D2.7. Mapping and Clustering - Final Report
Version 2.0

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Change Log

Version	Description of Change
V0.1	Initial Draft written by BSC
V0.2	Reviewed by the internal reviewer
V1.0	Final version ready for EC submission
V2.0	Version after PO comments

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Executive Summary

As part of WP2 (Task 2.3) this report aimed at mapping and clustering Latin-American HPC related research and corresponding actors. The report also considered a variety of studies and strategic documents. It is based on HiPEAC, PRACE, PlanetHPC, ETP4HPC strategic documents and Roadmaps. It also took into account the US strategic document on Innovation as well as US Department of Energy studies. It considered the existing studies in the HPC and Computational Science area in the partner LA countries as well as the recent, EU-CELAC Strategic Plan 2013. Finally, the analysis was also based on the round 1 and round 2 consensus survey results of the RISC project together with the results of LA-EU opportunities study of RISC and the H2020 priorities.

Based on this analysis, two main actions are proposed:

First to recommend, to establish and proceed with the following four strategic research clusters:

- Bio - Life sciences, Health and Medicine
- Natural resources exploration and sustainable energy
- Natural disasters modelling
- Environmental modelling Weather and Climate research

Second to establish two crosscutting research and education clusters:

- One focusing on scalable algorithms, scalable mathematical models and advanced programming models to underpin the identified above four research clusters
- Education and training as a key crosscutting cluster enabling to reduce the identified skills gap.

1. Introduction

1.1. Background

As part of WP2 the objectives achieved were to map and cluster the Latin American related Computational Science and HPC research and industrial actors. The consortium achieved clustering Computational Science and HPC related research into research clusters per country as well as overall for the region. Key priority areas and clusters were identified and were studied how they are aligned with EU strategic research areas.
The current landscape is identified as follows:

There were several recent and there are a few current EC projects looking into general ICT research and education areas of EU-LA collaboration as well as several EC-LA projects focused on policy dialogue. In particular the projects dealing with policy dialogue in the area of ICT are:

The PRO-IDEAL EC FP7 project [1] focused on promotion of the ICT dialogue between Europe and Latin America and specifically on enhancing this dialogue through a moderated space for online discussion and exchange of views on topics related to the ICT policy dialogue providing selected documents of interest and providing “Angels” to increase EU-LA joint ICT grants submissions.

FORESTA EC FP7 project [2] promotes policy dialogue for ICT research cooperation between Europe and Latin America through activities such as: organization of conferences, policy dialogue forums, networking sessions, and the dissemination of information through the project website.

VertebrALCUE [3] is focusing on education and relevant policies; VertebrALCUE consortium just produced the following Green Paper “A higher education modernization agenda for Europe, Latin America and the Caribbean based on the concept of integration”.

The AMERICAS project [4] - LatinAMerica-EuRope Ict Cooperation Advanced Strategies project aims at “supporting sustainable ICT policy dialogues and fostering ICT R&D cooperation between the EU and strategic partner countries in Latin America, by enabling new synergies and effective collaboration through policy makers, researchers and key stakeholders networks in ICT and international cooperation.”

The WINDS-LA EC project [5] focused on Widening IST Networking Development Support – Latin America and produced a EU-LA ICT Research Collaboration Roadmap. The main areas identified were: ICT for research in Health, ICT for environment and biodiversity and ICT for learning.

There were aslo several studies and road mapping activities in the HPC and cognate areas in Europe and the United States:

There is an existing roadmap in Europe with relevance to our study, the HiPEAC (Network of Excellence on High Performance and Embedded Architecture and Compilation) Network on Computing Systems Roadmap, http://www.hipeac.net/ [6]. The focus is on six research objectives: design space exploration, concurrent programming models and auto-parallelization, electronic design automation, design of optimized components, self-adaptive systems and virtualization.

Planet HPC [7] produced the report: A Strategy for Research and Innovation through High Performance Computing, where the long term R&D priority areas identified in the report are:

- Highly scalable methods for modelling and simulation that can exploit massive parallelism and data locality.
- New programming models and tools, targeted at massively parallel and heterogeneous environments.
- Decoupling application development from HPC.
- Technologies to support new and emerging applications that require robust HPC with real-time capability.
- Data-intensive HPC.
- Low-energy computing from both an architectural and application perspective.

In April 2013 Planet HPC proposed a report focused on the Challenges facing HPC and the associated R&D priorities: a roadmap for HPC research in Europe [16].

The report outlines four challenges and the corresponding mid-term and long-term objectives:

- Mastering massive parallelism and heterogeneous systems
- Reaching new markets
- Dealing with massive data
- Developing skills

ETP4HPC [17] - Key European players in the HPC have decided to form a European Technology Platform to define Europe's research priorities to develop European technology in all the segments of the HPC solution value chain. HPC will strengthen European competitiveness in almost all industrial domains and provide a key capability for future research and innovation. ETP4HPC Mid-term objectives and milestones are [17]:

- Energy efficient computing technology roadmap
- Highly scalable IO and interconnect/networking system
- New layers in the HPC stack mixing OS and middleware functionalities focused on energy efficiency, performance optimization, improved resilience, etc
- Software ecosystem (compiler, library) related to energy efficient computing technologies, improved application design productivity, ease of use
- A suitable programming model for heterogeneous and massively parallel architectures
- API for memory hierarchy and thread management, power management and inter-node communication Software API for reliable system and application development
- Scalable performance analysis and prediction tools for exascale platforms
- Management system able to deal with energy optimization.

ETP4HPC Long-term milestones are [17]:

- Demonstration of an exascale system based on technologies developed by the ETP ecosystem
- European solutions are recognized as competitive at the worldwide level for performance, energy efficiency, scalability and usability
- The developed technologies are scalable and affordable not only for high-end centres, but for a broad set of industry segments
- European HPC ecosystem differentiating through innovation leadership
- European developed technologies represent a significant growing part of the added value of the worldwide HPC market and are relevant for other markets.

More general studies in HPC area have been done by IDC:

International Data Corporation (IDC-USA), produced a report in 2010 by Earl C. Joseph, Steve Conway, Chris Ingle, Gabriella Cattaneo, Cyril Meunier, Nathaniel Martinez A Strategic Agenda for European Leadership in Supercomputing: HPC 2020 — IDC Final Report of the HPC, Study for the DG Information Society of the European Commission (2010) [8].
The main recommendation of the report is that Europe must "*adopt a clear and concise HPC vision*" in order to "*provide world-class HPC expertise and resources to make EU scientists, engineers, and analysts the most productive and innovative in the world in applying HPC to advance their research, in pursuit of scientific advancement and economic growth*"

The detailed recommendations are:

- EU needs "to expand the number, size, and access to HPC resources across the EU (including broader access to tools by all EU researchers)"
- EU needs "to provide peer-reviewed access to large supercomputers for advanced industrial research"
- EU must "create a set of HPC Exascale development lab/testbed centers (techno-pools) — a new type of productivity center — to make HPC users more productive and innovative by creating the world's best tools, training, and development environment. This requires a new initiative.
- EU must "attract more students into scientific, engineering, and HPC fields, and to attract more experts from around the world to join EU projects. This requires additional funding and a new magnet program"
- EU "needs to increase funding in developing next-generation Exascale software"
- EU "needs to target a few strategic application areas for global leadership".

We should also note a recent IDC study on the talent and skills gap in HPC, done for US Department of Energy, by Earl C. Joseph, Steve Conway, Jie Wun, "A Study Of The Talent And Skill Set Issues Impacting HPC Data Centers, Conducted On Behalf On The US Department Of Energy (2010)" [9].
In this study IDC identifies the major inflection points in HPC area: Parallelism, and how to use it, Petascale/Exascale computing, HPC system heterogeneity, HPC system architectural balance, HPC system reliability, HPC system and data center power and cooling. IDC also identifies the skills which are most difficult to find to tackle the inflection points, for example: Scientists with HPC capabilities ("Combined scientific background and HPC programming

skills", "Computational scientists"), Parallel Programmers ("Experience in parallel software development", "Engineers and scientists that can program in HPC/parallel Fortran" , "Parallel code porting/optimization"), Algorithm Developers ("For computational science people who can help researchers develop and implement new algorithms"), System Administrators with high-end computing experience "Scientific computing system management experience", "System administrators with HPC expertise") [9].

Computational Science and HPC are key strategic assets for the EU and its innovative capacity [10]. Large scale computing in science and industry has become an indispensable way to tackle societal and scientific grand challenges, and to address the needs of industry to innovate in products and services. Computational approaches to scientific grand challenge problems such as the detection and treatment of diseases like cancer, modelling of the human brain, and climate forecasting are beginning to bear fruit. Computational Science, an interdisciplinary field that melds basic sciences, mathematical modelling, quantitative analysis techniques and HPC techniques, is proving integral in addressing the big problems in industries ranging from manufacturing and aerospace, to drug design and risk management.

Worldwide there are also major societal drivers such as Energy, Climate Change, Urbanization, Poverty etc., where Computational Science and HPC are the key methods for helping address these [11]. The platforms allowing us to advance on such scale and magnitude are the Exascale Computing systems. Recently, Exascale Computing, an attempt to harness a thousand fold projected increase in computational power, has emerged as a Grand Challenge research area. This highlights the need “to advance fundamental research in Computational Science and Engineering and in fundamental, applied and interdisciplinary mathematics and statistics” [12-13]. It has been observed that “beyond accelerating disciplinary progress, investments in these fields are needed to drive discovery in every science and engineering discipline and to power the use of next-generation cyber-infrastructure and networking” [14]. Meeting the Exascale Computing Challenge requires a sustained effort in key areas of computational science and HPC ranging from the development of novel multi- and many-core architectures, to new programming models, scalable algorithms, and new modelling techniques and paradigms. Computational science has been identified as being “crucial for the development of science” [14].

This is why based on the EC strategic communication on HPC, computational sciences, HPC and Exascale computing are the strategic components of Horizon 2020 programme [15] and, as outlined, are key for EU innovation and future development. This is also the reason to investigate their strategic importance for the LA region.

Finally, the EU-CELAC Summit in Santiago de Chile in January 2013 has agreed the EU-CLAC Action Plan 2013-2015 [18]. This plan provides the overall strategic framework concerning the EU-LA collaboration including collaboration in research, science and education and training. The focus is on capacity building in the following key areas presented below. Please note also that the key areas of EU-CELAC strategic plan (1,2, and 5) which have strong correlation with key research areas and emerging research clusters of our study are identified in bold below

1. Science, research, innovation and technology;
2. **Sustainable development, environment, climate change, biodiversity, energy;**
3. Regional integration and interconnectivity to promote social inclusion and cohesion;
4. Migration;
5. Education and employment to promote social inclusion and cohesion;
6. The world drug problem;

7. Gender;
8. Investments and entrepreneurship for sustainable development.

The background given in this section sets the baseline for comparison of the areas of interest in LA with the ones in EU and USA and also establishes the possibility to identify synergies between EU and LA.

1.2. Methodological Approach

The Clustering and Roadmapping activity process was an undertaking based on a complex analysis of existing studies, our own survey, other set questionnaires applied for identifying the LA–EU opportunities as well as for the Green Paper, consultation and consensus building with the key HPC stakeholders and policy makers.

The clustering and roadmapping activities considered collected and analysed number of inputs:

- A round 1 and round 2 Delphi survey. Delphi survey was planned and implemented as a two round consensus building survey.
- Questionnaires implemented for studying LA-EU opportunities and information gathering for the Green Paper.
- Comments received during the round tables and discussions on the Workshops in Chile, Mexico, Argentina, Colombia, Brazil and final workshop in Mexico as well as the two Summer School events.
- The analysis of number of policy related projects outlined in the introduction, with respect to overall ICT policies with possible relevance to HPC and HPC education.
- The analysis of the existing EU roadmaps with possible relevance to HPC.
- The analysis of the IDC team talent study and IDC report for the EC.
- Analysis based on the existing studies of the strategic research priorities in EU and LA.

After having analysed the information above, it was clear that there was no major study done in the HPC need of LA, and even some of the countries do not have a national HPC strategy. It was apparent that it is needed to analyse the HPC needs, discover the gaps and study how to bridge these gaps and provide the relevant recommendations. Therefore the following components were proposed:

Component 1. HPC Inflection points identification and HPC needs identification in LA.

The inflection points were identified based on the survey results as well studying national priorities and strategies (wherever these existed) and the inputs outlined in the paragraph above at the beginning of this section.

Component 2. Skills Gap and priorities for HPC skills in LA

The skills gap was identified based on the survey results as well studying national priorities and strategies (wherever these existed), and the inputs outlined in the beginning of this section.

Component 3. Identifying and prioritizing HPC research areas

The research areas were identified based on the survey results, national strategic document, discussions with experts on the Workshops, round tables, national studies of the needs (for example in Chile) as well studying national priorities and also taking into account the inputs outlined in the beginning of this section.

Component 4. Defining strategic goalposts and defining strategies and policies to reach them.

These are identified based on national strategic document, discussions with experts on the Workshops, round tables, national studies of the needs (for example in Chile) as well studying national priorities. These were further compared with existing relevant EU and US roadmaps and the detailed strategic goalposts can be found in the Roadmap D5.1.

In summary, our methodological approach is based on the following:

- Initial analysis as outlined above.
- Two round consensus building Delphi survey refining Components 1, 2, and 3.
- Small focused group discussion and consensus building on strategic goals and policies; one group per identified strategic research areas. This approach was complemented with round tables on the Workshops and consensus building via discussions.
- Progressive production and update of the clustering and mapping documents and the corresponding Green Paper and Roadmap.

2. Mapping and Clustering

2.1 Summary of RISC Survey Findings

This section gives a short and to the point outline of the RISC survey findings with relevance to the mapping and clustering.

2.1.1. Type of Applications and application areas

The application areas covered by respondents respondents in Round 2 of the survey are: Biology/Biodiversity (23%), Engineering (23%), physics (17%), environmental science/climate change (9%), Chemistry (8%), astronomy (5%), medicine (4%) and other (11%), see Figure 1. For comparison the spread in Round 1 is given on Figure 2. As it can be seen, in both cases the main areas mirror the RISC areas of interest but at the same time there is a wider spread.

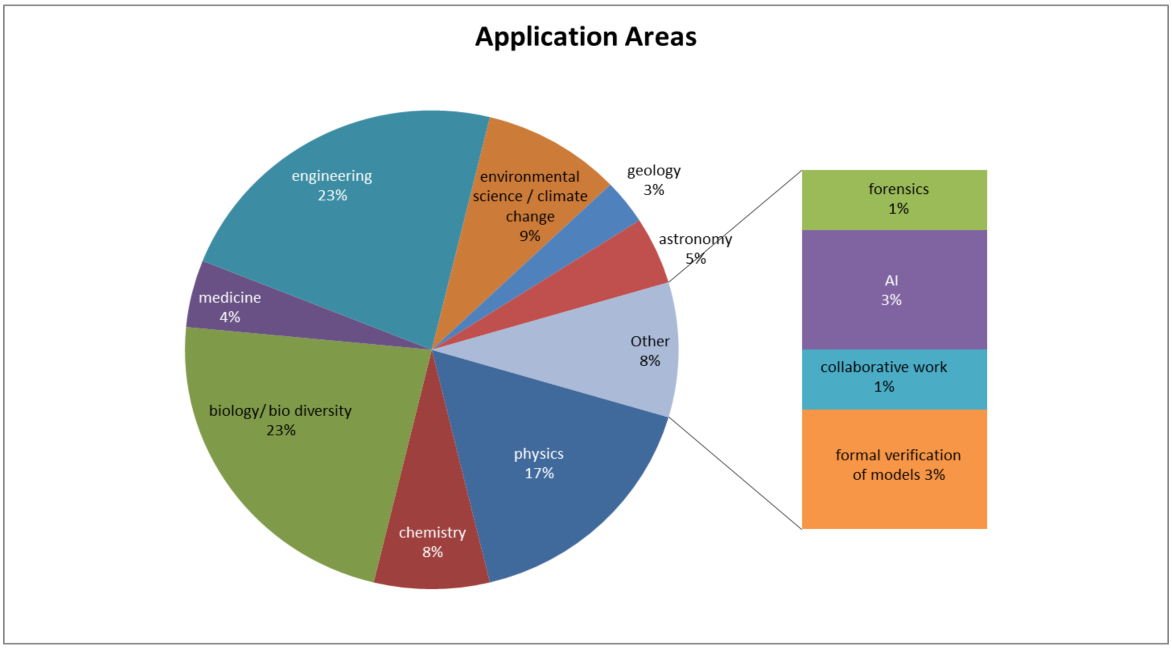

Figure 1 Application Areas Round 2

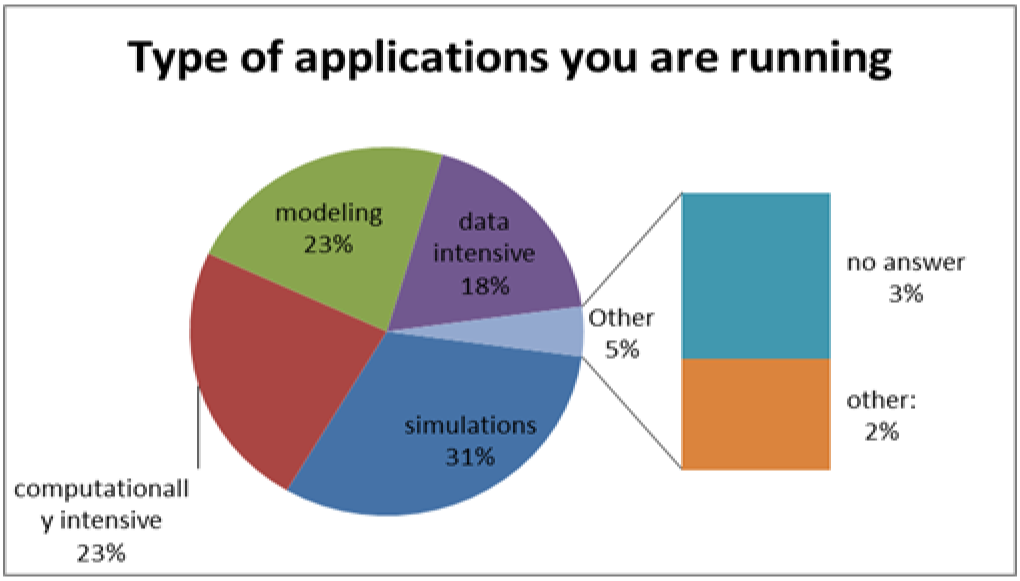

Figure 2 Application Areas Round 1

2.1.2. The Most Relevant Inflection Points and Technological Platforms to Tackle them

The most relevant Inflection Points identified are: HPC systems related problems, complexity of parallelism with the use of the new and emerging architectures (leading to the need of new programming models and algorithms) and reducing energy consumptions. Note, that the same issues are identified as the main inflection points by the specialists in EU and USA. The survey's initial results have shown that these are also the inflection points in Mexico and Chile. Round 2 has shown a strong covergence with 92% of respondents confirming the identified inflection ponts and the proposed ranking in the remaining LA countries surveyed and cofirmed the overall picture. Note that the transition to extreme scale is perceived as having less importance, which is natural in countries that currently do not have many machines in the Top 500 list of supercomputers (just topical presence of Brazil). So the final set of inflection points identified (with a convergence of 92%) is:

1. Complexity of parallelism with the use of the new and emerging architectures leading to the need of new programming models and algorithms;

2. HPC systems related problems:
    - HPC heterogeneity
    - HPC system architectural balance
    - HPC system reliability;

3. Reducing energy consumption through low energy solutions;
4. Transition to extreme scale is viewed to be of a lesser importance.

Technological platforms to tackle the inflection points:

In Round 2, 96% of the respondents has found that the proposed technological platforms to tackle the inflection points are the ones identified in Round 1 and we also observe very strong convergence here. The respondents also agreed with the proposed ranking presented below:

1. Scalability:
   - Scalable algorithms
   - Scalable mathematical models
2. Efficient programming models
3. Visualization and 3D
4. Green computing and data storage and management
5. Collaborative environments.

2.1.3. Skills Gap related to HPC

The algorithms developers, the parallel programmers and the programmers for heterogeneous systems are clearly the three HPC profiles with the highest demand (observing a correlation with the IDC skills study for USA [9]). Undoubtedly the biggest skills gap is identified in the most prominent user group - the scientists from other areas of research who need to be able to use the HPC ecosystem (this again is common for HPC community across the Globe and requires update of science curricula at university level to prepare the graduates for the new research environment). There is a strong convergence in opinion on the skills gap identified in Round 1. Over 84% of the respondents who answered the question have confirmed the skills gap and the ranking. The skills gap identified is depicted in Figure 3 and considers the following categories:

1. Scientists with HPC capabilities and multidisciplinary skills
2. Algorithm developers for computational science
3. Parallel programmers
4. Programmers for heterogeneous systems
5. HPC systems administration
6. Managers with expertise in computational science.

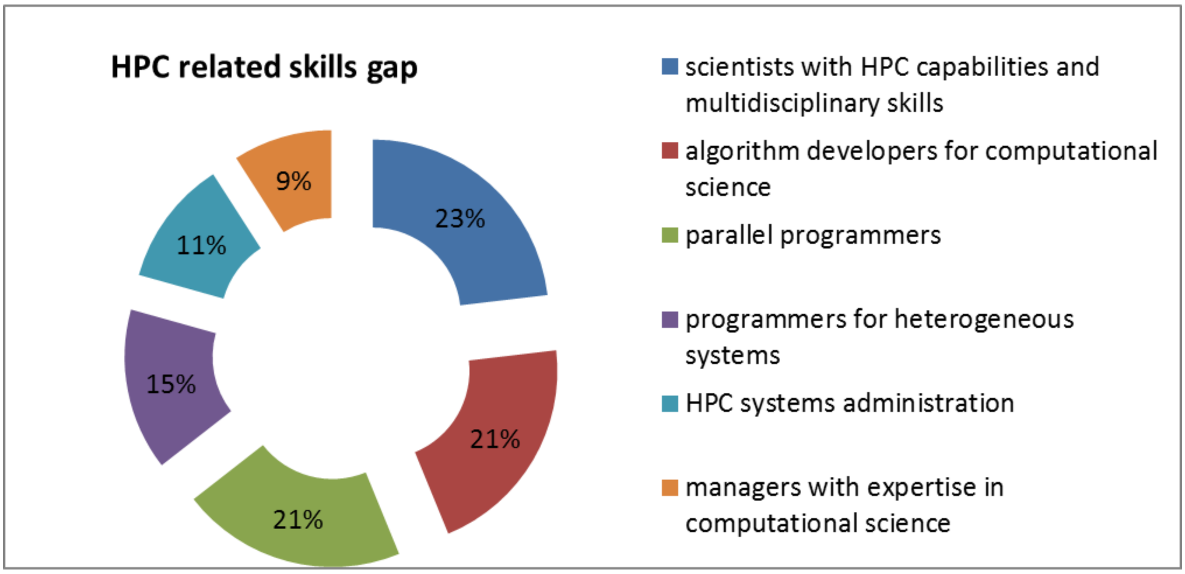

Figure 3 Skills Gap

2.1.4. Scientific and Industrial Domains of Interest

The five priority application areas for collaboration identified in Round 1 match closely to the areas identified in RISC (see Figure 4). Furthermore two other areas emerge also: engineering and sustainable clean energy.

After further scrutiny and the strong convergence in Round 2, where 87% agreed with the proposed top domains of interest and their ranking and 5% have agreed with the domains but disagreed with the order of importance of the domains proposing their own area as the most important, the domains focus was widened to cover cognate and related areas. Thus we were able align merge several domains arriving in the domains given below:

1. Bio - Life sciences, Health and Medicine
2. Natural resources exploration and sustainable energy
3. Natural disasters modeling
4. Environmental Modeling icluding Weather and Climate reserach

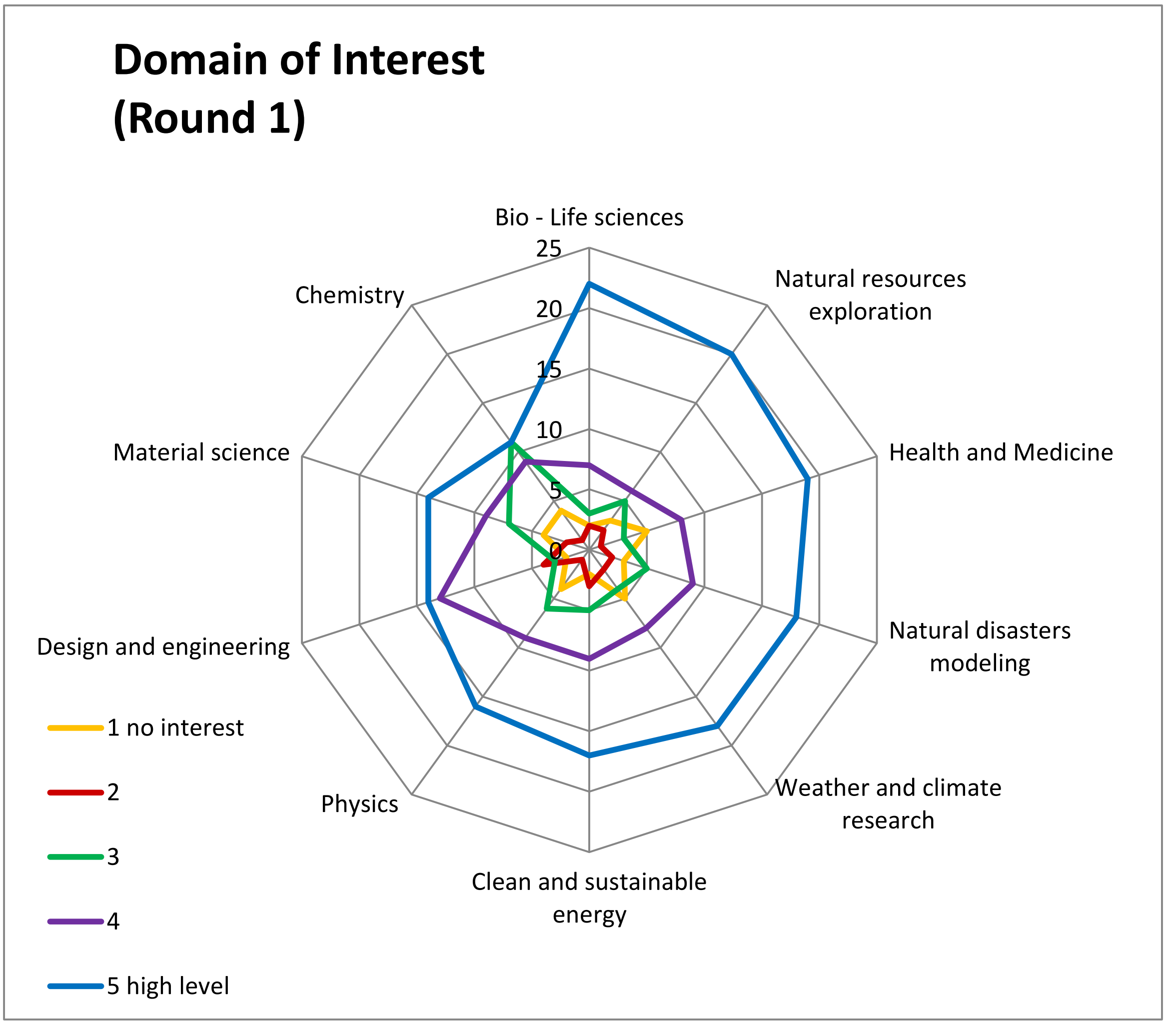

Figure 4 Domains of interest

3. LA Mapping and Clustering Specifics

3.1. Argentina

3.1.1 Strategic Goals and plans

Argentina's mid and long-term strategic plans are:

- To obtain a sustainable model of growth following a strategy for production with focus on mid and long term.
- To improve the employment and the income distribution
- Follow a path to regional equilibrium promoting developing to decrease the differences in the income level and quality of life in South America.
- Focus on innovation for production of goods and services. In this plane, applied scientific work results essential.

3.1.2 Argentina's strategic aims in Science and Research overall

For the very first time in Argentina history and since December of 2007, the country has a Ministry exclusively devoted to Science, Technology and Productive Innovation.
Argentina does not have currently a strategic plan or roadmap for HPC, the Science Minister recently presented a medium-term plan for strategic development of science and technology in the country for the next seven years (see http://www.argentinainnovadora2020.mincyt.gob.ar/).

The main policies can be summarized in the following goals:

- **Inclusion and Technological Innovation**: the new technologies should answer to the necessities of strategic areas focusing on high impact productive and social problems.
- **Global coordination of the national scientific system**: to follow a coordinate policy facilitating and optimizing the usage of existing resources. It is clearly necessary to incentive the cooperation between the different actors and to promote the construction of the system as a highly interconnected and coordinated network.
- **Science and Technology in the World:** The international relationships are precious instruments to foster the national capacity in science and technology and to generate the process contributing to the economic and social development of the country. The Science Ministry promotes the formation of research network between local and foreign researchers finding complementary interests and improving the capabilities through the knowledge interchange.
- **Strengthen the Science, Technology and Innovation System**: results of extreme importance to prepare facilities allowing the improvement of the infrastructure and the equipment of the different institutions.
- **Federalization**: It is necessary to identify the demand related to concrete social and productive problems in each part of the country. The Ministry should coordinate the actions to find the answer to the own necessities of each region, decreasing the technological gap and linking each regional research community with the productive sector.
- **Science, Technology and Society**: The role that Science and Technology play in the advance of modern society requires a constant dissemination effort. This task brings closer the people to the obtained results and their applications. One of the main objectives of the Ministry is to install the value of the scientific culture as a way to the social development.

As mentioned in the strategic plan, Argentina recognizes five main pillars:

- Agricultural industry

- Energy
- Environment and sustainable development
- Social development
- Industry
- Health.

HPC has not a particular place in the Argentina strategic document, but it has been recognized by the ministry local authorities that HPC brings innovation and its use should be encouraged. Its importance can be seen from the fact that recently an integrated system of HPC was created devoting resources to the development of the field (equipment and human resources).

3.1.3 Strategic Aims in HPC

- To increase the trained human resources capable of taking advantages of High Performance Computing equipment.
- To deepen the interconnection of HPC sites in the country through the SNCAD (High Performance Computing National System). In particular, the goal for year 2013 is the creation of a national grid.
- To acquire new equipment and boost the usage and development of new HPC applications in the scientific and productive communities.

3.1.4 Strategic goals for collaboration with EU

Argentina was the first country in Latin America who signed an agreement with EU in 1999, which became effective in 2001. The main goals are:

- To promote the cooperation between Argentina and EU at national and regional levels.
- To disseminate information about research opportunities with EU, in particular regarding to Argentinean scientists.
- To ease the participation of Argentina in R&D and education activities with EU.
- To co-finance projects under the priorities of FP7.

3.1.5 Priority Computational Science and HPC research areas identified within RISC

Some of the main research areas of interest for Argentina, like Energy, Health, Environment and sustainable development, Social development are mapping some of the recommended highest priority research areas identified in RISC:

1. Bio - Life sciences, Health and Medicine
2. Natural resources exploration (including oil and gas)
3. Natural disasters modeling
4. Environmental modelling (Weather and Climate research)

(note that mining falls in natural resources exploration but it is not indicated in the national strategic vision).

3.2 Brazil

3.2.1 Strategic Goals and plans

Barzil has defined a general strategic plan called Brazil Maior, and the part related toScience is is called TI Maior (2012-2015). The Brazilian Ministry of Science, Technology and Innovation (MCTI) is responsible for the Brazil's policy in research and innovation. MCTI acts primarily using two funding agencies, Conselho Nacional de Desenvolvimento Cientifico e Tecnologico (CNPq) and Financiadora de Estudos e Projetos. CNPq mission is to support research at large, by funding, on competitive basis, students, research and national and international projects. CNPq also has several National Research Institutes. FINEP main mission is to foster industrial innovation. Brazil today produces 2.7% of the world's scientific output (2013, Sociedade Brasileira para o Progresso da Ciencia, SBPC). The tStrategic Program for Software and IT Services (TI-Maior – 2012-2015) launched by MCTI in 2011, has five pillars:

- Social and Economic Development;
- International Recognition;
- Entrepreneurship and Innovation;
- Competitiveness;
- Research, Technology Development and Innovation, where HPC is an essential element for scientific and industrial support.

Some of the main actions (IC/Computing related areas) to be implemented in this program are:

- Support software and services certification;
- Broaden digital ecosystems;
- Extend IT education (*"Brasil mais"* TI Program);
- Attract Global Research Centres;

3.2.2 Brazil's strategic aims in Science and Research

Brazil's strategy in Science and Technology is centered into four main areas: (i) Expansion and consolidation of Brazil's National System of Science, Technology and Innovation; (ii) Promoting technological innovation in companies; (iii) Research, development and innovation in strategic areas; (iv) Science, technology and innovation for social development.
The main strategic research areas of interest for Brazil are:

- Biotechnology and nanotechnology
- Information and Communication Technologies
- Life Sciences
- Biofuels
- Electric, Hydrogen and Renewable Energy
- Oil, Gas and Coal
- Agro business
- Biodiversity and natural resources
- Amazon and semi-arid areas
- Meteorology and Climate change
- Space and aeronautical sciences
- Nuclear sciences
- National defence and public security.

The Health and Medicine objectives are also outlined in Brazil Maior program (see www.slideshare.net/julianelewis/brasil-maior-2013)

3.2.3 Strategic Aims in HPC

The main strategic actions to be developed, in the context of the digital ecosystems are:

- Education
- Cybernetic Security and Defence
- Oil & Gas
- Energy
- Agriculture and Environment
- Finance
- Strategic Technologies: Cloud Computing; Games, Internet and Mobile; High Performance Computing; Open software.

In this context, focusing more on the HPC area, the actions will be:

- Increase and expand HPC facilities
- Support for improving scientific research
- Computational simulations and data analysis
- Extend open source web services for: parallel execution; distributed data management scientific workflows and data provenance.

3.2.4 Strategic goals for collaboration with EU

The priority areas that are being fostered at Brazilian level are:

- Oil and Gas
- Aeronautical
- Governance
- Life Sciences
- Medicine
- Military.

Strategic goals for collaboration with EU could be identified in almost all these areas.

3.2.5 Priority Computational Science and HPC research areas in the RISC framework

The identified highest priority research areas are:

1. Bio - Life sciences, Health and Medicine
2. Natural resources exploration (including oil and gas)

And with a lower priority:

3. Natural disasters modelling
4. Environmental modelling (Weather and Climate research).

For these research areas, it is fundamental to recommend crosscutting research and education actions aimed at define and exploit scalable algorithms, scalable mathematical models and advanced programming models, sustained and integrated with specific education and training activities in the different topics of HPC.

3.3 Chile

3.3.1 Strategic Goals and plans

In 2010, CNIC (National Council fo Innovation and Competitiveness) proposed an Innovation and Competition Agenda as a guide to the Chilean public and private investment during the 2010-2020 periods.
The current CNIC's agenda is focused on the following main points:

Strengthening business innovation

- To develop the ecosystem for business innovation
- To develop the innovation clusters
    a. Mining
    b. Agriculture
    c. Special interests tourism
    d. Offshoring services
    e. Processed food.

Generate scientific capacities under a national strategic vision

- Astronomy and Astrophysics
- Computer Sciences and Telecommunications (including HPC)
- Biotechnology and Biomedicine (including Genomics, Proteomics, Bioinformatics, Computational Biology, Neurosciences and Ecology)
- Earth Sciences (Ocean, Climate, Earthquakes, Volcanoes)
- Nanotechnology and Nanomaterials
- Engineering.

Develop advanced human capital

- Promoting PhD formation in Chile and abroad
- To attract advanced human capital living abroad
- Promoting English based learning among students

Strengthen the relationship between universities and the society

- Consolidating the triple-helix (government, society, universities)

Consolidate an institutional framework for innovation

- Implementing local-based innovation
- Building innovation ecosystems
- Promoting awareness between the industry and the university.

3.3.2 Chile's strategic aims in Science and Research

The Chilean strategy in science and technology is mainly driven by the Corporación Nacional de Ciencia y Tecnología (CONICYT), a governmental agency whose main goal is to promote the advance of Chilean science and technology. According to CONICYT strategic plan, specific programs offer funding support for several areas:

- Research funding (grants)
- National and international scholarships for the formation of advanced human capital
- Attraction of advanced human capital from abroad
- Equipment acquisition (mid-size and high end)
- Regional specific programs (natural resources: fishing, breeding, vineyards and wine, agriculture)

- Innovation and technology transfer programs
- Scientific information (access to journals and databases)
- Outreach

To do so, main research CONICYT programs are (http://www.conicyt.cl/programa/):

- FONDEQUIP: funding for mid-size equipment acquisition (up to US$300.000)
- ASTRONOMY: funding for specific research in Astronomy
- FONIS: funding for specific research in health sciences and technologies
- PIA: funding for the creation and maintenance of centres of excellence for advanced scientific research
- FONDEF: funding for technology transfer and innovation
- FONDAP: funding for the creation and maintenance of centres of excellence for advanced scientific research in priority areas
- FONDECYT: funding for basic and applied research covering a variety of scientific disciplines

Whilst the FONDECYT program covers many scientific disciplines, the FONDAP program is focused in priority areas:

- Antarctic and sub Antarctic sciences
- Conflict and living in the modern society
- Early human development in extreme environments
- Medicine for chronic diseases of the XXI century
- Elderly processes and health risks factors in adulthood
- Hydric resources.

3.3.3 Strategic Aims in HPC

The Chilean government, through the PIA – CONICYT program, in 2010 decided the creation of national facilities for shared equipment. Among the earned facilities, CMM (Center for Mathematical Modelling, Universidad de Chile) created the National Laboratory for High Performance Computing (NLHPC) at the CMM:

- The NLHPC is funded by the *First National Competition for Major Scientific Equipment for Shared Services Centres*, coordinated by CONICYT's Programa de Investigación Asociativa (PIA – *Associative Research Program*).
- The NLHPC will consolidate in Chile a HPC capacity that would meet the domestic demand for high performance scientific computing, offering high quality services and promoting their use in both basic and applied research problems as well as industrial applications
- The NLHPC is formed by the University of Chile as sponsoring institution and other Chilean universities as associated institutions (CAI) – Pontificia Universidad Católica de Chile (PUC), Universidad Técnica Federico Santa María (UTFSM), Universidad de Santiago (USACH), Universidad de la Frontera (UFRO), Universidad de Talca (UTalca) and Universidad Católica del Norte (UCN) – in association with REUNA (the national university network). The HPC infrastructure of the NLHPC will be distributed along the CAI's –consolidating the satellite infrastructure–, whereas the central supercomputer node will be installed at the CMM.
- The NLHPC, in collaboration with REUNA, will foster the creation of the metropolitan photonic ring, the first stage to the creation of a National Lambda Rail.

In 2011 and 2012 Chile has surveyed the needs for HPC in the country, 50 research groups and approximately 300 researchers declared their HPC needs spanning diverse areas (see Figure 5) http://www.nlhpc.cl/about-nlhpc/scientific-demand-for-hpc/):

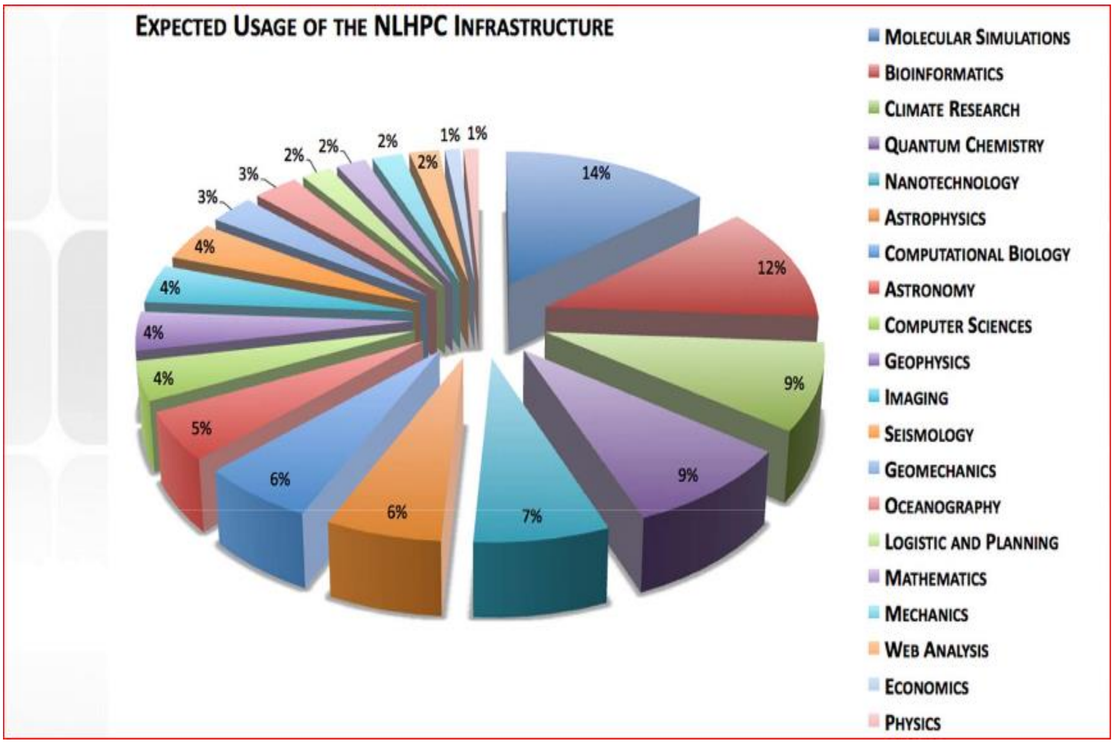

Figure 5. Chilean HPC needs

3.3.4 Strategic goals for collaboration with EU

Chile started slowly, but now is moving toward a country that has a very extensive computational knowledge, based on young people who put their hands on computers and got their head on it forever. So the potential of future development is in the computing area. It is strongly suggested that the collaboration with EU goes to the educational programs of many centres that offer training for the HPC activity, focusing in the motivation and knowledge that drives people.

3.3.5 Priority Computational science and HPC research areas mapped to RISC priorities

The recommended highest priority research mapped to RISC priorities areas are:

1. Bio - Life sciences: (computational biology and bio-informatics)
2. Natural disasters modelling: (earthquakes, volcanoes and tsunamis)
3. Environmental modelling: weather and climate research
4. Natural Resources Exploration: Mining Industry - optimal mine planning and exploitation

The aspects of education and training on HPC topics are key to tackle the above priorities so the more relevant topics are: high performance programming, scalable algorithms, mathematical modelling and massive databases. . We can observe that the crosscutting clusters enabling are key enablers in the above areas.

3.4 Colombia

3.4.1 Strategic Goals and plans for the next 3-5 years

- **Spread ICT technology** in the country through long term programs:
  - **Vive digital**: Plan of the ICT Ministry towards 2014 to make a "*quantum leap*" in ICT by promoting the mass use of internet.
  - **Compartel**: Social Telecommunications Program created by the Ministry of Information and Communications Technologies, aiming to enable remote areas and the lower strata of the country to benefit from telecommunications technologies such as rural telephony and Internet services.
  - **RECIIF**: the Colombian technology platform for the Internet of the future.
- **Bioinformatics** is a crucial factor in the Colombian policy for the commercial development of biotechnology on the basis of a sustainable use of biodiversity. For strengthening this sector MINTIC had funded the Centre for Bioinformatics, supported by Communications Fund and Colciencias, to encourage research, development and innovation in biotechnology.
- **HPC**: Colombia has many small clusters, mainly to support research groups in universities. The largest clusters are the ones of:
  - **CBBC**: the Centre for Bioinformatics and Computational Biology, located in Manizales, which will provide processing services of bioinformatics and biology throughout Colombia;
  - **Industrial University of Santande**r in Bucaramanga, which focuses on oil processing. The objective is to provide a high performance computing service to research groups and centres as well as local and external institutions with needs in supercomputing.

3.4.2 Colombia's strategic aims in Science and Research

The main strategic areas in science and research are:

1. **Computational Biology:** includes but not limited to: advanced modelling of the genome, genome sequencing, modelling of epidemics, etc.
   Bioinformatics becomes a crucial factor in the Colombian Policy for the commercial development of biotechnology on the basis of a sustainable use of biodiversity. For strengthening this sector, Colciencias (the Administrative Department of Science, Technology and Innovation) has supported the creation of the Centre for Bioinformatics and Computational Biology in Colombia.
2. **Oil Exploration Advanced Modelling:** includes but not limited to advanced computational methods and techniques for oil exploration, technological innovation to reduce costs and increase the exploration efficiency.
3. **Natural Disasters Modelling and Simulation:** includes but not limited to Hurricane a Catastrophe Modelling, Air Pollution Modelling, etc.
4. **HPC and Supercomputing**: driver for Innovation HPC applications and technologies.
5. **Other research topics of interest** for industry and academia requiring HPC and Supercomputing.

3.4.3 Strategic Aims in HPC and Computational Science

The topics of major interest in computational sciences are:

- Bionformatics and computational biology
- Oil, Gas and Energy processing
- Simulation of chemical processes

- Simulation of mechanical and civil structures.
- Computational fluid mechanics
- Advanced computer-aided visualization
- Database and data mining
- Software development on robust computing platforms
- Financial simulations
- Epidemiology and population
- Urban traffic simulations.

3.4.4 Strategic goals for collaboration with EU

A first strategic goals for collaboration with EU is identified in the ICT technology and digital services for future Internet.
Another important area of collaboration can be envisaged on the different themes of Bioinformatics, and Biotechnology.

3.4.5 Priority Computational Science and HPC research areas mapped to RISC priorities

The recommended highest priority research mapped to RISC priorities areas are:

1. Bio - Life sciences
2. Natural disasters modelling:
3. Environmental modelling: weather and climate research
4. Natural Resources Exploration: Oil Exploration

   The aspects of education and training on HPC topics are key to tackle the above so the important topics are: high performance programming, scalable algorithms, mathematical modelling and massive databases emerge as the more relevant. The crosscutting clusters enabling are key enablers in the above areas.

All these topics fit very well in the four pillars identified by the RISC Project.

3.5 Mexico

3.5.1 Strategic Goals and plans

Supercomputing in Mexico has been growing in recent years as a tool to support scientific research, development and technological innovation. Mexico is still in the process of getting to know and explore the advantages of supercomputers. This process has been slowed down due to lack of investment in research and the use of out-dated tools, thus positioning the country unfavourably with respect to other in the LA region.

According to the national development plan – NDP (http://pnd.gob.mx/), presented by Mexican president Enrique Peña Nieto in 2012, Mexico has a big challenge in productivity, which is currently limited by: institutional strength, social development, human capital, equal opportunities and international exposure. According to the NDP, Mexico has a disconnection between the actors related to the development of science and technology and those related to the business sector. In Mexico, the business sector has contributed little to the investment in research and development, which is contrary to that observed in other members of OECD, where this sector accounts for over 50% of total investment in this area.

The lack of linkage between business sector groups and scientific/technological research centres in the country and the lack of more private research centreshas put Mexico in disadvantage with respect to other nations.
Also, it is necessary to align the visions of all actors involved for companies leverage existing capabilities in higher education institutions and public research centres.
Mexico requires a high quality education to ensure comprehensive development and thus have a human capital , which happen to be a source of innovation. However, this effort would be incomplete if it fails to encourage greater and more effective investment in science and technology to feed the development of national human resource, as well as the ability to create products and services with high added value.

Mexican strategy for national growth has five pillars: Mexico in peace, Inclusive Mexico, Mexico with quality education, Mexico prosperous, and Mexico with global responsibility.

3.5.2 Mexico's strategic aims in Science and Research

According to the Mexican national development plan – NDP 2013-2018, there are two main pillars to reinforce competitiveness:

- **Mexico with quality education.** This pillar has five strategies to be followed by federal government: (1) Government will contribute to annually increase national investment in scientific research and technological development until it reaches 1% of GDP. (2) Government will contribute to the formation and strengthening of high-level human capital. (3) Promote the development of vocations and scientific and technological capacities and local innovation to enforce the regional, sustainable and inclusive development. (4) Contribute to the transfer and use of knowledge, linking higher education institutions and research centres with the public, social and private sectors. (5) Contribute to strengthening the scientific and technological infrastructure.
- **Mexico with global responsibility.** The second pillar has the following strategies related to research and development. (1) Deepen strategic partnerships with key partners to expand exchanges and cooperation. (2) Promote cooperation in a comprehensive way, especially in the cultural, educational, scientific and technological. (3) Consolidate Mexico as a key partner of the EU in Latin America, giving full content to the principles and objectives of the Strategic Partnership. (4) Promote a more active role in diplomatic missions, prioritizing investment in advanced technology and innovation cooperation.

3.5.3 Strategic Aims in HPC

In recent years, supercomputing in Mexico has focused on making a robust infrastructure available to researchers for use in projects that require HPC resources. The infrastructure has been successfully developed and evolved over the years. Thanks to this vision, many researchers have been able to carry out projects requiring such systems. That is why the main challenges in this area are coordinating research groups and team leaders in order to share both information and infrastructure to springboard Mexican science and technology. Now further investments are required not only for improving the HPC infrastructure but also for training the human resources to take advantage of this infrastructure. Currently, staff trained in supercomputing provide support for researchers, companies or government agencies and facilitate the use of HPC infrastructure. However, staff numbers are insufficient. It is important therefore to invest in training human resources and to update their knowledge in high performance infrastructure to efficiently use hardware and software resources to advance computational sciences.

3.5.4 Strategic goals for collaboration with EU

Mexico's aims to enhance cooperation efforts in science and technology with Europe. These efforts were present in the Science and Technology Cooperation Agreement with the EC and its adopted Country Strategy Paper (CSP) 2002-2006 by which CONACyT co-financed a cooperation programme in the area of Science and Technology. The new agreement is currently in a process of signing with the EC.

The main objectives for Mexico-EU collaboration are:

- Provide support to fulfil objectives from Bilateral Agreement in Science and Technology between Mexico and EU in the frame of H2020, for 2016-2017.
- Improve information and formation of researchers and project managers to have a bigger and better participation of Mexico in European consortiums by identifying potential partners that increase competitiveness of joint research.
- Better visibility of Mexican research in Europe.
- Develop of an innovative research centres network in Mexico
- Facilitate the participation of Mexicans in R&D and education activities..

3.5.5 Priority Computational Science and HPC research areas aligned with RISC priorities

The main goals of collaboration with EU are related to the scientific activity in different aspects of computational sciences in disciplines like, weather and air quality monitoring, civil protection in natural disasters, health, oil exploration, pharmaceutics and life science, e.g. it falls into:

1. Bio - Life sciences, Health and Medicine
2. Natural resources exploration (including oil and gas), Clean and Sustainable Energy
3. Natural disasters modelling and simulation
4. Environmental Modelling, including Weather and Climate research

Furthermore a strong cooperation is key in training and education activities in different aspects of HPC and computational science (see Deliverable D4.4).
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4. Overall Analysis and Recommendations

As outlined before, the agreed EU-CELAC Action Plan 2013-2015 focuses on capacity building in the following key areas:

1. Science, research, innovation and technology;
2. Sustainable development, environment, climate change, biodiversity, energy.
3. Regional integration and interconnectivity to promote social inclusion and cohesion;
4. Migration;
5. Education and employment to promote social inclusion and cohesion;
6. The world drug problem;
7. Gender;
8. Investments and entrepreneurship for sustainable development.

Especially objectives 1, 2 and 5 very closely match the identified RISC priority areas and research clusters. In addition, from national priorities of each country as well as the survey results and the additional questionnaires concerning the Green Paper and EU-LA opportunities we can firmly identify and recommend the four major research clusters:

1. **Bio - Life sciences, Health and Medicine (Computational Biology and Bioinformatics, DNA sequencing, Health care, etc.)**
2. **Natural resources exploration and Sustainable Energy (oil and gas, exploration, optimal mine planning and exploration, etc.)**
3. **Natural disasters modeling (earthquakes, volcanoes, tsunamis, forest fires, hurracaines).**
4. **Environmental modelling including Weather and Climate Research**

The four research clusters identified above represent the findings of the project during the two year study. They are aligned with the national strategic priorities outlined in section 3 of this report and represent an integrated view of the LA priorities for the countries involved in the project. These areas are also aligned with the EU-CELAC strategic priorities. As it can be seen there is very good match also between the H2020 research areas and the above research ares.

Two crosscutting research and education clusters have also emerged, based on our findings and strongly supported also by EU-CELAC strategic priorities:

• One focusing on **scalable algorithms, scalable mathematical models and advanced programming models to underpin the identified four research clusters**

• The second focusing on **Education and training as a key crosscutting cluster enabling to reduce the identified skills gap.**

These are summarized and depicted on Figure 6 below:

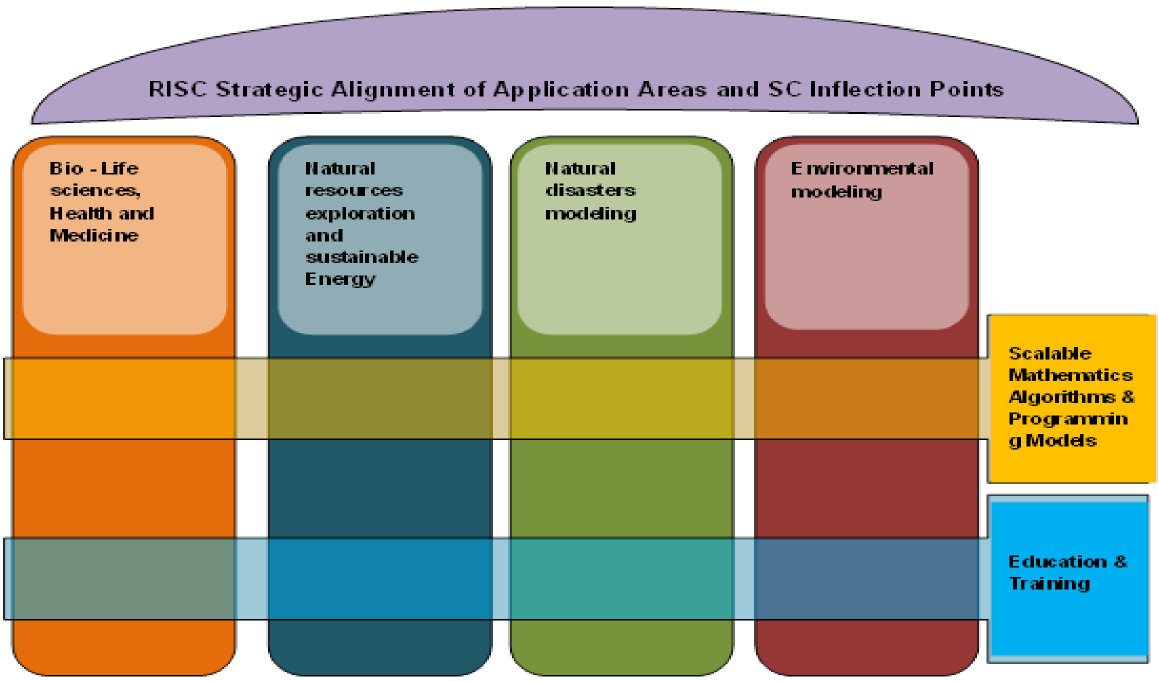

Figure 6. RISC Research Clusters

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Acronyms and Abbreviations

BSC- Barcelona Supercomputing Centre

CELAC - Comunidad de Estados LatinoAmericanos y Caribeños

ETP4HPC – European Technology Platform for High Performance Computing

IDC – International Data Corporation

HiPEAC - High-Performance and Embedded Architectures and Compilers Network

HPC – High Performance Computing

PRACE – Partnership for Advanced Computing in Europe

RISC- (A Network for Supporting and Coordination of Supercomputing Research between Europe and Latin America)

EC- European Commission

R&D- Research and Development

EU- Europe

LA - Latin America

HPC - High Performance Computing

ICT - Information and Communications Technology

WP <number> - Work Package <number>

D<number> - Deliverable <number>

M<number> - Month <number>

R - Report,

P - Prototype,

D - Demonstrator,

O - Other

PU - Public

PP - Restricted to other program participants (including the Commission Services).

RE - Restricted to a group specified by the consortium (including the Commission Services).

CO - Confidential, only for members of the consortium (including the Commission Services)