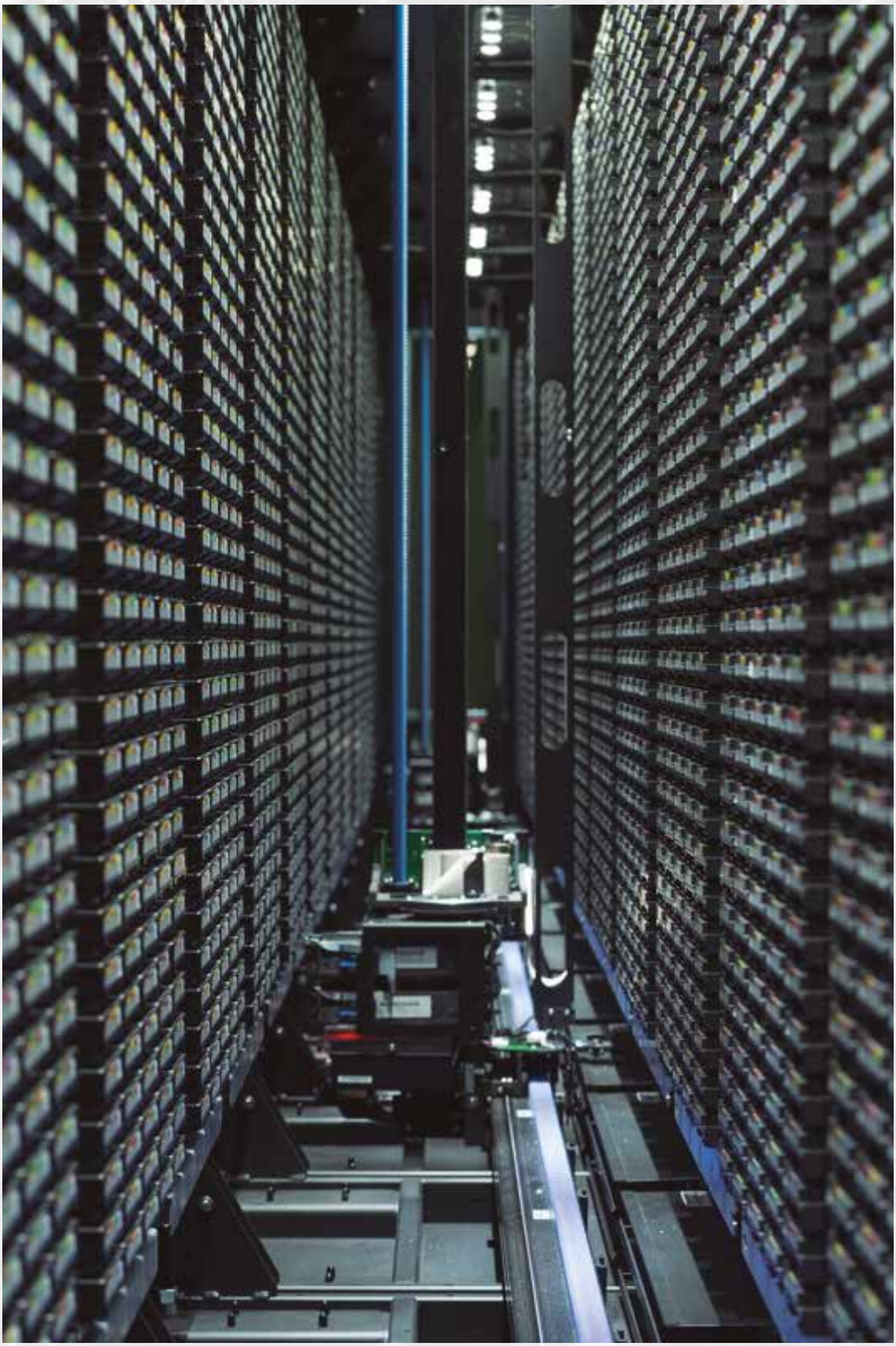
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

SUMMARY **2024**



Who we are

The Barcelona Supercomputing Center – Centro Nacional de Supercomputación (BSC-CNS) is the leader in supercomputing in Spain and an international center of reference for artificial intelligence (AI) and high-performance computing.

We are a leading multidisciplinary research center. We host high-performance computing and data management infrastructures, and one of the world's most powerful AI development platforms at the service of the international scientific community.

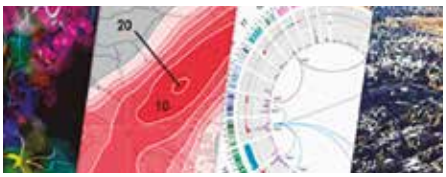
We are a EuroHPC pre-exascale hosting entity that provides supercomputing capacities, AI systems and data resources across Europe. We also manage the Spanish Supercomputing Network (RES), a Singular Scientific and Technical Infrastructure (ICTS) that distributes HPC and data management resources to the Spanish scientific community.

Created in 2005, based on the experience of fruitful collaborations between the public administration and private companies, such as CEPBA and CIRI, we have quickly grown from a staff of 67 people to around 1,200, thanks to the continuous commitment of our trustees and our ability to raise competitive funds from companies and public institutions.

We have installed five consecutive versions of the MareNostrum supercomputer and we are currently preparing the sixth version. In addition, we have built our first quantum computer, which will be integrated into MareNostrum 5 and will be key to advancing the new era of hybrid computing.

BSC's missions

Supercomputing and AI services for Spanish and European researchers



R&D in Computer, Life, Earth, Engineering and Social Sciences

Knowledge transfer (education, tech transfer and public engagement)

BSC is a public consortium made up of:

Generalitat de Catalunya
Departament de Recerca i Universitats

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

UPC
UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Where we are, where we are going

2024 was a key year in the history of BSC. In a complex geopolitical context, Ursula von der Leyen, the President of the European Commission, called for Europe's leading role in supercomputing to be harnessed to propel Europe to the international forefront in artificial intelligence in her State of the Union address in September 2023.

Mateo Valero and **Josep M. Martorell**
Director and Associate Director of BSC

In this context, in December, BSC was selected by the European High-Performance Computing Joint Undertaking (EuroHPC JU) to host one of the seven new European AI Factories. This unprecedented initiative seeks to make Europe's supercomputers, such as MareNostrum 5 hosted by BSC, available to startups and others interested in AI.

BSC will receive investment of almost €200 million from the European Commission, together with the Spanish Government (the Ministry for Digital Transformation and the Civil Service and the Ministry of Science, Innovation and Universities) and the Catalan Government. This will enable BSC to provide access to a new extension of MareNostrum 5, plus services for companies, startups and SMEs, which will be its main users. The aim is to enable Europe's industries to develop R&D with world-class competitive computing resources.

BSC's AI Factory will serve strategic sectors, such as biomedicine, public administration, climatology and agriculture, in line with the European vision of building safe, ethical and reliable AI. This commitment is fundamental to create an innovative AI system, as well as to move toward technological sovereignty in Europe. This is a strategic necessity to be able to compete with other powers at a time when the development and use of critical technologies is a priority.

Another major initiative approved in 2024 was the DARE project, the largest ever funded by the European Union (EU) to develop high-performance chips and AI. The project has an initial investment of 120M€ from the EC through EuroHPC and 120M€ from 38 European partners and their national funding agencies.

Led by BCS, it will develop hardware and software for the supercomputers of the future, such as MareNostrum 6, as well as autonomous cars and AI development in general. DARE is the result of BSC's experience and leadership in designing open-source RISC-V chips, a field it has been working in for more than 10 years in large-scale projects at the European level. This European commitment will mark a turning point in the development of high-performance chips and in boosting Europe's technological independence.

Also in 2024, the MareNostrum 5 supercomputer, commissioned in April, was made available to Spanish and European science. At the same time, MareNostrum 4 left our chapel, which has seen the arrival of BSC's first quantum computer, and will be integrated into MareNostrum 5 to take BSC into a new era of hybrid computing, combining traditional and quantum computing. This new infrastructure is funded by the Quantum Spain project. It is built with 100% European technology in which Spanish business is playing a key role. This quantum computer will be joined by a second computer, approved in 2024 by the EuroHPC JU, which will also put us in a leading position in Europe in this new technology.

In 2024 we broke the barrier of 1,200 people. This figure was unthinkable when the center started in 2005 with a team of 67 people who got this great project off the ground with enthusiasm and effort. Today we have researchers from 60 countries working in areas as diverse as new drugs or energy sources, digital twins of the human body and the planet Earth, open-source RISC-V chip design, and the social sciences.

This incredible team of professionals enabled us to end the year with impressive figures. For the first time in our history, our annual operating budget is approaching €100 million with more than 80% coming from competitive funds. In fact, our estimated competitive revenues in 2024 exceeded €82 million, more than 30% up on the previous year. These figures were unimaginable just a few years ago and underscore BSC's extraordinary ability to attract large-scale competitive projects. In 2024 we worked on more than 440 scientific projects and published 484 scientific articles in high-impact international journals. To speed up knowledge transfer, we have transferred 15 patents and created two new spin-offs, Talptech and Galtea, making a total of 13 since our inception.

Since no transformative projects can be performed without outstanding professionals, one of the great challenges we now face is attracting even more talent, especially in the field of AI. In July 2024, we launched the AI4Science (AI4S) program to boost AI training. Through this program, which is supported by the Ministry for Digital Transformation and the Civil Service, 158 new AI experts joined us this year. That makes us one of the leading institutions for the promotion of AI in Europe with more than 300 scientists working on this technology.

Another milestone in 2024 was the successful visit by our Scientific Advisory Board, made up of world-class researchers and chaired by Ron Perrott from Oxford University. Their 2022-2024 report highlights the center's growth and successes, and is a valuable guide to plan the next three years and focus on the most successful aspects.

BSC's purpose is to contribute to the advancement of knowledge, the only tool to build a better, fairer and more democratic society. We are especially grateful to all the people, governments, companies and organizations that are accompanying us on this journey. To our patrons for their trust and support. To the BSC team, a huge family that we are especially proud of. Without them, our center would not be what it is today. We hope that 2024 will be the prelude to much more good news to come.

The representatives of BSC's three trustees who are members of our Governing Board

Juan Cruz
President
Secretary of State for Science, Innovation and Universities

Maria Galindo
Vice-president
Secretary of Digital Policies

Eva Ortega-Paíno
Secretary-General of Research

María González Veracruz
Secretary of State for Digitalization and Artificial Intelligence

Josep Oriol Escardíbul
Secretary-General of Research and Universities

Joan Gómez Pallarès
Director-General of Research

Daniel Crespo
Rector

Jordi Llorca
Vice-Rector for Research

BSC in numbers

Research

Data as of December 31, 2024

72 Research groups

7 ERC projects in progress

10 ICREA researchers

234 Researchers with personal fellowships

Historical Horizon Europe **€122 M**

166 H2020 & Horizon Europe projects in progress

35 Horizon Europe projects begun in 2024

21 H2020 & Horizon Europe projects coordinated by BSC

Presence in Centers of Excellence for HPC applications

We participated in **13**

We led **2**

363 Articles in peer-reviewed journals — **314** in Q1

101 Articles in conference proceedings — **35** in top conferences

30 Doctoral theses

293 Open-access publications

8 Chapters in published books

Technology transfer

Data as of December 31, 2024

Technologies transferred or licensed

15 Patents

6 Methodologies

19 Software

13 Spin-offs created (total BSC history)

Billateral collaborations with companies

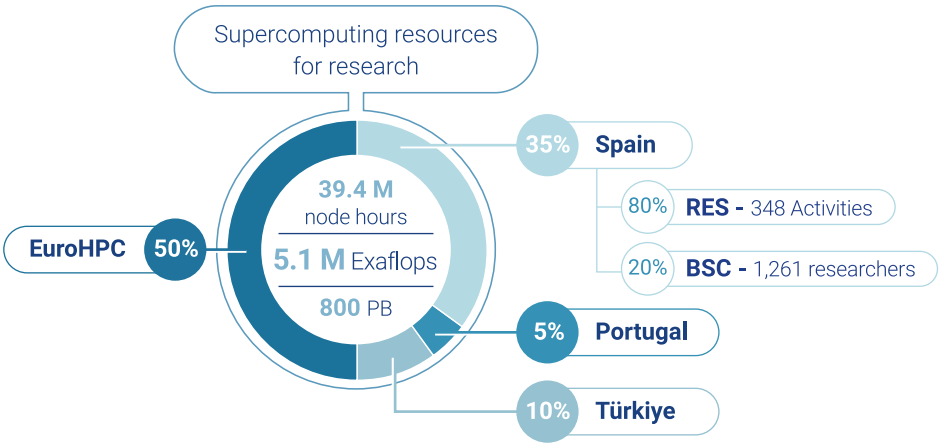
35 In progress

13 Started in 2024

60 Patents approved or pending approval

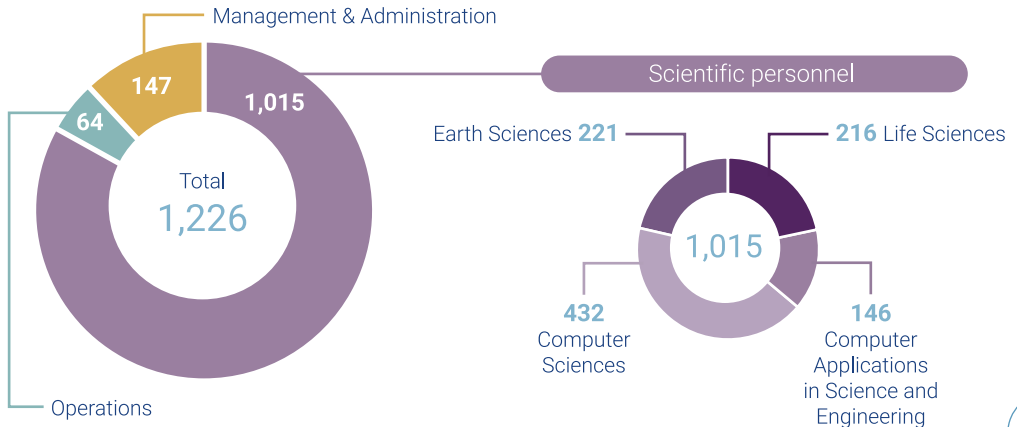
Supercomputing

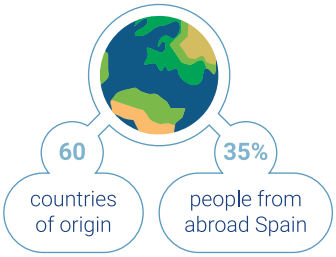
Data as of December 31, 2024



People

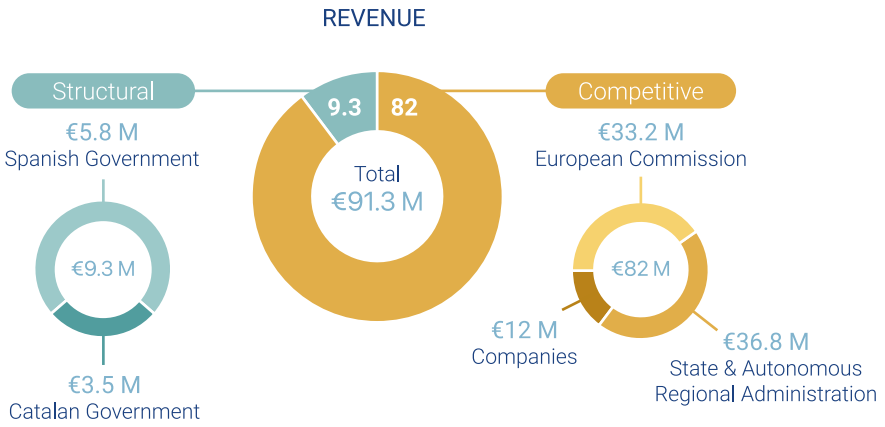
Data as of December 31, 2024

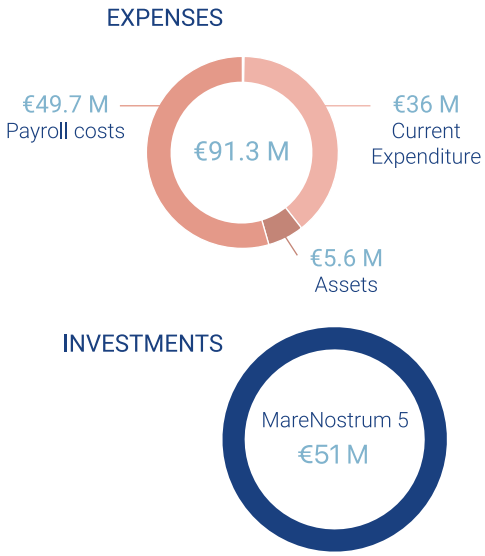




Resources

2024 executed budget





UPC contributes, in terms of assigned staff and room space, the equivalent of 10% of structural funds.

Revenue and expenses according to finance criteria. Investments according to budgetary criteria. Estimated data prior to the end of the 2024 financial year and the formulation of the annual accounts.

BSC to host one of the European Commission's seven AI factories

The European Commission announced in December the approval of the 'AI Factory' project, a further step toward European technological sovereignty. BSC will host one of the first seven European AI Factories, infrastructure that will provide access to computational resources and R&D services to public administrations, companies, startups, SMEs and scientists, accelerating the development of AI applications based on open models and following the standards of the European AI Act.

The BSC AI Factory's services will focus on the sectors and areas with the greatest potential for AI development, such as health, climate and agriculture, the public sector, legal and financial, energy, and media and communications.

The initiative, which will be implemented through the EuroHPC JU, envisages a total investment of around €200 million. The EC will contribute €98 million, the Spanish Government will contribute almost €62 million through the Ministry for Digital Transformation and the Civil Service and the Ministry of Science, Innovation and Universities, while the Catalan Government will contribute €14 million. The project also has contributions from Portugal, Türkiye and Romania.

Juan Cruz, Secretary of State for Science, Innovation and Universities, Núria Montserrat, the Catalan Minister for Research and Universities and Mateo Valero, BSC Director, presented the BSC AI Factory in society last December.

Expansion of MareNostrum 5's AI capabilities

One of the most significant actions undertaken by the BSC AI Factory will be to expand MareNostrum 5's AI capabilities. This will double the supercomputer's processing capacity for AI applications and will be key to providing public and private sector access and putting Spain at the forefront of AI globally.

The expansion is being funded with €154 million, half of which will come from the European Commission through the EuroHPC JU, and the rest from the Ministry of Science, Innovation and Universities, the Ministry for Digital Transformation and the Civil Service, the Catalan Government, and contributions from Portugal and Türkiye.

Scan the QR code for more details

BSC to lead DARE, Europe's largest chip development project

The European Commission has announced its support for the DARE project, an ambitious BSC-led initiative to develop high-performance chips to reduce Europe's technology dependence and move toward full digital autonomy. With an investment of €240 million and the participation of 37 European partners, DARE is the largest chip research and development project ever funded by the European Union.

DARE is the result of BSC's experience in open-source RISC-V chip design, a free and open architecture that is the hardware equivalent of what Linux is in software. RISC-V has already gained widespread support in academia and global industry for its versatility and adaptability without the cost and licensing restrictions of proprietary architectures.

New plan to boost training in AI and supercomputing

BSC will receive €50 million to develop the talent attraction and retention programs that are part of the Spanish Government's Artificial Intelligence Strategy. The AI training plan envisages training 158 professionals in this field at BSC by 2028. The aim is to promote new lines of research in the convergence of supercomputing and AI.

This initiative is part of the Generación D program, promoted by Red.es, an entity under the Ministry for Digital Transformation and the Civil Service, and is funded by the Recovery, Transformation and Resilience Plan with Next Generation EU funds.

European launch of the international Trillion Parameter Consortium

BSC hosted the European launch of the international Trillion Parameter Consortium (TPC) in June. The event brought together international industry leaders, researchers and practitioners to discuss the transformative potential of generative AI in scientific and engineering applications. TPC facilitates collaboration among the international community of HPC and AI experts to maximize the use of limited resources and reduce duplication of efforts to accelerate advances in AI.

Women and Science: advances to reduce the gender gap

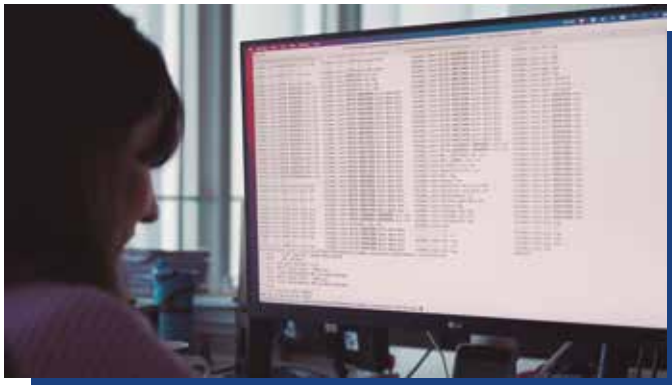
In recent years, BSC has made significant strides toward building a more inclusive and equal scientific community, particularly in STEM disciplines (science, technology, engineering, and mathematics), where gender equality has long been a challenge. The number of female researchers has increased by nearly 40% since 2017, reaching 26.8% of the workforce in 2024. Similarly, the number of women in leadership positions has also grown, with a nine-point rise since 2017, representing 22% by the end of 2024.

While these figures are still far from parity, they reflect a very positive trend in reducing the gender gap at BSC. Committed to promoting equity within the organization, the center renewed its Gender Equality Plan in 2022 and established the Equity, Diversity and Inclusion Unit. A year later, as part of its policy on preventing and responding to potential violence and discrimination, the center published its first protocol for prevention, detection and action against sexual harassment and harassment based on sex, gender identity, gender expression and sexual orientation. In 2025, the goal is to take another step forward with the launch of BSC's first LGBTIQA+ Plan.

These actions are complemented by research lines focused on integrating sex and gender perspectives into science, as well as training programs aimed at overcoming gender biases in research.

In 2018, the center also launched 'We are Young Researchers', an educational program designed to spark interest in supercomputing and scientific and technological careers, especially among girls. Over 32,000 primary school students have visited BSC in the first five years of this initiative, which aims to foster female role models in STEM fields.

These efforts are especially relevant at a time when the technological and digital revolution is reshaping our perception of the world and directly impacting our daily lives, whether in the workplace, business, culture or society.



20 years since the agreement to create the first MareNostrum

10 March 2024 marked 20 years since the signing of the agreement between the Spanish Government and IBM, at Palacio de la Moncloa, to develop the first version of the MareNostrum supercomputer. This alliance was Spain's introduction into the field of high-performance computing and laid the foundations for the creation of BSC, which would be formalized a year later in the form of a consortium, under the agreement between the Spanish Government, the Catalan Government and UPC.

Galtea and Talptech: two new BSC spin-offs

BSC is consolidating its commitment to technology transfer with two new spin-offs, bringing the number of companies created from its research since 2016 to 13. Backed by BSC's Language Technologies Unit and the computational power of MareNostrum 5, Galtea is the first company in Spain to offer companies a technology that allows them to promote the safe and responsible use of generative AI, ensuring that AI models are accurate and do not infringe European regulations.

Talptech, meanwhile, combines AI and supercomputing to democratize precision agriculture and improve the performance and sustainability of agricultural crops. The new technology will be integrated into agricultural machinery to analyze crops in real time and detect diseases or nutritional deficiencies early, thereby increasing yields and reducing pesticide use.

The power of supercomputing on stage at the MWC

BSC showcased its full potential at the Mobile World Congress 2024, one of the world's leading technology and connectivity events. During the congress, BSC presented two scientific art installations at the stands of the Catalan Government and Mobile World Capital Barcelona. Through these installations, thousands of visitors were able to discover the importance of supercomputing in advancing society, and its impact on diverse fields such as health care, climate change, chip design, and engineering. The center also presented 25 innovative technologies developed at BSC, while ten BSC spin-offs showcased their projects in the area for emerging tech companies.

BSC also had a significant presence at international supercomputing fairs international supercomputing fairs, including SC24 in Atlanta, the RISC-V Summit in Munich, and ISC24 in Hamburg, as well as other industry events and festivals, such as the Smart City Expo World Congress and Tech&Play, both in Barcelona.

First official visit by Catalan Government Minister Núria Montserrat to BSC

Núria Montserrat , the new Catalan Minister of Research and Universities, visited BSC for the first time in September, one month after taking office. Montserrat, who is internationally renowned for her pioneering work in tissue engineering and regenerative medicine, met with BSC directors to learn about the center's main challenges and projects. She had also the opportunity to see the MareNostrum 5 supercomputer up close, which she described as one of the cutting-edge scientific infrastructures on which to build the economy of the future.

Research in MareNostrum

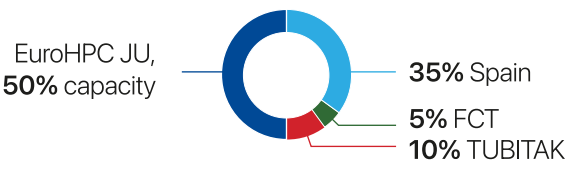
MareNostrum 4 and MareNostrum 5 provided 39.4 million node hours in 2024 (5.1 million Exaflops). Some of the research projects developed in these two supercomputers are:

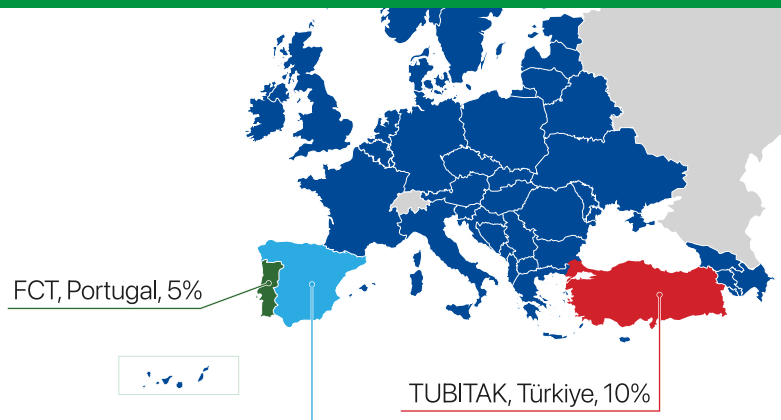
International

Project	Principal Investigator	Center
Destination Earth - Building a highly accurate digital twin of the Earth	Thomas Geenen	ECMWF
Quantum AI for development and training of LLMs in Europe	Faysal Ishtiaq Rabby	MULTIVERSE
Towards Linguistic Diversity: Optimizing Data Distribution for Multilingual NLP Inclusivity	Marta Villegas	BSC Barcelona Supercomputing Center Centro Nacional de Supercomputación
High-Fidelity Simulations of Supersonic Rigid Parachute Dynamics	Luca Placco	Università degli Studi di Padova
EuroLingua GPT: One Model for all European Languages	Joachim Köhler	Fraunhofer IAIS
Developing a High-Performance Generative LLM with Multilingual Capabilities for Portuguese and Galician	Paulo Quaresma	Universidade de Évora
MultiSenseGPT: Sensing Earth Through the Lens of Multimodal Large Language Models	Hacettepe University	Hacettepe University

Providing a service for researchers all around Europe

The MareNostrum 5 supercomputer is available to Spanish and European researchers through the competitive calls of the European High-Performance Computing Joint Undertaking (EuroHPC JU, 50% capacity), the Spanish Supercomputing Network (RES, 80% of the Spanish capacity), and the research access calls of Fundação para a Ciência e a Tecnologia (FCT, Portugal, 5%) and the Scientific and Technological Research Council of Türkiye (TUBITAK, Türkiye, 10%). The rest of the supercomputer's capacity access time is allocated to BSC research.





National (RES)

Project	Principal Investigator	Center
Expanding High-Resolution WRF Dataset for AI Training and Testing of a Novel Cyclone Detection Tool	Yseut Bahuet	Universitat de les Illes Balears
Deep Learning to understand the cellular fundamentals of aging using stem cell microscopy	Paula Petrone	ISGlobal Barcelona Institute for Global Health
Gravitational waves from dark matter string networks	Daniel Figueroa	CERN
Boosting the limits of Data-centric Deep Learning for Visual Food Computing	Petia Radeva	Universitat de Barcelona
Efficient embedding of Machine Learning potentials for biomolecular simulations	Kirill Zinovjev	Universitat de València
Materials Characterization: Navigating the Future with Excellence in Shared Data	Pilar Cea	ELECMI, Infraestructuras Científicas y Técnicas Singulares
Strategic projects		Gaia DPAC, European Genome-Phenome Archive, LHC, Biblioteca Nacional de España BNE, Euclid Consortium

The **MareNostrum 5** supercomputer has a maximum capacity of **314 PetaFlop/s** or, in other words, **314,000 European billion operations per second.**

RES Red Española de Supercomputación

Infraestructuras Científicas y Técnicas Singulares

The acquisition and operation of the EuroHPC supercomputer is funded jointly by the EuroHPC Joint Undertaking, through the European Union's Connecting Europe Facility and the Horizon 2020 research and innovation programme, as well as the Participating States Spain, Portugal and Türkiye

EuroHPC Joint Undertaking

Hosting Consortium:

Spain Portugal Türkiye

European Commission

Research acknowledgements

Mateo Valero's 2024 recognitions and international distinctions

In 2024, Mateo Valero received several prestigious honors. He was awarded the 'Barceloní de l'Any' prize by El Periódico, recognizing his significant contributions to defining and promoting the city of Barcelona. Additionally, he received the 'Innovation and Science' Prize at the second edition of the Premios Vanguardia for being a pioneer and leading figure in the supercomputing sector. Furthermore, he was conferred honorary doctorates by the University of Chile, the Autonomous University of Chile and the University of Murcia, bringing his total number of Honoris Causa degrees to thirteen.

BSC researchers Oriol Lehmkuhl and Pablo Ortega were awarded prestigious ERC Grants

BSC researcher Oriol Lehmkuhl is a principal investigator in the ERC Synergy Grant project TRANSDIFFUSE, which will develop AI models to revolutionize propulsion technologies and lay the groundwork for hydrogen-based engines. Also in 2024, BSC researcher Pablo Ortega received an ERC Consolidator Grant for his project PREDDYCT, which aims to enhance the realism and reliability of global climate predictions.

BSC's 'We are Young Researchers' program received an award from AMETIC

In October 2024, BSC's 'We are Young Researchers' program was honored with the Digital Skills Awards Spain 2024 in the 'Digital Competences for Women and Girls' category by AMETIC, the association representing Spain's digital industry sector. This initiative aims to encourage scientific and technological vocations among young girls, addressing the gender gap in STEM fields. Since its inception in 2018-19, approximately 32,000 students have taken part in the program. In 2022, 'We are Young Researchers' expanded its reach across various autonomous communities in Spain through the Spanish Supercomputing Network (RES).

BSC receives prestigious Ciutat de Barcelona and Premi Talent awards in 2024

In 2024, BSC was honored with the 'Ciutat de Barcelona Award' in Experimental Sciences and Technology. This accolade recognizes outstanding contributions in scientific research and technological innovation. Additionally, BSC received the 'Premi Talent' 2024 in the Technological Sovereignty category, awarded by Fundació Impulsa Talentum during the Integrated Systems Europe (ISE) 2024 event. This award acknowledges the center's significant role in advancing technological independence and innovation.

Scientific impact

One of the BSC's mechanisms to ensure the exploitation of the center's scientific production is by publishing the main research results in the most appropriate media and channels for each of them, including works derived from doctoral theses. This section shows the multidisciplinary nature of the BSC research through the top journals where BSC researchers publish their results and their scientific domains, as well as the evolution of the scientific production of the center in the last five years.

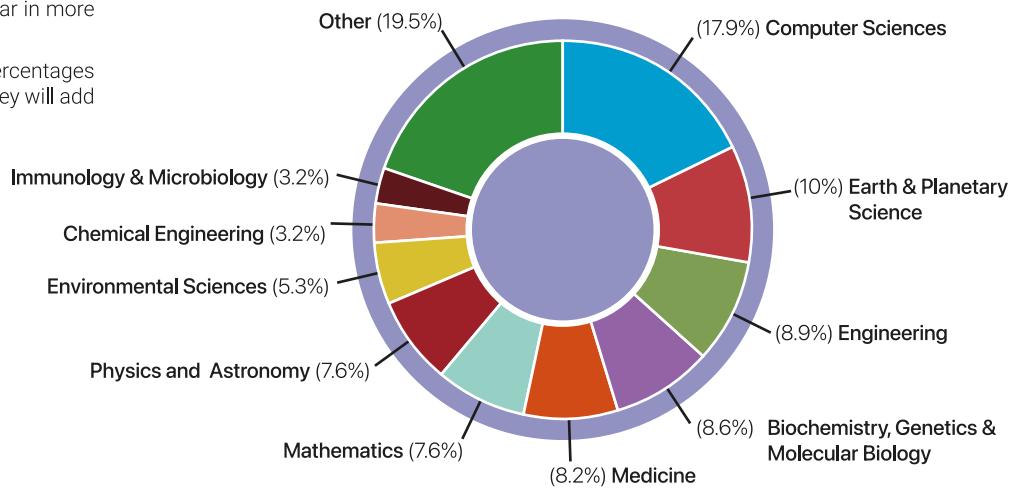
Top 10 journals with BSC publications in 2024

IEEE	35
Lecture Notes in Computer Science	14
ACM	12
Nature Communications	12
Atmospheric Chemistry and Physics	9
Nuclear Fusion	9
Future Generation Computer Systems	9
Nucleic Acids Research	7
Scientific Reports	7
LREC Conference	6

Multidisciplinarity

The subject area chart is based on the Scopus All Subject Journal Classification (ASJC); a publication may appear in more than one subject area.

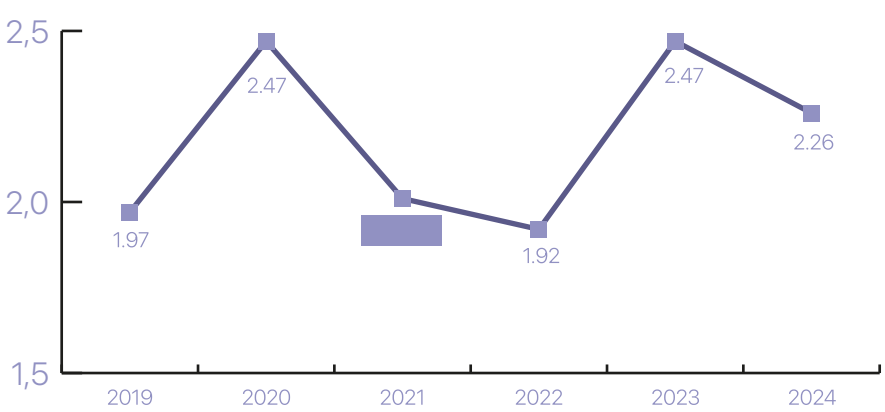
Therefore, if you add up the percentages in the pie or doughnut charts, they will add up to more than 100%.



Field-Weighted Citation Impact 2019-2024

The Field-Weighted Citation Impact (FWCI) measures an article's citations relative to the average in its field. An FWCI greater than 1 indicates that the article has been cited more than expected. A value close to or over 2 indicates a high impact, with citations well above the average.

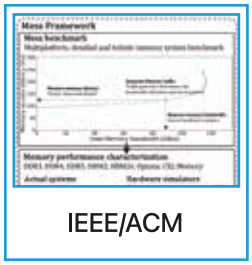
In 2024, scientific publications from BSC have been cited 126% more than the global average in their field of research.



Featured publications

The multidisciplinary nature of BSC can be seen in the wide range of fields in which researchers publish scientific articles.

Below is a selection of the most notable publications in 2024.



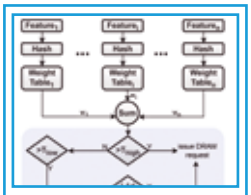
IEEE/ACM

A Mess of Memory System Benchmarking, Simulation and Application Profiling

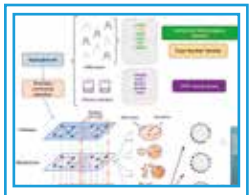
This paper presents the memory stress (Mess) framework, which provides a unified view of memory system benchmarking, simulation and application profiling. It makes use of the bandwidth-latency concept for memory performance simulation and integrates with widely-used CPU simulators, enabling modeling of all high-end memory technologies. This novel holistic received the best paper runner-up award. Esmaili-Dokht, P., Sgherzi, F., Soldera Girelli, V., Boixaderas, I., Carmin, M., Monemi, A., Armejach, A., Mercadal, E., Llort, G., Radojković, P., Moreto, M., Giménez, J., Martorell, X., Ayguadé, E., Labarta, J., Confalonieri, E., Dubey R., and Adlard, J. 57th IEEE/ACM International Symposium on Microarchitecture MICRO 2024: 136-152. May 2024.

A Two-Level Neural Approach Combining Off-Chip Prediction with Adaptive Prefetch Filtering

This paper presents the Two Level Perceptron (TLP) predictor, a neural mechanism that effectively combines predicting whether an access will be off-chip with adaptive prefetch filtering at the first-level data cache (L1D). It constitutes the first hardware proposal targeting both off-chip prediction and prefetch filtering using a multilevel perceptron hardware approach. Jamet, AV., Vavouliotis, G., Jiménez, D., Alvarez, Ll. and Casas M. 2024 International Symposium on HPCA 2024: 528-542. March 2024.



HPCA



Nature Communications

Rare disease research workflow using multilayer networks elucidates the molecular determinants of severity in Congenital Myasthenic Syndromes

Exploring the molecular basis of disease severity in rare disease scenarios is a challenging task in view of the limitations on data availability. Causative genes have been described for Congenital Myasthenic Syndromes (CMS), a group of diverse minority neuromuscular junction (NMJ) disorders; yet a molecular explanation for the phenotypic severity differences remains unclear. Here we present a workflow to explore the functional relationships between CMS causal genes and altered genes from each patient, based on multilayer network community detection analysis of complementary biomedical information provided by relevant data sources, namely protein-protein interactions, pathways and metabolomics. Núñez-Carpintero, I., Rigau, M., Bosio, M., O'Connor, E., Spendiff, S., Yoshiteru Azuma, Ana Topf, Rachel Thompson, 't Hoen, P., Chamova, T., Tournev, I., Guergueltcheva, V., Laurie, S., Beltran, S., Capella-Gutiérrez, S., Cirillo, D., Lochmüller, H. and Valencia, A. Nature Communications volume 15, Article number: 1227. February 2024.

Recent gene selection and drug resistance underscore clinical adaptation across Candida species

Understanding how microbial pathogens adapt to treatments, humans and clinical environments is key to infer mechanisms of virulence, transmission and drug resistance. This may help improve therapies and diagnostics for infections with a poor prognosis, such as those caused by fungal pathogens, including Candida. Here we analyzed genomic variants across approximately 2,000 isolates from six Candida species (C. glabrata, C. auris, C. albicans, C. tropicalis, C. parapsilosis and C. orthopsilosis) and identified genes under recent selection, suggesting a highly-complex clinical adaptation. Schikora-Tamarit, MA. and Gabaldón, T. Nature Microbiology volume 9, pages 284–307. January 2024.

Nature Microbiology

Artificial intelligence for climate prediction of extremes: state of the art, challenges, and future perspectives

WIRE's Climate Change

Extreme weather events, such as heatwaves, droughts and heavy storms, are difficult to predict due to their rarity, chaotic nature, and model limitations. Artificial intelligence shows promising improvements for predicting extreme events and uncovering their links to large-scale and local factors. Machine learning and deep learning enhance predictions, while causal discovery and explainable AI deepen our understanding of the underlying processes. The main challenges include data quality, model uncertainty and reproducibility. This review summarizes progress, identifies best practices, and outlines future directions for AI in predicting extreme events. Materia, S., García, L. P., van Straaten, C., O, S., Mamalakis, A., Cavicchia, L., Coumou, D., de Luca, P., Kretschmer, M., and Donat, M. WIREs Climate Change, e914. September 2024.

Nature Medicine

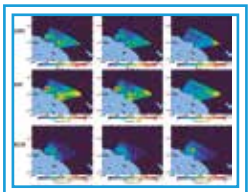
Geographic sources of ozone air pollution and mortality burden in Europe

Ground-level ozone (O3) is a harmful air pollutant formed in the atmosphere by the interaction between sunlight and precursor gases. Exposure to current O3 levels in Europe is a major source of premature mortality from air pollution. However, mitigation actions have been mainly designed and implemented at the national and regional scales, lacking a comprehensive assessment of the geographic sources of O3 pollution and its associated health impacts. Here we quantify both national and imported contributions to O3 and their related mortality burden across 813 contiguous regions in 35 European countries, representing about 530 million people. Achebak, H., Garatachea, R., Pay, MT., Jorba, O., Guevara, M., Pérez García-Pando, C. and Ballester, J. Nature Medicine, 30, 1732 - 1738. June 2024.

Stabilizer Tensor Networks: Universal Quantum Simulator on a Basis of Stabilizer States

Phys. Rev. Lett.

Efficient simulation of quantum computers relies on understanding and exploiting the properties of quantum states. This is the case for methods such as tensor networks, based on entanglement, and the tableau formalism, which represents stabilizer states. In this Letter, we integrate these two approaches to present a generalization of the tableau formalism used for Clifford circuit simulation. We explicitly prove how to update our formalism with Clifford gates, non-Clifford gates, and measurements, enabling universal circuit simulation. We also discuss how the framework allows for efficient simulation of more states, raising some interesting questions on the representation power of tensor networks and the quantum properties of resources such as entanglement and magic, and support our claims with simulations. Sergi Masot-Llima and Artur Garcia-Saez, Phys. Rev. Lett. 133, 230601. December 2024.



Nature Communications

A machine learning estimator trained on synthetic data for real-time earthquake ground-shaking predictions in Southern California

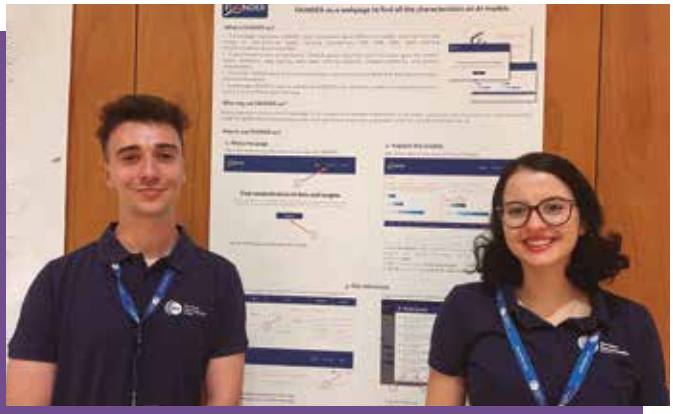
After large-magnitude earthquakes, a crucial task for impact assessment is to rapidly and accurately estimate the ground shaking in the affected region. To satisfy real-time constraints, intensity measures are traditionally evaluated with empirical Ground Motion Models that can drastically limit the accuracy of the estimated values. As an alternative, here we present Machine Learning strategies trained on physics-based simulations that require similar evaluation times. Monterrubio-Velasco, M., Callaghan, S., Modesto, D., Carrasco, JC., Badia, R., Pallares, P., Vázquez-Novoa, F., Quintana-Ortí, E., Pienkowska, M., and De la Puente, J. Nature Communications Earth & Environment volume 5, Article number: 258. May 2024.

EdgeAI-Trust: advancing the evolution of AI to transform industry

BSC researchers have joined EdgeAI-Trust, a 3-year project co-funded by the Chips Joint Undertaking to decentralize Edge AI technology. The initiative brings together a consortium of 53 partners from across Europe to help transform industries such as mobility, manufacturing and agriculture. BSC will deliver AI models that meet appropriate security requirements and provide software solutions to validate compliance.

Innostroke: new AI model to predict stroke risk using mobile devices

The Innostroke project, carried out in collaboration with Hospital de la Santa Creu i Sant Pau, aims to use artificial intelligence to transform the prevention and monitoring of strokes, one of the world's leading causes of death and disability. The technology, based on the use of electrocardiogram data collected by mobile devices such as smart watches, has been developed in an interdisciplinary way by the BSC's Computer Sciences and Life Sciences departments, with the participation of different profiles such as biotechnologists and computer engineers.



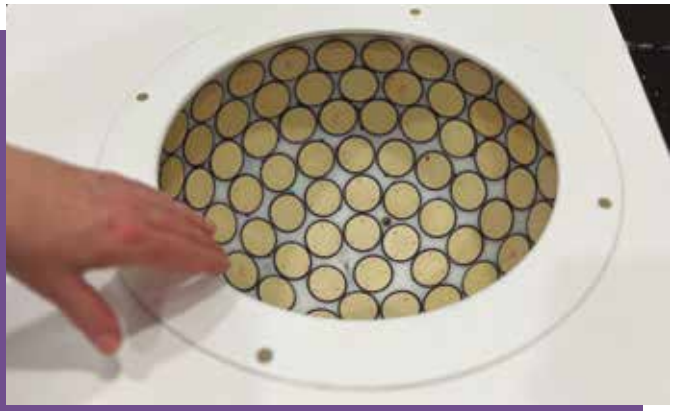
Collaboration with Micron to launch a tool to explore leading AI models

BSC and Micron Technology unveiled FAiNDER (Find comprehensive AI data and insights), an open-source web platform designed to transform how researchers and developers navigate the rapidly-evolving AI landscape. FAiNDER provides centralized, up-to-date information on the key system requirements of all major AI models to facilitate exploration and optimize hardware choices.

Scan the QR code for more details

CoEC: supercomputing to improve e-fuel performance

The Center of Excellence in Combustion (CoEC) has facilitated the development of software and methodologies to drive the design of the next generation of hydrogen turbines for energy production and aviation propulsion. The project, coordinated by BSC, uses cutting-edge supercomputing technologies to transform Europe's energy and transport sectors, encouraging the creation of new green fuels.



QUSTom: new radiation-free technology that could revolutionize breast cancer diagnosis

The European QUSTom project, coordinated by BSC, began clinical validation with patients at Vall d'Hebron University Hospital of a new technique for the early detection of breast cancer. This new medical imaging modality based on 3D tomographic ultrasound and supercomputing is completely harmless for women, as it does not use any type of radiation and offers superior image quality and better tumor monitoring.

WinDTwin: a digital twin of offshore wind farms to improve energy demand prediction

Using cutting-edge technologies such as the MareNostrum 5 supercomputer, the WinDTwin project, coordinated by BSC, will design accurate spatial models to explore hybrid and ecological energy solutions that improve our ability to harness and manage offshore wind energy. To address these challenges, WinDTwin will develop a sophisticated digital twin platform aimed at transforming the industry by providing accurate predictions of energy production and energy demand.

BSC's decadal forecast predicted that 2024 would be the warmest year on record

BSC's decadal climate prediction system predicted that 2024 would be the warmest year ever recorded and that the global annual average temperature would exceed, for the first time, the 1.5°C threshold above pre-industrial levels set in 2015 in the Paris Agreement. BSC is one of world's four WMO-endorsed centers that produce annual climate projections for the next decade.

Lancet Countdown Europe urges action to protect health from climate change

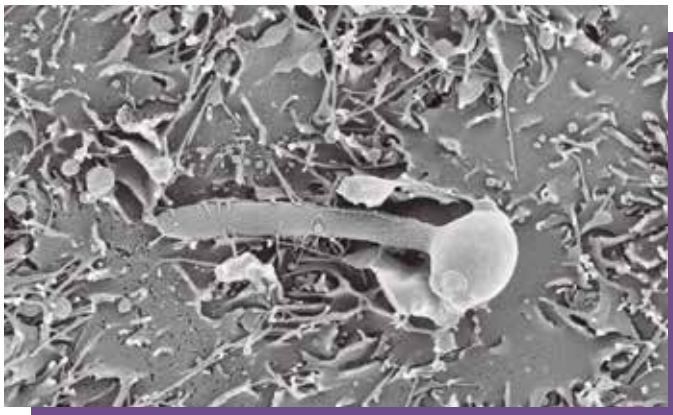
Lancet Countdown Europe's 2024 Report on health and climate change, led by BSC, highlighted the negative impacts of climate change on human health and warned of the need for urgent action to reduce greenhouse gas emissions. The authors also highlight that these effects tend to be unequally distributed, reflecting existing patterns of socio-economic development, marginalization and patterns of inequality.

Agreement with AEMET to improve atmospheric emissions representation systems

BSC and the Spanish State Meteorological Agency (AEMET) have joined forces to improve air quality forecasting and greenhouse gas (GHG) monitoring systems in Spain and its main metropolitan regions. The results and tools developed will be available to the administration and the public on a web portal that will allow the visualizing and downloading of data on the daily evolution of atmospheric emissions.

New insights into the adaptation of the Candida fungus to humans

A BSC-led study has identified hundreds of genes subject to recent evolutionary selection that are clinically relevant in six species of the pathogenic fungus Candida. This work, in which approximately 2,000 genomes have been analyzed to gain a deeper insight into the evolutionary landscape of these pathogens, highlights how they adapted to humans and antifungal drugs and provides valuable knowledge that could lead to better treatments for Candida infections.

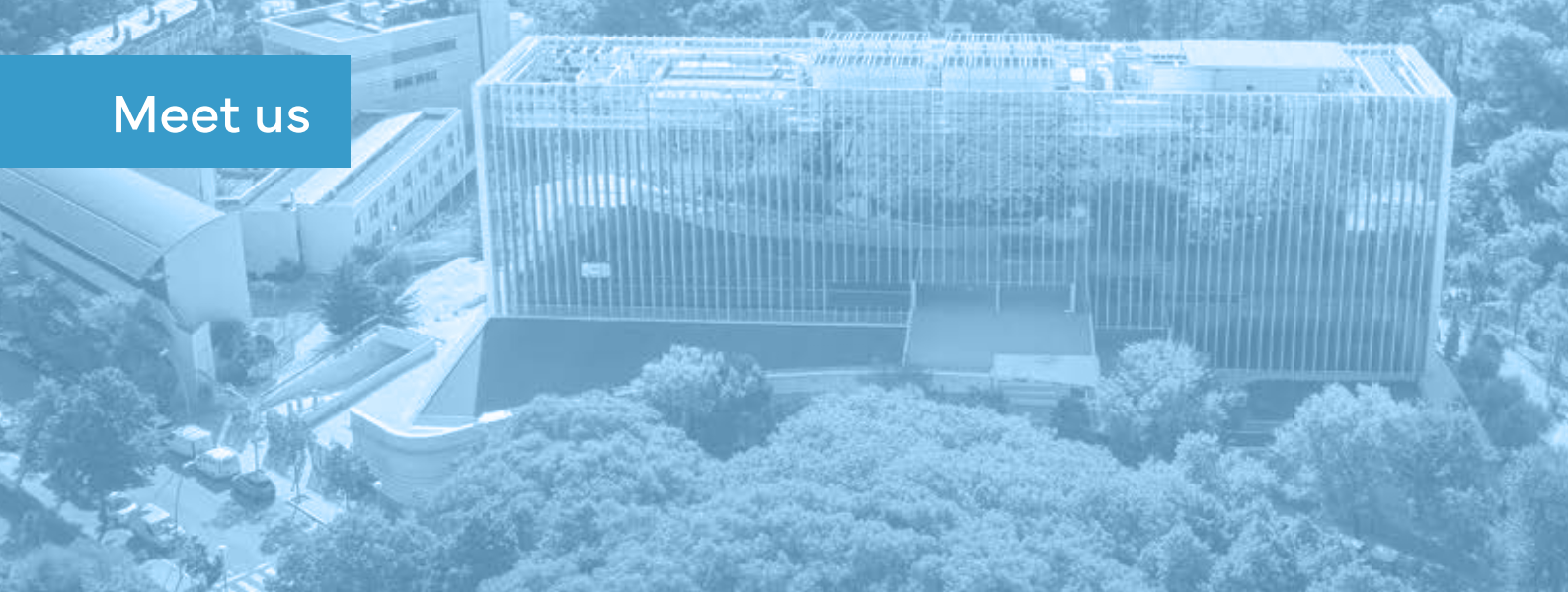


Pioneering AI technology to improve treatments for rare diseases

A BSC-led research team has developed an AI-based technology for studying rare diseases and successfully applied it to identify potential causes of myasthenic-congenital syndromes, rare inherited disorders that limit movement and cause muscle weakness. The study involved more than 10 years of collaboration between scientists from 20 institutions in seven different countries.

Big data analysis in MareNostrum to detect harmful drug interactions

A study led by BSC researchers has revealed that women are more often recommended drugs that may have harmful drug interactions than men. The study was made possible by analyzing the electronic medical records of six million patients from Catalonia, the United States and Brazil on the MareNostrum supercomputer to better understand drug co-administration patterns, especially in cases where these drugs interact.



The MareNostrum 5 supercomputer goes 'on tour'

The transformative power of supercomputing in tackling global challenges has been showcased across Catalonia and beyond. The tour kicked off with the installation 'Catalonia: Shaping the Future with Supercomputing', unveiled at the Catalan Government's stand at the Mobile World Congress in Barcelona.

Funded by the Catalan Government, this unique initiative uses the metaphor of a grain of sand to illustrate the complexity of supercomputing and its potential to advance scientific and technological progress in areas as diverse as climate change, biomedicine, technological sovereignty and linguistic diversity in the digital age.

The exhibition also made its way to the National Museum of Science and Technology of Catalonia (MNACTEC) in Terrassa, where it has been on display since November 2024. Prior to that, it was showcased at the District of Les Corts headquarters in Barcelona and at the Tech&Play festival —an event dedicated to making the latest technological innovations accessible to the public in a fun and educational way— held at the Fabra i Coats exhibition center in the Catalan capital.

At the Mobile World Congress, BSC also showcased a prototype of a digital twin through a scientific and technological installation at the MWCapital booth. This experience, jointly promoted by MWCapital and BSC in collaboration with BSC spin-off ELEM Biotech, featured a simplified version of a digital heart twin, highlighting its potential to enhance the detection and treatment of heart disease.

The installation later traveled to Palau Robert in Barcelona, attracting over 40,000 visitors, and to the BeFuture! festival in Tarragona, an event designed to connect people of all ages with the latest innovations.

These initiatives were enhanced by a unique 360º experience, offering an exclusive inside look at the MareNostrum 5 supercomputer—from the intricate network of cables connecting its components to the advanced chips at its core. This virtual experience, backed by MWCapital and BSC, made its way to other major events such as Tech&Play in Barcelona, ISC High Performance in Hamburg, and the International Conference for High-Performance Computing, Networking, Storage and Analysis in Atlanta, USA.

BSC gratefully acknowledges the support of:

BSC is a public consortium made up of:

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

Generalitat de Catalunya
Departament de Recerca i Universitats

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

EXCELENCIA SEVERO OCHOA
2023 - 2027

HR EXCELLENCE IN RESEARCH

UNIÓN EUROPEA
Fondo Europeo de Desarrollo Regional
Una manera de hacer Europa

EuroHPC
Joint Undertaking

GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSFORMACIÓN DIGITAL Y DE LA FUNCIÓN PÚBLICA

red.es

Plan de Recuperación, Transformación y Resiliencia

@BSC_CNS
/bsc_cns
bsc.es/linkedin
@bsc-cns.bsky.social
/@bsc_cns
/BSCCNS
/BSCCNS

Plaça Eusebi Güell, 1-3
08034 Barcelona (Spain)

info@bsc.es
www.bsc.es