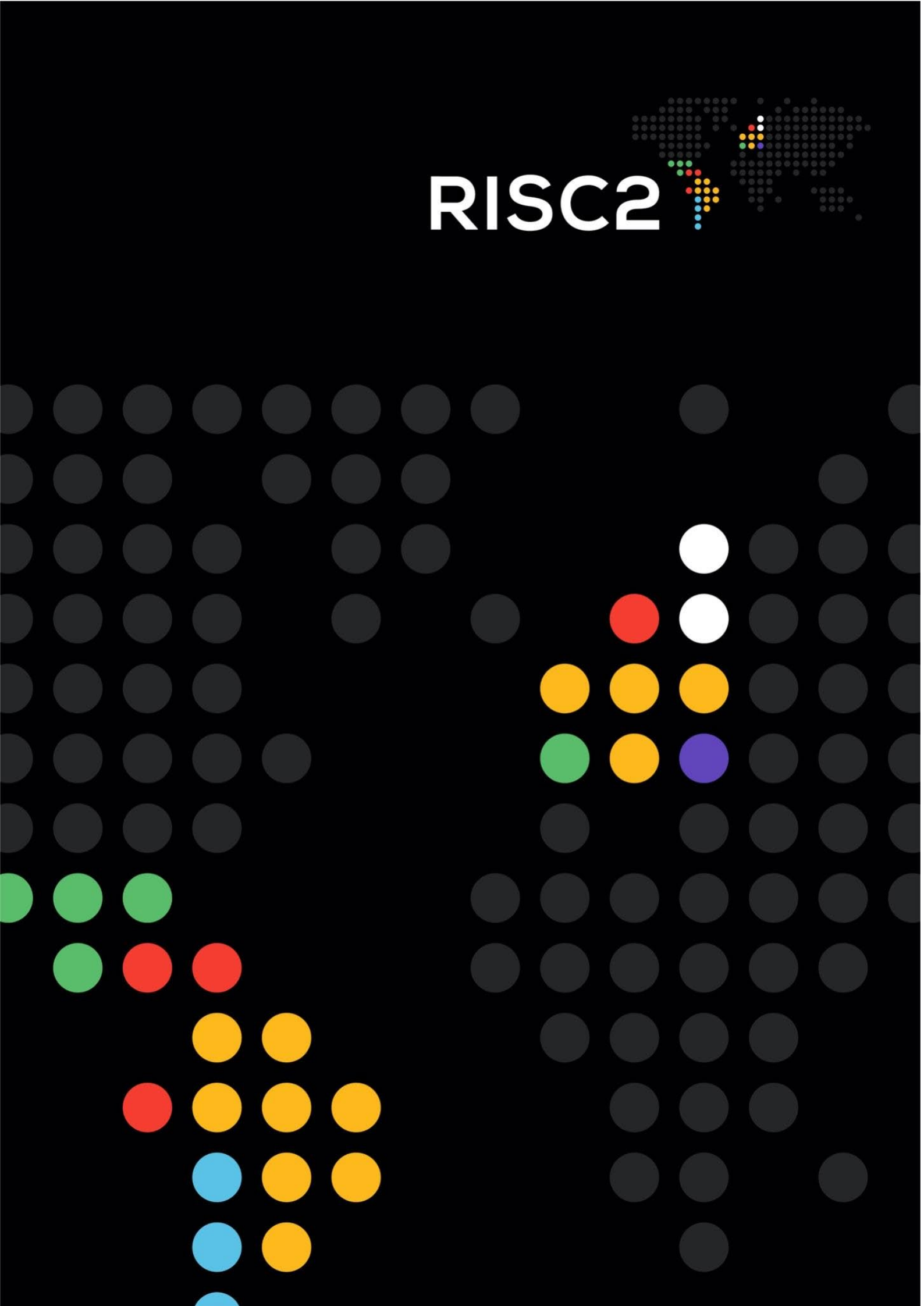
RISC2

RISC2

Deliverable 2.5

Roadmap for HPC R&I between Europe and the LATAM

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Table of Contents

DISCLAIMER

1 Executive Summary

Science and Technology (S&T) developments increasingly depend on collaboration between countries and regions in a globalised and interconnected world. The overall aim of RISC2 is to upgrade strategic cooperation between the European Union (EU) and Latin America (LATAM) in the fields of High-Performance Computing (HPC) Research, Development and Innovation (RDI) by assessing and implementing support actions.

This report was prepared for Work Package 2 (WP2) – Roadmap, which describes the HPC landscape in LATAM and the policy priorities, identifying research and technology areas, requirements, available resources and funding schemes to foster HPC RDI collaboration between the EU and LATAM and Latin America.

This document is one of RISC2's deliverables within WP2. The Roadmap identifies key HPC-related technology areas in LATAM and explores the commonalities and synergies between them and their European counterparts. The roadmapping task within RISC2 aims to identify the key technology areas that are current research priorities, are in use in the industry or are emerging in HPC centres and might have a relevant impact on RDI collaboration opportunities.

2 Introduction

Almost ten years ago, the European Commission (EU) funded the RISC project to deepen strategic research cooperation between the EU and Latin America (LATAM) in High-Performance Computing (HPC). The project focused on building an international and multi-stakeholder community with researchers, policymakers, and users' representatives of relevant European and Latin American HPC RDI actors. The RISC project identified common needs, research issues and opportunities for bi-regional cooperation in HPC RDI.

RISC2 leverages the work initiated by the original RISC project to strengthen the bridge between European and Latin American HPC communities with researchers and innovators in all areas of society with access to expertise, knowledge, algorithms and tools for developing, deploying HPC-based services to tackle societal, industrial and environmental challenges.

The **Roadmap for HPC R&I between Europe and the LATAM** builds upon two documents elaborated by the RISC consortium: the *Green Paper on High-Performance Computing and Supercomputing Drivers and Needs in Latin America* and the *Roadmap for High-Performance Computing and Supercomputing Strategic R&I in Latin America.* Moreover, it focuses on one of the aspects addressed by the RISC2 *White Paper on HPC RDI in Latin America*: the HPC research priority areas.

This Roadmap aims to trace HPC Research, Development and Innovation (RDI) existing priorities. It includes recommendations for the future by mapping the highly complex and

evolving landscape of HPC technologies in LATAM and exploring the potential for collaboration with the EU.

During the last ten years, research priorities have increasingly shifted towards a stronger focus on societal, industrial and environmental challenges. As an enabler for advancing in many research fields, HPC is no exception. This Roadmap will pay special attention to the recent developments in technologies used to address these challenges.

The Roadmap is organised as follows:

Introduction. This section offers an overview of the HPC landscape in Latin America, especially drawing from the White Paper elaborated within RISC2. This section describes the approach and methodology followed to produce this Roadmap.

HPC-related technologies in LATAM. This section reviews relevant reports and roadmaps about the HPC field in Latin America. In addition, it addresses the key HPC-related technology areas in the seven Latin American countries participating in RISC2: Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico, and Uruguay.

Synergies between LATAM and the EU. This section explores potential synergies between both regions that could allow for stronger bi-regional cooperation in the HPC field.

Conclusions. This final section summarises the most promising HPC areas for bi-regional collaboration and links them to the recommendations in the RISC2 *White Paper on HPC RDI in Latin America*.

2.1 Methodological Approach

The main objective of this document is to identify the key technology areas (in use or emerging) and study their readiness level in Latin America to produce a roadmap for research and innovation in HPC. Based on this mapping exercise, the document explores the potential for EU-LATAM collaboration in each area.

This roadmapping exercise was conducted with a multidisciplinary and collaborative perspective that draws from different sources:

- Review of **analyses, reports and existing roadmaps and surveys**.
- Review of **recommendations and impact of EU-LATAM collaboration projects**.
- Analysis of existing **bilateral agreements between the EU and LATAM** countries.
- The partners from RISC2 representing LATAM institutions gathered the necessary information to produce the national reports within the **RISC2 White Paper on HPC RDI in Latin America**. The research approach focused on secondary sources such as international and national studies, project reports and articles. In addition, this exercise leveraged these institutions' central role within their national research ecosystems and

their contacts with key stakeholders in each targeted country. This Roadmap focuses on expanding their reports about the HPC research priorities in their respective countries.

- Latin American partners in RISC2 critically reviewed and updated the "research clusters" identified in the **Roadmap for High-Performance Computing and Supercomputing strategic R&I in Latin America** that was elaborated during the previous RISC project.
- This Roadmap considers the outcome of the **policy dialogues** in each Latin American country and the insight of the RISC2 High-Level Advisory Board members.

The output of this Roadmap will be the basis for elaborating on D2.6 *Joint Action Plans*. The topics that show a more substantial collaboration potential will be addressed as specific and tailored roadmaps for collaboration between EU and LATAM organisations, describing collaboration topics in more detail, indicating potential partners to involve, funding schemes, programmes and initiatives to make collaboration effective.

3 HPC-related Technologies in LATAM

This section reviews relevant reports and roadmaps about RDI in LATAM. In addition, it addresses the key areas related to HPC in the seven LATAM countries participating in RISC2: Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico, and Uruguay.

3.1 Research, Development and Innovation in LATAM

RDI developments and the policies that drive them forward in LATAM are heterogeneous. There is a general interest in encouraging developments in emerging technologies related to AI, the Internet of Things (IoT), Big Data analytics, and Cloud computing since these are also considered enablers for a broad range of R&D fields, from industry to e-government. Global challenges such as climate change, health threats, and energy transition are prioritised in several countries in the region, leveraging the potential of these developments.

Overall, although research spending is stagnating in the region, and science indicators -such as the number of researchers, scientific publications and patents- show modest growth over the last 6 years, according to UNESCO (2021), some positive trends can be identified:

- LATAM scientific communities are increasing interest in researching **cross-cutting strategic technologies**, such as AI and robotics, biotechnology, and energy.
- There is an increasing dynamism in **space science and technology**, with some of the region's most remarkable contributions to science stemming from large projects in astronomy developed in collaboration with foreign research groups. Earth observation

initiatives in the region have also contributed to advancements in other fields, such as soil, wildfire, and agricultural plague monitoring, linked to climate change.

- New areas of research specialisation are aligned with the **UN's SDGs**, from biodiversity management to climate-ready crops and smart grids for energy.
- Regional initiatives show a trend toward the **integration of scientific bodies**. For example, the Open Science Forum for Latin America and the Caribbean (CILAC), the United Nations Economic Commission for Latin America and the Caribbean (ECLAC), and the Ibero-American Programme of Science and Technology for Development (CYTED) have promoted scientific collaboration and increased the flow of knowledge between research networks.

Moreover, recent calls and reports addressing the LATAM R&D landscape reflect synergies and pave the way for regional collaboration. For example, CYTED's 2022 call for thematic networks includes the following research areas: agro-food, health, industrial development, sustainable development, ICTs, science & society, energy, and business incubation.

EULAC ResInfra, a European-funded project within Horizon 2020 (H2020), reviewed the research infrastructure mappings produced by the European Strategy Forum on Research Infrastructures (ESFRI), EULAC Focus, the Working Group on Research Infrastructures, and the H2020 projects "Mapping of the European Research Infrastructure Landscape" (MERIL), and "European Research Infrastructures in the International Landscape" (RISCAPE). EULAC ResInfra summarised the scientific grouping as follows:

- Energy Health (or life sciences, including biological and medical sciences)
- Food (can be together with Health)
- Agriculture (can be together with Food)
- Environment (including Ocean)
- Climate change
- ICT (including data, computing and e-infrastructures)
- Physical sciences (including physics, chemistry, astronomy and possibly engineering)
- Social sciences (including culture, humanities and arts).

Regarding RDI policies, many countries have policies to promote AI developments or are developing national AI strategies. Brazil has set up several initiatives to support AI research, including the Brazilian AI Institute (C4AI) and announced the establishment of six AI Innovation Centers. Mexico was the first LATAM country to release a national AI strategy, enhanced by the IA2030MX Coalition in 2020. Colombia published its strategy in 2019. Uruguay presented its national AI strategy for e-Government in 2019. Argentina published its national plan for AI in 2020, Chile and Brazil released their national strategies for AI in 2021, and Costa Rica will be the first country in Central America to develop a national AI strategy in 2023. The analysis of the national AI plans conducted by the Organisation for Economic

Cooperation and Development (OECD) in 2022 identifies investments in HPC infrastructure as one of the critical topics to foster public and private AI systems.

Differently from other regions, like the EU, which counts on an AI Coordinated Plan since 2018 -reviewed in 2021- LATAM does not count yet with a regional framework for AI. However, the region has demonstrated their will and capacity to align its plans, strategies and approaches in the research, development and innovation field, as exemplified by the e-Government Network for Latin America and the Caribbean (Red GEALC), the countries' adoption of the principles established by the Inter-American Development Bank (IADB) initiative fairLAC, and the national innovation agencies association through the RELAI network, also promoted by the IADB.

3.2 The HPC landscape

As indicated in the RISC2 *White Paper on HPC RDI in LATAM*, the situation of HPC in LATAM varies. On the one hand, it shows promising signs for developing new initiatives and strengthening existing ones in terms of infrastructure development to enhance the interconnection of HPC resources, the number of bi-regional cooperation projects centred on (or leveraging) HPC resources, and the support of international coordination and other initiatives that contribute to a sustainable HPC RDI in the region.

On the other hand, the LATAM context shows factors that might hinder HPC research and development. Overall, LATAM develops only half of its potential in science and technology, according to the 2021 analysis by the Iberoamerican Observatory of Science and Technology. The main concern is the unstructured nature of the research space, which hampers access to resources. The lack of financial capacities at the regional level, the diverse Science, Technology and Innovation policy prioritisation, and government changes in several countries were identified as the main challenges for international cooperation, according to the EULAC Focus project (2019). UNESCO (2021) states, "Policy-making in Latin America remains characterised by U-turns that can undermine investor confidence and hamper innovation. Some countries are also backtracking on broad public participation in decision-making".

Moreover, several key technological advances are impacting HPC research and development worldwide and stimulating increased competition between regions:

- Advancements in processor technology, including multi-core and many-core systems, have allowed for higher processor speeds and greater computational power. These processors enable the execution of complex simulations and applications that were previously impossible. The international race towards exascale computing reflects this context.
- Networking technology has enabled faster communication and data transmission. This technology has facilitated parallel computing and distributed memory systems,

enabling HPC systems to handle enormous data sets and complex simulations. In addition, this allowed for sharing of data and computing resources between organisations located in different regions. Important investments in data infrastructure worldwide, such as the BELLA programme, respond to this trend. It is also important to note the growing relevance of the security of such networking infrastructure.

- Recent breakthroughs in Artificial Intelligence (AI) and Machine Learning (ML) technologies are changing how HPC systems are designed and operated. These technologies are being integrated into HPC systems to improve efficiency and enable real-time decision-making. In addition, the growing use of AI and ML systems for research and industry impacts energy consumption and calls for developments in energy-efficiency technologies in the context of growing environmental concerns.

3.3 Research priorities related to HPC per country

The following sections describe the research priorities related to the HPC ecosystem in seven LATAM countries: Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico, and Uruguay.

3.3.1 Argentina

Argentina's ongoing socio-economic and political crisis since 2015 has negatively impacted the country's plans for science, technology, and innovation. During 2015-2019, the Argentinian government set goals and initiatives to foster socio-economic development, including aligning national priorities with the SDGs and establishing adequate monitoring mechanisms. However, the budget for RDI and higher education has decreased since 2015, according to UNESCO (2021). Research and infrastructure projects in satellite networks, the nuclear industry, and industrial and agricultural RDI have been cut back or cancelled.

In 2022, Argentina published its Science and Technology Plan for the year 2030 with a chapter focused on Information and Communication Technologies (ICT). The objectives defined in this chapter include fostering research and training in **Artificial Intelligence**, **Machine Learning**, **Big Data** and **Quantum Computing**, among others. Even though HPC is not explicitly mentioned in this context, advanced computing resources and techniques are fundamental to promote research in these areas.

The National System for High-Perfomance Computing (SNCAD) is an initiative of the Ministry of Science, Technology and Innovation (MINCYT) and the Interinstitutional Council of Science and Technology (CICyT) within the framework of the Large Instruments, Facilities and Databases Programme. The SNCAD seeks to consolidate a national network of HPC resources to satisfy the needs of the RDI community in the country. The SNCAD's Advisory Board coordinates activities, projects and programmes, and it advises the MINCYT on policies related to HPC. The Advisory Board is composed of representatives of universities and RDI-

related bodies, which reflect the research areas that are closely involved in HPC: **Geology and Mining, Atomic Energy, Industrial Technology, Space**, and **Agriculture**.

Among the goals of the Strategic Plan for High-Performance Computing 2019-2024 is the replacement of obsolete HPC resources in Argentina. In this context, Argentina acquired in September 2023 a new supercomputer, Clementina Siglo XXI, which is expected to be among the top 100 supercomputers worldwide. The new supercomputer is hosted at the National Meteorological Service, but it will be used by other institutions and researchers in the country as a national node for the SNCAD.

Regarding the potential for bilateral cooperation Argentina-EU, the last Argentina-EU S&T Joint Committee Meeting, in June 2022, addressed strategic areas for cooperation such as **oceans monitoring**, through the All-Atlantic Ocean Research and Innovation Alliance, and **Earth observation** through the Copernicus programme. Both parties also agreed on positioning health, nanotech applied to food value and agriculture at the centre of an enhanced R&I cooperation between EU and Argentina. In addition, during the EU-LAC Summit, held in July 2023, Argentina and the EU signed a Memorandum of Understanding to step up bilateral cooperation in the **energy transition**, focusing on renewable energy, hydrogen, and methane emissions abatement.

3.3.2 Brazil

The convergence of HPC and AI in the scientific realm is a crucial area for exploration in Brazil. Large-scale, high-fidelity simulations employ parallel-enabled numerical methods for model-driven computations, but big data analyses use machine learning techniques for data-driven calculations. Their integration may benefit both worlds:

- **Machine learning techniques** initially relied only on learning from a lot of data; incorporating knowledge about physical laws within these techniques requires less training data and accelerates training.
- **Numerical methods** are as good as the accuracy of the problem model; incorporating machine learning techniques within these methods leverages the underlying physical laws through sophisticated pattern extraction.

The application research areas expected to benefit from this convergence between HPC and AI include agriculture, aerospatial, climate, energy, health, and material sciences. Brazilian researchers already explore HPC or AI intensively as part of their work and are increasingly focusing on integrating these two technologies to improve their results. To give some examples:

- **Health**: a vaccine against the Zika virus was developed in 2018 with the aid of the SDumont supercomputer at LNCC in Brazil. Researchers developed the simulation work from the Federal University of Pernambuco (UFPE) and the Virology Department

of the Aggeu Magalhães Institute of the Oswaldo Cruz Foundation (FIOCruz) (López-Camacho *et al*., 2018). More recently, this group started exploring artificial neural networks to predict the structure-based protein-protein free energy of binding based on interface and folding properties for a set of protein-protein complexes computed with HPC resources (Ferraz, Neto, Lins & Teixeira, 2023). Besides, projects facing COVID-19 challenges required wide access to HPC resources from SDumont and also the LoboC supercomputer at COPPE/UFRJ in Brazil, with a *fast-track* for these projects being implemented in the two facilities to support studies of the mechanisms of interaction of the SARS-CoV02 virus with human host cell targets. The aim was to understand how new strains could have greater infective potential, as well as the interactions of molecules and materials designed to interact with molecular targets of the virus, either for diagnostic purposes or even to inactivate SARS-CoV-2 (Ferraz & Lins, 2021). Additionally, HPC resources have been associated with machine learning methods to face similar future problems (Guedes *et al.*, 2021).

- **Material Sciences**: in the area of biomimetic and/or bioinspired materials, Brazil has been at the forefront of the development of several related technologies with diverse applications (e.g. high-adhesion materials that can replace those currently used in dental prostheses) (Das *et al.*, 2016), the development paradigm of these functional materials being the simultaneous and synergic performance of experimental investigations and computational simulations, most of the latter being executed in SDumont (Sun *et al.*, 2018; Yeom *et al.*, 2018; Jiang *et al.*, 2020; Lu *et al.*, 2021). Many other projects in the larger area of material sciences have been similarly conducted with the help of HPC facilities, making the creation of large data repositories on new materials obtained through high-throughput computer simulations feasible. These large data repositories have been recently used for training machine learning algorithms capable of classifying materials (Acosta, Ogoshi, Souza & Dalpian, 2022).
- **Aerospatial**: the SDumont supercomputer has been fundamental for the development and application of new numerical methods for flow simulations involving turbulence and aeroacoustics by a group of researchers from the State University of Campinas (Unicamp) and the Federal University do Paraná (UFPR), in collaboration of researchers from the Boeing company and the American space agency NASA. In this context, structure noise is considered one of the most important aviation problems in terms of environmental impact. Reducing structure noise is a complex task, as its generation is intrinsically related to aircraft aerodynamics, which involves complex turbulent flows. Thus, improving techniques for predicting noise generation and propagation in aircraft is a fundamental topic in aeroacoustics research and requires the application of HPC technologies (Ricciardi *et al*., 2021). A recent focus of this study lies in developing robust and accurate reduced-order models for fluid flows with applications in aeroacoustics and aerodynamics, which tackle physics-based and data-driven techniques combining machine learning and system identification (Lui & Wolf, 2019).

3.3.3 Chile

According to UNESCO (2021), Chile registered economic growth of 3.9% in 2018, primarily due to the dynamism shown by exports of goods and services and private consumption. However, growth has been affected by social unrest and the Covid-19 crisis. Research intensity in Chile dipped slightly from 2013 to 2018, even as the researcher population surged by 55%, suggesting that the amount of funding available to each researcher has dropped. Chile's national development plan for 2018-2022 recognises the importance of building an innovative and entrepreneurial culture based on new technologies to enable the country to play an active role in the Fourth Industrial Revolution. In 2018, the National Commission for Scientific and Technological Research (CONICYT) was broken down into two new entities: the Ministry of Science, Technology, Knowledge and Innovation; and the National Agency for Research and Development (ANID). Policy-making and coordination fall to the ministry, while policy implementation falls to ANID.

Several state agencies use HPC capabilities in applied research projects for project evaluation, critical infrastructure monitoring, simulation and evaluation of natural risks. The Chilean state, as a whole, has become the tenth user of NLHPC capabilities, and its use is increasing. In this context, it is essential to regularly finance the operation of the NLHPC beyond the use of competitive funds.

The research domains in Chile leveraging HPC resources are heterogeneous.

- **Astronomy**. Several research groups have entered astroinformatics to perform large simulations and handle the avalanche of data from large astronomical centres, several installed in Chile. These include the areas of galaxy formation and evolution, the formation of supermassive black holes, gravitational collapse, stellar dynamos and astronomical brokers. An iconic example is ALeRCE, an astronomical broker developed in Chile using the NLHPC infrastructure.
- **Climate change**. Chilean climate science has also had a spectacular HPC-based breakthrough. Studying how climate change will impact Chile's ecosystem and society is crucial. Chile's complex topography and latitudinal extension demand higher-resolution simulation domains than regions with simpler topography. Climate variability and weather dynamics in the Antarctic have been studied by fixing ocean boundary conditions. A research group was able to simulate 20 years of the climate of the Antarctic Peninsula (several million hours of computation), allowing them to understand and simulate the weather fluctuations of the southern cone of the American continent will have, with the consequent impact on our country, the safety of its citizens, and the economy; and to propose mitigation actions that will have to be taken years in advance (Bozkurt, Bromwich, Carrasco & Rondanelli, 2021).
- **Quantum physics and chemistry**. Many research sub-areas are being developed in Chile thanks to HPC: tunnelling magnetoresistance, computer-assisted materials

discovery, flexible materials, the study of metabolism for drug discovery and prediction of new stable compounds, among others.

- **Bioinformatics**. Have also used NLHPC resources, for example, the 1000 Chilean Genomes Project, the single-cell sequencing and the TARA Ocean initiative, an oceanographic expedition on a global scale, which is collecting a massive quantity of information that will require HPC capabilities for our national associates (CMM-TARA). NLHPC has played a critical role in providing computing and storage capacity for several national projects related to COVID-19, where 14 research groups throughout Chile have used its infrastructure. Their research has advanced their understanding of this pandemic, enabling them to propose public health strategies to control/mitigate its effects.

3.3.4 Colombia

Colombia's economy and research intensity has slipped since 2015, but scientific output grew by 52% between 2015 and 2019, according to UNESCO (2021). The government has established regional pacts through Colciencias to nurture strengths and achieve the SDGs, such as the Science and ICTs for Peace Pact and the Colombia Bio programme. The Bio programme in Colombia promotes biodiversity conservation, management, and sustainability in Colombian territories. The Ministry of Science, Technology and Innovation replaced Colciencias in 2019 and now handles policy-making, evaluation, and implementation with an autonomous unit tasked with implementation.

The research priorities related to HPC in Colombia are

- **Energy transition and sustainable distribution**: The new Colombian Energy Transition Law, sanctioned in July 2021, denotes the Government's commitment to achieve its objectives regarding climate change and achieve a national energy matrix with a net balance of emissions equal to zero. Data and multi-stakeholder dialogue will be essential to chart paths toward a sustainable transition and to keep track of climate commitments. The Petro Government, *Colombia power of life*, in the National Development Plan 2022 -2026 (https://www.dnp.gov.co/plan-nacional-desarrollo/pnd-2022-2026), makes this axis a priority.
- **Forecasting and extreme weather events.** Due to climate change, Colombia as equatorial/tropical country, It is a country quite sensitive to extreme events. The institute responsible for forecasting and hydrology, IDEAM (http://www.ideam.gov.co/), acquires importance within the Colombian science and technology actors, calling for universities and other centers to support their functions with supercomputing and data analytics.
- **Amazon, paramos, oceans and water sources monitoring**. The protection of the amazon, the moors and the water, has been classified as essential by the united nations. At the previous United Nations Assembly (April 2023), observing that the Amazonas

has the 23.3% of the national territory and 6.8% of the total of the Amazonas Forest, also that Colombia is the first country that produces drinking water in the world, from the "paramos", proposed two programs, entrusted to the ministry of the environment (https://www.minambiente.gov.co/), the fist one, called "sustainable Amazon For Peace" (https://www.undp.org/es/colombia/projects/amazonia-sostenible-para-la-paz) and "Water for All, Water for the Life (https://www.un.org/esa/sustdev/sdissues/water/WWDR-spanish-129556s.pdf). The main goal of the two projects is to create a framework for the development of both scientific and development projects to protect the Amazon, the "Paramos" and the water.

- **Digital humanities** focus on the social and environmental challenges of inclusion, poverty reduction, sustainability, and total peace: The Petro Government, *Colombia power of life*, propose in the National Development Plan 2022 -2026 (https://www.dnp.gov.co/plan-nacional-desarrollo/pnd-2022-2026), the reduction of socioeconomic gaps and guarantee inclusion, observing both the objectives of sustainable development and total peace. In this sense, an important space has been given to the development of specific areas such as numerical humanities, that will be considered in the calls of minciencias.
- **Network infrastructure**, through creating the Colombian Center for Advanced Computing to provide HPC resources to other organisations in Colombia:
- **Extreme health risks and climate change-related emerging diseases**.
- **New mathematical methods** and **parallelism** addressing **quantum computing** and hybrid solutions.

All these subjects are grouped together into the politics proposed for the current government via Science and Technology Ministery, Minciencias (https://minciencias.gov.co/).

3.3.5 Costa Rica

Costa Rica is a world leader in conservation and environmentalism, with more than half of its terrestrial territory part of the UNESCO World Network of Biosphere Reserves. It launched a national pact for the fulfilment of the SDGs in 2016, signed by various branches of the government and other stakeholders. Costa Rica's Ministry of Science and Technology absorbed the telecommunications sector in 2012 and, in 2015, approved a national plan for science, technology, and innovation and a national development plan for telecommunications, both updated in 2021. The National Plan for Science, Technology and Innovation (2022-2027) identifies strategic areas such as bioeconomy, health and life sciences, digital technology, AI, and aerospatial.

Specifically related to the use of HPC resources, priority research areas are the following:

- **Computational Earth Sciences**. Considering that Costa Rica sits on the Pacific Ring of Fire (a region with high seismic and volcanic activity globally), both seismology and volcanology will require simulation, data analysis and machine learning to push the envelope in their respective fields. Costa Rica is also an oceanic country (most of its territory is in its patrimonial sea), and marine modelling is fundamental for boosting economic activities. Additionally, climate change will force Costa Rican institutions to use more complex climate modelling and simulation.
- **Bioinformatics**. Costa Rica enjoys significant biodiversity. Half a million species are estimated to live in the country, representing 5% of the world's biodiversity. Therefore, developing sophisticated bioinformatics pipelines for genomic sequence analysis will be crucial. Furthermore, protein folding algorithms and molecular dynamics simulations will be fundamental for drug discovery and other pharmaceutical applications.
- **Computational Physics**. As Costa Rica is committed to maintaining more than 99% of its electricity production from renewable sources, developing more plasma physics reactors is imperative. A country with substantial water resources begs for precise computational fluid dynamics models to understand the dynamics of all rivers. Also, as the National Development Plan points out, space exploration in astrophysics and space engineering will play a significant role in the country's future. Both will demand a massive amount of computation. Finally, health physics will be increasingly crucial for reaching better health services.
- **Big Data Analytics**. As data sources become more prevalent and productive, developing a solid platform for data exploration and understanding will be essential. Massive datasets are available from vehicle traffic, health records, and social welfare institutions. Those databases require the best techniques for data analysis and pattern recognition. In addition, bioacoustic analysis from marine mammals and birds will need that platform. This platform must be coupled with machine learning/deep learning large-scale capabilities.

3.3.6 Mexico

Since December 2018, a substantial political and administrative change in the Government of Mexico occurred, bringing a new perspective regarding the priorities in public policy and government allocation of the federal budget. The Mexican government has been gradually reducing funding for its sectoral funds programme, which aims to promote business innovation and assign public resources to priority sectors, including agriculture, energy, environment, and health. The program has not issued any calls for project proposals in 2019 and 2020, and the government decided to eliminate it in 2020. According to UNESCO (2021), research intensity in Mexico has been declining. A new bill on humanities, science, technology, and innovation, approved in April 2023, concentrates power in the National Council of Humanities, Science and Technology (CONAHCYT), reducing the participation of federal and state-level

communities in decision-making bodies. This move may generate conflicting objectives and accountability problems, and it is contested by part of the Mexican scientific communities.

As a consequence, investment in HPC and similar technologies has been postponed. Determining the near or medium perspective for HPC development and investment in the nation is hard. There is a tendency to centralise the telecommunications, internet and advanced computing services in several government agencies that agglomerate the existing nationwide platforms, resources and infrastructures. The different HPC centres in Mexico have determined different strategies to continue offering advanced computing services to the research groups in their institutions. A possible government investment can yet occur in the energy sector to acquire a computer with several petaflops of computing performance since the government has tagged this sector as a strategic priority.

In Mexico, ABACUS, the Laboratory for Applied Mathematics and HPC at the Centro de Investigación y de Estudios Avanzados (CINVESTAV), exemplifies the diverse HPC initiatives grouped in the Mexican Network in HPC (REDMEXSU). Examples of HPC research areas include:

- **Numerical simulation of vascular malformations in the brain.**
- **Studies of racemisation of molecular helices.**
- **Numerical simulation of environmental hazards.**
- **Sandpile simulations and applications.**
- **Covering arrays and software testing.**
- **Cryptographic algorithms.**
- **Simulation of subatomic processes.**
- **Simulation of astrophysical phenomena.**
- **Energy.**

3.3.7 Uruguay

According to UNESCO (2021), Uruguay has made remarkable progress in achieving its renewable energy targets by increasing wind turbine production, solar power, and hydropower, accounting for 90% of the country's power generation in 2017. Furthermore, the government established the country's first Centre for Training in the Operation and Maintenance of Renewable Energies to train personnel for the new sector. The government has focused on auctions, fiscal incentives, and net metering to mainstream renewable energy, which has been costly, corresponding to an annual investment of 3% of GDP annually. The government has also put efforts into national climate policies by having the National Climate Change Response System and approving the National Climate Policy in 2017.

The priority research areas for applying HPC resources align with those defined as strategic for the country in the Strategic Plan for Science and Technology. All priority research areas are

focused on fostering and improving social and sustainable development to advance toward a better quality of life for citizens. The most relevant research areas include:

- **Chemistry, biology and bioinformatics**, a research area where both Universidad de la República (UdelaR) and Institute Pasteur Montevideo have developed significant contributions, particularly in protein chemistry, molecular biology, structural biology, and genomics. Important scientific projects are using HPC techniques, including the SIRAH-CoV2 initiative, which aims to provide coarse-grained molecular dynamics trajectories for all SARS-CoV2 reported in the protein data bank and a project which studies novel therapeutic and diagnostic agents for cancer by targeting the PD-1/PD-L1 axis with aptamers. Many other institutions and collectives will benefit from proper training of local human resources in HPC and scientific computing to expand the horizon of the proposed research.
- **Agricultural and agro-industrial production**, a field where the National Institute for Agricultural Research (Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA) generates and adapts knowledge and technologies to contribute to the sustainable development of the agricultural sector in Uruguay, taking into account state policies, social inclusion, and demands from the market and consumers. Uruguay is one of the most valued food producers and exporters in the world due to the excellence of its products and its food safety standards. Optimising and monitoring its production and logistics processes through applying state-of-the-art technologies present a solid opportunity to apply HPC for the agro-industrial chain. Some relevant research projects are:
    - Genome editing for improving soybean seed value,
    - the Generalisation of wireless sensor networks as a recovery tool in intensive plant systems,
    - The development of a simulation program for decision-making in the feeding planning of sheep production systems.
- **Energy**, with the primary goal of strengthening the current leadership of Uruguay in renewable energy, with a strong focus on wind and solar energy generation. The National Electricity Company (UTE) plays a significant role in research and innovation in this regard, and it is a key partner of the National Supercomputing Center initiative. Both academia and private companies are also developing sophisticated projects, models, and big data applications that will undoubtedly benefit from high-performance computing capabilities. Relevant projects currently applying HPC over the infrastructure of the National Supercomputing Center (Cluster-UY) are:
    - i) Big data analysis and computational intelligence for the characterisation of residential energy consumption in Uruguay, a project that develops intelligent

tools to analyse and categorise the electricity consumption in households, under different scenarios,

- ii) Analysis of demand and global generation, and investment planning, a project that studies the short- and medium-term features of the global energy market in Uruguay and applies HPC, optimisation, and computational intelligence techniques to devise a correct investment plan for the National Energy Company in the medium and long term.

During the EU-LAC Summit held in July 2023, Uruguay and the EU signed a MoU to boost bilateral cooperation in renewable energy, energy efficiency and renewable hydrogen.

- **Biotechnology**, a research area for which the National Biotechnology Plan proposes key developments related to the training of human resources, the creation of an adequate regulatory framework for biotechnology, and a better coupling of industry and academia as the main goals for developing this research area in the 2020's decade. Despite having a less significant human capital pool and a more reduced internal market (compared to neighbouring countries), Uruguay has introduced biotechnology research, services and products through small and medium-sized enterprises and the knowledge generated in academia.

  The biotechnology industry is emerging, and entrepreneurship is starting to develop. In addition to investment in the longer term, biotechnology also requires consolidation of high-performance computing infrastructures and services and also to gather local and virtual communities in the country, including professionals with specific capacities in biology, medical sciences, and computer sciences, to develop and transform that knowledge into successful initiatives. Relevant projects in this area are the development of veterinary vaccines, especially for large animals; diagnostics for different illnesses, including Chagas, HIV and cancer; and DNA analysis. The Sectorial Fund for Agriculture, Energy, and Health from National Agency for Research and Innovation is a specific fund for this type of initiative and research.

- **Technology research and development**, where the Uruguayan Technology Laboratory (Laboratorio Tecnológico del Uruguay, LATU) is a national reference in innovation, technology transfer, and value solutions in analytical services, conformity assessment, metrology and technological services. LATU promotes scientific research, entrepreneurial culture, and the development of technological platforms. HPC services can play a significant role in fostering new initiatives related to developing technical solutions for the industry, the agro-industrial chains and national manufacturing and production initiatives. A relevant initiative, specifically related to several research projects in both the academic and industrial sectors, is the Green Hydrogen program,

promoted by the Ministry of Industry, Energy and Mining, with the main goal of developing the conditions for full decarbonisation of transportation, without the participation of fossil fuel (i.e., the production of green hydrogen is carried out solely from renewable energies). This initiative aligns with the country's energy matrix transformation, which started over fifteen years ago. The underlying and related problems and the massive data processing for a proper evaluation of specific developments and initiatives are also a priority line of research for HPC and innovative computing techniques.

4 Synergies between LATAM and the EU

This section explores the potential synergies between the EU and LATAM that could allow for stronger bi-regional cooperation in the HPC field.

Strong historical, cultural and economic ties link the EU, Latin America and the Caribbean. According to the European External Action Service (EEAS), LAC is also the region with the closest formal ties to the EU, which has association, trade or political & cooperation agreements with 27 of the 33 countries. The EU is the leading investor in the region and its third external trade partner. It is represented in all 33 countries and physically present in 26 through its Delegations and Member States' Embassies.

Since 2020, the world has suffered the impact of recent events that deeply affected the global geopolitical scenario: the emergence of the CoViD-19 pandemic, deep disruptions in international commerce, extreme weather events associated with global warming, and the Russian invasion of Ukraine. These events have significantly altered geopolitical priorities and global economic, political, and social dynamics. The pandemic challenged traditional models of globalisation, leading to an emphasis on resilience and self-sufficiency; the invasion of Ukraine provoked a major crisis in European security and demonstrated the need for a new approach to foreign policy; and the extreme weather events that have occurred in recent years have demonstrated the urgent need for action to address climate change, which is increasingly seen as an existential threat. These crises have also highlighted the need for global cooperation and international partnerships to address pressing issues such as public health, cybersecurity, human rights, and environmental sustainability. As a result, geopolitical priorities have shifted to building resilience, creating a more sustainable and inclusive future, and strengthening international cooperation.

The EU, to maintain a relevant geopolitical role and foster European values and principles, argues for the need to strengthen the relationship between Europe and the countries of Latin America and the Caribbean.

As an example of this approach, based on data by UNESCO (2021), joint calls under the Horizon 2020 programme have led to the selection of 27 project proposals. Topics included the impact of transportation on air quality, personalised medicine, the bioeconomy, and the establishment of an international network of research centres in social sciences.

Under the Horizon Europe (HE) programme's Destination 6 ("A human-centred and ethical development of digital and industrial technologies"), projects are expected to contribute to a human-centred and ethical development of digital and industrial technologies through a two-way engagement in the development of technologies, empowering end-users, and workers, and supporting social innovation. The European Commission (EC) proposed a "Declaration on European Digital Rights and Principles" for a human-centred digital transformation to complement and strengthen the "Path to a Digital Decade", adopted in 2021. The Declaration explicitly calls for promoting the vision of digital transformation in the EU's international relations. International cooperation actions are vital to achieving a human-centred digital transformation since they will contribute to building solid international digital partnerships and promote a human-centred digital agenda when tackling the world's social, economic, and environmental challenges, which are inherently global in their scope, in line with the UN's Sustainable Development Goals (SDGs).

Moreover, the EU, Latin America, and the Caribbean (LAC) launched the EU-LAC Digital Alliance, a joint initiative to promote a human-centric approach to digital transformation. The Alliance will support the development of secure, resilient and human-centric digital infrastructures under a values-based framework emphasising privacy and digital rights. The D4D Hub (Digital4Development) for Team Europe partners and ECLAC (UN Economic Commission for LAC) for LAC partners will be used as a platform for coordination. The Alliance will work on infrastructure, regulatory environment, skills development, technology, entrepreneurship and innovation, and digitalisation of public services as well as Earth observation data and satellite navigation applications and services. Examples of the Digital Alliance in action include extending the BELLA fibre-optic cable, building secure digital backbone connectivity and bringing the research communities of the EU and LAC closer together, and implementing a regional Copernicus strategy, including two regional Copernicus data centres in Panama and Chile.

4.1 Bi-regional collaboration opportunities

International collaboration in HPC, in particular, can contribute to strengthening the ties between the EU and LATAM in several ways:

- International collaboration in HPC plays a critical role in addressing global challenges. Through pooling resources and expertise, researchers can access the power and capacity of HPC infrastructure to solve complex problems that require massive computing power and big data processing.

- Regarding global challenges, many issues require a multidisciplinary approach. For example, climate change, drug discovery, and understanding the human brain require expertise from different fields, including physics, chemistry, biology, and engineering. HPC facilitates this collaboration by providing a platform for researchers to collaborate, regardless of location.
- International collaboration in HPC also offers opportunities to build international research partnerships and promote scientific diplomacy. These partnerships can promote the exchange of knowledge, skills, and resources, leading to the development of new technologies and innovative solutions to global challenges.

There are several potential R&D collaboration opportunities between the EU and the seven LATAM countries in the scope of this document at the bilateral level. For example,

- A potential research and development collaboration opportunity between the EU and **Argentina** could involve a joint project on marine research and ocean monitoring following the administrative arrangement in force since 2018. Similarly to Chile, several joint initiatives to maintain observatories in the scope of programmes such as Copernicus and Galileo exist.

- Both the EU and **Brazil** have advanced research in AI and robust healthcare systems, making it a good fit for collaboration. With AI, precision medicine can customise prevention, diagnosis and treatment approaches according to individual genetic profiles, making healthcare more efficient and effective. In addition, the EU has established several projects related to tropical diseases, such as the zika virus.

- **Chile** and the EU have been collaborating in astronomy in several initiatives. The Copernicus strategy within the scope of the EU-LAC Digital Alliance, which implies the establishment of a new data centre in Chile, will drive this collaboration forward.

- **Costa Rica** is a partner country in the Euroclima programme. It counts on a Bioeconomy strategy that could pave the way for stronger collaboration with the EU, especially in bioinformatics and sustainable agriculture programs.

- A potential area for collaboration between the EU and **Mexico** could leverage from experience in collaborative work on energy efficiency, as demonstrated by the ENERXICO project.

- Both the EU and **Uruguay** have initiatives promoting the development of smart cities, making it a good fit for collaboration. Smart cities can improve urban areas' energy efficiency, transportation systems, and climate change responses, as the activities proposed by Team Europe indicate. In addition, Uruguay has several initiatives in sustainable agriculture that its membership in the Euroclima programme can leverage.

The RISC2 Consortium has identified ten common areas to foster collaboration based on the research priorities per LATAM country and the ongoing collaboration initiatives with the EU. The table below shows the synergies that will be further detailed in D2.6 Joint Action Plans.

Research area	AR	BR	CL	CO	CR	MX	UY	EU
Data science and scientific computing		x						x
HPC training				x				x
HPC infrastructure for Artificial Intelligence	x	x		x	x			x
Material science		x						x
Bioinformatics		x		x	x			x
Astronomy			x					x
Energy transition & smart cities	x	x	x	x		x	x	x
Water management				x				x
Oceans monitoring	x		x	x				x
Digital Humanities				x		x		x

5 Conclusions

This final section links the research priorities related to HPC to the recommendations in the White Paper.

I. The recent engagement by the EU Commission to allocate to the region 45 B€ for the **Global Gateway Investment Agenda** should be exploited to propose investments in the HPC infrastructure and AI to support rapid development of critical applications at scale. The priority research areas in LATAM countries identified in this document are in line with the EU's priorities in the Investment Agenda: a fair green transition, an inclusive digital transformation, human development, and health resilience and vaccines. In this vein, the RISC2 Consortium recommends to **establish Centres of Excellence (CoEs) at the regional level in LATAM to support scientific applications in these priority areas**, introducing new computational methods and techniques to enhance the research and innovation in essential application domains, such as renewable energies, bioinformatics, smart cities, weather forecasting and oceans monitoring. These Centres of Excellence could build upon the experience of the European CoEs for HPC, and the research centres focused on AI research created in Brazil.

II. Foundation models at the base of generative **Artificial Intelligence** are getting traction at international levels. LATAM cannot afford to be left behind, therefore RISC2 partners in the region should educate their governments to take quick and effective action and avoid the cost associated to be left behind and exposed to predatory actions from those regions already well advanced in this domain. From 2019 onwards, LATAM countries have worked towards defining AI strategies at the national level. **Elaborating on a regional framework fo AI would allow the region to leverage the countries' resources in terms of AI research-focused expertise.** In addition, access to HPC infrastructure, and training of specialised human resources should be key aspects of a regional strategy.

III. RDI in advanced computing implies access to HPC resources. Thus, the priority research areas and the assoaciated emerging technologies need to consider the resources availability at the local, national and regional levels. Differently from Europe, LATAM does not have a coordinated large-scale plan to invest in HPC. The only LATAM country that counts with HPC systems included in the Top500 -as of June 2023- is Brazil. Argentina will enter the list once the recently acquired Clementina Siglo XXI is installed. LATAM countries are working towards establishing HPC networks at the national level and national supercomputing centres, as exemplified by the National High-Perfomance Processing System (SINAPAD) in Brazil and the National Laboratory of Scientific Computing (LNCC); the National Supercomputing Network in Mexico (REDMEXSU) and the National Supercomputing Laboratory (LNS) in Puebla; and the National System of High-Perfomance Computing (SNCAD) in Argentina. **The different national HPC systems in LATAM should federate together and cooperate in creating a solid regional HPC ecosystem, providing joint programmes in terms of support, research, cooperation, and education**. This ecosystem should cooperate and make synergies at the European level as well by establishing bilateral agreements between LATAM countries and the EU to develop HPC applications in domains of common interest, following the experience of HPC cooperation EU-Mexico and EU-Brazil started in 2018. The EuroHPC JU flagship is an excellent example of procurements of large HPC systems in a coordinated and centralised way and, at the same time, using them for creating a federated international HPC structure also capable of delivering services in a Cloud distributed approach. The existence of an EU central funding agency makes this plan easier. The opportunity of a new and higher capacity link between Europe and LATAM (**BELLA programme**) should be exploited to foster applications jointly developed between EU and LATAM. **RedCLARA**'s widespread presence in LATAM should be leveraged to foster a possible federation of HPC resources in the region, a common education programme for HPC and emerging technologies as foundation models. Moreover, association with EuroHPC Joint Undertaking at the European level could be established for joint HPC

initiatives, establishing a partnership so that Latin American researchers could access the more prominent European HPC infrastructure.

IV. **Specialised degrees in HPC at the higher education level should be encouraged and organised in cooperation between LATAM and EU academic partners**, designing standard curricula and activating joint degrees at MSc and PhD levels. The LATAM students could spend part of their educational activity in one of the European partner institutions. The funds to organise the mobility of these students could be identified via common EU-LATAM programmes. PhD level training could involve research activities linked to specific computational projects in cooperation between LA and the EU. Tools and curricula produced by the recent EUmaster4HPC, as an initiative of the EuroHPC JU, could be made available to LATAM partners.

6 Acronyms and abbreviations

AI	Artificial Intelligence
BSC-CSN	Barcelona Supercomputing Center – Centro Nacional de Supercomputación
CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
CINVESTAV	Centro de Investigación y de Estudios Avanzados
CLEI	Centro Latino Americano de Estudios en Informática
CoEs	Centres of Excellence
COVID	Coronavirus Disease
CPU-GPUs	Central Processing Unit – Graphics Processing Unit
CRA	Common Research Area
CUDI	Corporación Universitaria para el desarrollo de Internet
DoE	Department of Energy
ECP	Exascale Computing Project
EPI	European Processor Initiative
ETP4HPC	European Technology Platform for High-Performance Computing
EuroHPC JU	Europe HPC Joint Undertaking
EU	European Commission
Flop/s	Floating-point operations per second
G20	Group of Twenty
GDP	Gross Domestic Product
HPC	High-Performance Computing
ICT	Information and Communication Technology
INFRAG	Infrastructure Advisory Group
JAIIO	Jornadas Argentinas de Informática
JIRI	Joint Initiative on Research and Innovation
LATAM	Latin America
LNCC	Laboratório Nacional de Computação Científica
MoU	Memorandum of Understanding

MSc	Master of Science
NRENs	National Research and Education Networks
PhD	Doctor of Philosophy
PRACE	Partnership for Advanced Computing in Europe
R&I	Research and Innovation
RDI	Research, Development and Innovation
REDMEXSU	Red Mexicana de Supercómputo
RIAG	Research and Innovation Advisory Group
RICAP	Red Iberoamericana de Computación de Altas Prestaciones
RIs	Research Infrastructures
S&T	Science & Technology
SADIO	Sociedad Argentina de Informática
SBC	Sociedade Brasileira de Computação
SCALAC	Advanced Computing System for Latin America and the Caribbean
SCCC	Sociedad Chilena de Ciencia de la Computación
SINAPAD	Sistema Nacional de Processamento de Alto Desempenho
SMEs	Small & Medium Entreprises
SOMEXSU	Sociedad Mexicana de Supercómputo
SRA	Strategic Research Agenda
UAM	Universidad Autónoma Metropolitana
UNAM	Universidad Nacional Autónoma de México
WG	Working Group
WP	Work Package

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