computer Networks and Cloud Computing	6
Distributed Algorithms	6
Technology-Based Entrepreneurship	5
Organizational Design and Project Management	5
Business Modelling and Innovative Financing	5

First Year - Electives	
Course Name	**ECTS**
Quantum and Non-classical Computing	6
Secure and Privacy-preserving Computing	6
Sustainable and Digital Transformation of Business Systems	5
Innovative Business Development and Market Research	5
Summer School (Solving Business Case Studies)	4

Second Year - Mandatory Courses	
Course Name	**ECTS**
Big Data System Architectures	6
Cloud Computing in Infrastructure Systems	6
High Performance Computing in Artificial Intelligence	6
Applied Business Analysis	6

Second Year - Electives	
Course Name	**ECTS**
AI-based Business Support Systems	6
High Performance Computing in Data Science	6

4.6.8 UR

Participation in the program: Entry point & exit point
Exit point specialization(s): Smart city services
Local degree awarded: Master of Computer Science

First Year - Mandatory Courses	
Course Name	**ECTS**
Innovation and entrepreneurship	5

Knowledge and intangible assets management	5
Business development lab 1	5
Business development lab 2	5
Services and cloud technology	4
Analysis and object-oriented design	5
Big data infrastructure and data storage	6
Performance modeling and evaluation	5
Innovative networking technologies	5
Parallel programming	5
Distributed systems	5
Advanced programming	5

First Year - Electives	
Course Name	**ECTS**
n/a	

Second Year - Mandatory Courses	
Course Name	**ECTS**
Advanced cloud infrastructures	4
Scalable Network infrastructures	4
Smart city services	4
Personal cloud project	4
Internship preparation	6
Innovation and entrepreneurship study	6
Internship	24

Second Year - Electives	
Course Name	**ECTS**
Advanced probabilistic data analysis and modeling	4
Data mining and visualization	4
Internet of Things	4
Architecture of new generation networks	4
Network performance evaluation	4

4 Admission Requirements

To qualify for admission, applicants need to provide official evidence of their educational qualifications in the relevant field of studies and demonstrate proof of English language proficiency. More details are covered in subsections below: Subsection 4.1 for the BSc Degree, Subsection 4.2 for the relevant field of studies, Subsection 4.3 for the language skills and Subsection 4.4 for additional application materials.

4.1 Bachelor's Degree

Applicants must have completed a Bachelor's Degree encompassing a minimum of 180 ECTS credits or equivalent academic qualifications from an internationally recognized university. Students in their final year of undergraduate education may also apply and if qualified, receive a conditional acceptance. They must include a written statement from the degree administration office (or equivalent department), confirming that they are enrolled in the final year of their education and giving their expected completion date – which should be before the start of ACHIEVE Master Programme.

4.2 Relevant Field of Studies

The Cloud and Networking Infrastructure and HPC Master's programme is open to applicants who either hold a Bachelor of Science degree or who are in their final year of study in:

- Computer Science
- Computer Engineering
- Information Systems

4.3 Proof of English Language Proficiency

All programmes are taught in English. As a result, applicants must provide proof of their English language proficiency. This is generally verified through an internationally recognized test such as TOEFLS or IELTS. Most TOEFL and IELTS tests results are only valid for 2 years from the test date.

4.3.1 General Language Requirements

- **IELTS Academic test** (www.ielts.org) An overall band score of at least 6.5, with no section lower than 6.0, is required. IELTS-tests are verified online by the Admissions office, submitting a photocopy of the test together with the application documents from the applicant's part is therefore sufficient.
- **TOEFL Internet-based test, iBT** (www.toefl.org) A total score of at least 92 with a minimum for each section of at least 21 and for writing section 22 is required.

4.3.2 English Test Proficiency Waiver

English proficiency tests are waived for applicants who have completed a degree instructed in English at a university that is physically located in one of the following countries: USA, Canada, UK, Ireland, Australia or New Zealand.

4.4 Necessary Documents for the Application

To apply to the ACHIEVE Master's programme, candidates are required to upload into the application portal the following documentation:

- **Degree Certificate/Diploma** in its original language and translated into English (If their university does not provide this service, the translation has to be done by an authorised translator and his/her credentials, signature and stamps must be visible in the translated document). In case of ongoing studies, a statement certifying that the applicant is in the final year of their studies. The statement must be written by the degree administration office (or equivalent department) confirming that the applicant is enrolled on the final year of their education and giving their expected completion date.

- **Official and stamped transcript of records in original language and translated into English.** All courses taken must be included. A scan of the front and back of every document is needed - all stamps and signatures must be fully visible.

- **Proof of English proficiency.** The requirement of English proficiency will vary depending on the higher education institution/country selected by the applicant. All information is available on the EITD Master School website 'Admissions' tab (https://masterschool.eitdigital.eu/admissions) and also listed above. .

- **Curriculum Vitae** including details on the applicant's academic and professional career.
- **A letter of motivation** (maximum 3 pages) to prove the innovative potential of the applicant and their need for financial support. In this letter applicants will be required to discuss and/or propose an entrepreneurial idea and to explain their financial situation and need for financial support.
- **Supporting documents regarding the applicant's financial situation** (e.g. credit report).
- **An official ID**, such as passport or National ID.
- **Optional:** Document stating the GPA or the Relative Ranking, a 2-minute video to accompany the motivation letter.

4.5 Selection Process

The application and selection process is managed centrally by EIT Digital in line with the procedures of the Master School. The admissions team determines whether candidates meet the specific requirements for the ACHIEVE Master Programme while the Selection Committee, composed of academic representatives from the partner universities, evaluates and ranks eligible applicants.

In order to support the evaluation these elements will be considered:

1. previous academic and professional experience of an applicant,
2. curriculum vitae, and
3. letter of motivation, which also includes the motivation for an applicant to receive financial support.
4. Any optional/additional material that the applicant uploads (recommendation letters, introductory video, certificates of other education, etc.)

To evaluate these dimensions, the applicants will be ranked based on a total evaluation of the following criteria:

- Quality of University
- Suitability of Degree
- Study Success & Grades
- Work Experience & Entrepreneurial Excellence
- General Impression & Innovative Potential

Each criterion is assessed on a 5-point scale: 1 (very poor); 2 (poor); 3 (moderate); 4 (good) and 5 (very good).

Selected applicants are offered a spot in the Master's Programme delivered in a certain Partner University based on preference and availability. If an applicant cannot be offered a seat in the preferred study track, an alternative track will be offered.

The application portal for admissions opens in November each year. There are three admission batches:

- Period 1: The first deadline closes around mid-February.
- Period 2: The second batch opens immediately after and closes around mid-April.
- Period 3: The third batch opens immediately after Period 2 and closes at the end of May -or early June.

Students have the possibility to choose three options for their Entry university and three options for their Exit university, indicating the order of preference for each.

The universities selected as the first preference are involved in the evaluations.

In some cases, the application is evaluated by the next university chosen by the student according to their order of preference. These cases include:

- Insufficient evaluation (below the required threshold) by the selected university;
- Lack of admission requirements for the specific local program;
- Entry-Exit combination involving two universities from the same country.

If any of the evaluating coordinators (either from the entry or exit university) rejects an applicant, the Master's Programme Lead asks for a third or even fourth opinion from the coordinators of the universities ranked second or third on the applicant's preference list. If any of them accept the applicant, that university will be designated as the assigned entry or exit university.

The final score assigned to the student is an average of the evaluations from the assigned Entry and Exit universities, based on the criteria described above. If the final score is below 3.0, the applicant is rejected.

During the selection process, the Master's Program Lead assigns the applications to evaluate to each Local Programme Coordinator, indicating the deadline by which the evaluations must be submitted.

4.7 Financial Support to Students

Financial Support to Third Parties (FSTP) will be given with the support of the European Commission[1]. This support will be provided through open calls, each Call for FSTP will be published in the Funding and tender portal, in alignment with the Call: DIGITAL-2022-SKILLS-03 and the Grant Agreement Project 101190015 — ACHIEVE, targeting individuals from eligible countries, ensuring wide access and inclusivity.

4.6.1 Eligible Countries

The ACHIEVE scholarship programme is open to students who are nationals of eligible countries, specifically those belonging to EU Member States, overseas countries and territories (OCTs), countries associated with the Digital Europe Programme.

4.6.2 Eligible Recipients

To qualify for financial support, students must first be registered and accepted to the double-degree Master's programme offered by ACHIEVE—in The Cloud and Networking Infrastructure and HPC. Scholarships are awarded exclusively to those who meet these criteria and who demonstrate merit through a rigorous selection process. Merit is assessed primarily through the candidate's

[1] *Sponsored by SPECTRO, EMAI4EU, RESCHIP4EU & ACHIEVE*

academic path to date, especially their performance in their bachelor's studies, and is evaluated as part of the selection process that precedes admission to the Master's programme.

4.6.3 Activities to be Founded

The financial support provided through the ACHIEVE scholarship programme is intended to enable student participation in the two-year double-degree Master's programme. Funded activities include tuition fee coverage and, in some cases, living support to facilitate student mobility and engagement across partner universities.

There are three types of merit-based scholarships, awarded for the full two-year duration of the programme

1. Scholarships of Excellence, which include a full tuition fee waiver and a monthly living allowance adjusted according to the cost-of-living index of the host country (this adjustment is computed using the "Correction coefficients" published but Eurostat on its website);
2. Full tuition fee waivers, covering the entire tuition cost for both years; and
3. Half tuition fee waivers, which cover 50% of the tuition costs. These funding schemes are designed to reduce financial barriers and support talented students in accessing high-quality education in key digital technology domains.

4.6.4 Maximum Amount per Student and Criteria for its Determination

In the original Grant Agreement, the monthly allowance for the Scholarship of Excellence was set at a base rate of €800. However, in order to strengthen the attractiveness of the programme and ensure its competitiveness with other leading European education initiatives, the consortium decided to increase the allowance to €900 per month. This adjustment was motivated by the need to better reflect the actual cost of living in the countries where students will be studying, and to ensure that financial support is sufficient to cover essential living expenses, particularly in higher-cost locations. The increment also aligns with ACHIEVE's commitment to inclusiveness, as it helps reduce economic barriers for students from underrepresented or financially disadvantaged backgrounds. The decision does not compromise the overall financial sustainability of the project, nor the total number of scholarships to be awarded.

The maximum financial support available per student depends on the type of scholarship awarded. The Scholarship of Excellence includes a full tuition fee waiver valued at €6,000 for EU nationals and €18,000 for non-EU nationals per academic year (€12,000 and €36,000 for the two years, respectively) and a monthly living allowance of €900, adjusted based on the Country Correction Coefficient (CCC) of the study location. Over the two years, this may result in a total support package exceeding €29,000 per student.

Students receiving a Full Tuition Fee Waiver are granted €6,000 per year for EU nationals and €18,000 per year for non-EU nationals (€12,000 and €36,000, respectively, for the two years), while those with a Half Tuition Fee Waiver receive €3,000 per year for EU nationals and €9,000 per year for non-EU nationals (€6,000 and €18,000, respectively, for the two years).

In all cases, 50% of the financial support will be directly financed by the EU through the ACHIEVE grant, while the remaining 50% will be covered by the co-financing component provided by the EIT Digital Education Foundation.

4.6.5 Minimum Number of Students

The ACHIEVE project foresees the allocation of 120 financial support packages (scholarships) to students enrolled in its Master's programme over the course of the project. These scholarships are planned to be evenly distributed across the two programme cycles, with approximately 60 scholarships allocated in Cycle 1 (academic years 2025–2027) and 60 in Cycle 2 (academic years 2027–2029).

4.6.6 Distribution per Year and FSTP Allocation

Each year, the scholarship budget allocation process will take place before the application and evaluation phase, aligned with the issuance of the admission letters. Scholarships are composed of two distinct components:

- Tuition fee waivers (half or full), which are not paid directly to students but applied as a reduction of the tuition cost. The value of the waiver is determined before the start of Year 1 and covers both academic years of the programme. Students are invoiced for tuition fees twice per academic year—once in the fall semester and once in the spring semester. For students receiving financial support, the invoices will reflect the reduced tuition amount, and this is the moment when the support is formally materialised.
- Monthly allowances (only for recipients of the Scholarship of Excellence), which are paid directly to students to support their living costs. These monthly payments starts from a basis of €900 per month and are calculated based on the Country Correction Coefficient (CCC) of the country where the student is studying, and may vary between Year 1 and Year 2 depending on the country of study for the supported student.

This structure ensures both administrative clarity and financial predictability for students throughout their studies. At a high level, the scholarships in each cycle will be split across the three categories as follows:

- Scholarships of Excellence (full waiver and allowance): ~7 per cycle
- Full Tuition Fee Waivers: ~30–35 per cycle
- Half Tuition Fee Waivers: ~18–21 per cycle

During each recruitment cycle, the following scholarships are planned to be awarded:

	Beneficiaries	Amount per beneficiary	Total
Scholarship of Excellence	~7	€ 12.000,00	€ 84.000,00
Full tuiton waiver	~30–35	€ 12.000,00	€ 360.000,00 - € 420.000,00
Half tuiton waiver	~18–21	€ 6.000,00	€ 108.000,00 - € 126.000,00
Total			€ 552.000,00 - € 630.000,00

Table 6: Financial support budgeted for award in each recruitment cycle

The students receiving a scholarship of excellence will also receive a financial support in the form of a monthly allowance for the two years of study. The budgeted projections of costs for the different locations are shown in Table below.

	Country	Coefficient	Allowance per beneficiary	
			Monthly	Yearly
POLIMI	Italy	0,957	€861,00	€10,329,00
METU	Turkey	0,526	€473,00	€5,679,00
KTH	Sweden	1,143	€1.029,00	€12.351,00
UPM	Spain	0,879	€791,00	€9.492,00
UCA	France	1,066	€959,00	€11.508,00
UNITN	Italy	0,957	€861,00	€10.329,00
UR	France	1,066	€959,00	€11.508,00
AALTO	Finland	1,119	€1.007,00	€12.084,00
UNS FTN	Serbia	0,907	€816,00	€9.792,00

Table 7: Summary table of monthly and yearly allowances awarded to students for each consortium partner university

This initial distribution is indicative and will be refined during each recruitment cycle based on the profile of applicants, strategic priorities (e.g. gender balance, RIS representation), available budget, and decisions made collectively at project level by the consortium. The goal is to ensure both fairness and strategic alignment while maintaining high levels of programme participation and diversity.

4.6.7 Awarding Criteria

The type and amount of financial support awarded to each student are determined through a structured, transparent, and merit-based evaluation process. Each eligible applicant is assigned a merit score on a scale from 1 to 5, which serves as the primary reference point for ranking and scholarship allocation.

This score is based on five core elements:

1. Suitability of acquired bachelor degree for intended study programme;
2. Quality of Home University
3. Academic and professional background, with a particular emphasis on the performance in the applicant's bachelor's degree;
4. Curriculum Vitae, including any relevant work experience, extracurricular activities, and achievements, and entrepreneurial experience;
5. Motivation letter, in which candidates present their "Innovative potential". They are expected to describe their motivation for applying to the programme, propose an entrepreneurial idea, and explain their financial situation and need for support.

The merit score is initially assigned by two independent evaluators: the Local Programme Coordinators from the Entry and Exit universities selected by the applicant. These evaluations are then reviewed and harmonised by the Programme Lead and the Quality Assurance Manager to ensure consistency across institutions and countries. Final scholarship decisions are taken by the agreement of all relevant academic and administrative stakeholders.

In addition to the merit score, scholarship awarding criteria include:

- Promotion of diversity and inclusion, with priority given to female applicants and applicants from EIT Regional Innovation Scheme (RIS) countries;
- Balance of scholarship distribution across partner universities and countries to maintain equity and ensure efficient use of available capacity.

4.6.8 Promotion of Diversity

The ACHIEVE scholarship programme will thrive to promote diversity and inclusion through its scholarship opportunities:

- Priority is given to female applicants from any EU country or EU-associated country. The scholarship programme for women will aim to increase female participation in the master's programme.
- Priority is given to applicants from RIS countries - included in the EIT Regional Innovation Scheme (RIS), as listed below. The scholarship programme for participants from RIS countries is aimed to support the participation of students from countries with moderate or modest innovation score and with lower gross domestic product. Countries eligible to take part to the RIS include 1) EU members states, 2) Horizon Europe associated countries, and 3) outermost regions such as Guadeloupe, and Réunion (France), the Azores and Madeira (Portugal), and the Canary Islands (Spain).

5 Conclusions

HPC, cloud computing, and advanced networking form the backbone of Europe's digital future. These domains are increasingly interdependent, and this convergence necessitates professionals with wide knowledge in these three fields of technology, together with deep understanding and skills in areas they focus on. The convergence of HPC cloud and networking is the basic tenet of the ACHIVE master program and the connected self-standing modules, together with the realization that innovation and entrepreneur skills are necessary for the young professionals to further strengthen the European industry and development.

This deliverable provides the detailed description of the curriculum of the master program co-designed by the ACHIVE partner universities, UNITN, POLIMI, KTH, AALTO, METU, UBB, UR, AALTO, UNS FTN, together with EIT Digital and associated industry and research partners. The curriculum provides graduates with a strong technical foundation, deep knowledge and skills in a selected technology area, and innovation and entrepreneurship skills necessary to translate technology into business and societal impact.

Finally, the deliverable gives the foundation for further curriculum design in ACHIEVE, covering the continuous improvement of the courses of the master program itself, but also the design and delivery of the self-standing study modules . . These modules have been designed using the same skills framework and curriculum architecture developed in WP1 for the ACHIEVE Master's programme, but they target a different audience and purpose. While the Master's programme delivers a full, structured academic path for enrolled students, the self-standing modules translate and extend selected technical and innovation topics into flexible, focused training offers for professionals who need upskilling or reskilling in specific areas of Cloud, Networking Infrastructure and High-Performance Computing. In this sense, the modules are not separate initiatives; they build on the same core technological competencies identified for the Master's, and expand them into applied, practice-oriented learning units that can be delivered stand-alone to industry staff and other learners outside the full degree.

Appendix A: Detailed Implementations of the Programme

This section illustrates how the general structure of the CNI/HPC programme developed in ACHIEVE will be implemented in the different universities of the Consortium.

It should be underlined that the general structure and constraints are defined in such a way to be compatible with all the national regulations in the partners' countries.

5.1.1 UNITN:

Study plan:

ENTRY YEAR (60 ECTS)				
MANDATORY Cloud/Networking	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
Networking	**30**	12	1	
HPC for data science		6	1	
Advanced Computing Architectures		6	2	
Fog and Cloud Computing		6	X	
ELECTIVES CS/Engineering	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
Embedded Systems	**6**	6		
Free choice		6		
I&E MANDATORY	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
Innovation and Enterpreneurship Basics	**15**	6	1	
Business Development Lab		9	2	
I&E ELECTIVE	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
ICT Innovation (including summer school)	**9**	9	2	
EXIT YEAR (60 ECTS)				

MANDATORY Cloud/HPC	ECTS (group)	ECTS	Semester	Comments
Project course on HPC, or		6	1	
Project course on 5G and beyond		6	1	
ELECTIVES	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
Network Security	**12**	6		
GPU Programming		6		
Machine Learning		6		
Sistemi embedded (Sinan)		6		
Quantum Computing		6		
Scientific Computing		6		
Distributed Systems		6		
Research Project		12		
I&E	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
Innovation and Enterpreneurship Studies in ICT	**6**	6	2	
Thesis / internship	**30**	**30**		

Exit Specialization:
2 available: (i) 5G and beyond; (ii) HPC

Prerequisite Requirements:

- **B.Sc. in ICT, ECE, CS**
- **B2 English proficiency**

Course syllabi:

Networking

https://unitn.coursecatalogue.cineca.it/insegnamenti/2024/50520_647098_96282/2023/50521/10756?coorte=2024&schemaid=8569

Advanced Computing Architectures

https://unitn.coursecatalogue.cineca.it/insegnamenti/2024/50176_642650_91609/2023/50176/10756?coorte=2023&schemaid=8342

High Performance Computing

https://unitn.coursecatalogue.cineca.it/insegnamenti/2024/50176_642651_96277/2023/50176/10756?coorte=2023&schemaid=8342

Fog and Cloud Computing

https://unitn.coursecatalogue.cineca.it/insegnamenti/2023/50176_642622_93765/2023/50176/10756?coorte=2023&schemaid=8342

GPU Computing

https://unitn.coursecatalogue.cineca.it/insegnamenti/2023/50176_642618_95885/2023/50176/10756?coorte=2023&schemaid=8342

Next Generation Networks

https://unitn.coursecatalogue.cineca.it/insegnamenti/2023/49520_638745_95469/2019/49520/10712?coorte=2021&schemaid=7935

Project course on (*)

https://unitn.coursecatalogue.cineca.it/insegnamenti/2023/50176_642643_90390/2023/50176/10756?coorte=2023&schemaid=8342

5.1.2 AALTO:

Study plan:

ENTRY YEAR (60 ECTS)				
MANDATORY Cloud/Networking (19 ECTS)	**ECTS (group)**	**ECTS**	**Semester**	**Comments**

ELEC-E7315 Networking at Scale and Advanced Applications	**19**	5	III-IV	
ELEC-E7321 Advanced Networking		5	III-IV	
CS-4580 Programming Parallel Computers		5	V	
LC-xxxx Language course		3		
SCI-E1011 Introduction Course for Master's Students: Academic Skills		1		
ELECTIVES CS/Engineering (total 17 ECTS)	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
Too many to list	**17**			
I&E MANDATORY	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
TU-E4300 Introduction to Digital Business and Venturing	**24**	3	I	
TU-E4311 Digital Business Management		3	II	
TU-E4101 Entrepreneurship Lab		10	III-IV	
TU-E4320 Global Business in the Digital Age		4	V	
TU-E4340 ICT Innovation Summer School		4	summer	
EXIT YEAR (60 ECTS)				
MANDATORY Cloud/HPC	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
SCI-E1012 Introduction Course for Master's Students: Career and Working Life Skills	**14**	1	I-II	
LC-xxxx Language course		3	I-II	

Select 10-20 ECTS from below				
CS-C3170 Web Software Development		5	I-II, III-V	
CS-E4265 Multimedia Systems		5	I-II	
CS-E4300 Network Security		5	II	
ELEC-E7131 Internet Traffic Measurements and Analysis		10	III-IV	
ELEC-E7315 Networking at Scale and Advanced Applications		5	III-IV	
CS-4580 Programming Parallel Computers		5	V	
ELECTIVES	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
Too many to list	**10**			
I&E	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
TU-E4330 I&E Study Project	**6**	6	I-III	
Thesis / internship	**30**	**30**		

Exit Specialization:

Aalto University has an extremely wide range of studies and courses in ICT. There are two schools and two departments that offer courses in computer science, networking, cloud computing, wireless communications, user interfaces, and many more.

In ACHIEVE, the most relevant specializations are:
- Cloud and edge computing (including high-performance computing)
- Cloud services and platforms
- Networking
- Wireless communications, 5G and 6G
- Sustainable ICT

Prerequisite Requirements:

Applicants need to have a suitable bachelor's degree worth 180 credits. The degree needs to have courses in the areas of the specialization, in computer science, networking or communications engineering. There are no strict numbers for each type of course, but the degree must have many elementary courses in computer science and networking; wireless communications is seen as complimentary knowledge.

Language requirements defer, but English language proficiency needs to proven through an IELTS Academic minimum overall score of 6.5 and writing score of 6.0 or a TOEFL minimum score of 92 and 22 fro writing.

Other details are online at: https://www.aalto.fi/en/admission-services/language-requirements-in-masters-admissions

Course syllabi (mandatory courses):

The syllabi of all Aalto courses are available from the sisu.aalto.fi website. The mandatory courses of ACHIEVE are given here:

Advanced networking: https://sisu.aalto.fi/student/courseunit/aalto-CU-1150972298-20240801/brochure
Networking at Scale and Advanced Applications: https://sisu.aalto.fi/student/courseunit/aalto-CU-1150972295-20240801/brochure
Programming Parallel Computers: https://sisu.aalto.fi/student/courseunit/aalto-CU-1150973094-20240801/brochure
Web Software Development: https://sisu.aalto.fi/student/courseunit/aalto-CU-1150973150-20240801/brochure
Multimedia Systems: https://sisu.aalto.fi/student/courseunit/aalto-CU-1150973234-20240801/brochure
Network Security: https://sisu.aalto.fi/student/courseunit/aalto-CU-1150973088-20240801/brochure
Internet Traffic Measurements and Analysis: https://sisu.aalto.fi/student/courseunit/aalto-CU-1150972296-20240801/brochure

See following example:

https://unitn.coursecatalogue.cineca.it/insegnamenti/2024/146225%2F1/2023/50521/10756?coorte=2024&schemaid=8569&adCodRadice=146225

5.1.3 KTH:

Study plan:

ENTRY YEAR (60 ECTS)				
MANDATORY Cloud/Networking	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
II2202 Research Methodology and Scientific Writing	**30**	7.5	1	
ID2221 Data-Intensive Computing		7.5	1	
IK2215 Advanced Internetworking		7.5	1	
DD2360 Applied GPU Programming		7.5	1	
ELECTIVES CS/Engineering	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
EP2200 Queuing Theory and Teletraffic Systems	**7.5**	7.5	2	Select one
EP2950 Wireless Networks		7.5	2	
ID2203 Distributed Systems, Advanced Course		7.5	2	
ID2211 Data Mining, Basic Course		7.5	2	
IK2227 Network Systems with Edge or Cloud Datacenters		7.5	2	
IK2221 Networked Systems for Machine Learning		7.5	2	
DD2356 Methods in High Performance Computing		7.5	2	
I&E MANDATORY	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
ME2072 Entrepreneurship for Engineers	**15**	6	1	

ME2073 Business Development Lab of Entrepreneurship Engineers		9	2	
I&E ELECTIVE	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
ME2094 Internet Marketing	**19**	7.5	1	Select one
ME2062 Technology-based Entrepreneurship		7.5	2	
Summer school		4		Select one
EXIT YEAR (60 ECTS)				
MANDATORY CS/Engineering	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
II2202 Research Methodology and Scientific Writing	**7.5**	7.5	1	If not covered at Entry
ELECTIVES CS/Engineering	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
EP2420 Network Analytics	**12**	7.5	1	Select 3 or 4 depending on the mandatory course.
EP2500 Networked Systems Security		7.5	1	
ID2207 Modern Methods in Software Engineering		7.5	1	
ID2209 Distributed Artificial Intelligence and Intelligent Agents		7.5	1	
ID2222 Data Mining		7.5	1	
ID2223 Scalable Machine Learning and Deep Learning		7.5	1	
IK2206 Internet Security and Privacy		7.5	1	
DD2367 Quantum Computing for Computer Scientists		7.5	1	
DD2360 Applied GPU Programming		7.5	1	
DD2375 Project Course in High-Performance Computing		7.5	1	

EQ2461 Seminars in Information and Network Engineering		3	2	
I&E	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
ME2096 ICT Innovation Study Project	**6**	6	1	
Thesis / internship	**30**	**30**	**2**	

Exit Specialization:

Networked Intelligence KTH offers courses in the area of data intensive distributed computing, covering both the design of network infrastructures that can support these emerging applications, and the design of the distributed computing applications itself, focusing on scalable machine learning and on distributed artificial intelligence.

Prerequisite Requirements:

Internationally recognized bachelor's degree in Electrical/Electronic Engineering, Computer Science, Computer Engineering, Computer Science or Information Technology, including at least 60 ECTS (credits) courses in computer science, computer systems/computer architecture and programming, and at least 30 ECTS in mathematics, including analysis (calculus), linear algebra and mathematical statistics.

English proficiency equivalent to the Swedish upper secondary course English 6. You can meet the requirement with an English test, for example an overall IELTS score of 6.5 or a TOEFL score of 90. Depending on your country of previous studies you could also meet the requirement through completed upper secondary or university studies. Visit University Admissions to see all recognized English tests and what applies to your country of previous studies.

Course syllabi (mandatory courses):

Entry:
https://www.kth.se/student/kurser/kurs/ME2072
https://www.kth.se/student/kurser/kurs/ME2073

https://www.kth.se/student/kurser/kurs/ME2078
https://www.kth.se/student/kurser/kurs/II2202
https://www.kth.se/student/kurser/kurs/ID2221
https://www.kth.se/student/kurser/kurs/IK2215
https://www.kth.se/student/kurser/kurs/DD2360

Exit:

https://www.kth.se/student/kurser/kurs/ME2096
https://www.kth.se/student/kurser/kurs/II2202
https://www.kth.se/student/kurser/kurs/DA258X

5.1.4 METU:

Study plan:

ENTRY YEAR (60 ECTS)				
MANDATORY Cloud/Networking	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
Introduction to HPC, Parallel and Distributed Systems		6	1	
Computer Networking for HPC and Cloud		6	2	
Software Architecture for HPC	**30**	6	2	
Cloud Computing: Technology and Business		6	1	
Research Methods and Ethics		5	1	
Graduate Seminar		1	1	
ELECTIVES CS/Engineering	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
Numerical Methods		3	2	
Programming and Operating Systems		3	2	One 6-ECTS course or two 3-ECTS courses out of these
Advanced Parallel Programming	**6**	6	2	
Performance Analysis and Optimization		3	2	

Compilers and Optimizations		3	2	
Computer Architecture for HPC		6	2	
Quantum Computing		3	2	
Applied Parallel Programming on GPU		6	2	
Web Services and Service Oriented Architecture		6	2	
Devops Essentials		6	2	
I&E MANDATORY	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
I&E Basics	**19**	6	1	
Business Development Lab I&E		9	2	
Summer School I&E programme		4	Summer	
I&E ELECTIVE	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
Digital Transformation: Management, Technology and Organization	**5**	5	2	1 out of 3
Technology Entrepreneurship and Lean Startups		5	2	1 out of 3
Business Process Management		5	2	1 out of 3
EXIT YEAR (60 ECTS)				
ELECTIVES	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
Foundations of Deep Learning	**30**	6		Five out of these courses
Spatio-Temporal Data Mining		6		
Transformers and Attention-based Deep Networks		6		
Reinforcement Learning		6		
Machine Learning Systems Design and Deployment		6		
Deep Learning: Methods and Applications		6		

Generative Models for Multimedia		6		
Introduction to Data Informatics		6		
Knowledge, Discovery, and Mining		6		
Social Media Analytics		6		
Social Network Analysis		6		
Big Data		6		
Deep Learning for Text Analytics		6		
Artificial Intelligence for Cognitive Science		6		
Machine Learning Design and Application for Cyber Security		6		
Statistical Learning for Bioinformatics		6		
I&E	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
I&E Study	**6**	6	2	
Thesis / internship	**30**	**30**		

Exit Specialization:

METU offers a wide range of specialization topics, considering the focus areas and existing programs under the METU Graduate School of Informatics. The specialization areas could align with core computational and data-driven disciplines as well as interdisciplinary applications of HPC, including data science, big data, deep learning, HPC software technologies and management, digital transformation, modeling and simulation, bioinformatics, HPC security, and cryptography.

Prerequisite Requirements:

Students are expected to have a strong foundation in computational, mathematical, or engineering disciplines. For application requirements: https://ii.metu.edu.tr/application-requirements

Course syllabi (mandatory courses):

HPC 501 Introduction to HPC, Parallel and Distributed Systems:
https://docs.google.com/document/d/1foZ-PZzYT2x9wwkB2iRuqTFpM5u2PaE2/edit?usp=drive_link&ouid=108240418789331485498&rtpof=true&sd=true

HPC 502 Computer Networking for HPC and Cloud:
https://docs.google.com/document/d/1rFDS65m1xI3Q0OyolESezwoWiBebKVTm/edit?usp=drive_link&ouid=108240418789331485498&rtpof=true&sd=true

HPC 503 Software Architecture for HPC:
https://docs.google.com/document/d/1l_3NnXjm66SShC7JjOASGiXlcHVEFr-E/edit?usp=drive_link&ouid=108240418789331485498&rtpof=true&sd=true

IS 547 Cloud Computing: Technology and Business:
https://docs.google.com/document/d/16SoVFBCtQkYtZvuBaz9htgK1hpAatWVo/edit?usp=drive_link&ouid=108240418789331485498&rtpof=true&sd=true

IS 520 Research Methods and Ethics:
https://docs.google.com/document/d/1PDXuND3ME6MTi-aYaVuq0CBaJ2McDVij/edit?usp=drive_link&ouid=108240418789331485498&rtpof=true&sd=true

Current Status:
Study plan to be locally approved in the first quarter of 2026.

5.1.5 POLIMI:

Study plan:

ENTRY YEAR (60 ECTS)				
MANDATORY	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
PARALLEL COMPUTING	**26**	5	1	
NUMERICAL LINEAR ALGEBRA		5	1	
QUANTUM COMPUTING		5	1	
COMPUTING INFRASTRUCTURES		5	2	
ADVANCED COMPUTER ARCHITECTURES		6	2	
ELECTIVES	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
ADVANCED METHODS FOR SCIENTIFIC COMPUTING	**5**	6	1	One from the group numerical methods
NUMERICAL METHODS FOR PDE		6	1	
APPLIED STATISTICS		5	2	
DISTRIBUTED SYSTEMS	**5**	5	1	One from the group communicatio n
QUANTUM COMMUNICATION		5	2	
NETWORK COMPUTING		5	2	
I&E MANDATORY	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
DIGITAL BUSINESS LAB (10 CFU)	**19**	10	2	
SOFTWARE PRODUCT MANAGEMENT FOR HPC		5	2	
SUMMER SCHOOL		4	2	
I&E ELECTIVE	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
HIGH-TECH STARTUPS: CREATING AND SCALING UP I	**5**	5	1	One from the group
HIGH TECH ENTREPRENEURSHIP		5	2	

DIGITAL BUSINESS		5	2	

Exit Specialization:
ONLY ENTRY POINT

Prerequisite Requirements:
Previous studies in ICT, Engineering of Computing Systems, Computer Engineering or equivalent qualifications. Students for Mathematical Engineering can be accepted to Polimi provided solid foundations in relevant computer science areas such as computer architecture, data structures, algorithms design and analysis, programming languages, foundations of communication networks.

Course syllabi (mandatory courses):

Parallel Computing:
https://www11.ceda.polimi.it/schedaincarico/schedaincarico/controller/scheda_pubblica/SchedaPublic.do?&evn_default=evento&c_classe=836280&__pj0=0&__pj1=95aac6b79d0d102c0353c7d7bfe031ab

Numerical Linear Algebra:
https://www11.ceda.polimi.it/schedaincarico/schedaincarico/controller/scheda_pubblica/SchedaPublic.do?&evn_default=evento&c_classe=837635&__pj0=0&__pj1=1633552ad40709c7f703c26549fe5a78

Quantum Computing
https://www11.ceda.polimi.it/schedaincarico/schedaincarico/controller/scheda_pubblica/SchedaPublic.do?&evn_default=evento&c_classe=814325&__pj0=0&__pj1=f7721e7dbb9a07f727d9fcdac1c19519

Computing Infrastructures
https://www11.ceda.polimi.it/schedaincarico/schedaincarico/controller/scheda_pubblica/SchedaPublic.do?&evn_default=evento&c_classe=811784&__pj0=0&__pj1=a04d5431feb3abde2354f7888e35103c

Advanced Computer Architectures

https://www11.ceda.polimi.it/schedaincarico/schedaincarico/controller/scheda_pubblica/SchedaPublic.do?&evn_default=evento&c_classe=811665&__pj0=0&__pj1=b578fca6b3bfddfa6793c29a454be77e

5.1.6 UBB:

Study plan:

ENTRY YEAR (60 ECTS)				
MANDATORY Cloud/Networking	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
Grid, Cluster and Cloud computing	**42**	7	2	
Cloud databases		6	2	
Computer Ethics and Academic Integrity		8	1	
Network Virtualization		9	1	
Algorithms, models, and concepts in distributed systems		6	2	
Parallel Programming		6	2	
ELECTIVES CS/Engineering	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
I&E MANDATORY	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
Digital Economy Principles	**15**	8	1	
Innovation Management		7	2	
Thematic Project with Innovation Challenge		4	2	summer school carrier course

I&E ELECTIVE	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
Business Forecasting and Predictive Modelling	**9**	5	1	
Strategic Business Process Automation		5	1	
EXIT YEAR (60 ECTS)				
MANDATORY Cloud/HPC	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
Multimedia Communications in IP Networks	**24**	8	3	
Operating Systems for Parallel and Distributed Architectures		8	3	
Security of Cloud Infrastructure		8	3	
ELECTIVES	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
I&E	**ECTS (group)**	**ECTS**	**Semester**	**Comments**
Entrepreneurship in IT	**6**	6	3	
Thesis / internship	**30**	**30**		
Internship in specialization	**30**	**20**	4	

Project in Cloud and Network Infrastructure		**6**	4	
Elaboration of the dissertation thesis		**4**	4	
OPTIONAL				
Fundamentals of Entrepreneurship		3		
Fundamentals of Humanities (Argumentation Theory)		3		

Exit Specialization:

UBB offers in the exit year specialization in multimedia communication, high performance computing and security of cloud infrastructure and applications.

Prerequisite Requirements:
Bachelor's in computer science
Certificate of English language proficiency at B2 level minimum

Course syllabi (mandatory courses):
https://ubbcluj-my.sharepoint.com/my?id=%2Fpersonal%2Fadrian%5Fsterca%5Fubbcluj%5Fro%2FDocuments%2FDepartament%2F2024%2D2025%2FMaster%20Cloud%20and%20network%20infrastructure%2FFise%20discipline&ga=1

See following example:
https://unitn.coursecatalogue.cineca.it/insegnamenti/2024/146225%2F1/2023/50521/10756?coorte=2024&schemaid=8569&adCodRadice=146225

5.1.7 UNS FTN:

Study plan:

ENTRY YEAR (60 ECTS)			
MANDATORY Cloud/Networking	**ECTS**	**Semester**	**Comments**
Parallel and Distributed Programming	6	1	
Distributed Systems and Blockchain	6	1	
High Performance Computer Systems	6	1	
Computer Networks and Cloud Computing	6	1	
Distributed Algorithms	6	2	
ELECTIVES CS/Engineering	**ECTS**	**Semester**	**Comments**
Quantum and Non-classical Computing	6	2	1 out of 2
Secure and Privacy-preserving Computing	6	2	1 out of 2
I&E MANDATORY	**ECTS**	**Semester**	**Comments**
Technology-Based Entrepreneurship	5	1	
Organizational Design and Project Management	5	2	
Business Modelling and Innovative Financing	5	2	
I&E ELECTIVE	**ECTS**	**Semester**	**Comments**
Sustainable and Digital Transformation of Business Systems	5	2	1 out of 2
Innovative Business Development and Market Research	5	2	1 out of 2
Summer School (Solving Business Case Studies)	4	2	
EXIT YEAR (60 ECTS) - Specialization: HPC and Artificial Intelligence			
MANDATORY Cloud/HPC	**ECTS**	**Semester**	**Comments**
Big Data System Architectures	6	1	
Cloud Computing in Infrastructure Systems	6	1	
High Performance Computing in Artificial Intelligence	6	1	
ELECTIVES	**ECTS**	**Semester**	**Comments**
AI-based Business Support Systems	6	1	1 out of 2
High Performance Computing in Data Science	6	1	1 out of 2
I&E	**ECTS**	**Semester**	**Comments**

Applied Business Analysis	6	1	
Thesis / internship	**30**		

Exit Specialization: High Performance Computing and Artificial Intelligence

Prerequisite Requirements:

Internationally recognized bachelor's degree in Electrical/Electronic Engineering, Computer Science, Computer Engineering, Computer Science or Information Technology, Information Engineering, or Software Engineering.

A certificate proving proficiency in English language.

Course syllabi (mandatory courses):

Parallel and Distributed Programming
https://docs.google.com/document/d/10-JT2-JffRisE57hR7NCvKqA5RJfxuW4Nd1SRnNY9pc/edit?tab=t.0

Distributed Systems and Blockchain
https://docs.google.com/document/d/17lvdmql6ahIsKWL2Bd2-l8nJuSqF_CMJXP3gy2jqKH4/edit?tab=t.0

High Performance Computing
https://docs.google.com/document/d/1afPQua6cfNeRHoHBqr50GhGVXKiEWvdCpunCO67eLPY/edit?tab=t.0

Computer Networks and Cloud Computing
https://docs.google.com/document/d/1MKoWF3G8lsS5Du1GvegufUoOGLU_TV1SWF2iut22nHU/edit?tab=t.0

Distributed Algorithms
https://docs.google.com/document/d/1HNrJQo-cM9GjiTrfOxkU9JXhgO-pjfMv/edit

Big Data System Architectures
https://docs.google.com/document/d/1afPQua6cfNeRHoHBqr50GhGVXKiEWvdCpunCO67eLPY/edit?tab=t.0

Cloud Computing in Infrastructure Systems
https://docs.google.com/document/d/15Ce2AVOeFquUZyI2h27a0LujUxLVYHRa/edit

HPC in Artificial Intelligence
https://docs.google.com/document/d/1Bf7jhur2Py2lsD_6KN6BlaFrzPAr7IMZf3jtoj4lMXQ/edit?tab=t.0

Current Status:
Study plan is approved by the University of Novi Sad Faculty of Technical Sciences, waiting for the approval of its accreditation from the National Accreditation Council of the Republic of Serbia.

5.1.8 Rennes University:

Study plan:

ENTRY YEAR (60 ECTS)			
MANDATORY Cloud/Networking	**ECTS (group)**	**ECTS**	**Semester**
Big Data Storage and Processing	25	5	1
Service and Cloud Technologies		5	1
Distributed Systems and Algorithms		5	2
Future Networking Technologies		5	2
Safety and Performance modeling for software		5	1
MANDATORY CS/Engineering	**ECTS (group)**	**ECTS**	**Semester**
Object-Oriented software engineering	**15**	5	1
Advanced Programing		5	2
Parallel Programming		5	2
I&E MANDATORY	**ECTS (group)**	**ECTS**	**Semester**
Business Development Lab 1	**20**	10	1
Innovation and Entrepreneurship		5	1
Business Development Lab 2		5	2

Knowledge and Intangible Assets			2
I&E ELECTIVE	**ECTS (group)**	**ECTS**	**Semester**
Knowledge and Intangible Assets		5	2
Summer School		4	1
EXIT YEAR (60 ECTS)			
MANDATORY Cloud/HPC	**ECTS (group)**	**ECTS**	**Semester**
Scalable Network Infrastructures for Optimized Services	**16**	4	1
Advanced Cloud Infrastructures		4	1
Smart City Services		4	1
Personal Cloud Project		4	1
ELECTIVES	**ECTS (group)**	**ECTS**	**Semester**
Internet of Things	**8**	4	
Performance Evaluation of Networks		4	
Data Mining and Evaluation		4	
Advanced Probabilistic Data Analysis and Modelling		4	
I&E	**ECTS (group)**	**ECTS**	**Semester**
Innovation and Entrepreneurship study	**6**	6	3
Thesis / internship	**30**	**30**	**4**

Exit Specialization: Smart City Services

Prerequisite Requirements:

Bachelor's in computer science
Certificate of English language proficiency at B2 level minimum

Course syllabi (mandatory courses):

https://istic.univ-rennes.fr/master-informatique-parcours-cloud-and-network-infrastructures-cni

Appendix B: Detailed list of questions used for the survey

This section presents the complete list of questions included in the survey. The questionnaire has been designed to address both HPC and cloud computing contexts and gather information relevant to the market analysis and Master's programme definition in WP1, as well as the self-standing modules market analysis in WP3.

Introductory questions

- Company Name (if you want to reveal it)
- Country of your company
- Which of the following best describe your organization's industry or domain?
- What is the size of your organization (based on full-time employees)?
- What percentage of your business operations involve the following technologies? (This will help us understand the relative importance of each technology to your business.)
- Which technologies does your organization currently use? (You will be asked detailed questions based on your selection.)

This last question of the section has been used to drive the participant of the survey to more HPC-related or Cloud-related questions (or both).

HPC related questions

These questions were addressed to all participants who declared to use HPC-technologies on the last introductory questions.

- Approximately how many employees in your organization currently specialize in High-Performance Computing (HPC)?
- What are the most common HPC-related job roles in your organization?
- How difficult is it to find qualified HPC professionals for your organization?
- What academic backgrounds or technical skills do you prioritize when hiring HPC professionals?

- What is the approximate annual salary range for HPC professionals in your organization?
- Compared to other technical roles in your organization, how do HPC professionals' salaries compare?
- Which HPC applications are relevant to your organization's work?
- How does your organization currently access HPC resources?
- What are the biggest challenges your organization faces in HPC adoption?
- Which software tools does your organization use for HPC workloads?
- How does your organization manage or optimize HPC workloads?
- Which topics should an HPC training program cover to support your industry's needs?
- What technical skills do you look for when hiring HPC professionals?
- What are the biggest skill gaps you observe among new HPC hires?
- Does the current university curriculum in Computer Science/Engineering meet industry demands for HPC?
- If you could recommend one HPC-related course to be added to university programs, what would it be?
- What is your preferred method of HPC training delivery?
- How important is it for employees to have industry-recognized HPC certifications?
- Would your company encourage new employees to complete an HPC certification program? (Do you think it is beneficial to encourage new employees to complete an HPC certification program?)
- Would your company fund HPC certification or training for employees?
- What are the main barriers to upskilling employees in HPC at your company?
- Would your company collaborate with universities to co-develop industry-focused HPC training?
- Would your company participate in an HPC internship or apprenticeship program?
- How do you expect the demand for HPC professionals to evolve in your sector over the next 5 years?
- What are the biggest challenges you face in hiring HPC professionals?

- In which ways would your company be open to collaborating with universities or research centers on HPC?
- Do you have any additional comments or suggestions regarding HPC training or collaboration?
- Based on your earlier selection, do you want to proceed to the Cloud section now?

CLOUD related questions

These questions were addressed to all participants who declared to use only cloud computing technologies on the last introductory questions or if at the end of the HPC-related questions, positively answered to proceed on the Cloud section.

- Approximately how many employees in your organization currently specialize in Cloud Computing?
- What are the most common Cloud-related job roles in your organization?
- How difficult is it to find qualified Cloud Computing professionals for your organization?
- What educational backgrounds are most commonly preferred for cloud professionals in your organization?
- What is the approximate annual salary range for cloud professionals in your organization? (Euro)
- Compared to other technical roles in your company, how do cloud professionals' salaries compare?
- Which Cloud Computing applications are relevant to your organization's work?
- How does your organization currently access cloud services?
- What are the biggest challenges your organization faces in adopting or scaling cloud computing?
- Which tools or platforms does your organization use for cloud-based workloads?
- How does your organization manage or optimize cloud-based workloads?

- Which topics should a Cloud Computing training program cover to support your industry's needs?
- What technical skills do you look for when hiring Cloud Computing professionals?
- What are the biggest skill gaps you observe among new Cloud Computing hires?
- Does the current university curriculum in Computer Science/Engineering meet industry demands for Cloud Computing?
- If you could recommend one Cloud-related course to be added to university programs, what would it be?
- What is your preferred method of Cloud Computing training delivery?
- How important is it for employees to have industry-recognized Cloud Computing certifications (e.g., AWS, Azure, GCP)?
- Would your company encourage new employees to complete a Cloud Computing certification program?
- Would your company fund Cloud Computing certification or training for employees?
- What are the main barriers to upskilling employees in Cloud Computing at your company?
- Would your company collaborate with universities to co-develop industry-focused Cloud Computing training?
- Would your company participate in a Cloud Computing internship or apprenticeship program?
- How do you expect the demand for Cloud Computing professionals to evolve in your sector over the next 5 years?
- What are the biggest challenges you face in hiring Cloud Computing professionals?
- In which ways would your company be open to collaborating with universities or research centers on Cloud topics?
- Do you have any additional comments or suggestions regarding Cloud training or collaboration?

Conclusive questions

These questions were addressed to all participants who completed the survey and are mainly intended to explore potential opportunities for future interactions.

- Would you like to stay informed about the ACHIEVE program or be contacted for follow-up? If yes, please enter your email address:
- Would you like to share any additional comments, suggestions, or feedback with us?

□

Bibliography

[1] European Comission, “High Performance Computing,” [Online]. Available: https://digital-strategy.ec.europa.eu/en/policies/high-performance-computing. [Accessed 2025].

[2] Fortune Business Insight, “High Performance Computing Market Size, Share & Industry Analysis,” [Online]. Available: https://www.fortunebusinessinsights.com/industry-reports/high-performance-computing-hpc-and-high-performance-data-analytics-hpda-market-100636. [Accessed 2025].

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