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IMPACT ASSESSMENT

Accompanying the document

Proposal for a Council Regulation

on establishing the European High Performance Computing Joint Undertaking

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GLOSSARY

The below table explains the key terms or acronyms used in this document.

ASCR	Advanced Scientific Computing Research
CEF	Connecting Europe Facility
CoE	Center of Excellence
cPPP	Contractual Public-Private Partnership
DoE	(US) Department of Energy
DSM	Digital Single Market
EC	European Commission
ECI	European Cloud Initiative
EEIG	European Economic Interest Grouping
EIB	European Investment Bank
ERIC	European Research Infrastructure
ETP	European Technology Platform
ETP4HPC	European Technology Platform for High-Performance Computing
Exascale	Computing systems capable of 10^{18} Floating Point Operations per Second
FET	Future and Emerging Technologies
Flop	Floating Point Operations per Second
FP7	7^{th} EU Framework Programme for Research & Innovation
FPA	Framework Partnership Agreement
GDP	Gross Domestic Product
H2020	Horizon 2020 Framework Programme for Research & Innovation
HPC	High-Performance Computing
ICT	Information and Communication Technology
IPCC	Intergovernmental Panel on Climate Change
IPRs	Intellectual Property Rights
ISV	Independent Software Vendors
ITER	International Thermonuclear Experimental Reactor
JTI	Joint Technology Initiative
JU	Joint Undertaking (as defined by Article 187 TFEU)
LEIT	Leadership in Enabling and Industrial Technologies
MFF	Multi-annual Financial Framework
NSA	(US) National Security Agency
NSCI	National Strategic Computing Initiative
OJ	Official Journal of the EU
PCP	Pre-Commercial Procurement
PPI	Public Procurement of Innovative solutions
PPP	Public-Private Partnership
PRACE	Partnership for Advanced Computing in Europe
Pre-exascale	Computing power near the exascale performance (i.e. 0.1-0.6 exascale)
R&D	Research and Development
R&I	Research and Innovation
ROI	Returns on Investment
SME	Small- and Medium-sized Enterprise
SRA	Strategic Research Agenda
SSC	(PRACE) Scientific Steering Committee
TFEU	Treaty on the Functioning of the European Union
WP	Work Programme

PREAMBLE

In this document the terms High Performance Computing (HPC) systems, HPC machines and supercomputers are used indistinctly. The terms leading-class/world-class computers or systems refer to supercomputers that are ranked amongst the most powerful in the world. An important point is the level of computing performance of supercomputers: the next HPC computing frontier is the **exascale performance**, i.e. supercomputers capable of executing 10^{18} or 1 billion billion Floating Point Operations per Second. These systems are expected to be built around 2022. The term pre-exascale is used to refer to performance levels close to exascale (i.e. 0.1 to 0.7 exascale). Pre-exascale systems are expected to be available on the market around 2019-2020.

1. INTRODUCTION

This document explains that High Performance Computing (HPC) is a strategic priority for Europe. The European Commission (EC) and several Member States (MS) have already taken the decision to co-invest in a joint structure that would allow Europe to reach the strategic goals defined in this domain through optimal use of available public funding.

The document explores which form of legal and financial instrument would serve best the objectives of this joint HPC structure (called in the sequel ***the EuroHPC entity***) that would start operating as of 2019 onwards and assesses its impact to implement the EuroHPC strategy in Europe.

1.1. Background

Europe's scientific capabilities, industrial competitiveness and sovereignty critically depend on access to world-leading HPC computing and data infrastructures to keep pace with the growing demands and complexity of problems to be solved.

In 2012, the Communication "*High performance Computing: Europe's place in a global race*"[1] highlighted the strategic nature of HPC as a crucial asset for the EU's innovation capacity and called on Member States, industry and the scientific communities, in cooperation with the EC, to step up joint efforts to ensure European leadership in the supply and use of HPC systems and services by 2020.

On 19 April 2016, the EC adopted the *European Cloud Initiative (ECI)*[2,3] as part of its Digitising European Industry strategy.[4] The Communication invited the EC and the MS to work together in the creation of a leading European HPC and Big Data ecosystem, underpinned by a world-class HPC, data and network infrastructure. Such infrastructure would support the EU to become one of the world's top supercomputing powers by realising exascale supercomputers around 2022, based on European technology, ranking among the first three places in the world.

1 COM(2012) 45 final

2 COM(2016) 180 final

3 SWD(2016) 106, accompanying the ECI Communication

4 COM(2016) 180 final

The European HPC Strategy aims at establishing a world-class HPC ecosystem in Europe, acquiring leadership-class supercomputers which secure Europe's own independent HPC technology and system supply, and deploying HPC services for science, industry and SMEs. To be able to implement this strategy we need to coordinate and pool national and European efforts in developing and procuring world-class supercomputers.

In May 2016, the Competitiveness Council[5] expressed its political support to HPC followed by the European Parliament in January 2017.[6] The Competitiveness Council took also note of the intention of France, Italy, Luxembourg and Spain to launch a joint project for developing a commercial offer in HPC and big data serving industrial applications.

Moreover, the European Council of 28 June 2016 *called for swift and determined progress to create the right conditions for stimulating new business opportunities by coordinating EU efforts on high-performance computing*; *and looked forward to the launch of an important project of common European interest in this field.*[7]

On 23 March 2017 at the Digital Day in Rome, which was organised as part of the 60th Anniversary celebrations of the Treaty of Rome, seven MS – France, Germany, Italy, Luxembourg, the Netherlands, Portugal and Spain – signed the *EuroHPC declaration.*[8] They were more recently joined by Belgium, Slovenia, Bulgaria, Greece, Croatia and Switzerland. These countries agreed to work together and with the EC for acquiring and deploying by 2022/2023 a pan-European integrated exascale supercomputing infrastructure called *EuroHPC*. Other MS and Associated Countries (AC)[9] are invited to sign the EuroHPC declaration. Several countries have already signalled their intention to do so by the end of 2017.

The EuroHPC Declaration is an agreement in which the signatory MS commit to work together and with the EC for acquiring and deploying an integrated world-class HPC infrastructure, which will be made available across the EU for scientific communities as well as public and private partners, no matter where supercomputers are located, upraising Europe's scientific capabilities and industrial competitiveness and for jointly procuring and deploying exascale supercomputers accessible from everywhere in Europe based on competitive European technologies.

On 10 May 2017, in the Communication on the *Mid-Term Review of the Digital Single Market (DSM) Strategy*[10], the EC confirmed its plans to invest on HPC and announced its

5 The Competitiveness Council on 29-30 May 2016 adopted conclusions on the ECI Communication, highlighting the role of HPC in the EU's innovation capacity and stressing its strategic importance to the EU's industrial and scientific capabilities as well as to its citizens.

6 European Parliament, Report on the European Cloud Initiative (2016/2145(INI)), Committee on Industry, Research and Energy, Brussels, 26 January 2017.

7 http://www.consilium.europa.eu/en/press/press-releases/2016/06/28-euco-conclusions/

8 http://ec.europa.eu/newsroom/document.cfm?doc_id=43815, and https://ec.europa.eu/digital-single-market/en/news/belgium-joins-european-cooperation-high-performance-computing

9 Countries associated to H2020: https://ec.europa.eu/research/iscp/pdf/policy/h2020_assoc_agreement.pdf

10 COM(2017) 228 final

intention to propose by end-2017 ***a legal instrument that provides a procurement framework for an integrated exascale supercomputing and data infrastructure***.

1.2. Context

The EuroHPC declaration and the communication on the DSM mid-term review have soundly supported the decision on establishing the joint EuroHPC entity that allows the co-investment of the Union with MS and ACs to establish an integrated world-class supercomputing and data infrastructure.

The EuroHPC entity would permit to ***coordinate and pool national and European efforts in a framework to procure jointly*** between the Union and the MS a world class HPC and data infrastructure and their interconnection. In order to be able to procure such infrastructure based on competitive European technology, the EuroHPC entity will also be used to ***develop further the European HPC ecosystem,*** *i.e., a reinforced technology supply chain, a richer applications offer in various sectors and the tools necessary to provide these applications as an HPC Cloud service across Europe.* This includes support to Research and Innovation (R&I) on both hardware and software required for building competitive exascale machines as well as support to the development of skills needed for reaping the benefits of investing in such leading infrastructure.

There is an urgent need to act now, driven by the triple need to: (i) procure and deploy in Europe in competitive timeframes a world-class pre-exascale HPC infrastructure; (ii) make it available to public and private users for developing leading scientific and industrial applications that would foster the development of a broad pre-exascale ecosystem in Europe; and (iii) support the timely development of the next generation European HPC technologies and their integration into exascale systems in order to be ready to procure them in competitive timeframes with respect to our world competitors.

These three objectives are within reach if the EuroHPC entity could be set up and start operating in 2019. The entity would not need extra funds from the current Multiannual Financial Framework (MFF), as it will draw funds from the budgets already committed for HPC activities in the different work-programmes (WPs) of the last two years of Horizon 2020 (H2020) and the Connecting Europe Facility (CEF). A total budget of approximately EUR 1 billion would be available: an EU contribution of around EUR 486 million matched by a similar amount from the MS/AC. This would ensure the operations and payments of all the activities that the EuroHPC entity would launch at the latest by the end of 2020 until their termination around 2025/2026.

The EuroHPC entity may also receive financial support from the next MFF. Should this be the case, the entity would be ready to fulfil further the objectives of the European HPC strategy. This would imply in particular the possibility for the entity to procure exascale HPC systems based on European technology; support the development of a thriving exascale ecosystem in Europe; and prepare for the next generation of HPC technologies and their link to quantum computing.

2. PROBLEM DEFINITION

2.1. A brief introduction to HPC and its strategic value for science and the digital economy

HPC is a branch of computing that deals with simulation and modelling of scientific and engineering problems and with data analytics that are computationally so demanding that computations cannot be performed using general-purpose computers. Today, these computations typically run on very powerful systems with highly parallelized computing units of hundreds of thousands or millions of processors. Those computers are often referred to as supercomputers. The speed at which computing power increases is so fast that today's state of the art machines are obsolete after five years of operation on average.

As the problems modelled in computer simulations and decision support systems grow in size and complexity (to enable more detailed predictions, to cope with ever larger amounts of data or both), so do the demands on computational resources. In many areas spanning from health, biology and climate change to automotive, aerospace energy and banking general-purpose computers cannot provide a practical solution to address complexity anymore and access to HPC becomes essential.

HPC is at the core of major advances and innovations in the digital age, where to out-compute is to out-compete. It is a key technology for science, industry, and society at large. Annex 5 provides data on how impactful HPC is today on the economy and society, provides data on its high returns on investments, and illustrates the importance of HPC with many examples of the most prominent HPC applications in science, industry and the public sector.

To fully reap the benefits of HPC, ***it is necessary to support a full ecosystem*** comprising hardware and software components, applications, skills, services and interconnections. In fact every new generation of HPC systems pushing further the performance limits is the result of a cooperative effort between suppliers, operators, users and researchers, tailor-made and optimised for the scientific or industrial application users, which HPC systems are intended to serve. Such an interdisciplinary approach leads to a more efficient use of often expensive supercomputing systems and develops training capabilities for programming such systems.

2.2. What is the problem that requires action and its size

The 2012 Communication on "High-Performance Computing: Europe's place in a Global Race"[1], laid down the foundations for a European HPC strategy. The overall objective was the *development of the European HPC infrastructure and a pooling of national investments in HPC*. This was broken down into the specific objectives to *provide a world-class European HPC infrastructure*, *ensure independent access to HPC technologies*, *pool enlarged resources*, *increase efficiency*, s*trategic use of joint and pre-commercial procurement,* and ultimately*, ensure the EU's position as a global actor*.

The Communication called on the European Commission, the Member States, the industry and PRACE[11] to put in place a number of actions to reach these objectives. As a consequence the following actions were implemented:

- The contractual public-private-partnership (cPPP) European Technology Platform ETP4HPC[12] was created in 2013. It is an industry-led technology platform of HPC

[11] PRACE (http://www.prace-ri.eu/) offers a pan-European supercomputing infrastructure providing access to computing and data management resources and services for large-scale scientific and engineering applications at the highest performance level. PRACE is an association of 24 member countries. The PRACE top computer systems (so-called Tier-0) are provided by five PRACE hosting members (BSC Spain, CINECA Italy, GCS Germany, GENCI France and CSCS Switzerland.

[12] http://www.etp4hpc.eu/

suppliers with the mission to develop a joint research agenda and coordinate its implementation, thereby creating critical mass of R&D in HPC, building a world-class HPC technology supply chain in Europe, increasing the global share of European HPC technology vendors and maximising the benefits that HPC technology brings to the European HPC user community.

- The EC made a commitment towards the ETP4HPC to invest EUR 700 million in H2020 for the period 2014-2020. The cPPP should leverage a similar amount of resources on the private side.
- PRACE hosting member countries supported the European science community, providing access to most powerful computers in Europe, as well as training facilities and skills development opportunities. The EC supports financially PRACE to facilitate the access to the computing resources. In addition, the EC and the MS are also investing in GÉANT, the pan-European data network for the research and education community linking national research and education networks as well as supercomputing centres across Europe. [13]
- Centres of Excellence (CoEs)[14] were established and funded by the EC for the application of HPC in scientific domains of importance for Europe. They also provide support, competences and training to the user communities.
- MS continued to invest in their national HPC capabilities, developing technology and regularly procuring new machines to replace the outdated ones.

Lessons learnt in the implementation of the HPC strategy

Despite all the above activities that were put in place, the implementation of the HPC strategy is still not very efficient and effective today.

The main reason for this is the existing fragmentation of efforts at EU programme level and between EU and MS level. As reported in the 2016 Communication on the European Cloud Initiative[2] and in the accompanying Staff Working Document[3], many of the challenges identified in the Communication of 2012 are still largely unresolved:

- ***Provide a world-class European HPC infrastructure***: PRACE is an effective tool to provide computing cycles, but the procurement of systems is still done by MS in an uncoordinated way. This situation for example leads to periods of abundance of top-class systems (i.e. in 2012, with several MS acquiring top machines) followed by a period of low resources for researchers (i.e. in 2016-2017, due to obsolescence of previous machines and lack of further investments). A pan-European vision with a more strategic and rational planning of procurements is necessary.
- ***Fragmentation of European and national efforts:*** The implementation of the R&I agenda proposed by the cPPP is fragmented: First, MS have their own national programmes. And second, the way the EC implements the HPC strategy is not well-coordinated, since it uses two different programmes (CEF and H2020) and three different H2020 WPs (FET, LEIT-ICT and Research Infrastructures). This is due to the different nature of the supported activities (R&I, infrastructure development, etc.) and annual budget limitations. Such implementation is complex: it involves discussion with four

[13] https://www.geant.org

[14] Centres of Excellence (CoE) ensure EU competitiveness in the application of HPC for addressing scientific, industrial or societal challenges. The Centres are conceived to be user-focused, develop a culture of excellence, both scientific and industrial, and place computational science and the harnessing of "big data" at the centre of scientific discovery and industrial competitiveness.

different programme committees with different delegates often from different entities within each MS, making coordination between committees more difficult. Moreover, as the four different programmes have their own timing, the synchronisation of the calls addressing the various but interlinked aspects of the European HPC strategy, becomes a real challenge. At EU level, a single R&I programme is necessary for an efficient production of European HPC technology.

- ***Innovation procurement is not used in HPC:*** Innovation procurement instruments like the Pre-Commercial Procurement (PCP) and the Public Procurement for Innovation (PPI) have not been used so far by the MS in the area of HPC. In contrast, the USA, China and Japan use legal instruments that ensure a flexible process for the production of national technology in R&D programmes and their integration in the systems that are acquired by the national agencies. Europe would benefit from a joint structure that would permit to pool national and EU resources and jointly procure HPC systems by making systematic recourse to innovation procurement.

- ***Ensure the EU's position as a global actor:*** European suppliers face limitations in acceding to public procurements of HPC in USA, China or Japan. In contrast the EU is still the most open market, with no restriction in most of the public procurements on HPC (except e.g. for military purpose machines in some countries). Making systematically recourse to mechanisms like the one provided by Article 30.3[15] of the H2020 model grant agreement (to object under certain conditions to the transfer of Intellectual Property Rights (IPR) to third countries) and to new procurement and exploitation strategies would permit protecting IPRs produced in the EU and first exploiting in Europe the EU-funded R&I results.

The above issues will be analysed in the sections below. In summary, the EU is now confronted with the following situation:

The EU does not have the best supercomputers in the world even in areas of key importance; the available supercomputers do not satisfy the demand; the MS spending in HPC is not coordinated and the industrial take-up of HPC technology developments is low. We still fail in turning the technology development into HPC systems that are procured in Europe, i.e. we lack an effective link between technology supply, co-design with users, and a joint procurement of systems.

Figure 1 provides an overview of the main problems, their drivers and their consequences.

[15] [OPTION 1 for EU grants]: The [Commission][Agency] may — up to four years after the period set out in Article 3 — object to a transfer of ownership or the exclusive licensing of results, if:
(a) it is to a third party established in a non-EU country not associated with Horizon 2020 and
(b) the [Commission][Agency] considers that the transfer or licence is not in line with EU interests regarding competitiveness or is inconsistent with ethical principles or security considerations.

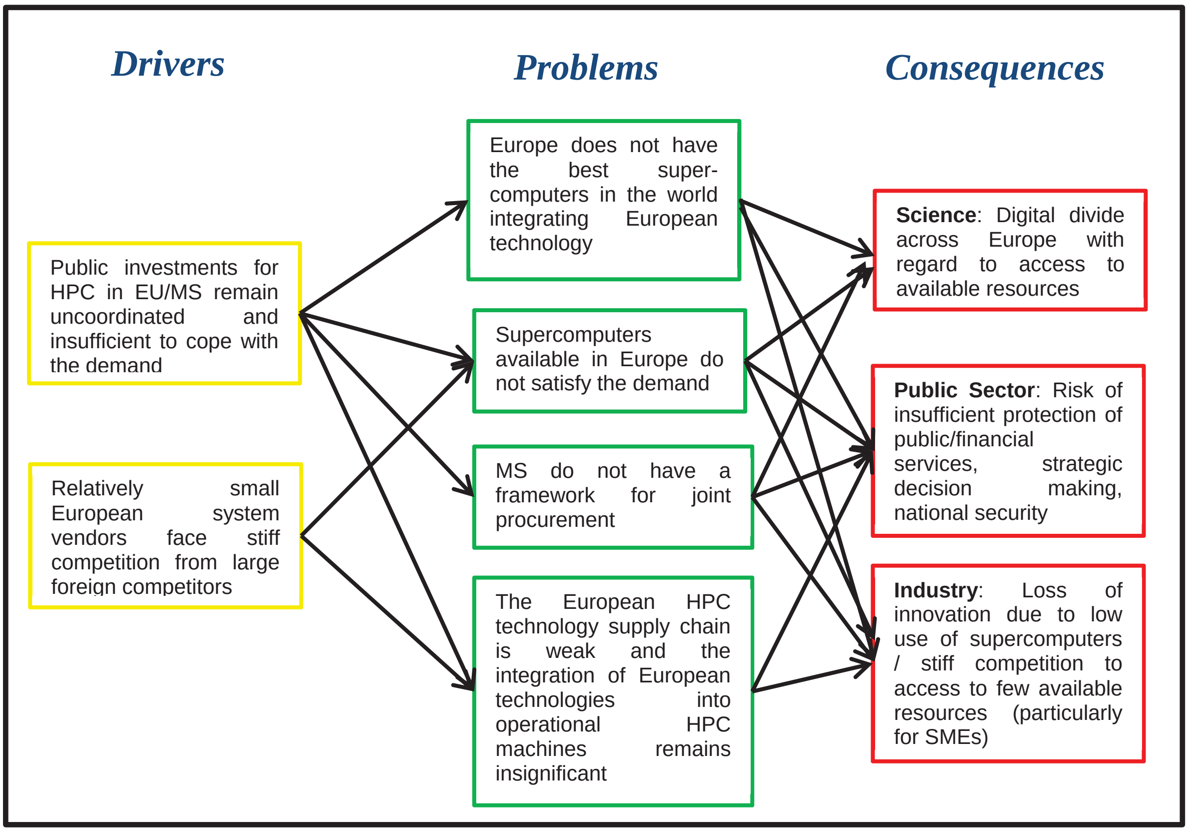

Figure 1: Overview of the main problems, their drivers and consequences

Problem Nr 1: The EU does not have the best supercomputers in the world but, in addition it is largely dependent on non-European HPC supply chains with the increasing risk of not having access to latest strategic technology even if resources were available.

Today, none of the 10 leading supercomputers in the world – i.e. supercomputers with a performance level necessary to sustain leading-edge research – is located in the EU (5 are in the USA, 2 in Japan, 1 in Switzerland and the 2 top systems are located in China).[16]

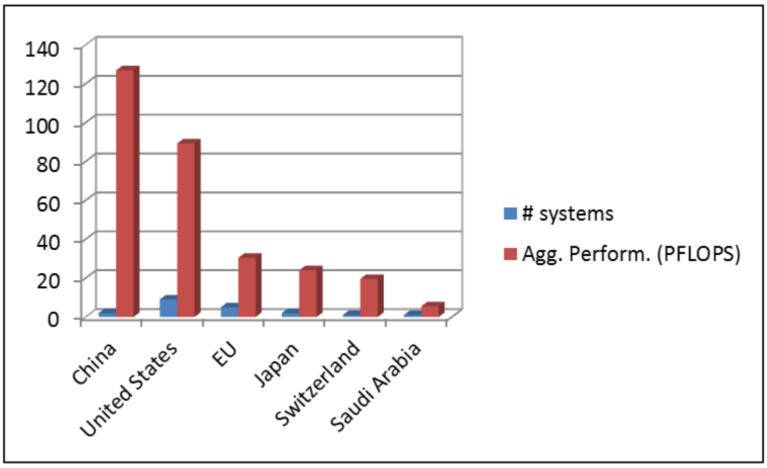

Figure 2: HPC World Top 20 as of June 2017 and their computing power

[16] See: https://www.top500.org

1	China	11	United Kingdom
2	China	12	United States
3	Switzerland	13	Spain
4	United States	14	Italy
5	United States	15	United States
6	United States	16	United States
7	Japan	17	Germany
8	Japan	18	Saudi Arabia
9	United States	19	France
10	United States	20	United States

Figure 3: HPC World Top 20 as of June 2017

Europe's top performing machine is located in Switzerland and it is based on US technology (i.e. Cray). A more detailed analysis shows that while the US and the EU machines have similar capacities in terms of number of available computer cores, the performance of the two systems is very different with the average EU being below 30% of the average US performance.[17]

The main reason for this situation is that

> Collectively, the EU and the MS are significantly under-investing in HPC technology supply and infrastructures when compared to the investments of USA, China or Japan. The current funding gap with the USA is estimated in at least EUR 700 million per year.

So far, the EC invested EUR 330 million on HPC-related activities of H2020 between 2014 and 2017 and further investments of the order of EUR 750 million are foreseen in the period 2018 – 2020. The total EU support in HPC will be over EUR one billion in the period 2014-2020. As for the collective investments of the MS for the same period these are estimated to be at around EUR 1.5 billion. The four PRACE countries hosting the Tier-0 machines made available to European scientists of computing time equivalent to the cost of EUR 400 million.

A study conducted for the EC in 2015[18] on the progress of the implementation of the European HPC strategy concluded ***that the present pace of growth of European investment in HPC will not be enough to attain and maintain leadership***, meaning at minimum parity with best-in-class HPC resources in the USA, Japan, or China. In 2015, the estimations of the study of the public and private investments for Europe to achieve leadership by 2020 were in the order of additional EUR 5.3 billion in 7 years (2016 to 2022). When compared to current investments of the EU and MS, ***the gap with the USA can be estimated at least at EUR 700 million per year*** (see Annexes 5 and 6 for further details).

Moreover, HPC has now become an indispensable technology for supporting policy making and maintaining national sovereignty, supporting strategic decision-making for energy, home security, or climate change, or in the context of national security applications.

> Access to indigenous world-class HPC machines has become an asset to a country

[17] Calculated as the average Rmax and Rpeak from Top500

[18] Study IDC SMART number 2014/0021 - *High Performance Computing in the EU: Progress on the Implementation of the European HPC Strategy*

to an extent that it is considered not only as a strategic resource for its economy, but also a matter of ***national security***. A recent report from the US[19] states *"... national security requires the best computing available, and loss of leadership in HPC will severely compromise our national security ..."*.

Access to own higher computing power provides a competitive advantage in scientific innovation and industrial competitiveness, and is indispensable technology for supporting policy making and maintaining national sovereignty (see Annex 5 for a detailed analysis of the impact of HPC). The USA, China and Japan have declared HPC to be a strategic priority for their country. They consider ***HPC as too strategic to be largely dependent on foreign suppliers*** and put focus on developing indigenous HPC supply chains and ecosystems that are essential for economic development and for security and safety.

The top 5 supercomputers installed in the EU are supplied by vendors outside Europe, 3 from the United States (Cray, HPE) and 2 from China (Lenovo). They all integrate Intel processor technologies. Similarly, the technology used to interconnect the system originates from outside Europe (Cray, Intel, Mellanox).

If the EU does not have its indigenous supply of supercomputers, it will find difficulties to acquire state-of-the-art machines or the technology to build them, as the supplying regions would not want to lose their competitive advantage to innovate. A recent example is China, which was deprived from the supply of USA state-of-the-art technology and as a consequence developed its own HPC supply chain. As a result China now has the two world-wide fastest supercomputers.

The concern that Europe's supercomputing capabilities depend on non-EU suppliers for critical technologies and systems and that Europe is relegated against its global competitors in a field as strategic as supercomputing have been put forward by stakeholders, and in particular by the user industry, in the EuroHPC targeted consultation[20] (see Annex 2) to go for a new action at the EU level that goes beyond current actions.[21]

EU depends on other regions for the supply of critical technology for its HPC infrastructure. ***EU risks getting technologically deprived of strategic know-how for innovation and competitiveness***. The availability of the best supercomputing capacity is strongly linked to the ability to master and produce indigenous HPC technology in Europe. If the EU is not able to produce and integrate leading-edge HPC technology, ***it will systematically become a mere buyer of foreign systems that are behind the latest HPC technological generation that is produced, used and exploited first elsewhere***.

Therefore, it is of strategic importance for the EU to be able to produce its own HPC technologies and integrate them into leading-edge HPC machines that it procures.

In order to fully reap the benefits of leading-edge HPC machines, it is also necessary to create a full HPC ecosystem. Every new generation of machines pushing further the limits of performance is custom designed. These machines are not off-the-shelf products. On the

[19] U.S. Leadership in High Performance Computing (HPC) – A Report from the NSA-DOE Technical Meeting on High Performance Computing, December 1, 2016.

[20] "Targeted Consultation on the HPC Initiative in Europe and the EuroHPC Inception Impact Assessment"

[21] The other one being overall inefficiency resulting from the current fragmentation of efforts.

contrary, they are a product of the cooperative effort of the suppliers, operators and users, tailor-made and optimised for the class of applications they are intended to solve and taking into account the boundary conditions (e.g. availability of affordable electricity). This last aspect is crucial to develop a sustainable HPC environment. To reap the benefits of the use of a supercomputer requires ownership of the infrastructure. In addition, it is necessary to coordinate the supply of hardware and software components and tailor it to meet scientific and industrial application requirements. This means that such diverse communities as low-power microprocessors designers, resource management software developers, system integrators and computational scientists and engineers have to work together from an early stage of the design and development phases of supercomputing systems. Such an interdisciplinary approach leads to a more efficient use of often expensive supercomputing systems and calls for developing training capabilities for programming such computers for different user communities.

Problem Nr 2: Supercomputers available in Europe do not satisfy the demand

Because of the lack of highest performing HPC machines available in the EU, the European scientific and engineering research community prefers to use USA supercomputing facilities rather than PRACE. Two US programmes provide such opportunity.[22]

Comparing PRACE with its overseas counterpart in the USA (the Advanced Scientific Computing Research (ASCR) programme) shows the extent to which the European HPC offer is insufficient to satisfy the demand.

Access to ASCR supercomputer facilities is open to the scientific and engineering research community including universities, industry, and the US national labs through a peer review process. Data collected for the Fiscal Year 2015 reveals that the US is the major user of ASCR facilities[23] with a total of 25993 users, whilst Europe with 3501 users (UK, Germany, France and Italy in the lead) is their second major user.

Not only Europe does not have the best machines but it also cannot sufficiently satisfy the demand. If we compare ASCR and PRACE by the number of awarded projects by both programmes[24], we can see that the total number of projects awarded by PRACE in each call (PRACE has 2 calls per year) has never exceeded 60 projects, while solely in the 2016 Fiscal Year ASCR awarded 921 projects to entities from the European countries.[25] This comparison is indicating that the European scientific and engineering research community obtain more support from the US ASCR supercomputing facilities than from the European PRACE.

A striking fact is that even the four PRACE members (Germany, France, Spain, Italy) that are providing computer systems to the PRACE association obtained more projects from ASCR than the maximum PRACE could offer. This holds also for some associated members of PRACE like the Czech Republic, Poland, Denmark, and the UK that do not provide computing systems to PRACE. In conclusion, there is a strong demand for HPC access in the EU, a demand which is not sufficiently satisfied by PRACE.

Insufficient access to HPC resources was also among the main reasons why respondents to the EuroHPC consultation indicated that there is currently a problem with HPC in Europe (for

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22 ASCR facilities available at https://science.energy.gov/user-facilities/user-facilities-at-a-glance/ascr/

23 https://science.energy.gov/~/media/_/pdf/user-facilities/Reports/DOE-SC-User-Facilities-FY2015-report.pdf

24 The comparison is indeed relevant since both programs have a similar allocation mechanism awarding one year or multi-year core hours.

25 ASCR source data available at https://science.energy.gov/user-facilities/user-statistics/by-project/

details see Annex 2). Regarding specifically the role of existing EU-funded HPC actions, such as PRACE, ETP4HPC and GEANT, they confirmed that in a future EU initiative on HPC existing actions should be improved, especially PRACE, and collaborate closer to complement each other.

While we cannot take it for granted that Europeans can always use the best supercomputers existing in other regions, it is also a fact that ***the most demanding European applications have to run on the machines provided by the EU competitors***, while only less demanding applications can run on the supercomputers available in Europe. This means that data produced by EU research and industry risks getting processed elsewhere for lack of corresponding capabilities in the EU.

> Ultimately our scientific and industrial leadership will become dependent on the accessibility to the highest-end machines that are outside Europe.

The high dependence on the access to non-European supercomputers raises several problems:

- The data produced by European scientists and industry is processed outside the EU. This creates problems related to privacy, data protection, commercial trade secrets, and ultimately loss of ownership of critical data. This is particularly critical for sensitive applications, for example in security, health, or engineering, where the data for national security reasons should not leave the EU.
- European users do not have the priority to use the machines and are at the mercy of the access policy of the hosting country. Even if the selection of users is based on a peer review process, European users always face the risk that indigenous users get preferred access, computing time or computing power. This is in particular a problem for industrial users that cannot afford to wait for the machines they need.
- In the long term, European users, scientific as well as industrial, might move outside the EU to get the same access rights, access conditions and price as the indigenous users. The brain drain from researchers relocating to third countries may not be limited to the loss of excellence in scientific disciplines, but Europe can also lose its competences in developing applications for supercomputers if users no longer co-design the applications with the supercomputing centres.
- The demand for more computing power will continue increasing and new applications will soon emerge notably in health, energy, environment, fintech, manufacturing etc. which we cannot satisfy with the computing power of today's HPC machines. The problem will become even more acute in the next 5-7 years when the development of exascale applications comes to maturity.

Problem Nr 3: Member States do not have a framework for joint procurement

The PRACE Association provides access to the most powerful supercomputers in Europe (Tier-0 machines). However, it does not cover the coordination of national programmes, nor joint investments for the procurement of systems, e.g. there is no common European strategy to develop and acquire pre-exascale or exascale machines.

The design, the specifications and the procurement of the machines are done by each of the supercomputing centres on their own and are mainly guided by own or by national interests, without any incentive to coordinate with the other countries. Although most MS share the same interests in advancing science, they try to satisfy as much as possible the requirement of their national scientific communities. This however does not guarantee an optimal coverage of the different scientific communities at European level.

In the USA, China and Japan the high-end supercomputing resources are acquired through public procurement of innovation with a national strategy. For example in the USA, there is a federal coordination of procurements between different agencies, like the National Strategic Computing Initiative (NSCI) and the Exascale Computing Project (see Annex 6) to frame the national efforts in a coherent strategy. ***These initiatives provide a critical mass for procurement, obtaining better value for money in acquisitions, and are also tightly linked to the technology supply, ensuring that national suppliers stay at the forefront of technology advancements.***

In Europe, the large fragmentation of HPC programmes and efforts, the non-coordinated activities and the lack of a common procurement framework lead to a waste of resources. This has been identified by stakeholders in the EuroHPC consultation as one of the current two top ranked problems of HPC in Europe (see Annex 2), independent of their type of organisation (i.e. scientific user, industrial user, technology supply industry, computing centre).

Current funding instruments have limitations when applied to large mission-oriented initiatives. The existing implementation tools are well adapted mainly to support R&D of marketable HPC technologies, but are complicated to coordinate for example several synchronised procurements in different MS with different legislation and rules.

> Most MS and Associated Countries to Horizon 2020 have their national HPC strategies and investment plans according to their national needs and programmes. In particular those countries that have not the capability to invest in their own leading-class machines are prepared to co-invest to get access to the Tier-0 machines. Most of them participate in the PRACE programme. Europe thus misses the opportunity to take advantage of efficiency gains by aligning the strategies and pooling resources.

As for the EC, so far it has provided limited support to a joint procurement of supercomputers, mainly because of the hesitation of the Tier-0 countries to participate in such joint procurement. In 2016, the EC put in place a first call for procurement of innovation with the PRACE hosting countries. In return of the financial support from H2020 (at the level of 35% of the overall costs), the participating countries agreed to provide access to the procured machines.

Problem Nr 4: The European HPC technology supply chain is weak and the integration of European technologies into operational HPC machines remains insignificant

Today, Europe consumes about 29% of HPC resources worldwide, but the EU industry provides only ~5% of such resources worldwide.

In addition, close to one fifth of the top 500 HPC systems are located in the EU, and out of these, ~20% are provided by EU vendors (oscillating between 20% and 25% over the last years).[26] Between 2015 and 2016, their exports outside the EU consisted of 3 systems installed in South America and 5 in Asia.

[26] French Bull-Atos is the leading European integrator, followed by the Dutch ClusterVision and the German SME Megware. The first system in the top 500 list installed by the European vendor Bull-Atos has rank 38. Bull-Atos has 10 systems in the top 100, all but one installed in Europe. ClusterVision has the first system at rank 329 and SME Megware at rank 357.

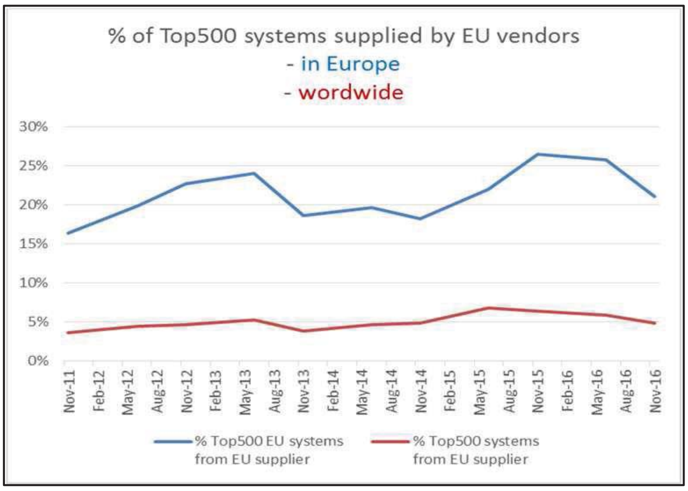

Figure 4: Contribution of EU vendors to the 500 most performant HPC systems (2011-16)

The market share of EU vendors in Europe is even smaller when considering the HPC server market (beyond the top 500 systems), although the growth rates have been largely beating the market average (15% vs 3.4%). This growth raised the EU suppliers' market share from 2.8% in 2013 to 3.7% in 2016. During the same period, EU suppliers' share of the global HPC server market expanded at a robust 16.1% annual growth rate. Although this growth substantially exceeded the market's 5.8% growth rate during this period, it enlarged EU suppliers' share of the global HPC server market merely from a marginal 0.8% in 2013 to an equally marginal 1.1% in 2016.

On the global market the European suppliers face unequal treatment on public procurement. ***The USA and China restrict the development and procurement of the high-end machines to domestic suppliers.*** As a consequence, non-European suppliers have a clear competitive advantage as they get direct funding support for the development of the national machines that they later on sell on the global market. In Europe there is an open market, without a policy to favour European suppliers. Therefore, in the absence of a prospective lead market and a risk sharing with the public sector, European suppliers hesitate to take the financial risk to develop the technology on their own.

Despite the national and European R&D funding programmes, Europe ends up with a weak supply industry, while it has one third of the application markets. As the non-European HPC suppliers participate in the European R&D programmes, **the EU ends-up paying non-EU-suppliers twice: for the development of their underlying technology and for the acquisition of their HPC machines built with non-EU technology.**

It is also to be noted that the functional HPC components and prototypes developed by the projects funded through the European Framework Programmes for Research (FP7, H2020) are rarely integrated in the machines that are procured. There are three main reasons for that:

- Firstly, there is a lack of incentives of the supercomputing centres that specify the machines to be procured to privilege solutions developed by the European R&D programmes. The procurements are in general implemented by the MS according to their national rules and the EC cannot impose measures to favour European suppliers.

- Secondly, the H2020 rules for participation[27] make it difficult to ensure continuity of the investments made between different calls. Each call is an open and competitive process, with the possibility to limit a follow-up call to the successful projects of the previous call only in exceptional cases. This leads to the situation where R&D results are rarely integrated in the subsequent calls addressing the development phase of the supercomputer, and are replaced by a solution that was developed elsewhere, including from a non-European supplier. The R&D investments are then inefficient to transfer European R&D results into marketable products, or to foster a European supply industry. European companies have then an increased risk of not getting funded in the subsequent call. The problem is further exacerbated by the fact that the H2020 calls are open also to non-EU beneficiaries.
- Thirdly, the EC (and MS) do not use the innovation procurement instruments (PCP combined with PPI) to accompany the route from HPC technology development to procurement that would help support a competitive European supply industry and create a lead market in Europe. The main reason so far is the hesitation of the Tier-0 countries to participate in joint procurement actions, even less to ones that may favour procurement of European technologies that may be perceived as not sufficiently competitive.

Finally, the development of exascale technologies is not for the sake of having the fastest supercomputer in the world, but the goal is to build "first of a kind" systems rather than "one of a kind". ***Indeed, HPC technology of today, and in particular low-power processing units and systems, is the mainstream technology that we will find in the next five years integrated in our cars, homes, factories and personal devices. Not investing in HPC technologies makes it difficult to be present in any digital technology in the future, like the autonomous vehicles, the connected car, or the smart home***.

The transition to exascale computing is an opportunity for the European supply industry to leverage on technologies in the computing continuum from smart phones, to embedded systems (for example in the future driverless cars), and to servers, feeding the broader ICT market within a few years of their introduction in high-end HPC – giving a competitive advantage to those developing them at an early stage. The size of these target markets is estimated to EUR 1 trillion.

The industrial users who responded to the public consultation identified as their main concern the dependence on non-EU technology. This clearly shows their awareness of the risks related to the dependence of a foreign technology supply-chain for a resource that is a critical for their competitiveness on a global market.

2.3. What are the problem drivers?

The following are the main drivers contributing to the problem:

Problem Driver Nr 1: Public funding for HPC in EU/MS remains uncoordinated and insufficient to cope with the demand

MS investments are insufficient and uncoordinated to acquire enough high end HPC systems that satisfy the demand. According to the 2014 International Data Cooperation study[19], Europe started to narrow down the former wide gap separating the most capable US and Japanese supercomputers at the very high end of the supercomputers segment from their European counterparts. Indeed, at first, spending increased substantially in the EU for large

[27] OJ L 347 of 20.12.2013, pp. 81-103

supercomputers from 2009 (112 million EUR) until 2012 (658 million EUR). However, in 2014, it started to decline again (362 million EUR in 2014).

No MS has the capabilities to develop the necessary HPC ecosystem on its own in a competitive timeframe with respect to the USA, China or Japan. The individual MS do not have the full value chain or competences and most lack the necessary funding levels. Lack of sufficient resources is one of the main reasons put forward in the EuroHPC consultation (see Annex 2) to go for a new action at EU level.

The leading regions in the world are racing ahead and are massively investing in strategic HPC programmes to boost their HPC ecosystem and prepare it for the upcoming next generation computing (exascale and beyond). These programmes are driven by the public authorities with some leverage of private investments (mainly on the technology supply side).

If the EU is entirely dependent on non-European supply, this puts at risk our capacity to acquire the latest HPC systems and our capacity to build a digital industry all together given that HPC technology has a spill over effect on all digital technologies.

Regaining world-wide leadership in HPC cannot be achieved on the basis of Europe's current HPC industry set-up and market conditions alone. No European industrial player currently has all competences in-house. The required investments levels for industry exceed their capacity and the risks of failure to develop an exascale system are too high to be borne by industry alone.

Equally, public funding alone will not be sufficient to finance the broad uptake of HPC in the European industry in coming years and notably SMEs.

Problem Driver Nr 2: European HPC system vendors face stiff competition from large foreign corporations

Relatively small European HPC system vendors face stiff competition from large foreign corporations supported by their governments on the open European HPC market. European HPC vendors face asymmetries in major HPC markets outside of Europe due to national regulations e.g. for national security.

The concern that the EU is relegated against its global competitors in a field as strategic as supercomputing is among the main reasons for respondents to the consultation for a new action at EU level that goes beyond current actions (see Annex 2).

Other countries such the USA have long-standing models for R&D collaborations with indigenous HPC vendors, many of which include supercomputer procurements with strong R&D requirements.

Building an HPC ecosystem is a significant challenge, because the EU has historically been the most open major HPC market in the world, in part because it has not had an indigenous HPC system vendor large enough to compete with US, Japanese or Chinese vendors. As a result, in 2014, 81.2% of all European HPC server system spending profited US vendors. The only sizeable Europe-based vendor, Atos-Bull, accounted for only ~2% of European HPC server spending in 2014. It has had some successes outside of Europe, but still relies on European sales for a large majority of its HPC revenues.

This unsatisfying situation is exacerbated by three factors:

i. European HPC system vendors face asymmetries in major HPC markets outside the EU due to national regulations, e.g. related to national security.

ii. The EU market for HPC hardware systems and parallel software is still too small and fragmented to support EU-based HPC vendors. They cannot thrive and continually fund world-class innovation unless they can match the investments of competitors (especially USA and China) that have strong domestic demand and easier access to the global market.

iii. Intellectual property rights developed in EU research projects relevant to HPC often benefit non-EU parents of participating companies as the current EU Framework Programme for Research and Innovation imposes limited restrictions on the transfer of rights to affiliates in third countries.

Concerning the 1st factor, in the USA the acquisitions of supercomputers by US federal agencies are restricted by the "Buy American" Act, although purchasing of software and components of non-US origin is often allowed. In China, the fast-growing HPC market has been dominated historically by US supercomputer vendors, because Chinese HPC vendors have not been able to compete effectively. More recently, the Chinese government directed investment banks and other "critical infrastructure" sites to cease acquiring non-Chinese HPC systems. In Japan, the government market has historically tended to favour Japanese supercomputers, although non-Japanese ones also had some success in this market.

Concerning the 2nd factor, the EU has a lower aggregate level of HPC resources compared to other large economies around the world. With regard to the top 500 machines, the USA have ~50% more HPC resources than the EU, and China and Japan together have approximately twice the resources of the EU. These differences are significant as these three global blocs have comparable nominal economic GDP outputs. In other words, there is currently indeed a structural weakness in EU HPC resources.

Concerning the 3rd factor, there are provisions in the EU Research Framework Programme that can contractually oblige an organisation to disclose such transfers. These restrictions are certainly helpful although not as severe as in other countries developing HPC technologies outside the EU. In addition to issues related to IPRs and their transfers, probably an even more important aspect is that a stronger HPC ecosystem in the EU is likely to open up new and attractive career opportunities for top scientists and engineers and reduce the brain drain from the EU.

2.4. Who is affected and in what ways?

A joint structure coordinating and pooling the resources at European level will mobilise the necessary resources at European level to provide a world-class pan-European infrastructure and a strong European HPC ecosystem with lasting benefits in Europe. Europe in principle has the human potential and technological know-how to develop such an ecosystem along the whole HPC value chain.

The following group of stakeholders are likely to be directly or indirectly affected by the initiative (see Annex 3 for an extended analysis).

MEMBER STATES

MS are expected to significantly benefit from the initiative. The EuroHPC initiative will enable them to coordinate together with the EC their HPC investments and strategies. The joint initiative will make it possible for them to access a world-class HPC infrastructure that no single country on its own can afford in particular those with little or no significant HPC resources in place.

The increased availability and accessibility of top HPC resources will motivate the users to keep their activities and data in Europe, helping to keep critical know-how and human potential in MS.

SCIENCE - UNIVERSITIES AND RESEARCH CENTRES

Thanks to a joint structure that ensures the sustainability and availability of resources in the short, medium and long terms, EuroHPC will ensure a European-wide access for researchers in Europe's Universities and Research Centres to supercomputers and data with a guaranteed high level of resources, and irrespective of their geographical location or scientific discipline. This factor is critical to ensure that the academic and scientific potential stays in Europe and is not exploited in other regions with more competitive HPC resources.

A sustainable joint structure supported by the EC and MS will also consolidate the already existing vibrant mix of national, regional and pan-European initiatives in intra-EU scientific collaboration, and will provide EU-based teams with powerful resources to strengthen the European presence in international scientific endeavours.

INDUSTRY INCLUDING SMES

The new initiative will revitalise the European HPC ecosystem, where industry and in particular SMEs will benefit as both users and suppliers of HPC technology and applications.

- **As users**; EuroHPC will consolidate European leadership in many HPC-empowered applications by making available more resources for industrial use accessible at EU level, complemented with specific measures to widen the usage of HPC technologies. This is of critical importance to industry and particularly SMEs without in-house capabilities that will benefit from easy to use HPC resources, applications and analytics tools to create new innovative products and processes.
- **As suppliers**; a European-wide initiative with a focus on the supply of a European source of HPC technology and the protection of European IPR will have the necessary critical mass and a catalytic effect on the European suppliers. A clear R&I roadmap at European level provides a unique opportunity for industry, including SMEs, to participate in the co-design and development of such new technologies and systems, and to develop IPR and solutions to be further used in their business endeavours.

EUROPEAN COMMISSION (EC)

The EuroHPC initiative would solve the current complexity of implementing the HPC activities through two different programmes (CEF and H2020) and three different H2020 WPs (FET, LEIT-ICT and Research Infrastructures). The EuroHPC entity will provide a single structure and financial framework to coordinate the different activities in synergy. Most importantly, it will provide a single forum for strategic discussions with the MS and leverage EU and national efforts and resources.

The EuroHPC entity will also be a privileged interlocutor for institutions, agencies and bodies addressing critical scientific, industrial or social-impact areas. It will become a focal point for better supporting the EU policy development and implementation in areas like digitising industry (DSM), security, and many other related to societal challenges.

SUPERCOMPUTING CENTRES

The EuroHPC entity will provide the appropriate frame to strategically plan for the further development and the federation of supercomputing centres at European, national and regional level. The joint structure will avoid redundancies and will exploit complementarities with a European-wide planning of the different architectures across Europe (for example avoiding isolated and uncoordinated procurements that may end up in dependencies on single vendors and technological suppliers). EuroHPC also provides the opportunity to fully exploit the world-class HPC infrastructure and human resources of the European supercomputing centres in a synergetic way, encompassing the co-design and integration of technology with a coordinated procurement of supercomputers at European level.

CITIZENS

EuroHPC will ensure that world-class HPC resources and data are available for applications that are of direct interest for citizens. Given the inter-disciplinary nature of HPC and the wide range of scientific and industrial applications that will be made available at EU level, citizens will benefit from an increased level of resources provided by EuroHPC in areas like:

- Health, demographic change and wellbeing
- Secure, clean and efficient energy
- Smart, green and integrated urban planning
- Cybersecurity
- Weather forecasting and Climate change
- Food security

THIRD COUNTRY ACTORS

Successfully building a European HPC ecosystem will have an effect on the non-EU supply industry. The focus on the new instrument to produce, co-design and take-up of European technology in the next generations of European supercomputers will make EU technology more competitive. This will eventually decrease the market share of non-EU HPC components and systems in Europe, potentially worldwide.

The increased protection of European IPR resulting from the R&I programmes supported by the EuroHPC, may stop the current situation of non-EU suppliers taking advantage of EU programmes to export the resulting IPR and improving their domestic developments.

Provided access conditions on equal terms becomes a global practice, the European HPC resources could become attractive for scientists from outside the EU, sending their data for processing to Europe. The risk Europe currently faces with losing its data sovereignty may thus be reversed.

2.5. How would the problem evolve?

There is an arms-race world-wide to develop and operate ever more powerful supercomputers. This is driven by the strategic importance for a nation and an economy for top-level computational power, but also driven by the growing demands of the scientists to solve ever more complex problems. The renewal of a machine every 5 years at the end of its lifetime increases the costs for the development, installation and operation of the machine by a factor two.

The costs have now grown to an extent that they have become prohibitive for most market actors, including for most national governments in Europe. The effect has started to show as Europe is slowly dropping out of the first league of supercomputers. After a height of four machines ranking in the top 10 most performing supercomputers worldwide in 2012, the number has been steadily decreasing since, until EU based machines dropped out altogether from the top 10 list in 2017, despite recent acquisitions/upgrades at several sites across the EU. Without an increased effort to invest more or more efficiently, for example by pooling resources in Europe and coordinating acquisition planning, this trend will continue and accelerate.

According to the IDC study on High Performance Computing in the EU: Progress on the Implementation of the European HPC Strategy[19] *"... High-end supercomputers at national centres in Europe, the U.S., and Japan (but not China) are regularly oversubscribed – the demand for computing cycles typically exceeds the supply by a factor of two to three. European high-end supercomputers are no exception…*". The demand for HPC is expected to increase considerably in the coming years, for example as more and more users, in particular SMEs, become part of the digital economy and make use of HPC for their business processes. This is paired with a hunger for higher computing power as the applications increase in complexity and include big data analysis. The gap between demand and supply of the most performant computing facilities will thus increase.

A growing gap of available computing performance will motivate more and more European scientists to implement their calculations outside Europe. Europe thus runs the risk of losing control of its scientific data, but eventually also the brain drain of its scientists as they move closer to the computing facilities. The situation is similar for the industrial users who will not renew their service contracts with European supercomputing centres, but replace them with contracts outside the EU in order to stay competitive on a global market.

The move of the users outside Europe would have a cascading effect on the supercomputing skills in Europe. Indeed, the supercomputing centres work closely with the users, equipment suppliers and program developers to adapt the applications to the architecture of the supercomputers and optimize the use of computing resources. This co-design approach is essential for an effective exploitation of the supercomputers and requires a profound understanding of the machine's architecture and behaviour. Breaking this co-design chain will gradually erode the skills of the supercomputing centres to offer competitive computing services as they would not be involved in the design of the most powerful machines. Ultimately, Europe runs the risk to lack the competences to design and operate exascale machines and offer computing services to the most demanding applications. The European suppliers with the competences and financial resources to provide the European market with the required machines, without public intervention hesitate to take the risk to invest in this field. Indeed, the market size of high-end machines is very small, maximum 100 machines per year worldwide but mostly in very closed and inaccessible markets for European vendors.

The situation is identical for the European competitors in the USA, China and Japan. Those countries have already declared HPC to be a strategic priority for their country**.** As a consequence their governments fund programmes to develop national HPC ecosystems and work on the deployment of exascale supercomputers. As a consequence USA vendors (with new Chinese players) will continue to dominate the market.

If no effective measures are taken to bring the EU back in the HPC race with EU technology, the dependency of Europe on non-EU suppliers will continue to grow. Otherwise the industrial base of European suppliers will continue to decrease as the companies either stop their HPC products (e.g. Eurotech), or do not find sufficient market share to survive. As a consequence the European HPC ecosystem will further erode.

The dominant suppliers like Intel, due to their market share, are dictating the prices and are gradually pushing European competitors out of the market. Initially those suppliers were in essence supplying the cores of the supercomputers, giving European suppliers the possibility to provide the other components (e.g. interconnects) and integrate them in the computing boards. Gradually the dominant suppliers started to provide the other components too, proposing complete solutions. The procurers of the machines on one hand have less and less the choice to include components from European suppliers as the solutions offered by dominant suppliers provide less and less integration possibilities. In the absence of a European supplier of the computing cores, the procurers are becoming more and more dependent on complete packages, limiting their possibility to co-design the machines according to their needs.

Moreover, there is a risk that due to certain strategic or political decisions, such as export restrictions, sooner or later Europe will not have access to the most competitive and innovative technology, exacerbating the gaps described above. Therefore, to mediate the risks, the European HPC strategy has identified an action to develop one of the critical components of the exascale machines, i.e. the multipurpose low power processor.

3. WHY SHOULD THE EU ACT?

3.1. Why do we need to act now?

The problems and risks detailed in the previous section require urgent action at European level. Our world competitors massively fund programmes to develop national HPC ecosystems and work on the deployment of exascale supercomputers, with a particular focus on the development of indigenous HPC supply chains that are essential for economic development and for security and safety.

> To stay competitive in the HPC race Europe needs to acquire exascale supercomputers by 2022/23 and develop its technology supply chain that guarantees access to latest HPC systems. **To reach the target the work has to start now, since a development cycle typically takes 5 years. USA, China and Japan have also set 2022/23 as a target date.**

From the drawing board to the operational machine, the different components have to be developed and then integrated into the machine. An intermediate, key milestone is the development of the pre-exascale machines by 2020, where the initial design will be validated and the prospects of reaching the exascale target will be assessed. Any delay in the acquisition of the pre-exascale would equally delay the development of the exascale targets. Without more investments in the years 2018-2020 there is the risk that the pre-exascale target cannot be met, jeopardizing the longer term objective of the exascale machines.

The EU funds to acquire the pre-exascale machines and develop its ecosystem are available now (EUR 486 million, already committed in H2020 and CEF WPs 2019-2020 to HPC activities). There is also evidence from several MS/AC (at least those which signed the EuroHPC declaration) that they are prepared to commit similar funding levels in the same period to implement the joint EuroHPC activities.

Setting up a self-standing EuroHPC entity in 2019 will ensure that Europe takes action in a timely and coordinated way, with joint investments in leading-edge HPC technology and infrastructures. It would allow Europe to acquire world-class pre-exascale machines and stay competitive in leading scientific and industrial applications for the period 2020 to 2025; and, equally important, to build in Europe the necessary ecosystem to develop competitive European technology for the pre- and full exascale computing era.

In an eventual support of the EuroHPC entity under the next MFF, this would allow to continue its operations and in particular to: procure and deploy two world-class exascale machines (based on European-funded technology); support the development of ambitious extreme scale applications for public and private users and of HPC skills; and, continue to support R&I activities, notably a competitive low-power European microprocessor and post-exascale HPC machines and their linking to the first quantum computing infrastructures that would have been developed under the Quantum Technologies FET Flagship.

3.2. The right to act at EU level

The fragmentation of public HPC services across the EU and within MS leads to inefficient use of resources and only partial cross-border exchange of expertise. The increasing costs of building and maintaining HPC infrastructures require stronger governance at EU level and the rationalisation of HPC resources to reduce the current fragmentation.

HPC is an essential instrument to address societal challenges like health and security. Both are policies of shared European interest, as exemplified in the NIS Directive[28] or the Cybersecurity Communication[29], addressing issues that do not stop at national borders. The level of security or the quality of public health in one MS depends from the situation in the rest of the EU.

HPC is fundamental to build the data economy. Controlling how the data is used, who has the ownership and right for exploitation, where it is stored, and who has access to it are sensitive issues. It touches commercial and copyright issues, but also data protection and privacy issues. All these issues have been identified as political priorities in the Digital Single Market (DSM). Sending sensitive European data for processing in other regions of the world, where the high European standards of privacy, data protection, copyright, etc. are not necessarily respected, undermines the intention to gain sovereignty on European data and its exploitation.

The scale of the resources that are needed to realise a sustainable exascale level HPC infrastructure and ecosystem is beyond what national governments can nowadays afford to invest. **No single Member State has the financial means to acquire exascale computing capabilities and develop, acquire and operate the necessary exascale HPC ecosystem on its own and in competitive time frames with respect to the USA, China or Japan**. Member States and national actors have now realised that they will only be able to remain competitive through a joint and coordinated EU-wide effort – c.f. the EuroHPC declaration of 23.03.2017.

This justifies the right for the EU to act in the field of HPC under Article 179 that states that *"The Union shall have the objective of strengthening its scientific and technological bases by achieving a European research area in which researchers, scientific knowledge and technology circulate freely, and encouraging it to become more competitive, including in its industry, while promoting all the research activities deemed necessary by virtue of other Chapters of the Treaties"*. In addition, Article 187 TFEU gives authorisation to *"set up joint undertakings or any other structure necessary for the efficient execution of Union research, technological development and demonstration programmes"*.

3.3. Subsidiarity

Knowledge and resources available in Europe need to be put together for the building of a leading edge HPC ecosystem across all value chain segments. National resources alone are insufficient. EU coordination of investments and resulting services is necessary in order to have HPC computing and data infrastructures as well as a full HPC ecosystem in Europe on a par with the USA, China or Japan.

The importance of HPC for science, and the public and private sectors has grown in recent years together with the exponential rise in the investments required to stay globally competitive. This has led to a common understanding that the "Europeanisation" of this domain via a shared infrastructure and common use of existing capabilities would benefit everyone. This also applies to Member States with difficulties in creating self-sufficient

[28] OJ L 194, 19.7.2016, p. 1–30

[29] JOIN(2017) 450 final

national HPC infrastructures whereas they can make valuable contributions to and benefit from federated and interconnected EU-level HPC capabilities.

Cooperation exists already in some areas among Member States, industry and science actors. Examples include PRACE, the HPC cPPP, the Big Data PPP and GÉANT. EuroHPC builds on them as the key investors in the EuroHPC signatory countries are already represented there.

There is however a need for a legal and financial framework closing the chain from R&D to the delivery and operation of the exascale HPC systems co-designed between users and suppliers. Such new framework would support the development of a pan-European HPC and data infrastructure built on European technologies, allowing the blending of different EU financing sources with national and private funding. It would stimulate joint investment to cover the ever increasing costs of building and maintaining world class HPC and data infrastructures and to optimise a number of important procurement factors, such as strategic planning for funding of top-level systems, user's coverage, diversity of systems architecture, etc. Ultimately, it would permit to build-up a critical mass in the HPC market to foster a true European HPC ecosystem that encourages and supports a competitive European HPC supply industry.

As described in the introduction, political support from Member States on EuroHPC has already been explicitly given by the Council, by the signatories of the EuroHPC Declaration, and by the European Parliament.

3.4. EU added value

The proposed initiative represents a natural candidate for European action with the EU and Member States implementing the EuroHPC strategy via the most appropriate legal instrument.

It is only by acting at EU level that we will be able to pool together the necessary effort and create the critical mass needed to acquire leading next generation exascale systems which are in the order of hundreds of millions of Euros. Only by working at EU-level and combining investments, knowledge and skills Europe has a chance to keep-up to its competitors. At the same time, pooling the investments to jointly acquire exascale machines will create significantly higher return-on-investment (ROI) for each of the partial-owners of the machines, than the ROI of the full ownership of a lesser performing machine.[30]

Availability of top class HPC systems would enable European players to further develop a whole range of present and future scientific and industrial applications that would require exascale performance. It would permit funding the HPC related research and developing the necessary expertise, skills and capabilities for programming such systems efficiently and exploiting their full potential. And, most importantly, it will enable all European scientists, public administrations and industry to access this infrastructure and foster a wide range of cross-border collaboration and new products and services.

Finally, by pooling the fragmented knowledge and the expertise existing all around, Europe can build the full supply chain for HPC systems: from technology components and systems to full machines. These are at the same time essential technologies in a variety of other mass markets (such as automotive, consumer electronics, servers, etc.). The transition to exascale computing, supported by joint EU/MS investments acting as lead market users, would provide

[30] IDC special study 2016 "Investigation of the Ripple Effects of Developing and Utilizing Leadership Supercomputers in Japan: The Scientific and Financial Returns from the K Computer and Possibilities from the Post-K Computer"

an opportunity for the European supply industry to leverage on such investments and get access to new markets estimated to EUR 1 trillion.

Overall, the creation of a globally competitive HPC environment in Europe, triggered by public intervention, creates goods and services that are of a truly public value for European science and industry: It will help the private and the public sectors to create leading-edge science, technologies and solutions benefiting all areas of the economy and society, contributing to the EU's objectives of economic growth, jobs and competitiveness.

4. OBJECTIVES: WHAT SHOULD BE ACHIEVED?

4.1. Overall objectives of the EuroHPC entity and instrument

To address the problems identified in section 2, we propose to establish a new legal and financial instrument that would permit to implement the joint EuroHPC entity. Its overall mission would be to provide European scientists, industry and the public sector with the latest HPC and data infrastructure and support the development of its technologies and applications across a wide range of fields.

The (EuroHPC) instrument would have to address the following three overall objectives:

1. Support a joint procurement framework for an integrated world-class exascale supercomputing and data infrastructure in Europe. Such infrastructure will be accessible on a non-economic basis to public and private users for publicly funded research purposes[31];
2. Ensure a EU level coordination and adequate financial resources to support the development, procurement and operation of such a public infrastructure;
3. Support the research and development of an integrated European HPC ecosystem, covering all scientific and industrial value chain segments (hardware, software, applications, services, interconnections and skills).

4.2. Functionalities of the EuroHPC instrument

To reach its objectives, the EuroHPC instrument has to meet several functional requirements:

[Pooling together public and private resources] The legal instrument would have to support the joint procurement and operation of a European HPC infrastructure as well as R&I activities for the development of European HPC technology and excellence in applications. To reach the necessary investment levels to meet its objectives, the instrument has to make possible the pooling of public funds (from the EU and the MS/AC), as well as financial or in-kind contributions from the private sector. The Union's financial contribution would come from the budgets already allocated to H2020 and CEF WPs in 2019 and 2020. Those funds would have to be matched by a similar amount from the MS and AC, as well as by the private sector.

[Procuring HPC machines] The legal instrument should enable the EuroHPC entity to launch calls for tender to acquire the pre-exascale machines and select the successful tenderers. As EuroHPC is a joint initiative it would act as trusted manager of the procurement process on behalf of all participating countries. To reduce the administrative burden the legal instrument should permit the application of European procurement rules. Ideally, the legal instrument should allow an exemption from VAT to reduce the overall cost of the systems to be procured.

[Openness to new partners] The legal instrument would have to allow new MS/AC to join

[31] HPC services to industry for private use may also be provide under commercial conditions.

the EuroHPC entity upon their request, subject to their financial commitment. EuroHPC could then start with a core group of participants that are ready at the launch of the instrument and gradually accept new members.

[Enabling participation of the private sector] for defining and implementing the EuroHPC strategic R&I and application development agenda, stimulating large private investments in the field… ***while mitigating any eventual conflicts of interest in public procurement processes:*** While enabling private participation would be fundamental, the EuroHPC instrument would also have to make possible to include provisions for avoiding conflicts of interest, notably by making sure that there is no interference of the participating technology supply industry neither in the joint public procurement process of the pre-exascale machines nor on how the public funds are spent.

[Implementing a R&I programme which can address the present programme coordination inefficiencies in implementing the HPC strategy], in particular the difficult coordination and synchronisation of the different H2020 and CEF HPC WPs. This could be addressed by ***delegating the implementation of the related budget to the EuroHPC (legal) entity***. Its governing body could then align the content and the respective timings of the different calls with the HPC strategic agenda; ensure coherence between the topics of the different calls; and put in place the appropriate funding instruments to reach the objectives, in particular innovation procurement for accompanying the route from European HPC technology development to the procurement of European machines. Furthermore, by using the H2020 rules, the EuroHPC instrument should make it possible to introduce provisions to protect the economic and strategic interests of the Union, i.e. protecting IPRs produced in the EU and first exploiting in Europe all EU-funded R&I results.

[Safeguarding the Union's interest through EC participation] The EuroHPC instrument should foresee the possibility for the EU represented by the Commission to be part of its governance. That would ensure that the EC can play a significant role in the definition of the strategic orientation and priorities of the EuroHPC entity, and take part in the decisions on how its budget is allocated and spent. In essence, the legal instrument would have to permit a delegation of the EC funds to the legal entity, rather than a co-fund.

[Lifetime] The EuroHPC instrument would have to exist until the termination of all its activities that would be launched in 2019 and 2020. Considering the typical duration of the H2020 grants and the typical lifetime of an HPC machine, the legal instrument would have to operate until approximately end 2026.

To summarise, the EuroHPC instrument would have to address the following functionalities:

Pool public and private funds
Execute joint procurements while operating under EU-law (e.g. VAT exemption, procurement rules, …)
Implement a R&I programme which can address the present coordination inefficiencies in implementing the HPC strategy
Remain open to incorporate new MS/AC willing to join
Enable participation of the private sector
Safeguard the Union's interest (the Union will be represented by the Commission)

4.3. Specific Objectives

Considering the general objectives of the previous section within the broader context of the European HPC Strategy, the EuroHPC entity and its related instrument should achieve the following specific objectives, grouped in three pillars. The overall EuroHPC objectives can only be achieved if all the three pillars are implemented, as each of them is necessary to create the European HPC ecosystem.

Pillar 1: Infrastructure development, acquisition and operations	
T1	Procurement and operation of world-class HPC and data infrastructures for European use, in particular aiming at procuring and operating two pre-exascale HPC machines (2020).
T2	Interconnecting regional, national and European HPC resources (pre-exascale machines, data centres and associated software and applications) through an HPC and Big Data service infrastructure facility.
T3	Providing access to HPC-based infrastructures and services to a wide range of users (scientific and industrial users including SMEs, and the public sector) for new and emerging data and compute-intensive applications and services.
Pillar 2: Applications and skills development and a wide use of HPC	
T4	Achieving excellence in HPC applications through, for example, development and optimisation of codes and applications in a co-design approach, support to Centres of Excellence in HPC applications, and large-scale HPC-enabled pilot demonstrators and test-beds for big data applications and services in a wide range of scientific and industrial areas.
T5	Increasing the innovation potential of industry, and in particular of SMEs, using advanced HPC infrastructures and services, for example via dedicated digital innovation hubs.
T6	Outreach and training actions for attracting human resources to HPC and increasing skills and engineering know-how of the EuroHPC ecosystem.
Pillar 3: Research & Innovation agenda for European technology & know-how development	
T7	Developing the next generation of key HPC technologies and systems towards exascale addressing the whole European technology spectrum from low-power microprocessors and related technologies to software, algorithms, programming models and tools, to novel architectures and their system integration through a co-design approach.

5. Available Policy Options

5.1. Option 0: Baseline from which the policy options are assessed

The HPC strategy is implemented at EU level mainly via H2020 and CEF:

- *The development of the European HPC technology* is addressed in the H2020 FET and LEIT-ICT WPs, from the research of the underlying concepts up to their integration; including the co-design and prototyping of HPC machines. The EC is supported by the cPPP (ETP4HPC) which submits every year its strategic research agenda (SRA) to the EC. The SRA provides the long term planning of activities necessary each year to reach the objectives of building a world-class HPC technology supply chain in Europe, including an estimate of the required budgets. Based on this input the EC then drafts the relevant work-programmes.
- *The development of the HPC infrastructure* is addressed in the H2020 Research Infrastructures and CEF WPs. The EC provides funding to facilitate access of European scientists to the Tier-0 machines operated by PRACE. This includes financial support to the additional services PRACE provides to the user communities, complementing the work of the HPC Centres of Excellence (CoE).[14] While PRACE is an organisation independent from the EC, the CoEs are a creation of the EC and are almost exclusively funded from the H2020 budget.

Due to the different nature of the HPC activities funded by the EC, their difference in scope, and annual budget limitations, the activities are implemented in four different WPs: FET, LEIT-ICT, Research Infrastructures and CEF, each with its own selection process and timing.

The EC publishes open and competitive calls for proposals. Any beneficiary eligible for H2020 funding can apply, irrespective of whether it is member of the HPC cPPP. For the period 2018-2020, around EUR 110 million have been committed for HPC activities in CEF and another EUR 640 million in H2020.

The R&D projects funded through the H2020 calls are generally reaching their objectives (as this is acknowledged by the project reviews carried out by independent experts) and contribute to establishing the European HPC ecosystem. However, as mentioned in section 2.2, today the EC has difficulties in implementing coherently and effectively the HPC research roadmap because its activities are funded through four different WPs of H2020 and CEF; and there is a lack of continuity in supporting research teams from R&D components to systems development and integration and ultimately to innovation.

The current implementation has also weaknesses with respect to the protection of the IPRs. The H2020 calls are open to any legally established legal entity, based in a MS or third country. As non-European entities can participate in H2020 grants, either directly, or through their European subsidiaries, R&I results are often transferred and exploited out of the EU. The H2020 Grant Agreement includes optional provisions to protect the European interests such as Article 30.3 which requires beneficiaries to notify the EC before they transfer the results and gives the EC the right to object. This option is validated by default for the running and upcoming H2020 HPC projects. Any further measure to protect the European IPR is unlikely to be implemented before the end of H2020, as this would require an amendment of the H2020 rules for participation.

Could the shortcomings of the baseline scenario be effectively addressed by revising the existing instruments, i.e. amend the mandate of the HPC cPPP, extend the mission of PRACE, or evolve the H2020 rules and procedures?

PRACE provides the most powerful supercomputers in Europe but PRACE does not aim to coordinate national programmes or investments in the procurement of HPC systems. PRACE was created in 2010 and a new agreement entered into force in 2016/2017. With the new agreement, there is a small financial contribution to PRACE of the members not hosting a Tier-0 machine. Eventually a new agreement could be negotiated to include the Union, represented by the EC, as a member; a coordination of the procurement; and a revision of the governance. However this is unlikely to happen because: (i) the hosting countries will continue to protect their national interests and not lose control over their Tier-0 supercomputers; and (ii) the PRACE machines are owned by the Tier-0 hosting countries and are designed and developed to primarily satisfy national research needs, in accordance with the relevant national strategies and programmes and do not necessarily cover wider European user needs.

The mandate of the HPC cPPP is limited in time and is foreseen to be revised after 2020. The cPPP is playing a valuable role in defining and implementing the HPC strategic research agenda and leveraging private funding. One of its weaknesses is that its membership is open to non-EU actors. As a result the dominant, non-EU suppliers are today part of it, influencing the definition of the H2020 workprogrammes. This makes it more difficult for European market actors to develop European technology that finds its way into the subsequent procurement of machines.

Finally, the use of different H2020 and CEF WPs for HPC and their challenging coordination can only be resolved by a revision of the H2020 Regulation, by integrating them into a single pillar. Such revision is not feasible any more. Even if it this was the case, it would resolve coordination of H2020 activities but not the coordination with CEF.

Therefore, this option does not allow neither the pooling and efficient synchronisation of the EU investments (as they are split across multiple programmes and areas), nor the coordination of the EU activities funded by the EU budget with those of the MS. This kind of approach already proved to be insufficient in bringing about an EU-wide HPC ecosystem as this is also reflected in the 2017 EuroHPC Declaration by MS and further validated by the findings of the EuroHPC targeted consultation. Fragmentation of HPC programmes and efforts in Europe and the lack of coordination of activities was the main problem for the computing centres and the scientific users that responded to the public consultation.

5.2. Options considered for implementing EuroHPC but discarded at an early stage

<u>*Option: EEIG*</u>

The European Economic Interest Grouping (EEIG)[32] is a cooperation form, similar to national consortia, but ruled mainly by European law. That means its core rules are common throughout the whole EU, and national rules are required only for a few issues (e.g. nullity, dissolution, some profiles of a grouping's administration).

An EEIG is a type of legal entity designed to make it easier for companies in different countries to do business together or to form consortia to take part in EU programmes. A main usage of this supranational type of enterprise is to facilitate co-operation in European programmes especially for small and medium-sized enterprises (SMEs).

The EEIG differs from other companies first and foremost in its purpose. It is supposed to help its members to develop or improve their own fields of activity. Thus, the EEIG can be used to develop certain common activities which would be too expensive for single members. Because of this auxiliary nature the activity of an EEIG has to be connected to the economic activity of its members. Not only SMEs, but basically every company or firm and all institutions governed by public or private law can be a member of an EEIG.

[32] Legal basis for the EEIG is Regulation No. 2137/85. The implementation of some provisions was deferred to Member States; each state passed implementation laws which rule certain matters relating to groupings and set up the necessary rules for the registration of groupings. EEIGs thus are harmonised as they refer to one single law, the EC Regulation, which is equal for all Member States.

The EEIG is eligible to participate in procurement procedures. However, the EEIG can only participate as a beneficiary. It cannot coordinate the procurements of the EC and the MS, nor can it implement a joint procurement. The procurement would still have to be implemented by the MS and/or the EC.

As the EEIG has full legal capacity, its participation in EU R&I projects as partner or coordinator is possible. The EEIG is eligible to receive community funds. However, this option does not effectively address the problem of fostering the supply of European technology. As in the baseline scenario, the EEIG would be in competition with non-European applicants for the H2020 calls. Also the problem of ensuring continuity of the actions between subsequent calls remains as well as the problem that the EC has with the synchronisation of HPC investments under different H2020 and CEF WPs.

Option: Galileo-type programme

In a Galileo-like programme the EU has the sole ownership of the programme and delegates its implementation to a separate legal entity. ***In discussions with the EuroHPC signatory countries, they have clearly expressed their preference for a legal instrument where they would have co-ownership of the activities, in particular for the procurement and operation of the EuroHPC machines***.

The legal basic act setting up the Galileo-like programme would have to be followed by a delegated act to a legal entity for its implementation. The overall process is expected to take around 3 years. Such timing is incompatible with the EuroHPC plans as discussed above, making it impossible for the EuroHPC to reach the targets set for jointly procured pre-exascale systems by 2019-2020. It would also highly compromise all the longer term plans in developing and procuring exascale systems based on European technology by 2022/2023.

Option: Intergovernmental organisations

An intergovernmental organisation like the European Space Agency (ESA) is an agency established by a convention between its participating states, establishing a joint programme between Member States. The Member States signing EuroHPC have not proposed the creation of an intergovernmental organisation and the EC does not have the right in the Treaty to put forward such a legal form in a regulation. The EC can only participate in joint activities after negotiating a Cooperation Framework. As the EC would not be part of the governance the EC would have a limited influence on the definition of the calls for funding the joint activities, nor would the EC have a say on the acquisition and operation of the supercomputers. Finally, establishing such an organisation is unlikely to be operational by 2019, when the activities of the new legal entity have to start, as discussed above. In summary, this option would not lead to a legal entity that can jointly procure and operate HPC machines.

The following table compares the baseline scenario and the discarded options against the functionalities which the new legal instrument should fulfil. As can be seen, none of them fulfils all the functionalities.

	Baseline Scenario	EEIG	Galileo-type	Intergovernmental Organisation
Pool public and private funds	0	0	0	0
Execute joint procurements while operating under EU-law	0	0	OK	0
Implement a R&I programme	OK	maybe	0	OK
Remain open to incorporate new MS/AC willing to join	OK	0	0	OK
Enable participation of the private sector	OK	OK	OK	0
Safeguard the Union's interest through EC participation	OK	0	OK	0

5.3. Option 1: ERIC

The Community legal framework for a European Research Infrastructure Consortium (ERIC) is a specific legal form to facilitate the establishment and operation of research infrastructures[33] with a clear European interest and the involvement of several European countries.[34]

The principal task of an ERIC is to establish and operate a research infrastructure on a non-economic basis. An ERIC can be used for establishing new research infrastructures or for operating existing research infrastructures which consider it useful to change their legal structure to become an ERIC.

The ERIC can thus interconnect and federate regional, national and European HPC resources provided the research infrastructure meets the requirements set out in the ERIC regulation. The ERIC can provide the management of the coordination between the infrastructure and existing national computation resources and also, if agreed, regional computation resources.

The ERIC framework has been developed primarily for new high-profile research infrastructures with a European dimension.[35] Complementing national and inter-governmental schemes, the ERIC Regulation provides a common legal framework based on Article 187 TFEU. The ERIC has legal personality and full legal capacity recognised in all MS.

Although an ERIC can be the beneficiary of H2020 grants, its current mandate does not allow it to get delegation to implement part of the H2020 programme. Therefore the ERIC would

[33] According to Article 2(a) "Research infrastructure" means facilities, resources and related services that are used by the scientific community to conduct top-level research in their respective fields and covers major scientific equipment or sets of instruments; knowledge-based resources such as collections, archives or structures for scientific information; enabling Information and Communication Technology based infrastructures such as Grid, computing, software and communication, or any other entity of a unique nature essential to achieve excellence in research.

[34] Council Regulation (EC) No 723/2009 of 25 June 2009 on the Community legal framework for a European Research Infrastructure Consortium (ERIC), OJ L 206, 8.8.2009, p.1.

[35] ERIC examples are the Integrated Carbon Observation System (ICOS ERIC), the European Multidisciplinary Seafloor and Water Column Observatory (EMSO ERIC), the Central European Research Infrastructure Consortium (CERIC ERIC).

not be able to define a strategic R&I agenda and implement it, but would depend on the H2020 WPs defined and implemented by the EC.

ERIC's basic internal structure is flexible, leaving the members to define the statutes, membership rights and obligations, as well as the bodies of the ERIC and their competences, while complying with the essential requirements provided for in the ERIC Regulation.

The members of an ERIC can be MS, ACs, third countries other than the AC and intergovernmental organisations.

The EU represented by the Commission may participate in an ERIC. However, the EU participation as a full member in the ERIC and the way it would make available its financial contribution are currently not foreseen[36] and would have to be defined in some way. While the ERIC Regulation leaves open the possibility of the EC (as an international organisation) to become a member of an ERIC and to contribute through its membership to the ERIC, this has not been the case in any of the 17 ERICs that have been established until now. In practice, the participation of the EC in an ERIC in whatever form would create a situation of conflict of interest whenever the ERIC would participate in calls from EU programmes, as the EU would both be allocating budgets for the ERIC from EU programmes (notably H2020 and CEF) and would be co-responsible in a wise spending of such funds.

The participation of industry is not foreseen in an ERIC. An ERIC as such is also closed to private funding, in turn restraining the participation and financial contribution by industry players to any future initiative. This is because the principal task of the ERIC is to establish and operate on a non-economic basis[37].

In principle, ***ERICs are not designed to pool resources from the EU and MS but mainly from the MS themselves.*** Likewise, it would make it difficult for an ERIC to implement a joint EU/MS procurement.

An ERIC is recognised by the country hosting its seat as an international body or organisation for the purposes of the directives on VAT and excise duties.[38] It also qualifies as international organisation for the purpose of the directive on public procurement.[39] An ERIC may therefore,

[36] Council Regulation (EC) No. 723/2009 of 25 June 2009 on the Community legal framework for a European Research Infrastructure Consortium (ERIC) – Recital (6): *"In contrast to Joint Technology Initiatives (JTI) constituted as Joint Undertakings of which the Community is a member and to which it makes financial contributions, a European Research Infrastructure Consortium (hereinafter referred to as 'ERIC') should not be conceived as a Community body within the meaning of Article 185 of Council Regulation (EC, Euratom) No 1605/2002 of 25 June 2002 on the Financial Regulation applicable to the general budget of the European Communities (1) (the Financial Regulation), but as a legal entity of which the Community is not necessarily a member and to which it does not make financial contributions within the meaning of Article 108(2)(f), of the Financial Regulation.*

[37] See Recital (8) of Council Regulation (EC) No. 723/2009: *"An ERIC set up under this Regulation should have as its principal task the establishment and operation of a research infrastructure on a non-economic basis and should devote most of its resources to this principal task. In order to promote innovation and knowledge and technology transfer, the ERIC should be allowed to carry out some limited economic activities if they are closely related to its principal task and they do not jeopardise its achievement. The establishment of research infrastructures as ERICs does not exclude that research infrastructures of pan-European interest that have another legal form can equally be recognised as contributing to the progress of European research, including to the implementation of the roadmap developed by ESFRI. The Commission should ensure that ESFRI members and other interested parties are informed about these alternative legal forms.*

[38] Council Directive 92/12/EEC of 25 February 1992 on the general arrangements for products subject to

[39] 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement and repealing Directive 2004/18/EC

under certain limits and conditions, benefit from exemptions from VAT and excise duties on its purchases in all EU MS and it may adopt procurement procedures respecting the principles of transparency, non-discrimination and competition but not subject to the directive on public procurement as implemented in national law.

The advantage of the ERIC is that it can be setup with a rather lightweight and fast process. This would give confidence that by 2019 the ERIC would be operational and could implement, at least partially, the objectives of the HPC strategy. However, this would not solve some of the present shortcomings of the baseline scenario, like the difficult synchronisation of calls. To include in the mandate of the ERIC the possibility to implement H2020 calls on behalf of the EC this would require a revision of the ERIC regulation, which in turn is a lengthy process.

Based on the above arguments, the table below summarises how the ERIC responds to the functional requirements the EuroHPC instrument should fulfil:

	ERIC
Pool public and private funds	ERICs are designed to pool resources mainly from the MS
Execute joint procurements while operating under EU-law	The EU participation as a full member in an ERIC is not foreseen, but under certain conditions the EC may participate. Joint EC/MS procurement is difficult
Implement a R&I programme	Current mandate does not allow ERIC to get delegation to implement part of the H2020 programme
Remain open to incorporate new MS/AC willing to join	OK
Enable participation of the private sector	Industry cannot become member of an ERIC
Safeguard the Union's interest through EC participation	The EU participation as a full member in an ERIC is not foreseen, but under certain conditions the EU may participate

5.4. Option 2: Joint Undertaking

A Joint Undertaking (JU) is a Union Body established under Art 187 TFEU[40], which can be used for the indirect management of the EU budget.[41] A JU is therefore an autonomous EU legal entity, with its own staff, budget, structure, rules and governance that can be tasked to implement actions under programmes such as H2020 and CEF. It can combine EU budget with other sources of funding (national, private, etc.), allowing the implementation of R&I and demonstration programmes in an integrated way. Public authorities at different levels from the MS (national, regional), the Union represented by the EC and other stakeholders like industry can become members of a JU.

JUs have been used in FP7 and H2020 to establish the Joint Technology Initiatives (JTIs): Public-Private Partnerships (PPPs) that define and implement the Strategic Research Agendas (SRAs) of a limited number of areas where the scale and scope of the objectives is such that

40 A JU is established by a Council Regulation, taking into account the opinion of the European Parliament and the European Economic and Social Committee.

41 In accordance with Art 58.1(c)(iv) of the Financial Regulation (FR)

loose co-ordination through European Technology Platforms (ETPs) and support through the regular instruments of the Union's Research Framework Programme are not sufficient.

According to their founding regulations JUs have their own governance structure but can also share some functions (e.g. internal audit) with other already existing JUs for efficiency reasons. Each JU includes a Governing Board, an Executive Director as well as other bodies, including advisory bodies, depending on its specific operational and governance needs.

JUs have a dedicated budget and staff and provide a framework for the public and, when appropriate, private players to work and take decisions together. They can organise calls for proposals and put in place implementation arrangements. They thus allow funds from different sources to be jointly managed and they are responsible for the related planning, monitoring and reporting activities.

JUs can also carry out procurement procedures. Each JU has its own procurement and financial rules adopted by the Governing Board, based on the Union's model Financial Regulation. Established as a Union body, a JU can benefit from VAT and excise duties on its purchases in all EU MS and may adopt procurement procedures not subject to the Directive on public procurement as implemented in national law.

JUs provide the legal, contractual and organisational framework to structure the joint commitments of public and private stakeholders and monitor the implementation against agreed Key Performance indicators (KPIs). In addition, they offer a firm governance structure and budgetary certainty to all stakeholders. JUs offer the possibility of joint activities between MS and the EU, allowing to keep e.g. MS/AC participation flexible according to country-specific priorities. Nevertheless, there is co-responsibility in the strategies and modes of implementation chosen.

A report of the Estonian presidency[42] reflected the very positive view that industry partners and researchers express on this kind of PPPs. The report indicates that such partnerships are a good instrument for strengthening the industrial base of Europe by connecting the European ecosystem to global companies and by encouraging good quality industry-led research which enables the EU to remain competitive and a leader in innovation and technology.

There are several good reasons to establish a JU in the area of HPC: (i) the added value of the combining EU and national funding; (ii) the coordination and rationalisation of procurement and R&I investments at European level; (iii) the possibility to safeguard the Union's interests as the EU can be member of the JU, by exerting its decisional powers in the JU Governing Board; (iv) the possibility to combine innovation procurement instruments (PCP and PPI) to fund the development of innovative European technology and procure afterwards this technology; (v) the possibility to protect the Union's economic interests (by activating the option provided for in Article 30.3 of the H2020 Model Grant Agreementrestricting the transfer of IPRs and Article 28 to first exploit the project results in the Union).

The ECSEL JU[43] is a good example for establishing and operating a JU in HPC. ECSEL has just been the object of an interim evaluation by an independent expert panel which concluded that ***the combination of EU, national and private investments under a single R&I scheme optimises the leverage of public funding and ensures a strong alignment of effort along a***

[42] "Increased coherence and openness of European Union research and innovation partnerships". Final Report, Republic of Estonia Government Office, Technopolis group, June 2017, http://www.technopolis-group.com/report/increased-coherence-openness-european-union-research-innovation-partnerships/

[43] ECSEL (http://www.ecsel-ju.eu/) attracts the industry and research community in the semiconductor and embedded systems domains, *OJ L 169, 7.6.2014, p. 152–178.*

unified European strategy. Over the years 2014-2016, the EU has invested in ECSEL EUR 460 million out of a total of EUR 1.2 billion until 2020. This has leveraged roughly the same amount of national funding and a double amount of funding from industry (corresponding to an EU funding leverage factor of 4.26). ECSEL JU is clearly recognised as successful in attracting the best European players in the semiconductor and electronic components and systems domains and has so far been instrumental in structuring the sector in Europe around a common SRA. A similar effect is expected with the EuroHPC JU. It is to be noted that the EC (DG CNECT) has an extensive experience acquired in the establishment and operation of the ECSEL JU, which can be used in setting up and running the EuroHPC JU.

Based on the arguments presented above the table below summarises how the JU responds to the functional requirements of the EuroHPC legal and financial instrument:

	Joint Undertaking
Pool public and private funds	Can combine EU budget with other sources of public and private funding
Execute joint procurements while operating under EU-law	Can carry out joint procurement - is recognised by the country hosting its seat as an international body or organisation for the purposes of the directives on VAT and excise duties
Implement a R&I programme	JU is a Union Body established under article 187 TFEU and can be tasked to implement actions under programmes such as H2020 and CEF
Remain open to incorporate new MS/AC willing to join	OK
Enable participation of the private sector	Industry can participate in the JU
Safeguard the Union's interest through EC participation	The EU represented by the Commission can be member of the JU and exert its decisional powers in the JU Governing Board

6. WHAT ARE THE IMPACTS OF THE POLICY OPTIONS?

This section analyses the economic, environmental and social impact of the options in line with the Better Regulation Guidelines together with the coherence with other policy and the views of stakeholders.

6.1. Option 0: Baseline scenario

Effectiveness
Pillar 1: Infrastructure development, acquisition and operations
H2020 has a dedicated instrument for innovation procurement that sets the EU financial support at maximum 35% of the cost of a procurement action. The experience that the EC has developed when using this instrument for procuring HPC machines in H2020 is that the procurement process should be attractive for the Tier-0 supercomputing centres of the PRACE hosting countries, since these centres are always mandated by the MS to do the national HPC procurements. The following procurement principles were thus agreed and put in place: General specifications of the HPC machines were collectively defined by the supercomputing centres. Customised "local specifications" were then added by each supercomputing centre to address the specific national user needs of the hosting country. Then these became the basis for each centre to procure its machine. The procured machines are then co-designed with national scientific communities to optimize performance. Overall, such procurement process, while attractive for the supercomputing centres, is not suitable for the European agenda. It is optimized to serve national scientific needs and it results in procuring machines that may not be the most performing ones required at EU level. A different design would not attract supercomputing centres to participate in the procurement process. Once in operation, access to procured PRACE Tier-0 machines is essentially reserved to those MS hosting the machines (~60 to 90% of machine time). The other MSs pay a contribution to the operating costs of the machines to get access, but their scientists have to participate in a peer-review process based on excellence. As already explained in previous sections, there is a high demand and only a small number of applications are satisfied. Furthermore, this peer-review process is not adapted to industrial users because their applications are not necessarily driven by scientific excellence. In conclusion, the baseline scenario is not effective for implementing Pillar 1.
Pillars 2 and 3: Research and Innovation and Applications and skills development
The H2020 WP 2018-2020 supports well actions for HPC application and skills development through: (i) the HPC CoEs[14]; (ii) large-scale HPC-enabled industrial pilot test-beds for big data applications and services; and (iii) the Fortissimo-2 project[44], providing access of user SMEs to HPC resources. In addition, the CEF WPs support application development for the public sector. The baseline scenario is effective in developing applications and skills and supporting user SMEs (Pillar 2). The H2020 WP 2018-2020 also supports technology and knowhow development through a different set of activities, ranging from fundamental research to the development of prototype systems. The funded R&D projects are generally reaching their objectives and contribute to establishing the European HPC ecosystem. However, as already explained in previous sections, the present way in implementing Pillar 3 is not effective as the funding of its activities is fragmented in two different programmes (CEF and H2020) and in three different

[44] https://www.fortissimo-project.eu/. Fortissimo Marketplace offers to SMEs a self-service of HPC resources, software applications, expertise and tools, delivered by Europe's major HPC technology providers.

WPs of H2020 (FET, LEIT-ICT and Research Infrastructures). Even if the individual projects are successful and deliver functional components and prototypes, these are rarely integrated later on in the machines that are procured. As a result, the Union's R&D investment does not result in the development of European HPC machines that could be further supported through a lead market perspective. The baseline scenario is thus not effective to implement the EuroHPC strategy and to develop the world-class supercomputers based on European technology.
Efficiency / Impact on economy, competitiveness, competition and SMEs
The baseline scenario fails to foster a European supply industry of HPC technology and the take-up of the R&D results into commercial products is too limited compared to the R&D investments the Union is making. Moreover, due to the open nature of the H2020 calls non-European industry can directly benefit from the H2020 activities, increasing their competitiveness, which helps them to keep or expand their market share in Europe. The baseline scenario can foster the innovation potential of user SMEs (see above). However, it fails to provide the computing facilities European industry users need. As supported by the stakeholders' survey findings, industry users either have to turn towards machines of lower computing performance than their non-EU competitors, resulting in longer development processes or products of lower quality, or they take their product developments outside the EU to access the computing power they need to stay competitive. In conclusion, the baseline scenario has a limited impact on the economy and on competitiveness, competition and the technology supply SMEs.
Social and Environmental Impact
The availability of world-class computing capabilities and a high accessibility would accelerate the research on topics of environmental relevance like weather forecast, climate change, agriculture, urban planning, renewable energy production, natural hazard prevention, traffic management, etc. The baseline scenario can have only a limited social and environmental impact since it cannot provide the performance levels and accessibility required to make advances in these fields in pace with the non-EU competitors.
Stakeholder support
More than 80% of the respondents to the consultation indicated that the current implementation model is insufficient to address the challenges Europe currently faces in HPC and advocate for a new instrument. on the basis of two main arguments: • The level of EU-wide coordination and cooperation of HPC initiatives is currently insufficient in a qualitative and quantitative sense, resulting in a strong fragmentation of individual efforts across Member States, across different stakeholders (e.g. industry/science) as well as across current EU-wide initiatives. • Continuing in the current mode of fragmented and insufficient efforts, the EU is relegated against its global competitors (USA, China) in a field as strategic as supercomputing.

6.2. Option 1: ERIC

Effectiveness
Pillar 1: Infrastructure development, acquisition and operations

ERIC was conceived as an instrument for the MS to jointly establish and operate pan-European research infrastructures on a non-economic basis. Potentially, an ERIC can become a very effective instrument for procuring and operating world-class HPC and data infrastructures for European use. The statutes of the ERIC would also guarantee that all MS will have open access to the ERIC procured machines under conditions announced from the beginning.[45] The ERIC would provide free access for researchers and the public sector to the ERIC machines. Access to industry for private purposes would have to be done on a pay-per-use basis at market prices, since ERICs are established to work on a non-economical basis.[46]

Overall, the effectiveness of an ERIC for procuring and operating HPC machines would depend on how MS would put it in place. As there are already many ERICs operating since several years, the established experience would help MS to set up the HPC ERIC in an effective way.[47] In conclusion, ERIC can be an effective instrument for implementing Pillar 1.

Pillars 2 & 3: Research and Innovation; and Applications and skills development

ERIC was not conceived as an instrument for the MS to jointly plan and support R&D activities and for application development. Its current mandate does not give it the possibility of defining and developing a strategic R&I agenda; and, it does not allow it to get delegation to implement part of the H2020 programme. The ERIC cannot implement itself calls for R&I proposals and would have to be combined either with the baseline scenario for financing such activities or with another legal and financial instrument supporting such activities.

An alternative scenario for an ERIC could be to participate in the co-design of world-class HPC machines, if it sets up a consortium including the relevant industrial and academic partners. This is possible, provided its mission is defined in its statutes in very broad terms, so that it can be a beneficiary of H2020 grants. However, this would require altering in a rather fundamental way the ERIC's mandate; it would also require for the ERIC to assemble the right consortium (academia and industry partners) in an open and transparent way to participate in an open H2020 R&I call on co-designing HPC systems; and, finally, to make sure it is selected in the call. This last would mean that MS are involved both in defining the respective call priorities and budgets and in bidding for getting the funds.

In conclusion, ERIC is not an effective standalone instrument to achieve excellence in applications, or for technology and innovation development that would be integrated in world class HPC machines.

Efficiency / Impact on economy, competitiveness, competition and SMEs

The ERIC would have an effect on the coordination of the national HPC strategies. It would lead to the joint procurement and management of a world-class HPC infrastructure. It would

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45 According to Article 4 of the ERIC regulation, the research infrastructure must meet the requirement of an "… (c) effective access, in accordance with the rules established in its statutes, is granted to the European research community, composed of researchers from Member States and from associated countries …"

46 Up to 20% of an ERIC activity can be run on market conditions. If the demand is higher, it would require the establishment of a spin-off entity to manage such activities.

47 As an ERIC is an international organisation (within the meaning of the procurement directive), it can choose to adopt its own procurement policy respecting the principles of transparency, non-discrimination and competition. It is expected that the MS would be represented in the ERIC by their national supercomputing centre. Relying on these centres for the HPC machine procurement would add value, as they are the most experienced organisations in handling procurement of supercomputers. This might though compromise the possibility of cooperation of these centres in the procurement process as the centre will be both a member of the ERIC and participate at the same time in the co-design process of the HPC machines to procure.

achieve a better allocation of resources at European level, avoiding duplication of efforts, and optimisation of spending focusing on the relevant areas. The ERIC could set clear targets for the development of the world class HPC machines, creating a lead market. This would incentivise to some degree the research centres and HPC technology suppliers to develop and integrate, at least part of, the European HPC technology. The ERIC would thus permit to support to some extent the European suppliers to develop technology and sell it giving them opportunities to become more competitive. This would in particular benefit the SMEs, as the majority of European HPC suppliers are SMEs. However, as the ERIC cannot implement a R&I agenda and guarantee the integration of European technology developments into future HPC machines, its impact on economy and on European industry competitiveness is expected to be rather limited.
Social and Environmental Impact
The availability of world class computing performance and a high accessibility that the ERIC would achieve would permit accelerating the research on topics of social and environmental relevance like health, environment (weather forecast, climate change), agriculture, renewable energy production, safety (e.g., natural hazard prevention), smart cities and traffic management, etc. The ERIC would thus have a clear societal and environmental impact.
Stakeholder support
The respondents to the consultation (see Annex 2) ranked the current state of interaction between industry and academia on the exploitation of high-end computing systems, application codes and services as a key problem area, in particular the respondents from the technology supply industry. The choice of an ERIC would not permit to improve drastically this situation.

6.3. Option 2: Joint Undertaking (JU)

Effectiveness
Pillar 1: Infrastructure development, acquisition and operations
A JU can define its own procurement and financial rules and carry out its procurement procedures following rules to be agreed by its governing board that need to be based on the Union's model Financial Regulation. By being responsible for the HPC machine procurement process (with the help of experienced national experts), the JU will open the possibility for future hosting supercomputing centres to cooperate in this process and in particular to participate in the co-design activities of the JU machines. This is a very effective way to benefit from the supercomputing centres in designing and procuring a leading HPC and data infrastructure in Europe. Within the competences established by the statutes of the JU, the JU governing board would define the access conditions for the users of the JU machines. The JU governing board would have to define and manage the access of public and private users to the machines under similar conditions as the ones mentioned above for ERICs. In conclusion, the JU is an effective instrument for jointly procuring world-class HPC and data infrastructures for European use.
Pillars 2&3: Research and Innovation; and applications and skills development
A JU can be used for the indirect management of the EU budget. It is an autonomous EU legal

entity that can be tasked to implement actions under programmes such as H2020 or CEF. It can combine EU budget with other sources of funding (national, private, etc.), allowing the implementation of research, technological development, pilot application and demonstration programmes in an integrated way.

The JU would be tasked to implement all those HPC activities foreseen in the CEF and H2020 WP 2018-2020 through the launch of competitive open calls. Firstly, it would ensure a seamless continuation of the present calls, serving different scientific and industrial user and technology supply communities. Secondly, it would implement calls for R&I proposals according to the H2020 rules that would be open to any eligible beneficiary. The JU would provide transparency and openness in its operations.

The JU would include in its governance structure a scientific advisory board bringing together scientific and industrial users and technology suppliers, supercomputing centres, CoE representatives and other researchers to define the long term strategic research agenda (SRA) of the JU and give advise on the draft yearly Work Plans to implement this SRA. The latter would be decided and adopted by the governing board of the JU. This will ensure coordination with national programmes and will permit to plan and synchronise the different calls and activities towards the achievement of the overall goal of the JU, i.e. the development of a European HPC ecosystem. Each subsequent call would build on the results of previous calls ensuring continuity.

In particular calls for innovation procurement would be planned that make the participation to the procurement conditional to the successful conclusion of prior European R&D projects and/or specify a preference for the integration of R&D results previously developed by the European R&D programmes.

The JU can thus become a very effective instrument to achieve excellence in applications, and for technology and innovation development that would be integrated in world class HPC machines based on European technology.

Efficiency / Impact on economy, competitiveness, competition and SMEs

As in the case of ERIC, a JU would have a clear positive effect on the coordination of national HPC strategies, enabling the joint procurement of leading HPC infrastructure and avoiding duplication of efforts and waste of resources. Its possibility to pull together funds from different public and private sources, including the structural funds, to be jointly managed combined with its possibility to implement a stakeholder-defined strategic R&I agenda would permit: (i) to increase the JU's overall programme efficiency; (ii) to achieve a better allocation of resources at European level; (iii) to optimise the spending on the relevant European priority areas; and (iv) industry players to contribute to defining the JU's strategic R&I agenda and annual calls, in line with their own strategic developments in the field.

Furthermore, by procuring innovation, the JU can set clear targets for the development of HPC machines integrating European-based technology, creating a lead market. This would permit to further incentivise the European HPC suppliers to work with research centres and invest into HPC technology development and into integrated machines which could be acquired by the JU.

Through its activities, the JU could thus achieve a significant leverage effect on private investment and related economic activity. It could lead to a larger market share of European suppliers, and impact directly the competitiveness of European industry. These are confirmed by the findings of the recent study on partnerships of the Estonian presidency[38] and those of the interim evaluation of the ECSEL JU confirm such potential economic impact of the JUs:

every one Euro invested by the public sector leverages two Euros from the private sector. In conclusion, the JU can have a clear positive impact on economy, competitiveness, competition and SMEs, much higher than that of the baseline scenario or ERICs.
Social and Environmental Impact
Similar to an ERIC, the JU would also enable the availability of world class computing performance and a high accessibility and would permit accelerating the research on topics of social and environmental relevance. Furthermore, as the JU would have a direct positive impact on the competitiveness of European industry, this in turn is expected to be translated on a positive effect on jobs.
Stakeholder support
There is a large majority of respondents to the targeted consultation arguing in favour of setting up a new instrument for the implementation of a truly European, integrated, HPC strategy (see Annex 2). Indeed, the respondents to the consultation ranked the current state of interaction between industry and academia on the exploitation of high-end computing systems, application codes and services as a key problem area. A JU would certainly set the basis for improving the present situation in the future. The possibility that the JU offers to industry to directly participate in the definition of the JU's strategic R&I agenda and annual calls is also considered to be of key importance for the European supply industry for increasing its technological edge versus competing global companies. A clear industry support can thus be concluded for the JU instrument. The recent study on R&I partnerships of the Estonian presidency seems to confirm this.[48] In addition, from the non-polemic responses to the publication of the EuroHPC Inception Impact Assessment (see Annex 2) a clear support can be concluded not only for a new initiative but also explicitly for a JU as the best instrument.

7. How do the Options Compare?

This section presents a comparison of the options in the light of the impacts identified. The options are assessed against the core criteria of effectiveness, efficiency and coherence, as well as taking into account the support expressed by the different stakeholders.

Effectiveness of the instrument

Both the ERIC and the JU would have a positive impact compared to the baseline scenario. However, while the JU would have a positive impact on the 3 pillars, the ERIC is not an effective instrument to implement a research programme with the aim to develop the technology that would be integrated in leading European HPC machines. The ERIC is an effective instrument only for the development, acquisition and operation of the HPC infrastructure.

Impact on economy, competitiveness, competition and SMEs

Both instruments, ERIC and JU, would have a positive economic impact as compared to the baseline scenario. However, the impact of the ERIC is expected to be much lower than that of

[48] "*Industry partners and researchers express very positive views on JTIs. A common research agenda is implemented and there is a large emphasis on partnerships and collaboration to ensure that EU remains competitive and a leader in innovation and technology"*, Section 3.2 of the Estonian Presidency study.[42]

the JU. This is mainly due to the fact that the ERIC cannot be tasked to implement a R&I programme. Its economic impact would thus be more indirect, originating in essence from the increased availability and accessibility of world-leading HPC infrastructure. Furthermore, the JU can pull together funds not only from public sources (like ERICs do) but also from private ones. The JU also gives the possibility to industry players to steer the JU's R&I agenda which can lead to a significant leverage effect on private investment and related economic activity and impact directly the competitiveness of European industry.

Social and environmental Impact

Both instruments, ERIC and JU, have a clear positive almost identical societal and environmental impact.

Stakeholder opinion

According to the outcome of the public consultation (see Annex 2) there is a clear demand for a more effective instrument to implement the European HPC strategy. However, as the respondents to the consultation ranked the current state of interaction between industry and academia on the exploitation of high-end computing systems, application codes and services as key problem area, the choice of a JU would certainly set the basis for improving this situation in the future.

Based upon the impact analysis performed in Section 6, the following table compares the merits of a new EU-wide collaborative effort on HPC (i.e. options 1 or 2) against the baseline scenario (0):

Impacts	Option 0: Baseline Scenario	Option 1: ERIC	Option 2: JU
Effectiveness	x (Pillar 1: Infrastructure) x (Pillars 2&3: Applications and R&I agenda)	√ (Pillar 1: Infrastructure) x (Pillars 2&3: Applications and R&I agenda)	√ (Pillar 1: Infrastructure) √ (Pillars 2&3: Applications and R&I agenda)
Impact on economy, competitiveness, competition and SMEs	√	√√	√√√√
Social and Environmental Impact	√	√√	√√
Safeguarding Union interests through EC participation	√	0	√
TOTAL	√	√√√√	√√√√√√√√√

Table 1: *Comparing the Impact of the different options. The symbols "x" and "√" indicate respectively positive (√) and negative (x) impacts, the number of the symbols is the net result of the summing-up of the respective individual ratings of the policy option and indicates the magnitude of the change.*

The above comparison demonstrates that an EU-wide collaborative effort on HPC (i.e. Options 1 or 2) offers indeed significant added value for the European economy, society and environment vis-à-vis the baseline scenario option.

8. SELECTION OF PREFERRED OPTION AND HOW WILL THE EUROHPC JU WORK

The above analysis has shown that a Joint Undertaking (JU) represents the best instrument capable to implement the goals of EuroHPC while offering the highest economic, societal, and environmental impact while best safeguarding the Union's interests.

The business-as-usual option does not address the 4 key problems of the current European HPC strategy implementation model as identified in Section 2.2. Therefore, the business-as-usual option is considered as inappropriate to build up the EuroHPC strategy.

In summary, the main arguments in favour of a JU as the preferred policy option to implement the EuroHPC entity are:

- It fulfils all functional requirements of the legal entity to implement the objectives.
- It provides a visible legal, contractual and organisational common framework to structure the joint commitments of the public and private stakeholders.
- It provides of a firm governance structure and budgetary certainty to all stakeholders.
- It can implement a joint procurement and operate world-class HPC systems via promotion of technology, particularly European one.
- It can launch R&I programmes for developing technologies and their subsequent integration in European exascale supercomputing systems and contribute to developing a competitive European technology supply industry.
- It has a positive impact on all 3 pillars, for developing a thriving European HPC and Big Data ecosystem.

In addition, the following arguments speak in favour of the chosen option: The EC already has experience on setting-up and managing JUs. In particular the experience gained from implementing the ECSEL JU will be helpful. First, it is a tripartite agreement, bringing together the EC, the MS and the private sector, as would be the case for EuroHPC. The governance and the administrative processes are well understood, the strengths and weaknesses well known. The EuroHPC would build on the ECSEL structure taking over its strength and mitigating its weaknesses. In particular, EuroHPC would benefit from the revision of the ECSEL regulation that is going on, addressing the shortcomings that have been identified in the day-to-day operations of ECSEL.

How will the EuroHPC JU operate?

The members of the JU will be the Union (represented by the EC), the MS and AC, and the HPC and Big Data stakeholders, including academia and industry.

Only the public partners of the JU will be responsible for its Pillar 1 activities (Infrastructure development, acquisition and operations) in order to avoid any conflicts of interest of the private partners in the procurement process of the JU machines.

The governance of the Joint Undertaking will be structured in the following way:

- The Governing Board will be composed of representatives of the public partners of the JU. It will be responsible for strategic policy making and for the funding decisions related to the activities of all the three JU pillars. Voting rights and procedures will be, in principle, proportional to the financial contributions of its members.
- The Industrial and Scientific Advisory Board will be composed of representatives of the HPC and Big Data stakeholders. It will have an advisory role and will include two advisory groups:

(i) The Research and Innovation Advisory Group will include representatives of academia and industry users and technology suppliers. It will be responsible for elaborating a medium- to long-term research and innovation agenda on technology and applications, covering the research, innovation, applications and skills development activities of the JU (Pillars 2&3).

(ii) The Infrastructure Advisory Group will include experienced academia and user industry experts selected by the Governing Board. They will provide independent advice to the Governing Board on the procurement and operation of the machines owned by the JU (Pillars 1&4).

The JU machines will be interconnected with the existing Tier-0 PRACE and other existing national machines (via the GEANT network) and be made available to the public and private users. The Governing Board will have the responsibility of defining and assuring the overall monitoring of the access and use rules of the JU machines.

The EuroHPC JU will procure and own those HPC machines funded mainly by the Union, so that these machines are jointly owned by the JU members contributing to their procurement. For simplicity, the JU would not operate the procured machines itself but delegate their operation to a hosting entity (ideally to be selected by the JU following a competitive Call for Expression of Interest). The selection of the hosting entity would have to be done according to well defined criteria. The JU would remain the owner of the procured machines until they are depreciated (typically after 4 to 5 years of operation). Then ownership would be transferred to the hosting entity for machine decommissioning and disposal or any other use.

The budget of the JU will be of the order of approximately EUR 1 billion (composed of an EU contribution of around EUR 486 million matched by a similar amount from the MS/AC). It is also expected that the private stakeholders will significantly contribute to the JU activities related to Pillars 2 and 3. The JU budget would ensure the operations and payments of all the activities that the JU would have launched at the latest by the end of 2020 until their termination around 2025/2026. It could then be wound up.

9. HOW WOULD ACTUAL IMPACTS BE MONITORED AND EVALUATED?

Monitoring will start with the establishment of the new legal instrument. An explicit clause to monitor on an annual basis the key performance indicators (KPIs) will be included in the legal instrument. The first assessment will take place with the publication of the call for tender for the pre-exascale machines.

An explicit evaluation and review clause, by which the EC will conduct an independent evaluation, will be included in the legal instrument. The EC will subsequently report to the European Parliament and the Council on its evaluation accompanied where appropriate by a proposal for its review, in order to measure the impact of the instrument and its added value. The Commission Better Regulation methodology on evaluation will be applied. These evaluations will be conducted with the help of targeted, expert discussions, studies and wide stakeholder consultations.

The Executive Director of the legal entity should present to the Governing Board an ex-post evaluation of EuroHPC's activities every two years. The legal entity should also prepare a follow-up action plan regarding the conclusions of retrospective evaluations and report on progress bi-annually to the Commission. The Governing Board should be responsible to monitor the adequate follow-up of such conclusions.

Alleged instances of maladministration in the activities of the legal body may be subject to inquiries by the European Ombudsman in accordance with the provisions of Article 228 of the Treaty.

The list of KPIs that could be used to monitor progress towards meeting the objectives, impact and success of the JU is as follows:

- At least two pre-exascale machines jointly procured.
- Computing hours made available for European researchers increase with respect to the hours currently available through PRACE.
- Oversubscription of the machines made available at European level decrease well below the current levels.
- The number of user communities served and number of researchers getting access to the European pre-exascale machines increases when compared to the number of those having to look for computing resources outside Europe.
- Competitiveness of European suppliers starts increasing, measured in terms of global market share of European HPC systems, components and tools, and in terms of share of European R&D results taken up by industry.
- Contribution to next generation HPC technologies, measured in terms of patents, scientific publications and commercial products.
- Number of European applications adapted to pre- and exascale systems.
- Number of scientists, students, users (industrial and public administrations) trained.

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PART 2/4

COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT

Accompanying the document

Proposal for a Council Regulation

on establishing the European High Performance Computing Joint Undertaking

{COM(2018) 8 final} - {SWD(2018) 5 final}

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ANNEX 1:

PROCEDURAL INFORMATION

The initiative is led by DG CONNECT. The agenda planning reference is PLAN/2017/1304. The initiative on establishing EuroHPC was included in the Commission Work Programme for 2017.

The Impact Assessment was prepared by DG CONNECT and was closely coordinated with the Inter-Service Steering Group (ISG). In 2017, three meetings of the ISG were held. The first meeting took place on 28th July 2017, attended by DG CNECT, RTD, GROW, JRC, and the Secretariat General (SG). The second meeting was held on 21st September 2017, attended by representatives from DG CNECT, RTD, GROW, JRC, LS and the Secretariat General (SG). This was the last meeting of the ISG before the submission to the Regulatory Scrutiny Board on 27 September 2017. The third ISG meeting was held on 13th November 2017, focusing on the Draft Regulation for a EuroHPC Joint Undertaking. It was attended by representatives from DG CNECT, RTD, JRC, LS and the Secretariat General.

1. Recommendations of the Regulatory Scrutiny Board

The Regulatory Scrutiny Board (RSB) of the European Commission examined the draft Impact Assessment on 25 October 2017 and issued a positive opinion with reservations. These were addressed as follows:

RSB recommendations	Modification of the IA report
The report is not clear enough with regard to what decisions it is supposed to inform and what timing it covers.	*The report was redrafted to a large extent to describe what the decision sought is about and what are the problems that the decision will have to address. It focuses only on the decision related to setting up a self-standing joint structure that would operate with funding from this MFF, without depending on possible funding decisions of the next MFF. All the objectives that this joint structure will have to reach have been were re-written accordingly and the sections (e.g. sections 5 and 6) affected were revised.*
The report does not build sufficiently on past experiences and lessons from earlier applied research projects, such as Galileo, JUs, ERICs, or ECSEL.	*The report summarises existing activities and experiences built in when implementing the Union's HPC strategy since 2012. Wherever relevant, experiences were included from implementing past instruments such as JUs, ERIC or ECSEL and their applicability on the joint HPC structure and/or in running its operations.*
The report does not provide enough information about how the joint entity would operate. This makes it hard to judge how likely the public-private partnership	*This is now explicitly covered in particular in sections 4 and 8 of the revised Impact Assessment.*

is to deliver well on its different objectives.	
The report does not adequately present the views of the different groups of stakeholders.	*The analysis of the targeted consultation was expanded, detailing the responses per group of stakeholder – see Annex 2.*
The report should be refocused on the decision it is meant to inform, which is the legal form of the joint entity. The report needs to streamline its presentation of context and scope, and set these out vis-a-vis the decision at hand. The report should clarify relevant aspects of funding and the legal base. It should explain the purpose of the decision and why this needs to be taken now.	*In the introduction of the revised Impact Assessment the scope and context of the decision sought were re-expressed. In the same section a paragraph was added outlining the funding aspects. The need to act now is highlighted in a new section 3.1. Funding issues were clarified in the same section.*
The report should clearly explain that the current decision only covers the first phase (pre-exascale) and that this is a self-standing project. It should explain how this will not pre-empt the decision (or the financing) of the next step of the exascale HPC.	*In section 1 of the Impact Assessment a paragraph was introduced summarising that the decision is about setting up a self-standing joint structure that would operate with funding from this MFF, without depending on possible funding decisions of the next MFF. All the objectives that this joint structure will have to reach were re-written accordingly (section 4) and the other affected sections (e.g. sections 5 and 6) were revised.*
The report should better describe how the joint structure would work. This includes how it is to be funded, private and public participation, nature of activity and exit strategies. What is this structure supposed to do over time, and what would be its governance structure? Who should be partners and what are the criteria for the participation of private parties? What is the envisaged (exit) strategy when the HPC machines become obsolete? The report should also clarify the relations with third countries and what is meant by an 'indigenous' European project. The assessment criteria for the different legal options should reflect the functionalities that the envisaged structure would require. The intervention logic should adequately reflect the narrow scope of the decision at hand. A number of ambiguities and unnecessary complexities can	*Both the objectives and the specific objectives of the joint structure were revised (Section 4) and a new section (4.2) was introduced to describe in detail the functionalities that the joint structure should fulfil. Section 5 (available policy options) was partly rewritten and all options are now compared against the functionalities which should be fulfilled by the joint structure. Section 4.2 and section 8 (describing the preferred option) provide the requested details on the functioning of the joint structure (activities, partners, governance structure, exit strategy, etc.).*

therefore be removed.	
Given this narrower approach, there is no need to justify the decision to jointly invest with the Member States on HPC capability, except in terms of background and context. Repeated arguments on this can be placed in an annex or dropped.	*The background and context sections were rewritten to a large extent. The whole Impact Assessment document was streamlined, removing redundancies.*
The report should make clear that the project rests on a model that has already been tested and evaluated. In assessing which legal form is the most suitable, the report should review lessons learnt from past experiences about legal forms and pre-commercial procurement. It could usefully draw on experiences with such applied research projects as Galileo, previous JUs and ERICs, and the ECSEL joint undertaking.	*In section 5 of the Impact Assessment, describing the options, lessons learnt from past experiences with handling joint entities like ERICs or JUs (incl. ECSEL), were inserted.*
The report should clarify in which ways the joint entity will overcome existing barriers for applied research on coordination and synchronisation of Member States' research and HPC activities, in terms of open calls for research grants, and in terms of pre-commercial procurement and IPR rules.	*The redrafted sections 4 (Objectives) and 8 (preferred options) of the Impact Assessment clarify and detail how the joint structure will overcome existing barriers.*
The monitoring section should explain what success would look like. It should define some measurable success criteria, which could be divided into direct operational criteria for the HPC activity undertaken in itself and the wider indirect benefits for broader research and innovation in Europe.	*The success criteria were redefined to include measurable criteria, addressing both the HPC activities undertaken, as well as the wider benefits for research and innovation.*
The report should expand on how different groups of stakeholders have responded to the different options, highlighting both support and any concerns.	*The analysis of the targeted consultation was expanded, detailing the responses per group of stakeholder (Annex 2). This detailed breakdown reveals a large consensus among the different stakeholder groups. Where relevant, citations were included in the Impact Assessment.*

2. Evidence Base for the Impact Assessment

The Commission gathered qualitative and quantitative evidence from various recognised sources of the EU institutions:

- The *European Cloud Initiative (ECI)*[1] adopted by the Commission (EC) on 19 April 2016 as part of its Digitising European Industry strategy;
- The Communication adopted by the European Commission in April 2016 on the ECI[2] and underlying analytical study[3];
- The European Investment Bank study *Access-to-finance for European Cloud and High Performance Computing*[4];

Quantitative figures and arguments that have been used from other relevant officially recognised data sources include:

- Partnership for Advanced Computing in Europe (PRACE) official annual reports and data therein[5];
- The US Department of Energy program Advanced Scientific Computing Research (ASCR) statistics and data[6];
- Top 500 initiative's list of world's best supercomputers[7];
- STATISTA statistics and databases[8];

In addition, views were sought from the following type of stakeholders considered to represent to the best reasonable extent the European HPC community:

- National and EU-funded projects on HPC (*Projects*),
- Scientific user communities of HPC infrastructures (the 29 large ESFRI research infrastructures and the PRACE scientific users, each reaching hundreds of actors, EUDAT, EGI, etc.) *(Scientific Users),*
- Public-private partnerships on HPC and Big Data (*PPPs*),
- Centres of excellence for supercomputing applications, supercomputing centres, service providers, access providers (*Intermediaries*),
- HPC research & industry associations (*Associations*),
- Member State & governmental institutions (*MS*).

The goal was to reach all identified stakeholders and elicit their contributions on time with respect to the further process of the planned development of the EuroHPC Regulation.

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[1] COM(2016)178

[2] SWD accompanying the ECI Communication: COM(2016)178

[3] High-Performance Computing in the EU: Progress on the Implementation of the European HPC Strategy, Report of a study carried out for the European Commission, IDC, 2015

[4] EIB study

[5] Available at http://www.prace-ri.eu/

[6] Available at https://science.energy.gov/user-facilities/user-statistics/data-archive/

[7] Available at https://www.top500.org/

[8] Available at https://www.statista.com

An on-line targeted consultation was conducted through the DSM website of the European Commission between 3 August and 5 September 2017[9].

This consultation represented only the last step in a wider series of workshops and meetings with a wide range of relevant stakeholders that started in 2016 in which the European HPC strategy was already presented and discussed according to its status at that time, as follows:

Stakeholder engagement activity	*Scientific Users*	*MS*	*Projects*	*PPPs*	*Interme-diaries*	*Associ-ations*
Workshop on the European micro-processor on 18 January 2017 in Brussels						
General assembly of ETP4HPC on 21 March 2017 in Munich						
Digital Day of 23 March 2017 in Rome in the presence of 250 HPC stakeholders						
Workshop on EuroHPC governance in Rome on 23 March 2017 with 50 participants						
PRACE days on 15-18 May 2017 in Barcelona, gathering the whole HPC community						
Six meetings with the Sherpas of the Member States						
European Open Science Cloud summit on 12 June 2017 in Brussels						
Multiple meetings with key stakeholders (PRACE, ETP4HPC, visits to supercomputing centres, international conferences…)						

The quality of the studies can be considered high as they represent the currently best available information on HPC in Europe and globally, originating mostly directly from the HPC practitioners (e.g. official PRACE (EU) and ASCR (US) statistical figures).

[9] https://ec.europa.eu/eusurvey/runner/Eurohpc

Annex 3

Who is affected by the initiative and how?

This annex describes the practical implications of a joint structure at European level.

The analysis follows the structure by the group of stakeholders that are likely to be directly or indirectly affected by the initiative.

MEMBER STATES

Member States are expected to significantly benefit from the initiative. The EuroHPC initiative will enable Member States to coordinate together with the Commission their HPC investments and strategies. The end goal is to establish in the EU a world-class HPC and data infrastructure that Member States on their own cannot afford –in particular those with little or no significant HPC resources in place. No single country in Europe has the capacity to sustainably build and maintain such infrastructure and develop the necessary human and technological ecosystem. Pooling and rationalising efforts at EU level is a must.

The initiative will allow the joint procurement of world-class HPC machines, providing all Member States access to supercomputers with a performance comparable to the best machines in the world. These machines, integrated in a pan-European infrastructure, will be available to the scientific and industrial researchers and the public sector independently of their location. The increased availability and accessibility of top HPC resources will motivate the users to keep their activities and data in Europe, helping to keep critical know-how and human potential in Member States.

Member States will benefit from a world-class competitive infrastructure to provide improved public services and to support key policy making, e.g. strategic decision-making for energy, smart cities, civil protection or climate change. HPC has also become indispensable for maintaining national sovereignty and in the context of national security applications. Supercomputers are in the first line of the increasingly critical areas of cyber-war and cyber-criminality, helping to prevent and fight today's sophisticated cyber-attacks and security breaches, insider threats and electronic fraud. Increased availability of HPC resources will thus have a positive impact on the security of Europe.

UNIVERSITIES AND RESEARCH CENTRES

Access to world-class HPC capabilities has become fundamental to conduct innovative and leading-edge science. Modern science relies heavily on shareable research data, open data analysis tools and connected supercomputing computing facilities. Europe's researchers have to be able to access HPC resources irrespective of their geographical location or scientific discipline. EuroHPC will provide our universities and research centres with a world-class infrastructure, ensuring a European-wide access to supercomputers and data with a guaranteed high level of resources, thanks to a legal infrastructure that ensures the sustainability and availability of resources in the short, medium and long terms. This factor is critical to ensure that our academic and scientific potential stays in Europe and is not exploited in other regions with more competitive HPC and data facilities.

With the implementation of the European HPC strategy scientific cooperation in the EU will become easier, particularly multi-disciplinary cooperation based on big- data. A pan-

European leading infrastructure will consolidate the already existing vibrant mix of national, regional and pan-European initiatives in intra-EU collaboration, and will provide EU-based teams with powerful resources to strengthen the European participation in international HPC-supported scientific collaborations extending far beyond Europe – notably the Intergovernmental Panel on Climate Change (IPCC), the International Thermonuclear Experimental Reactor (ITER), and the Square Kilometre Array (SKA) project.

INDUSTRY INCLUDING SMEs

In industry, HPC enables traditional computational-intensive sectors to significantly reduce R&D costs and development cycles, and to produce higher quality products and services, for example in manufacturing and engineering industries (e.g. automotive, aerospace), health and pharma (e.g. drug discovery), energy (e.g. discovery of oil and gas resources, renewable energy generation and distribution). HPC also paves the way for new business and innovative applications in high added-value areas (e.g., in personalized medicine, bio-engineering, smart cities/autonomous transport, etc.), reinforcing the industrial innovation capabilities, in particular of SMEs.

The new initiative will revitalise the European HPC ecosystem, where industry and in particular SMEs will benefit as both users and suppliers of HPC technology and applications.

- **As users;** Europe is leader in many HPC-empowered applications. EuroHPC will consolidate this leadership position, providing an enhanced HPC infrastructure with more resources for industrial use accessible at EU level, complemented with specific measures to widen the usage of HPC technologies. This is of critical importance to industry and particularly SMEs without in-house capabilities that will benefit from easy to use HPC resources, applications and analytics tools to create new innovative products and processes.
- **As suppliers;** a European-wide initiative with a focus on the supply of a European source of HPC technology such as EuroHPC will have the necessary critical mass and a catalytic effect on the European suppliers. EuroHPC will provide a clear roadmap for technological implementation of leading-edge technologies in Europe and their integration in European systems, providing a unique opportunity for industry, including SMEs, to participate in the co-design and development of such new technologies and systems, and to develop IPR and solutions to be further used in their business endeavours. The benefits of this IPR will not be limited to HPC, but will span to broader sectors such as e.g. the ICT market within a few years of their introduction in high-end HPC – giving a competitive advantage to those developing them at an early stage.

  As an example, there is a dynamic European independent software vendors (ISV) supply chain in Europe that is still competitive world-wide. To remain competitive European-based ISVs and European software developers and owners have to participate in the design of next-generation HPC systems, understand the critical software requirements that these new hardware platforms engender, identify and define technical specifications for various elements of an emerging exascale software stack, glean best case situations for collaborative efforts among various ISVs and develop early on a sense of leading EU-based exascale architectural and algorithmic development efforts. This close link between European hardware and software industries will strongly be fostered by EuroHPC.

European Commission

The EuroHPC initiative would positively impact the workings of the European Commission. Currently, some the activities that EuroHPC will undertake are implemented through four different work-programmes (e-infrastructures, FET, and LEIT in Horizon 2020, and through the Connecting Europe Facility annual Calls). This implementation of the HPC strategy is particularly complex (e.g. discussion with four committees, synchronisation of budgets and activities with diverse budgetary and time constraints, etc.). The EuroHPC will provide a single structure to coordinate the different activities in synergy, and more importantly, will provide a single forum for strategic discussions with Member States and leverage EU and national efforts and resources.

HPC is becoming critical for an increasing number of applications. EuroHPC will be a privileged interlocutor for institutions, agencies and bodies addressing critical scientific, industrial or social-impact areas. EuroHPC will become a focal point for better supporting the EU policy development and implementation in areas like digitising industry (Digital Single Market), security, and many other related to societal challenges.

Supercomputing Centres

Several European supercomputing centres that host the most powerful supercomputing infrastructures in Europe (e.g. the PRACE Tier-0 systems) enjoy a world-wide reputation. These centres not only operate HPC infrastructure but possess a very wide set of human capital and expertise –ranging from technological development, to academic excellence and research, and support to industry and SMEs). EuroHPC provides the opportunity to fully exploit this valuable asset in a synergetic way, encompassing the co-design and integration of technology with a coordinated procurement of supercomputers at European level. EuroHPC will provide the appropriate frame to strategically plan for the further development of these centres, for example with a necessary European-wide planning of the different architectures across Europe (avoiding isolated and uncoordinated procurements that may end up in dependencies on single vendors and technological suppliers).

In addition, the EuroHPC initiative will support the federation of these top-leading centres with a wider range of national (Tier-1) and regional (Tier-2) centres, providing a real pan-European infrastructure capable of responding to the increasing demands of scientific, industrial, public sector users, and other stakeholders.

Citizens

A true European coordinated effort such as EuroHPC will make sure that world-class HPC resources and data are available for applications that are of direct interest for citizens. Citizens expect sustained improvements in their everyday life while at the same time society is confronted with an increasing number of complex challenges – at the local urban and rural level as well as at the planetary scale. Policy makers need tools to make better decisions HPC has become indispensable to transforming these challenges to innovation and creation of business opportunity, thanks to its ability to process large amounts of data and carry out complex computations. Responding to these challenges will create innovation and therefore the growth and jobs that the EU economy needs.

Given the inter-disciplinary nature of HPC and the wide range of scientific and industrial applications, citizens will benefit from an increased level of resources provided by EuroHPC in areas like:

- Health, demographic change and wellbeing: the development of new therapies will heavily rely on HPC for understanding the nature of disease, discovering new drugs, and customising therapies to the specific needs of a patient
- Secure, clean and efficient energy: HPC is a critical tool in developing fusion energy, in designing high performance photovoltaic materials or optimising turbines for electricity production.
- Smart, green and integrated urban planning: the control of large transport infrastructure in smart cities will require the real time analysis of huge amounts of data in order to provide multivariable decision/data analytics support in your mobile or car.
- Climate: HPC underpins climate study and prediction (weather forecast, catastrophes prevention and civil protection planning, etc.).
- Food security, sustainable agriculture, marine research and the bio-economy: HPC is used to optimise the production of food and analyse sustainability factors (e.g. plagues and diseases control, etc.).

3RD COUNTRY ACTORS

Successfully building a European HPC ecosystem will have an effect on the non-EU supply industry. The availability and large take-up of European technology in the next generations of European supercomputers would decrease their market share of HPC components and systems in Europe, potentially worldwide if the European machines prove to be more competitive. A knock-on effect on the micro-electronics mass market could also be expected, as the downsizing of the HPC components for applications like the autonomous and connected car or the internet of things, would foster the position of European suppliers in this market segment also.

The increased protection of European IPR resulting from the R&I programmes supported by the EuroHPC, may deprive the non-EU suppliers of European know-how and competences in the design of supercomputers. Currently, non-EU suppliers take advantage of EU programmes to export the resulting IPR and improve their domestic developments.

Provided access conditions on equal terms become a global practice, the European HPC resources could become attractive for scientists from outside the EU, sending their data for processing to Europe. The risk Europe currently faces with losing its data sovereignty may thus be reversed.

ANNEX 4

STAFF AND BUDGETARY ESTIMATES FOR THE EURO HPC JU OPTION

A. STAFF

A first estimation of the staff needed to run the EuroHPC Joint Undertaking is presented below:

	Temporary Agent Administrator Grade (TA AD)	Contract Agent (CA)	Seconded National Expert (SNE)	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
Directors' office											
Executive Director	X			1	1	1	1	1	1	1	1
Executive Assistant		X		1	1	1	1	1	1	1	1
Operations											
Head of programmes	X			1	1	1	1	1	1	1	1
Programme Officer	X			1	3	3	3	3	2	2	0
Assistant		X		1	1	1	1	1	1	1	1
Accounting & Finance											
Head of A&F (accountant)	X			1	1	1	1	1	1	1	1
Financial assistant		X		1	2	3	3	3	2	1	0
Administration											
Legal Officer	X		X	1	2	2	2	1	1	1	1
Administrative assistant		X		1	1	1	1	1	1	0	0
HR assistant		X		1	1	1	1	1	1	1	1
Secretariat		X		1	1	1	1	1	1	1	1
Total				**11**	**15**	**16**	**16**	**15**	**13**	**11**	**8**
	TA AD			4	4	4	4	4	4	4	3
	CA			7	10	11	11	11	9	7	5
	SNE			0	1	1	1	0	0	0	0

B. BUDGET

a) Commitment appropriations (M€)

This table presents the EU commitment appropriations. It should be noted that the amounts under title 3 (operational budget) will be complemented by equivalent amounts from the EuroHPC Member States. The total volume of operations is therefore of 2x476M€ = 952M€.

	2019	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**Total**
Title 1 - Staff Expenditure	**1.16**	**1.448**	**1.586**	**1.586**	**1.566**	**1.338**	**1.258**	**1.12**	**11.062**
11 Salaries & allowances	1.04	1.318	1.456	1.456	1.456	1.248	1.178	1.04	10.192
- of which establishment plan posts	0.69	0.828	0.966	0.966	0.966	0.828	0.828	0.69	6.762
- of which external personnel	0.35	0.49	0.49	0.49	0.49	0.42	0.35	0.35	3.43
12 Expenditure relating to Staff recruitment	0.04	0.04	0.02	0.02	0	0	0	0	0.12
13 Mission expenses	0.06	0.07	0.08	0.08	0.08	0.07	0.06	0.06	0.56
14 Socio-medical infrastructure & training	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.19
Title 2 - Infrastructure and operating expenditure	**1.185**	**1.235**	**1.345**	**1.355**	**1.405**	**1.395**	**1.345**	**0.935**	**10.2**
20 Rental of buildings and associated costs	0.3	0.35	0.45	0.45	0.5	0.5	0.45	0.04	3.04
21 Information and communication technology	0.08	0.08	0.09	0.09	0.09	0.08	0.08	0.08	0.67
22 Movable property and associated costs	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.08
23 Current administrative expenditure	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.12
24 Postage / Telecommunications	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.08
26 R&D support (evaluations and reviews)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	3.2
27 Innovation	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.08
28 Communication	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	2.4
29 Audits	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.53

	2019	2020	2021	2022	2023	2024	2025	2026	Total
Title 3 - Operational expenditure	**196**	**280**	**0**	**0**	**0**	**0**	**0**	**0**	**476**
R&D									
H2020 FET	68	100							168
H2020 RI	8								8
H2020 LEIT ICT	120								120
Procurement									
H2020 RI		80							80
CEF		100							100
TOTAL EXPENDITURE	**198.345**	**282.683**	**2.931**	**2.941**	**2.971**	**2.733**	**2.603**	**2.055**	**497.262**

b) Payment appropriations

	2019	2020	2021	2022	2023	2024	2025	2026	Total
Title 1 - Staff Expenditure	1.16	1.448	1.586	1.586	1.566	1.338	1.258	1.12	**11.062**
Title 2 - Infrastructure and operating expenditure	1.185	1.235	1.345	1.355	1.405	1.395	1.345	0.935	**10.2**
Title 3 - Operational expenditure	98	198.8	103.6	47.6	28	0	0	0	**476**
Total	**100.345**	**201.483**	**106.531**	**50.541**	**30.971**	**2.733**	**2.603**	**2.055**	**497.262**

C. REMARKS

- The staff needs are based on the structure of existing JUs (ECSEL in particular) and on the necessary roles to ensure the operations of a JU.
- The budget for the functioning of the EuroHPC Joint Undertaking is estimated by extrapolating the staff needs presented above and the budget of the existing JU ECSEL. It is however important to highlight that the ECSEL JU benefits from significant economies of scales under title 2 by sharing several infrastructures (building, IT,…) and services (security,…) with other JUs. In the case EuroHPC would be seated at a separate place, the budgets under title2 may need to be increased.

For the payment appropriations, it is estimated that expenses under titles 1 and 2 are paid on the year of the commitment, whilst expenses under title 3 are paid for 50 on the year of commitment N, 30% on year N+1, and 10% on the years N+2 and N+3.

ANNEX 5

HPC AND ITS STRATEGIC VALUE FOR THE DIGITAL ECONOMY

1. STRATEGIC VALUE OF THE HPC

High Performance Computing (HPC) is a branch of computing that deals with scientific and engineering problems that are computationally so demanding that computations cannot be performed using general-purpose computers. Today, these computations typically run on very powerful systems with highly parallelized computing units of tens or hundreds of thousands of processors. Those computers are often referred to as supercomputers.

Supercomputers were introduced in the 1960s, roughly 15 years after the first general-purpose computers were built and operated in the UK and the USA. Since those early days, the development of hardware and software technologies supporting modelling for science and engineering, design and product development and decision-making have advanced to a level of sophistication and predictive power that early pioneers could only have dreamt of 50 years ago. For instance, the computing power of the world's top supercomputer 25 years ago can be found in an ordinary laptop today. The speed at which computing power increases is so fast that top-notch machines are obsolete after just 5-7 years on average.

HPC is essential to address major ***scientific and societal challenges*** such as early detection and treatment of diseases (e.g. understanding cancer generation and evolution), new therapies (based on personalised and precision medicine, genome sequencing, etc.), deciphering the human brain, forecasting climate evolution, observing the space, preventing and managing large-scale natural disasters, designing renewable energy parks, accelerating the design of new polymers, etc. Its use has a growing critical impact ***on industries and businesses*** by significantly reducing design and production cycles, minimising costs, increasing resource efficiency, as well as shortening and optimising decision processes. For example, HPC has enabled automakers to reduce the time for developing new vehicle platforms from an average of 60 to 24 months improving crashworthiness, environmental friendliness, and passenger comfort.

HPC is also essential for ***national security and defence***, for example in developing complex encryption technologies, in tracking and responding to cyberattacks and in deploying efficient forensics, or in nuclear simulations.

At a macroeconomic level, returns on investment in HPC are high. A recent study shows that **in Europe every Euro invested in HPC has generated close to EUR 870 in revenues for businesses and EUR 69 in profits**[10] and that the companies and countries that most invest in HPC spearhead science and economic success.

[10] Study conducted by IDC in 2015 (SMART number: 2014/0021) based on information from 143 European HPC projects

HPC is at the core of major advances and innovation in the digital age. It dramatically increases our ability to process large amounts of big data and carry out complex computations, which is critical for a large number of scientific, industrial and social domains. HPC is also a critical tool for understanding and responding to the increasing challenges faced by our citizens in modern societies, by transforming them into innovation opportunities. This makes of HPC the engine to power the new global digital economy, where to out-compute is to out-compete, and a key technology for science, industry, and society at large. The benefits in the different domains are illustrated below:

In science, many of the recent breakthroughs simply would not be possible without HPC. The simulation of complex models and the HPC analysis of huge amounts of data has made possible that ***scientists can have today much deeper insights into previously unexplored areas and systems of the highest complexity, driving the innovation and discovery in almost all scientific disciplines:***

- In life sciences and medical research: HPC is enabling enormous advances in new therapies: scientists heavily rely on HPC for understanding the nature of diseases, for discovering new drugs, and for moving to precision medicine, customising therapies to the specific needs of a patient. In genome science, HPC is used for enabling faster and more effective analysis of genome sequences and genome assembly, and for simulating protein unfolding (critical for understanding major diseases such as cancer or Alzheimer). In biomolecular research, HPC is used for investigating the dynamics of biomolecules and proteins in human cells to understand how they contribute to cellular signalling mechanisms. In brain research such as in the Human Brain Project (HBP) FET Flagship[11], HPC is used for multi-scale and high-resolution simulation and modelling of the human brain to understand its organisation and functioning. HPC is increasingly used in population scale data analysis for understanding cancer generation and metastasis evolution and for developing predictive oncology and cancer precision medicine, etc.

[11] https://www.humanbrainproject.eu/

Throughout the application areas of ***the Human Brain Project (HBP) FET Flagship***, HPC is key to conduct collaborative research. There are two major application directions requiring access to advanced HPC capabilities: ***simulation and big data analytics***. Brain molecular simulations, cellular simulations (for example of the hippocampus), simulations of cortical columns and simulations operating at system level require the largest available highly parallel supercomputers in Europe, such as those located in the five Tier-0 supercomputing centres which are all members of HBP: Juelich (DE), BSC-Barcelona (ES), CEA (FR), Cineca (IT) and the Swiss National Supercomputing Centre (CH). Workflows for data analytics require mostly flexible parallel cluster computers where recently, the inclusion of deep learning techniques has contributed to increasing exponentially the request for application time of HBP users. Overall, HBP user groups of HPC require largest memory capacities, massive data storage and fast data access in the Peta-Bytes range including exchange of data on a European scale. HBP's Joint Platform will meet these demands via new dense memory technologies as well as a federated data infrastructure in the form of a cloudified infrastructure-as-a-service (IaaS), federated across the five Tier-0 supercomputer centres.

In 2010, the Centre for ***Pediatric Genomic Medicine*** at Children's Mercy Hospital, Kansas City, Missouri, was named one of Time magazine's top 10 medical breakthroughs. The centre uses HPC to help save the lives of critically ill children. Roughly 4,100 genetic diseases affect humans, one of the main causes of infant deaths. One infant suffering from liver failure was saved thanks to 25 hours of supercomputer time to analyse 120 billion nucleotide sequences and narrowed the cause of the illness down to two genetic variants. For 48% of the cases the centre works on, HPC-powered genetic diagnosis points the way toward a more effective treatment.

Swiss ***pharmaceutical*** giant Novartis & Schrödinger, a global life sciences and materials science software company, greatly accelerated the testing of drug candidates by using HPC. They tested 21 million drug candidate molecules, using a new technical computing (HPC) algorithm Schrödinger developed. The successful run cost only about EUR 10,000. Schrödinger has completed even larger runs since this.

- In earth sciences, HPC is used for ever higher resolution simulation in climate change (for example, studying the behaviour of the oceans), weather forecasting, earth resource evolution, but also for improving our knowledge of geophysical processes and of the structure of the interior of the Earth, for understanding earthquakes, etc.

More accurate models are needed to predict much in advance the path and the effects of the ***increasingly devastating hurricanes*** such as Irma and Harvey. The weather model from the European Centre for Medium-Range Weather Forecasts (UK) proved substantially more accurate than U.S.A. models in predicting the path of Hurricane Sandy that devastated America's East Coast in 2012. The MET Office, the UK's National Weather Service, relies on more than 10 million weather observations from sites around the world, a sophisticated atmospheric model and a £30 million IBM supercomputer to generate 3,000 tailored forecasts every day.

Agriculture is the principal means of livelihood in many regions of the developing world, and the future of our world depends on a sustainable agriculture at planetary level. HPC is becoming critical in agricultural activity, plague control, pesticides design and pesticides effects. Climate data are used to understand the impacts on water and agriculture in Middle East and North Africa, help local authorities in the management of water and agricultural resources, and assist vulnerable communities in the region through improved drought management and response.

- High Energy Physics (HEP) experiments are probably the main consumers of High Performance Computing (HPC) in the area of e-Science, considering numerical methods in real experiments and assisted analysis using complex simulation[12]. Starting with quarks discovery in the last century to Higgs Boson in 2012, all HEP experiments were modelled using numerical algorithms: numerical integration, interpolation, random number generation, eigenvalues computation, and so forth. Data collection from HEP experiments generates a huge volume, with a high velocity, variety, and variability and passes the common upper bounds to be considered Big Data. The numerical experiments using HPC for HEP represent a new challenge for Big Data Science.
- Future Energy technologies: HPC can hold the key in the future of energy for humankind – fusion. Today's nuclear power plants could soon be replaced by a safer, greener and virtually inexhaustible nuclear power on the horizon. Fusion power could be a global solution to future energy demand. With ITER slated to begin experimental tests around 2025, it is a critical time for the international teams of scientists and engineers who are planning how the reactor will perform at maximum efficiency

To develop the best ***predictive tools for ITER*** (and, by extension, other experimental fusion reactors), research teams are using HPC to resolve the behaviours of fusion plasma across the many spatial scales that impact reactor efficiency and plasma stability. Right now, it is only through HPC that researchers can simulate plasma kinetics for large experiments like ITER with enough simulated electrons to resolve important physics

Using the Mira supercomputer, ***physicists uncovered a new understanding about electron behaviour in edge plasma***, and new insights were gained into the properties of a self-generating electrical current that boosts power in a tokamak fusion reactor. Based on these discoveries, improvements were made that could enhance predictions of and, ultimately, increase fusion power efficiency.

- In materials science, HPC is used for example for molecular modelling and molecular dynamic simulation, for designing and studying the properties of new materials that can have an enormous impact in: renewable and clean energies (e.g. photovoltaics, new generation batteries); health (simulating the effect of new chemicals at molecular level); for understanding and exploiting superconductivity; for naval and marine engineering with new generation of super-hydrophobic coatings for underwater applications; etc.

Developments in the next generation of smartphones, fuel-efficient cars or powerful batteries for electric vehicles, as well as to catalysts for the production of methane or liquid fuels and high-performance solar cells, are practically always based on better, and

[12] High Performance Numerical Computing for High Energy Physics: A New Challenge for Big Data Science, https://www.hindawi.com/journals/ahep/2014/507690/

often ***completely new materials***. Several hundreds of thousands of different materials are known today, but that is only a fraction of all possible compounds. This can be changed by combining HPC with data mining technologies, enabling the prediction of unknown chemical compounds with desired properties or discover new properties of known substances. As an application case, candidate materials that can be easily exfoliated (like graphene) were reduced from 0.5 million to 1000 most promising through computational methods.

- In other scientific domains: HPC modelling and simulation techniques and data analytics approaches are the key for understanding phenomena and finding innovative solutions in many other scientific domains for high-impact science: for example in ***cosmology and astrophysics***, scientists are using HPC for simulating violent events following the Big Bang that may have produced gravitational waves, for detecting supernovae and binary star systems, or for estimating the neutrino mass and understanding dark matter and energy. Other scientific areas with important HPC use include ***renewable energy***, ***global systems science***, ***urban development***, etc.

In national security and cybersecurity: Mastering of HPC technologies and access to world-class HPC has become a national strategic priority for the most powerful nations. Supercomputers are in the first line for nuclear simulation and modelling, and for cyber-war, cyber-criminality and cyber-security. HPC is also increasingly used in the fight against terrorism and crime, for example for face recognition or for suspicious behaviour in cluttered public spaces.

Encryption of communications is necessary to safeguard business and personal online transactions, but there are some specific circumstances where it is desirable that authorities get access to encrypted communications. HPC can also help increasing the security of encryption, by learning how to build better, more efficient algorithms that require smaller keys.

In cybersecurity, HPC in combination with Artificial Intelligence and Machine Learning techniques is used to detect strange systems behaviour, insider threats and electronic fraud; very early cyber-attack patterns (in a matter of few hours, instead of a few days); or potential misuse of systems and take automated and immediate actions in order to act before hostile events occur. A recent report from the USA[13] states "… national security requires the best computing available, and loss of leadership in HPC will severely compromise our national security …".

The cyber-breach in June 2015 on USA Office of Personnel Management (affecting the data of four million federal employees) supports claims from senior military and intelligence officials that the U.S.A. is under more or less constant cyber assault. Several federal network intrusions and data breaches have been detected at the Inland Revenue Service, the Department of State and the White House. The scale of concern over the attacks suggests that they are 'far more serious…to national security' than 9/11 (Carolyn Maloney (D-NY)).

In industry, *HPC enables traditional computational-intensive sectors to significantly reduce R&D costs and development cycles, and to produce higher quality products and services,* for example in manufacturing and engineering industries (e.g. automotive, aerospace), health and pharma (e.g. drug discovery), energy (e.g. discovery of oil and gas

[13] U.S. Leadership in HPC: A report from the NSA-DoE technical meeting on HPC, December 2016

resources, renewable energy generation and distribution). HPC also paves the way for new business and innovative applications in high added-value areas (e.g., in personalized medicine, bio-engineering, smart cities/autonomous transport, etc.), reinforcing the industrial innovation capabilities, in particular of SMEs.

- HPC has enabled automakers to reduce the time for developing new vehicle platforms from an average of 60 to 24 months, saving 40 billion EUR while improving crashworthiness, environmental friendliness, and passenger comfort;
- Airbus currently uses HPC to perform complex simulations across the various components and entire passenger and cargo jets. The design of the Airbus A380 has exploited HPC to carry twice as many passengers for the same noise level, using less than 3 litres of fuel per person per 100 km and less than 75g of CO_2 per person per km. A single large passenger jet has well over two million individual parts that need to be simulated individually or as part of a larger system. Further, those millions of parts must stand up to varied pressure and strain over the course of the typical jet's lifetime, which is between thirty to fifty years. This complexity, coupled with the need for operational reliability of over 99%, puts computational demands that reach the exascale level and beyond.
- Renault used 42 million core hours on the PRACE Tier-0 CURIE machine for performing the biggest multi-physics car optimization study ever made, consisting on hundreds crash simulations on meshes of 20 million finites elements applied to more than 120 different parameter to study. This first study provided to Renault unprecedented results in mass reduction, CO2 limitation, safety improvement, and will be determinant for fulfilling future EuroNCAP6 safety rules
- Intelligent analysis of real-time data produced by airplanes can predict faults before they happen (predictive maintenance). Spirit AeroSystems Inc. – one of the largest manufacturers of aero structures – achieved 25% shorter production flow times, 30% lower assembly inventory levels; and 40% lower overtime expenses as well as $2 million in savings on inventory by using high-performance data analytics
- Total recently tripled the power of its supercomputer to develop more complete visualizations of seismic landscapes and run simulations at 10 times the resolution of existing oil and gas reservoir models. This new capability will enable more efficient upstream oil and gas exploration, as well as the discovery of reserves under more challenging geological conditions.
- HPC-enabled applications are becoming part of agriculture using e.g. radio-frequency identification tags (RFIDs) which can hold and automatically download a mass of data on the bale's moisture content, weight and GPS position. In the future, micro-tags of the size of soil particles will be deployed extensively to measure things as moisture, disease burden and even whether the crop is ready to harvest or not.

HPC is a key factor for the digitisation of industry and its innovation and competitiveness, contributing decisively to the objectives of the Digital Single Market Strategy. Considerable progress has happened in the last few years. Several MS continued or set up new HPC competence centres that facilitate access of industry and specifically SMEs to HPC services, with supercomputing centres giving support and transfer expertise to them. Some of these centres are world leaders in collaboration with industry. These models of industrial collaborations in MS include HLRS (Stuttgart), Teratec (Paris), SURFsara (Amsterdam), CINECA (Bologna), LRZ (Munich), Hartree Centre (Daresbury), to name a few. Europe, like the rest of the world, also has many HPC centres that have recently added industrial outreach programmes to work with industry. Centres with strong industrial experience are well positioned to mentor less-experienced centres, and to assume leadership roles in any future HPC competence centres.

At European level, there are several successful examples of programmes supporting industrial access and collaboration, such as PRACE Industry Access[14], PRACE SHAPE[15], or Fortissimo.[16]

- ***The PRACE Industry Access*** allows European companies access to world-class HPC resources and services. PRACE opened R&D access to industrial users since January 2012 and has supported more than 50 companies with more than 318 million CPU hours, (309 million on Tier-0 supercomputers), including nearly 1.8 million CPU hours for SMEs in the SHAPE programme.
- ***SHAPE*** (SME HPC Adoption Programme in Europe) is a pan-European PRACE-based programme supporting HPC adoption by SMEs. SHAPE aims to raise awareness and equip European SMEs with the expertise necessary to take advantage of the innovation possibilities opened up by HPC, increasing thus their competitiveness.21 SMEs have participated in the SHAPE pilot for SME access; PRACE reports 10 success stories of SMEs from 6 different countries benefiting from PRACE HPC and know-how in the PRACE centres
- ***Fortissimo*** enables European manufacturing SMEs to benefit from the increased efficiency and competitive advantage inherent in the use of simulation. SMEs don't have the pool of skills and resources to access advanced simulation (e.g. expensive HPC equipment, licensing cost of tools, etc). Fortissimo provides simulation services running on a cloud infrastructure exploiting HPC systems and making appropriate skills and tools available in a distributed, internet-based cloud environment. Around 215 partners (120 SMEs) benefit from 123 Fortissimo experiments.

2. THE IMPACT OF HPC ON THE DATA ECONOMY – SOME EXAMPLES

Governments around the world are increasingly concluding that HPC is too strategic to be outsourced to foreign suppliers and that the development of an indigenous HPC supply chain needs to be fostered. For instance, the case of the U.S. government blocking Intel from exporting its processors to upgrade some of China's most powerful supercomputers accelerated China's initiatives to develop indigenous processors.

Europe is leader in the use of HPC-powered applications: the users of HPC systems and applications in Europe include the most profitable and vibrant industrial sectors, e.g. manufacturing, oil & gas, health and pharmaceutical industry, aerospace and defence, chemical industry, etc. HPC is used in the following industry sectors that contribute significantly to jobs and economic output in Europe:

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[14] http://www.prace-ri.eu/industry-access

[15] http://www.prace-ri.eu/hpc-access/shape-programme/

[16] http://i4ms.eu/projects/projects_detail.php?post_id=6

Industry sector	Jobs supported	EU GDP
Manufacturing	25 million	13%
Health & pharma	17 million	10%
Automotive	12 million	4%
Oil & gas	0.17 million	2.8%
Aviation	5 million	2.1%
Chemical	1.15 million	1.1%

HPC has become already an integral component of business processes.[24] The three largest and most dynamically growing HPC sub-sectors are computer-aided engineering, bio-sciences as well as the energy sector[24]:

- Computer-aided engineering has a projected growth rate of HPC expenditure of 7.9% /year between 2013 and 2018. Bio-Sciences, including pharma and healthcare, have a projected growth rate of HPC expenditure of 5.1%. This trend is driven by the vision to provide individual patient treatment; consequently, a high computing demand is created to analyse each patient individually and find tailor-made solutions.
- The energy sector has a projected growth rate of HPC expenditure of ~5%: design and construction of intermittent renewable energy generation systems, testing of new and more efficient forms of materials for solar panels, optimisation of distributed generation, load management, etc.

Insurance and civil protection *is demanding more HPC simulations as demonstrated recently by the Harvey and Irma hurricanes. Severe weather forecasting on national and regional scales depends heavily on HPC, and Europe leads the world in numerical weather forecasting. From 1970 through 2012, severe weather cost 149,959 lives and €270 billion in economic damages in Europe.*

HPC simulation is an important alternative for ***animal testing****. The social and economic costs of experimental ("live") science and engineering research on animals have skyrocketed in the past decade. The EU REACH Regulation issued in 2006, the 7th Amendment of 2003 of the European Cosmetics Directive and the new European Regulation on cosmetic products issued in 2009 created an unprecedented need for alternatives to animal testing in Europe. On March 2013 a full ban on the marketing of cosmetics products tested on animals entered into force in the EU. This heavily triggered the development of alternative testing methods to reduce to a minimum the need for animal testing and, in the case of cosmetics, to fully substitute them. HPC is increasingly attractive here from both a social and financial viewpoint.*

The use of HPC is expanding to all industries as it becomes more accessible with today's and future broadband networks. **HPC is becoming a mainstream technology that Europe must master.**

European HPC investments are already producing excellent returns-on-investment (ROI) for science and industry. A 2015 study for the EC assessed the impact of recent HPC investments in scientific and industrial projects carried out within Europe.[17] Detailed ROI information was captured on 143 European HPC projects, of which 84 produced innovations and 59 produced quantifiable financial returns. In most cases, the investments consisted mainly of HPC systems and software acquired for the project, but payments for time on installed HPC systems also contributed to investments in some cases. The results are:

- *97% of the industrial companies using HPC consider it indispensable for their ability to innovate, compete and survive.*
- *Industrial sectors that leverage HPC could add up to 2-3% to Europe's GDP in 2020 by improving their products and services;*
- *Each euro invested in HPC on average returned €867 in increased revenue/income.*
- *Industrial projects averaged €75 in bottom-line profits or costs savings per €1 of HPC investment, and academic projects averaged €30 in cost savings per €1 invested.*
- *The total increased revenue for the 59 HPC-enabled, quantifiable projects was €133.1 billion, or about €230 million per project on average. Average increased profits/cost savings for the projects amounted to €69 billion.*

With almost 50% of the global HPC systems share owned by industry in 2017, the industrial sector has clearly shown over the last 23 years a growing interest in HPC. In contrast to this global picture, the majority of EU HPC capacity is currently installed at universities or academic research centres whereas the remaining minority is installed on a commercial basis in the context of commercial offerings or with HPC end users.[24]

Europe represents a favourable ground for a joint cooperation between academia and industry where the initiative would be of mutual benefit: on the one hand such cooperation would capitalize on the already existing infrastructures under a single European HPC structure, and on the other hand it would foster academic-industrial collaborations through knowledge and technology transfer to society.

Among all HPC actors, intermediaries[17] fulfil an important role as technology facilitators bringing together HPC centres (infrastructure owners), independent software vendors (ISV) and HPC customers for joint projects. This role is particularly important to help first-time users, primarily SMEs, to become acquainted with the potential of HPC for their business. With over 30000 potential beneficiaries SME type industrial companies provide a significant potential for the uptake of HPC in Europe. Large corporations which apply HPC to reduce research and development costs by simulating prototypes instead of physically building and testing them will also benefit from an EU-wide collaborative effort.

Regarding **the supply of HPC technology**, there is a potential for the European Union to build on its base of existing and planned European-wide HPC development programmes and to assemble exascale HPC capability that could, in some critical application sectors achieve world-class, if not global leadership.

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[17] HPC intermediaries provide the link between HPC centres as infrastructure providers and HPC customers. They mobilise and support SMEs to use the existing infrastructure or software development offering within their geographic vicinity, in their related sector or with those who share the same target group. Hence, their business model is to act as a facilitator for HPC customers seeking a service. Some are merely match-makers while others manage the co-development process with the customers, HPC centres and ISVs. Some intermediaries are grouped in independent Centres of Excellence, some are directly attached to an HPC centre.

In addition, there is a huge potential economic effect in the mass computing market from the investments in HPC technologies: **the development of exascale technologies is not for the sake of having the fastest supercomputer in the world**. The goal is to build "first of a kind" systems rather than "one of a kind". The transition to exascale computing is an opportunity for the European supply industry to leverage on technologies in the computing continuum from smart phones, to embedded systems (for example in the future driverless cars), and to servers, feeding the broader ICT market within a few years of their introduction in high-end HPC – giving a competitive advantage to those developing them at an early stage. The size of these target markets is of the order of EUR 1 trillion.

3. PUBLIC INVESTMENTS IN HPC IN EUROPE AND WORLDWIDE

Worldwide, the USA, China and Japan (and to a lesser degree the Russian Federation and India) have declared HPC to be a strategic priority for their country.˙ They fund programmes to develop national HPC ecosystems and work on the deployment of exascale supercomputers. **The current growth of European investment in HPC will not be enough to attain and maintain leadership, meaning at minimum parity with best-in-class HPC resources in the USA, Japan, or China, and fulfil the ambitious political goals of two pre-exascale systems around 2019-2020 and two exascale systems around 2022**.[18]

- U.S.A. government spending on HPC exceeded EUR 1.5 billion in fiscal year 2015 and more than EUR 1.7 billion in fiscal year 2016. (These figures do not count HPC spending by the U.S.A. intelligence community).
- Japan has set aside a EUR 1.2 billion undertaking for one near-exascale computer in 2022.
- China has fielded the two most powerful supercomputers and has extensive plans for the pre-exascale and the exascale systems (budget figures not available).
- **In 2015**[19]**,** the estimations of public and private investments for Europe to achieve leadership by 2020 were **of additional EUR 3.2 billion in 5 years (2016 to 2020) or EUR 5.3 billion in 7 years (2016 to 2022)** in order to match the developments of Europe's main competitors for HPC leadership in competitive time frames. These amounts entail a **funding gap** with respect to current investments in the order of **additional EUR 700 million per year.**

Regarding HPC infrastructures, Europe achieved a healthy HPC funding growth up until the period 2010-2012. The result was an increase of Europe's overall HPC capabilities by means of the purchase by MS of (then) most powerful supercomputers. [20] The predominant

[18] European Commission, Staff Working Document on the Implementation of the Action Plan for the European High-Performance Computing Strategy, SWD(2016) 106 final, 19 April 2016

[19] Study SMART 2014/0021 for the EC "High-Performance Computing in the EU: Progress on the Implementation of the European HPC Strategy"; IDC 2015.

[20] Study SMART 2014/0021 for the EC "High-Performance Computing in the EU: Progress on the Implementation of the European HPC Strategy"; IDC 2015.

funding model in the MS is one in which the central government finances 50% or more of the national supercomputing centre's entire budget, including the acquisition and upgrading of Tier-1[21] national supercomputing resources as well as operating costs. Given the important role supercomputing plays, central governments typically view this funding as a necessary investment in the economic future of their country (see Annex 6)[22] for a brief review of the organization type, funding sources and budgets of some of the most prominent national supercomputing centres in Europe, as well as national centres in some smaller countries.

Additionally, several MS are collaborating at European level through the PRACE agreement established in 2010.[23] PRACE establishes a pan-European computing and data management resource and services through a peer review process for large-scale scientific and engineering applications at the highest performance level, accessible to all researchers in Europe independently of their location. The PRACE top computer systems (Tier-0) were provided by four PRACE hosting members (BSC representing Spain, CINECA Italy, GCS Germany, GENCI France) who committed a total funding of EUR 400 million of computing time for the initial PRACE systems and operations until 2015. This agreement has been renewed recently until 2020 with the incorporation of a fifth hosting member (CSCS Switzerland). The PRACE programme is supported by the EU. PRACE also has specific programmes to strengthen the European users of HPC in industry through various initiatives (i.e. SHAPE for European SMEs).

Finally, Europe (both MS and the EC) are also investing in GÉANT[24], the pan-European data network for the research and education community linking national research and education networks as well as supercomputing centres across Europe.

Regarding the R&I actions to support the implementation of the HPC strategy, the EC has signed a cooperation agreement with two contractual private partnerships (cPPP): ETP4HPC and BDVA.

The ETP4HPC contractual Public Private Partnership[25] (HPC cPPP)[26] is based on the Contractual Arrangement signed on 17 December 2013 between the EC and the ETP4HPC Association.[27] The HPC cPPP formally started on 01 January 2014. The HPC cPPP focuses on the development of exascale technologies and the development of the applications. The HPC cPPP is complementary to PRACE, the former covering the R&I and the latter the pan-European HPC infrastructure. The two together reach all aspects of the HPC value chain. ETP4HPC is an industry-led think tank and advisory group made up of companies and research centres involved in HPC technology research in Europe. It was formed in 2011 with the aim to build a world-class HPC technology supply chain in Europe, increase the global share of European HPC and HPC technology vendors as well as maximising the benefits that

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21 Tier-1 systems are top supercomputers in which the access is managed by national authorities

22 Extracted from the IDC study

23 PRACE (http://www.prace-ri.eu/) offers a pan-European supercomputing infrastructure, providing access to computing and data management resources and services for large-scale scientific and engineering applications at the highest performance level. It is an association of 24 member countries.

24 https://www.geant.org

25 Contractual partnerships with industry in research and innovation, http://europa.eu/rapid/press-release_MEMO-13-1159_en.htm

26 High Performance Computing cPPP: Mastering the next generation of computing technologies for innovative products and scientific discovery, http://ec.europa.eu/research/press/2013/pdf/ppp/hpc_factsheet.pdf

27 http://www.etp4hpc.eu/

HPC technology brings to the European HPC user community. Today, ETP4HPC has more than 80 members from industry and research; 35% of the total number of members is SMEs.

The Big Data Value Association (BDVA)[28] is an industry-led contractual counterpart to the EC for the implementation of the Big Data Value PPP cPPP. As of December 2015, the BDVA has over 120 members including large and SME industry together with research institutions and academia. The Big Data Value PPP is a partnership between the EC and the BDVA which aims to strengthen the data value chain, cooperate in data research and innovation, enhance community building around data and set the grounds for a thriving data-driven economy in Europe. The BDV cPPP is driven by the conviction that research and innovation, focusing on a combination of business and usage needs, is the best long-term strategy to deliver value from Big Data and create jobs and prosperity.

Activities funded by the EU programmes: currently, the main instrument at EU level to implement the HPC strategy is Horizon 2020 (H2020). The activities covered span from fundamental research to development, integration and prototyping, addressing components to full scale systems, acquisition and deployment of equipment and infrastructure, as well as support services to the user community.

As the activities mentioned above are different in scope they are funded by different H2020 Programmes: FET, LEIT and e-Infrastructure.

The H2020 work-programmes (WP) 2018-2020 support the implementation of the HPC strategy along 3 main axes:

1. Developing the next generation of key HPC technologies and systems towards exascale: The LEIT-ICT WP supports a Framework Partnership Agreement (FPA) action for the development of European low-power microprocessors and related technologies, and Extreme Scale Demonstrators to integrate with a co-design approach the technology building blocks developed in the FET and LEIT ICT R&I actions for operational environments. The FET WP complements the microprocessor FPA to address the whole technology spectrum from software, algorithms, programming models and tools, to novel system architectures.
2. Acquiring and providing access to world-class supercomputing facilities and services for academia and industry: The e-Infrastructure WP supports PRACE (ensuring access to the best European HPC infrastructures for European researchers), GÉANT for high speed and highly resilient pan-European communication and the acquisition of innovative HPC solutions through a Public Procurement for Innovation action.
3. Achieving excellence in HPC applications, and preparing and widening HPC use: The e-infrastructure WP supports HPC Centres of Excellence (CoEs), developing, preparing and optimising the HPC codes and applications for future exascale systems, complemented with actions for increasing the innovation potential of SMEs using advanced HPC services and focusing on the areas addressed by CoEs. The LEIT-ICT WP supports the development of large-scale HPC-enabled industrial pilot test-beds for big data applications and services, providing secure access and provisioning of highly demanding data use cases for companies and especially SMEs.

This is complemented by actions supported through CEF, addressing the use of supercomputers to process open data for public services.

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[28] http://www.bdva.eu/

Currently, around 110 M€ are allocated in CEF and another 770 M€ is foreseen in the H2020 WP 2018-2020 for technology and infrastructure support, as follows:

- ~460 M€ for technology and application development through H2020 calls (LEIT ICT and FET) and ~230 M€ from H2020 e-Infrastructures for supporting European HPC Centres of Excellence, PRACE, GÉANT, and actions for supporting the innovation potential of engineering SMEs as users of advanced HPC services.
- Another financial envelope of ~80 M€ is to be allocated to the acquisition through joint procurement with the Member States of two pre-exascale computing machines and their data infrastructures. The main source of funds is H2020 (e-Infrastructure part) and CEF.

The following is a simplified comparative summary of investments in HPC[29]. Note that HPC investments in public programmes in different countries are not implemented in the same way, i.e. the EU is through multi-annual programmes whereas the US programmes' budgets are discussed and approved annually, therefore comparison is difficult.

<table>
<tr><th colspan="5">Annual investments in HPC programmes</th></tr>
<tr><td></td><td>U.S.A[30]</td><td>China</td><td>Japan</td><td>EU[31]</td></tr>
<tr><td>R&D (public and private)</td><td>1-2 b$/year (2016)</td><td>Over 1 b€ per year (2016)</td><td rowspan="2">0.24 b€ (1.2 b€ in 5 years)[32]</td><td rowspan="2">(EC ~0.3 b€ + MS 0.21 b€) per year (2014-2020)</td></tr>
<tr><td>Acquisition for pre-exascale and exascale systems</td><td>525 m$ for 2017-2018 (CORAL) and ~0.5-1 b$ for 2021[33]</td><td>1-1.5 b$ for 2017-2019 and 0.5-1 b$ for 2020[34]</td></tr>
</table>

[29] Source: Hyperion "Major Trends in the Worldwide HPC Market", April 2017

[30] These figures do not include the HPC spending of the USA intelligence agencies (NSA, FBI, CIA).

[31] Total R&D investments in EU programmes for the period 2014-2020 are in the order of 1 b€, with matching funds from private stakeholders. The Member States figures are an estimation in the high range for HPC in general; no specific budgets have been committed to pre-exascale or exascale systems yet

[32] Japan gives a single figure of ~1.2 b€ for R&D and the procurement of 1 exascale system plus a few smaller systems until 2021

[33] This only includes the Department of Energy (DoE) procurement CORAL. Budget for exascale machines has not been released

[34] Includes the estimations of pre-exascale and exascale systems as planned

In Annex 6, a detailed account is provided of the different major HPC initiatives in the USA, China and Japan as well as in the main European countries.

The Figure below provides an illustration of comparison of some of the biggest public programmes worldwide in HPC[35]. For the US, the NSCI is just one of the multiple federal programmes, and provides only a low estimation of public investments in HPC (see box in the beginning of section 3 above). Note also that public HPC programmes in different countries are not implemented in the same way, i.e. the EU is through multi-annual programmes whereas the NSCI US programme's budget is discussed and approved annually. To illustrate the underinvestment of European programmes with respect to the U.S.A., the NSCI (one of the several federal initiatives supporting HPC) invests ~285 m€ per year, whereas the Horizon 2020 programme would average only ~130 m€ per year (893 m€ across 7 years).

Summary of National HPC Strategies, by Country (Selection)

Country	HPC Strategy/Program and Description	Investment Level [1)]
United States	National Strategic Computing Initiative (NSCI)	approx. EUR 285 m/year
China	13th Five-Year-Development Plan (Develop Multiple Exascale Systems)	approx. EUR 178 m/year (for next five years)
Japan	Flagship2020 Program	approx. EUR 178 m/year (for next five years)
European Union	ExaNeSt, PRACE, ETP4HPC	approx. EUR 893 m total allocated through 2020 (annual allocations N/A)
India	National Supercomputing Mission	approx. EUR 124 m/year (for five years from 2016-2020)
South Korea	National Supercomputing Act	approx. 18 m/year (for five years from 2016-2020)
Russia	HPC Focus of Medvedev Modernisation Programme	N/A

1) USD amounts converted to EUR based on current exchange rate (08.06.2017)

Figure: Comparison of the several worldwide national programmes in HPC

[35] EIB study 2017

ANNEX 6

BRIEF REVIEW OF THE FUNDING SOURCES AND BUDGETS OF HPC INITIATIVES WORLDWIDE AND IN EUROPE

USA

The USA is the world leader in HPC systems and technologies (both use and supply). It has established a National Strategic Computing Initiative (NSCI) and the Exascale Computing Project (ECP)[36], a multi-agency strategic vision and Federal investment strategy to maximize the benefits of HPC for economic competitiveness and scientific discovery, and the delivery of the first exascale systems for the US.

Several exascale systems will be installed from 2023 onwards by different Federal agencies, mainly in DoE research labs (but also for homeland security agencies like NSA, defence, etc. but no corresponding information has been disclosed). The investments in R&D for HPC towards exascale amount to $1 to $2 billion per year (mostly public but this figure includes supplier's investments).[37] For pre-exascale systems, the DoE is deploying several pre-exascale systems with CORAL, a single $525 million procurement process to acquire three next-generation supercomputers operational in 2017, each capable of performing 0.1 to 0.25 Exaflops.

The US government has long-standing models for R&D collaborations with indigenous HPC vendors, many of which include supercomputer procurements with strong R&D requirements, typically for the national laboratories of the US Department of Energy (DoE). The Exascale Computing Project is a collaborative effort of two DoE organizations – the Office of Science and the National Nuclear Security Administration. It is a 7-years project that follows the co-design approach and runs through 2023 involving all major US HPC vendors: Intel, Cray, HPE, IBM, NVIDIA, and AMD. US HPC system vendors have the lion share of today's EU market. Four out of the seven PRACE Tier-0[38] systems installed in Europe are from US vendors.

CHINA

China is ramping up HPC spending faster than any other nation or region and already hosts the two most powerful machines that together account for 87% of the top 500 aggregate performance in the EU. However, utilization of Chinese supercomputers is typically much lower than in Europe, the USA or Japan. The first Chinese prototype with peak exaflop performance (although not in normal operation) is expected already by the end of 2020. Several exascale systems will be installed from 2023 onwards. The investments in R&D for HPC towards exascale will be over $1 billion per year (mostly public).[39] Three pre-exascale computers (already in development) are planned for deployment by the end of 2017 and during 2018, in a competition exercise to select the best architecture for the future machines.

China has developed indigenous technology that will come in the next few years into the mass ICT market and also has a strong HPC vendor base: Lenovo, Inspur, Huawei, and Sugon.

[36] https://exascaleproject.org/

[37] Source: Hyperion "Major Trends in the Worldwide HPC Market", April 2017

[38] Tier-0 systems are world-class supercomputers accessible at EU level through the PRACE pan-European HPC infrastructure

[39] Source: Hyperion "Major Trends in the Worldwide HPC Market", April 2017

Lenovo is taking assertive steps in the European market; after its 2014 acquisition of the IBM x86 server business it became one of the world's top 4 HPC server system vendors. For instance, Lenovo built two of the PRACE Tier-0 systems and is establishing a global HPC innovation centre in Stuttgart. China plans to deploy the first exascale level supercomputer in 2020.

JAPAN

Japan had twice in the past the world's most powerful supercomputer, most recently in 2011. The Ministry of Education, Culture, Sports, Science and Technology supports two exascale projects:

- First, the FLAGSHIP 2020 Project initiated in 2014. RIKEN, the largest comprehensive research institution in Japan, is the main organization for leading the development of next generation flagship supercomputers. A wide range of applications will address both science and industry. The deployment of the first exascale machine will be in 2022 with a cost of EUR 1.2 billion (this includes the R&D and the acquisition of the machine).[40]
- Second, the emerging supercomputer vendor ExaScaler Inc. and Keio University will develop another supercomputing design with exascale aspirations.

Fujitsu and NEC had considerable success in the past selling into EU markets, but they largely retreated when x86-based HPC systems began displacing their technology. Japan has three major HPC vendors, Fujitsu, NEC and Softbank's ARM, which was a leading European vendor until mid-2016.

GERMANY

- National Supercomputing Centre: Germany's Gauss Centre for Supercomputing (GCS) is an alliance of the country's three national HPC centres: HLRS (Stuttgart), LRZ (Munich) and FZJ (Jülich).

- Funding Sources and Management: GCS is jointly funded and managed by the German Ministry of Education and Science (Bundesministerium für Bildung und Forschung, BMBF) and the corresponding ministries of the three national states of Bavaria, Baden-Wuerttemberg and North Rhine-Westphalia. The states provide half of the funding for their respective centres and the German federal government provides the other half.
  Furthermore the federal government has started a Special Programme on Exascale Computing (SPPEXA www.sppexa.de) for the development of software. This complements a special program by the Federal Ministry of Science which has since 2010 started three calls for projects on scalable software with a special focus on industrial applications (details at https://www.gauss-allianz.de/en/projects).
- Budget: For the period 2007-2017, the federal government and the three state governments together have provided €400 million in funding for GCS. GCS also represents Germany in the PRACE alliance and has benefited from EC financing for PRACE.

- Other: The BMBF is separately investing €100 million over the next five years for the D-Grid infrastructure to support scientific collaboration. Germany was one of four European nations that committed to contribute €100 million in resources to the PRACE 1.0 budget. GCS represents Germany in the PRACE alliance and provides three of the current seven Tier-0 systems of PRACE.

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[40] Source: Hyperion "Major Trends in the Worldwide HPC Market", April 2017

FRANCE

- National Supercomputing Centre: France has two sites that function as national supercomputing centres: CEA, a secure site that addresses national nuclear security needs, and CINES, The National Computer Centre of Higher Education. Another important actor is Agence Nationale de la Recherche (ANR). In the end, however, GENCI (Grand Equipement National de Calcul Intensif) has the central role in HPC in France. Plan Investissement d'avenir is investing €50 million for HPC and is managed by CEA. Also noteworthy is Teratec, an association which unites over eighty technological and industrial companies, laboratories and research centres, universities and engineering schools who want to combine their resources in simulation and high performance computing.
- Funding Sources and Management: GENCI is a civil company (société civile) and is 49% owned by the State, represented by the Ministère en charge de l'Enseignement supérieur et de la recherche, 20% by the CEA, 20% by CNRS, 10% by participating universities, and 1% by INRIA. GENCI is invested with a central coordinating function by these organizations.
- Budget: ANR provides €25 million in HPC financing per year.
- Other: France was one of four European nations that committed to contribute €100 million in resources to the PRACE 1.0 budget. The Curie supercomputer, owned by GENCI and operated by CEA, is the first French Tier-0 system open to scientists through the French participation in the PRACE research infrastructure. Launched in October 2011 for a three year period, with a budget of €14.5 million euros, the purpose of the Mont-Blanc project, coordinated by BSC (Spain) and including GENCI together with the CEA, is to evaluate the potential of low energy components, such as the technologies used in our mobile phones, for the next generation of supercomputers.

UNITED KINGDOM

- National Supercomputing Centre: The UK has no permanent national supercomputing centre. Instead, major centres compete periodically for the contract for provide the HPC national academic service across the UK. At present, the Edinburgh Parallel Computing Centre has that role. Also of note, the Science and Technology Facilities Council's Daresbury campus manages the Hartree Centre, which has a major role in supporting the HPC needs of industry (as well as academia) in the UK.
- Funding Sources and Management: The UK Research Councils coordinate HPC academic research activities.
- Budget: The Engineering and Physical Science Research Council manages the budget for national capability, described as "support for excellent, long-term disciplinary and multidisciplinary research in engineering and the physical sciences." The allocation for this HPC- related budget item has been substantial and covers not just investments in supercomputers but also grants for research performed using supercomputers. The largest HPC-specific initiative within this budget is ARCHER, the UK's national academic supercomputing service. The UK government allocated £113 million (€157 million) for this program in 2014. The Hartree Centre was founded in 2012 with €52 million in funding from the UK's Science and Technology Facilities Council (STFC) to "develop, deploy and demonstrate HPC solutions," typically in partnership with industry.
- Other: The UK is a PRACE member but has not been a contributing/hosting member within the PRACE 1.0 period.

NETHERLANDS

- National Supercomputing Centre: SURFsara is the national supercomputing and e-science support centre in the Netherlands. SURFsara's customers include all Dutch universities, a number of large research, educational and government institutions, and the business community. SURFsara has been a partner in large European e-Infrastructure projects including PRACE 1IP, PRACE 2IP, PRACE 3IP, EESI2, EGI.InSPIRE and EUDAT, and partner in HPC- EUROPA2. The 1.6PF Cartesius supercomputer managed by SURFsara is the country's most powerful.
- Funding Sources and Management: Cartesius was funded by SURF, with contributions from the Dutch Organization for Scientific Research (NWO), the Ministry of Education, Culture and Science and the Ministry of Economic Affairs. SURF is the organization in the Netherlands which supports higher education and research in the area of e-infrastructures.
- Budget: About €7 million (€3-4 million operating funds plus an average €3 million/year for acquiring supercomputing resources).

SPAIN

- National Supercomputing Centre: BSC-CNS (Barcelona Supercomputing Centre - Centro Nacional de Supercomputación) is the national supercomputing facility in Spain and hosts the MareNostrum supercomputer. The mission of BSC-CNS is to investigate, develop and manage information technology in order to facilitate scientific progress.
- Funding Sources and Management: In 2004, the Ministry of Education and Science, Generalitat de Catalunya (Catalan Government) and Technical University of Catalonia founded the National Supercomputing Center in Barcelona. In 2004, the Ministry of Education and Science, Generalitat de Catalunya (Catalan Government) and Technical University of Catalonia founded the National Supercomputing Centre in Barcelona.
- Budget: BCS had an initial operational budget of €5.5 million/year to cover the period 20052011. The income of the BSC-CNS in 2009 was €20.1 million of which €6.6 M corresponded to the ordinary budget coming from the patrons of the BSC-CNS, the Spanish and Catalan Governments; and €8.1 million from competitive projects. Of particular note, €3.9 million of funding was derived from projects with private companies. In 2009, the BSC-CNS participated in 23 competitively funded EU projects, 37 collaborative projects with industry and 14 national projects.
- Other: In 2012, BCS upgraded MareNostrum at a cost of €22.7 million. The Spanish Supercomputing Network links MareNostrum to more than a dozen smaller HPC sites in Spain. BCS is a PRACE tier-0 host member.

ITALY

- National Supercomputing Centre: CINECA is Italy's national supercomputing centre and the country's PRACE host site. CINECA's Fermi supercomputer is one of the world's most powerful.
- Funding Sources and Management: CINECA is a non-profit consortium made up of 70 Italian universities, four Italian Research Institutions and the Italian Ministry of Education. 70% of CINECA's budget is funded by the Italian Ministry of Education

University and Research, for services to science and industry. The remaining 30% of the budget comes for providing other services. A framework agreement governs how CINECA and other Italian HPC centres collaborate with industry (PPPs). CINECA is led by a Board of Directors composed of the rectors of the member universities or their delegates, by a representative of CNR (National Research Council) and one of the Ministry of Education, University and Research (MIUR).The Board of Directors is represented by the Chairman, while the General Manager is responsible for the development, organisation and management of the Consortium's activities.

- Budget: As a PRACE hosting member, Italy made a commitment to spend €100 million during the course of PRACE 1.0. IDC estimates that Italy's annual monetary budget for HPC is about €20 million.
- Other: CINECA also acted as the procuring entity for the PRACE 3IP PCP (pre-commercial procurement) submission of March 9, 2015, representing partners CSC (Finland), GENCI (France), FZJ (Germany) and the University of Edinburgh. The goal of this PCP is "Whole System Design for Energy Efficient HPC." The budget is total €9.0 million over 26-months duration. CINECA is led by a Board of Directors composed of the rectors of the member universities or their delegates, by a representative of CNR (National Research Council) and one of the Ministry of Education, University and Research (MIUR).The Board of Directors is represented by the Chairman, while the General Manager is responsible for the development, organisation and management of the Consortium's activities.

FINLAND

- National Supercomputing Centre: CSC, the Finnish IT Centre for Science, is Finland's national supercomputing centre and supports both science and industry. CSC supports a European-wide customer base of thousands of researchers in disciplines such as biosciences, linguistics, chemistry and mathematical modelling.
- Funding Sources and Management: CSC is a non-profit limited company whose shares are fully owned by the Finnish state. CSC is directly governed by the Finnish Ministry of Education. The Finnish Funding Agency for Technology and Innovation (Tekes) provides about half of the HPC funding for Finnish universities, research institutes, and industry. Finland's innovative MASI (modelling and simulation) program, 2005-2010, was aimed at boosting the global competitiveness of Finnish firms through the use of HPC. Financing for MASI totalled €100 million over five years, with Tekes providing €53 million of that amount.
- Annual Budget: €31 million

DENMARK

- National Supercomputing Centre: Danish Centre for Scientific Computing (DCSC).
- Funding Sources and Management: DCSC is under the Danish Ministry of Education with government funding allocated for data processing capacity within the area of scientific computing for research assignments.
- Annual Budget: €3 million (estimated)

NORWAY

- National Supercomputing Centre: Norway has no single national supercomputing centre. NOTUR, the Norwegian Metacentre for Computational Science, oversees time allocation for Norway's four supercomputer centres. They are located at the Norwegian University of Science and Technology (NTNU) in Trondheim, the University of Bergen, the University of Tromsoe, and the University of Oslo.

- Funding Sources and Management. The Research Council of Norway (Norges forskningsråd), like its Finnish counterpart, provides about half the funding for Norwegian HPC initiatives of national interest. A major thrust is the eVITA program aimed at developing innovative tools to support HPC use in science and industry.
- Annual Budget: The eVITA annual budget is about €17 million. The Norwegian Intelligence Service's (NIS) annual budget was quadrupled in 2014 to more than €90 million, from which NIS plans to use a substantial but unspecified amount to acquire a powerful new supercomputer ("STEEL WINTER") for crypto-analysis.

SWEDEN

- National Supercomputing Centre: Like Norway, Sweden has no single national supercomputing centre.
- Funding Sources and Management: The Swedish National Infrastructure for Computing (SNIC) is a distributed infrastructure that is funded in part by the Swedish Research Council (Vetenskapsrådet) and in part by the participating universities: Chalmers University of Technology, KTH Royal Institute of Technology, Linköping University, Lund University, Umeå University and Uppsala University. SNIC is part of the Swedish Science Council, whose task is to coordinate and develop high-end computing capacity for Swedish research. Prominent among the universities aligned with SNIC is the KTH Royal Institute of Technology in Stockholm.
- Budget: In October 2014, KTH installed a 2PF supercomputer, the largest to that date in the Nordic countries. The budget for acquiring the computer and four years of operations (with spending over four years) is about €18 million and comes primarily from SNIC.
- Annual Budget: The SNIC annual budget is €4.8 million (45 MSEK).

GREECE

- National Supercomputing Centre: Greece has no designated national supercomputing centre, but in 2014 the state-owned company Greek Research and Technology Network (GRNET S.A.) teamed with Cosmos Business Systems to acquire a national supercomputer. IDC estimates the market value of the 180TF, Xeon-based supercomputer at about €6 million.
- Funding Sources and Management: The GRNET S.A. state-owned company operates under the auspices of the Greek Ministry of Education - General Secretariat for Research and Technology. Its mission is to provide high-quality infrastructure and services to the academic, research and educational community of Greece, and to disseminate ICT to the general public, including HPC. In 2014, GRNET signed a contract for Greece's first national supercomputer. The national supercomputer was developed under the “PRACE-GR - Developing National Supercomputing Infrastructure and Related Services for the Greek Research and Academic Community” project, which is co-funded by the Operational Programme “Attica” and the European Regional Development Fund (ERDF).
- Annual Budget: IDC estimates GR-NET's budget at €2-3 million per year.

SWITZERLAND

- National Supercomputing Centre: The Swiss National Supercomputing Centre (Italian: Centro Svizzero di Calcolo Scientifico; CSCS) acts in this capacity.
- Funding Sources and Management: CSCS is an autonomous unit of the Swiss Federal Institute of Technology in Zurich (ETH Zurich) and closely collaborates with the local University of Lugano (USI). In addition to the computers of the National User Lab, CSCS operates dedicated compute resources for strategic research projects and tasks of national interest. Since 2000, the calculations for the numerical weather prediction of the Swiss meteorological survey MeteoSwiss take place at the Swiss National Supercomputing Centre.

Annual Budget: €23.2 million

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COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT

Accompanying the document

Proposal for a Council Regulation

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Annex 2 (Part 1)

Analysis of the responses received to the targeted Consultation on the HPC Initiative in Europe and on the EuroHPC Inception Impact Assessment

1. Objective, scope and context of the consultation

The Commission is looking into the needs and most efficient options for establishing a future EU-wide initiative on High Performance Computing (HPC), the EuroHPC. The purpose is to coordinate EU and Member States activities and, together with private actors, pool efficiently resources in this area.

The targeted consultation with stakeholders aimed at contributing to the definition by the end of 2017 of a legal instrument that provides a procurement framework for HPC, in line with the Digital Single Market mid-term review Communication.[1] Specifically, this consultation provided input to guide the Commission in the design of this new legal and financial instrument which implements the goals of EuroHPC in the most effective, efficient and transparent manner.

2. Identification of Key Stakeholders

The levels of interest and knowledge determine the appropriate consultation method and tools. Considering the highly specialised domain of HPC, the Commission set-up a targeted consultation that addressed specifically those institutions and individual experts that have on one hand a deep involvement in HPC development and usage and on the other hand a practical experience in engaging in EU-wide projects in this area.[2]

Views were sought from the following type of stakeholders considered to represent to the best reasonable extent the European HPC community:

- National and EU-funded projects on HPC (*Projects*),
- Scientific user communities of HPC infrastructures (the 29 large ESFRI research infrastructures and the PRACE scientific users, each reaching hundreds of actors, EUDAT, EGI, etc.) *(Scientific Users)*,
- Public-private partnerships on HPC and Big Data (*PPPs*),
- Centres of excellence for supercomputing applications, supercomputing centres, service providers, access providers (*Intermediaries*),
- HPC research & industry associations (*Associations*),

The goal was to reach all identified stakeholders and elicit their contributions on time with respect to the further process of the planned development of the EuroHPC Regulation.

The on-line consultation was conducted through the DSM website of the European Commission between 3 August and 5 September 2017[3] (all inputs received until 08 September were considered in this analysis too).

1 COM(2017) 228 final

2 https://ec.europa.eu/digital-single-market/en/news/targeted-consultation-high-performance-computing-initiative-europe

3 https://ec.europa.eu/eusurvey/runner/Eurohpc

This consultation represented only the last step in a wider series of workshops and meetings with stakeholders that started in 2016 in which the European HPC strategy was already presented and discussed according to its status at that time (see below Section 4).

3. Consultation activities, formats & tools

The Commission informed the HPC community about the consultation via personalized e-mails, social media, a newsflash, intermediary organisations serving hundreds of stakeholders, and also via Commission contacts in the Member States.

The online consultation was performed via a web-based questionnaire developed for this specific purpose. Apart from general questions on the identification of respondents, it consisted of 18 technical questions covering the spectrum from the identification of the problems, the European added value, the objectives of a future EU initiative on HPC, the options to reach its objectives and its expected impacts.

Due to its common usage in the HPC sector, the consultation was performed in the English language only.

4. Time & resources

- Email invitation of stakeholders to participate in the consultation: 27/07/2017
- Start of consultation: 03/08/2017
- End of consultation: 05/09/2017
- Start of evaluation: 05/09/2017
- End of evaluation: 11/09/2017

5. Previous Consultations

A number of activities to engage with these stakeholders had already taken place, each covering a wide range of the relevant stakeholders (see Section 2):

Stakeholder engagement activity	*Scientific Users*	*EU Member States*	*Projects*	*PPPs*	*Interme-diaries*	*Associ-ations*
Workshop on the European micro-processor on 18 January 2017 in Brussels						
General assembly of ETP4HPC on 21 March 2017 in Munich						
Digital Day of 23 March 2017 in Rome in the presence of 250 HPC stakeholders						
Workshop on EuroHPC governance in Rome on 23 March 2017 with 50 participants						
PRACE days on 15-18 May 2017 in Barcelona, gathering the whole HPC community						
Eleven meetings with the Sherpas of the EU Member States						
European Open Science Cloud summit on 12 June 2017 in Brussels						
Multiple meetings with key stakeholders (PRACE, ETP4HPC, visits to supercomputing centres, international conferences…)						

6. Summary of the Results of the Targeted On-line Consultation

As questions were optional, the percentages in this document refer to the number of respondents per group that actually answered the particular question. The contributions of stakeholders who consented to publication[4] are available online.[5]

This analysis does not represent the official position of the Commission and its services, and does not bind the Commission in any way.

6.1 Geographical coverage

The consultation received a total of **92 replies** from stakeholders from a wide geographical coverage[6]: as Figure 1 shows, respondents originated from organisations situated in 17 out of the 28 EU Member States and in 4 from outside the EU[7]:

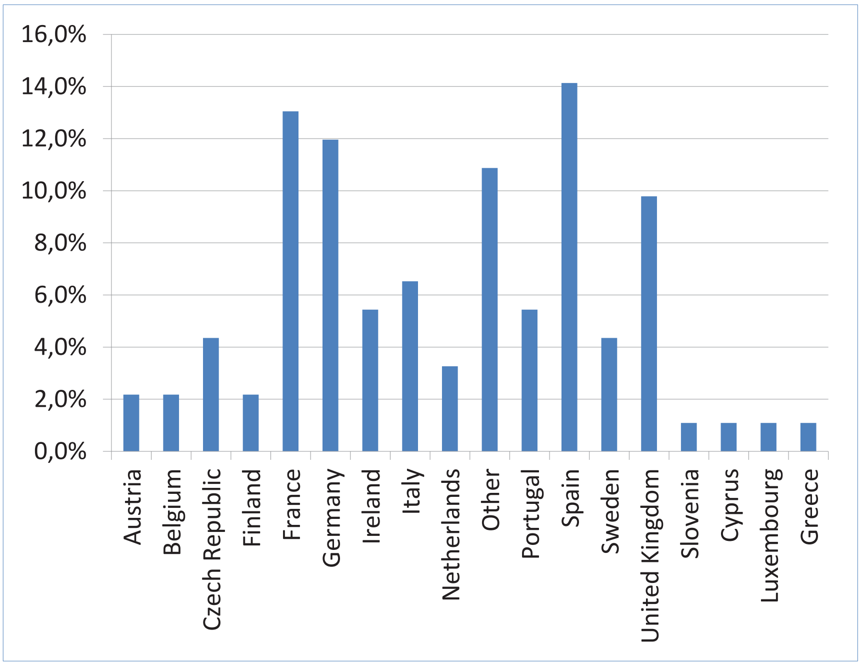

Figure 1 – Country of respondent's origin

The feedback has to be seen against the background of rather strict time constraints for the preparation of the entire EuroHPC file and the consequential need to place the consultation in the European summer holidays period.

The largest number of responses came from Spain (14.1%), France (13%), Germany (12%), UK (9.8%) and Italy (6.5%), totalling ~55% of responses. However, not only these larger Member States expressed an active interest in EuroHPC, but also smaller Member States[8], totalling ~34% of responses).

4 41% agreed that their contribution can be published anonymously, 59% agreed to publication of the full information.

5 https://ec.europa.eu/digital-single-market/news-redirect/608647

6 Status as of 7 September 2017 – end of business

7 Israel, Norway, Switzerland, USA.

8 Portugal, Sweden, Czech Republic, Netherlands, Ireland, Austria, Belgium, Finland, Slovenia, Cyprus, Luxembourg, Greece.

In summary, despite time pressure and resulting need to place the targeted consultation in the summer period, there is a representative European feedback including even around 10% feedback received from non EU countries.

6.2 Type of organisation responding

Regarding type of organisation responding, Figure 2 shows that 60% responded as representative of an academia / research organisation, 24% as of business, 6% as of the public sector and 3% as of industry associations.

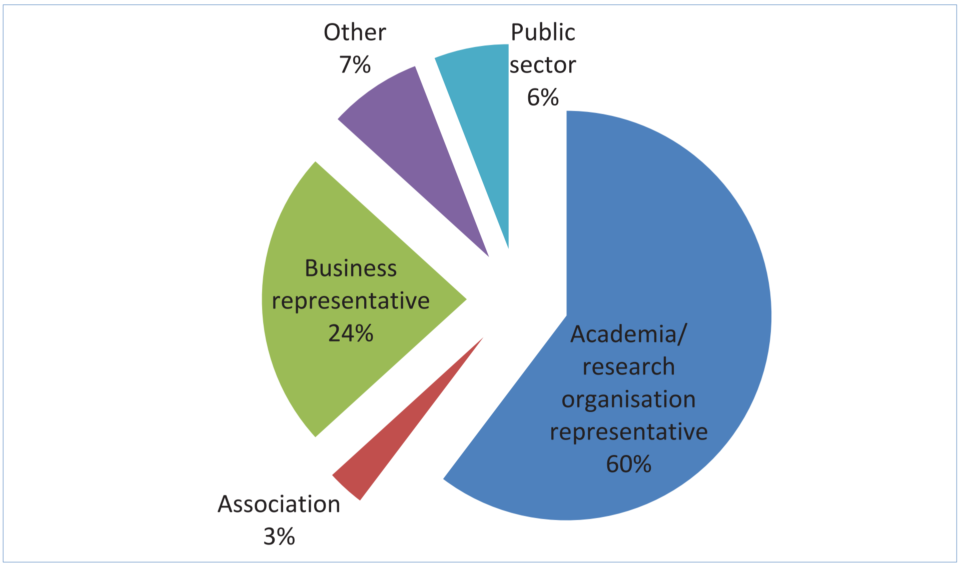

Figure 2 – Type of organisation of respondents

This result confirms the already great awareness that European science & research actors have on HPC. It also gives an indication on the future potential of HPC for European industry, including SMEs. The latter aspect is confirmed by the fact that 45% of business representative respondents originate from small, medium and micro sized enterprises which do not constitute a traditional group of HPC users (see Figure 3).

More than 80% (82.6%) of respondents have already applied for funding in HPC related activities under Horizon 2020 or previous EU Research Framework Programmes, which confirms that indeed specifically those institutions and individual experts that have a deep involvement in HPC and practical experience in engaging in EU-wide HPC projects have responded.

In addition, the fact that the respondents that have not yet done so represent a sizeable group (17.4%) confirms that interest in the EuroHPC initiative is not limited to stakeholders experienced with EU funding programmes but attracts also new constituencies.

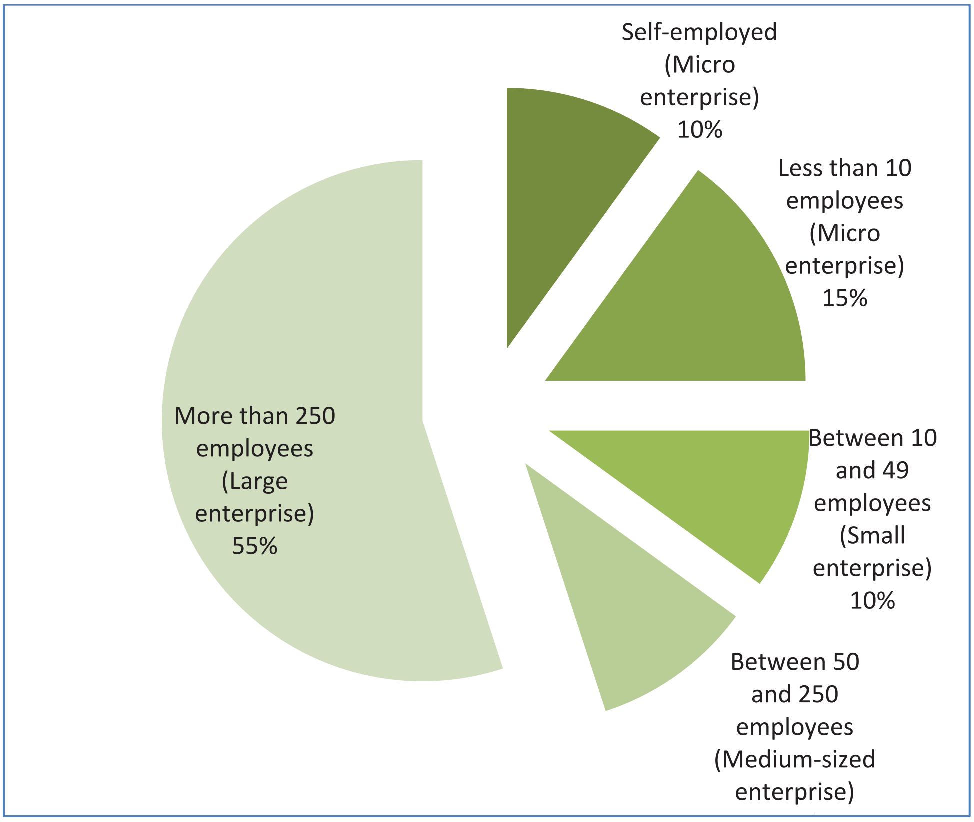

Figure 3 – Breakdown of Business representatives

In the remainder of the document, when analysing the breakdown of respondents by type of organisation, we have grouped the respondents as follows:

- Scientific users,
- Industrial users,
- Technology supply industry,
- Computing centres.

As shown in Figure 4, the widest geographical coverage has been reached by the computing centres covering 15 EU countries plus Switzerland (Other), followed by the scientific users covering 11 EU countries plus Switzerland (Other). The technology supply industry and the industrial users received each response from 4 EU countries plus Switzerland, USA, Norway, and Israel.

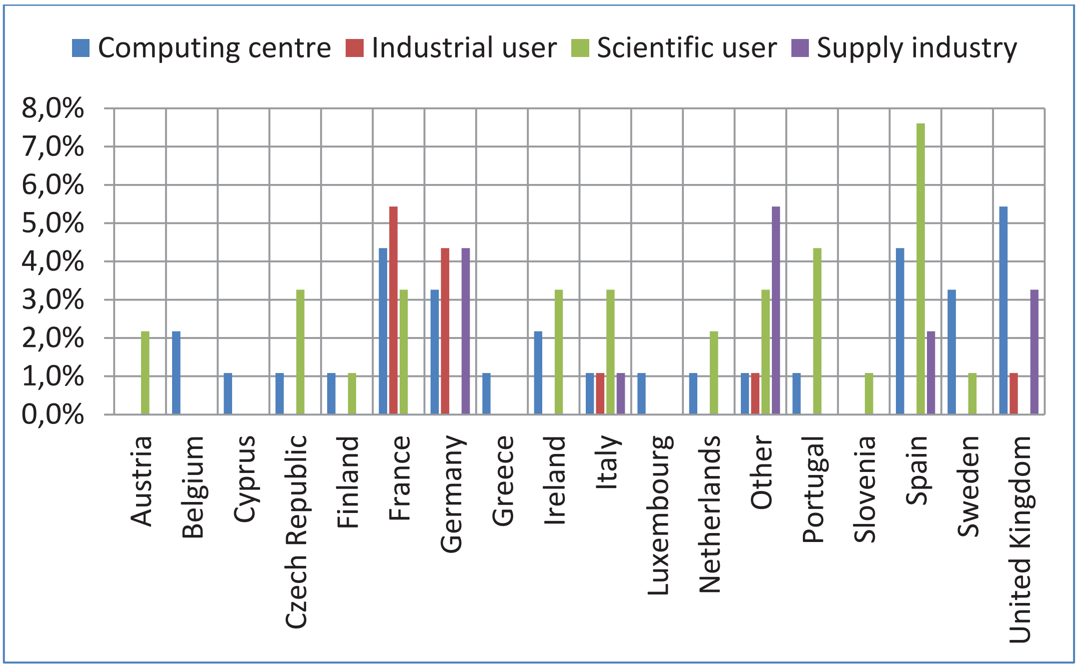

Figure 4 – Geographical split by type of respondents

In summary the EU's computing centres have obtained the widest geographical coverage in the consultation reflecting the pan-European involvement of this group in HPC. The industrial users were represented by large Member States like France (5.4%), Germany (4.3%), the UK (1.1%), and Italy (1.1%), who already make rather extensive use of HPC, plus Switzerland (1.1%).

Noteworthy is also the participation of the technology supply industry from Spain, the UK, and Germany, respectively amounting to 15%, 33%, and 36% of their respondents, confirming a strong presence of technology supply industry from those EU countries.

Interestingly, the participation of the technology supply industry from non-EU countries (Other) amounts to 50% of their respondents, which is the largest fraction per country. This rather large presence shows the great interest of non-EU technology supply industry for the European HPC market.

Without surprise, the non-EU technology supply industry respondents are located in the USA (40%), in Israel (40%), and in Norway (20%). Quite remarkably, the USA alone has the largest fraction of technology supply industry respondents per country, confirming once more the strategic interest of the USA for the European HPC market.

6.3 Identification of the problems

As a key result, 85% of respondents found that there is a problem with the current state of HPC in Europe; only 2% saw no problem, while 13% were undecided.

From those who saw a problem with the current state of HPC in Europe, the majority of respondents identified the following three issues as the most relevant problems:

- The *interaction between industry and academia* on the exploitation of high-end computing systems, application codes and services is limited, especially regarding the use of HPC for industrial and service innovation (55.6%);

- There is *large fragmentation of HPC programmes and efforts in Europe* and the non-coordinated activities and the lack of a common procurement framework lead to a waste of precious resources (55.6%);
- *Europe's supercomputing capabilities depend on non-EU suppliers* for critical technologies and systems (47.8%).

In addition to *lack of sufficient resources* and *insufficient access to HPC resources for science*, a recurring issue in responses was the perception that *too little emphasis is currently given on software developments*, especially against the background of a recognised world leading role of Europe in HPC applications.

When looking into a breakdown by type of respondents, the following issues were identified as the most relevant problems to each group:

GROUP	MOST RELEVANT PROBLEM (% relative to the group)
Computing centres	There is large fragmentation of HPC programmes and efforts in Europe and the non-coordinated activities and the lack of a common procurement framework lead to a waste of precious resources (69%)
Scientific users	There is large fragmentation of HPC programmes and efforts in Europe and the non-coordinated activities and the lack of a common procurement framework lead to a waste of precious resources (58%)
Industrial users	Europe's supercomputing capabilities depend on non-EU suppliers for critical technologies and systems (75%)
Technology Supply industry	The interaction between industry and academia on the exploitation of high-end computing systems, application codes and services is limited, especially regarding the use of HPC for industrial and service innovation (67%)

The following issues were identified as the second most relevant problems to each group:

GROUP	SECOND MOST RELEVANT PROBLEM (% relative to the group)
Computing centres	The scientific communities in Europe do not have access to the level of supercomputing performance they need for their research purposes (63%)
Scientific users	The interaction between industry and academia on the exploitation of high-end computing systems, application codes and services is limited, especially regarding the use of HPC for industrial and service innovation (52%)
Industrial users	The interaction between industry and academia on the exploitation of high-end computing systems, application codes and services is limited, especially regarding the use of HPC for industrial and service innovation (75%)
Technology supply industry	The EU does not have the supercomputing power that corresponds to its economic weight because it spends substantially less than other regions on acquiring high-end computing systems (60%)

As it can be seen from the above tables, the interaction between industry and academia was identified by all stakeholder groups as being among the most pressing problems, followed by the fragmentation of efforts and resources.

Noteworthy is the response from the industrial users, whose main concern is the dependence on non-EU technology. This clearly shows their awareness of the risks related to the dependence of a foreign technology supply-chain for a resource that is a critical for their competitiveness on a global market.

6.4 European added value

While only ~2.2% of respondents found that no action at all should be taken at EU level to improve the current state of HPC in Europe and 15% were satisfied with the level of the current EU actions, a clear majority of 83% confirmed the need for action at EU level that goes beyond the current actions (see Figure 5).

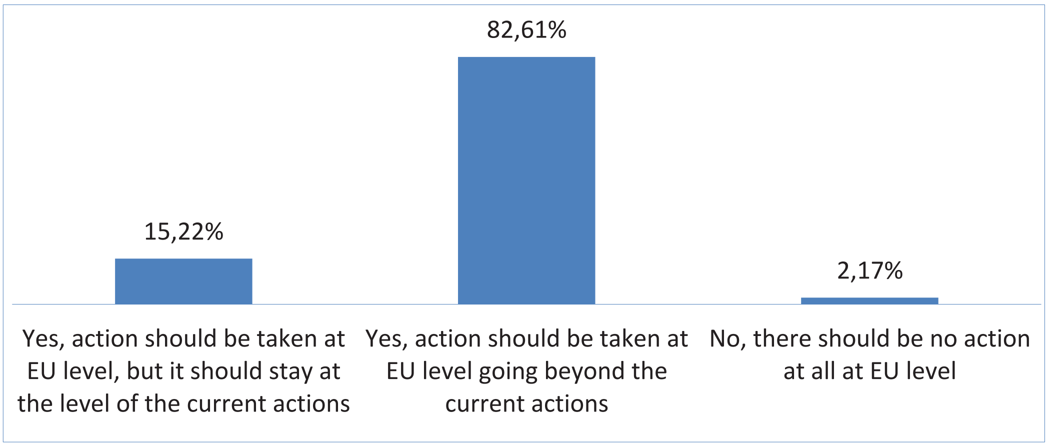

Figure 5 – Should action be taken at EU level?

Those who stated that action should be taken at EU level going beyond the current actions justified their responses on the basis of two main arguments:

- The level of EU-wide coordination and cooperation of HPC initiatives is currently insufficient in a qualitative and quantitative sense, resulting in a strong fragmentation of individual efforts across Member States, across different stakeholders (e.g. industry/science) as well as across current EU-wide initiatives.[9]

[9] Examples:

"Europe supercomputing power is not comparable to its economic weight mainly because national efforts, even if integrated in PRACE framework, cannot attain the world top level. As a result the scientific communities do not have access to the required computing power for leading edge simulations".

"Present actions are rather fragmented and non-coordinated contributions of the EU are channelled through supercomputing centres with diverse missions as they observe the national interests of the countries in which they reside. Actions are mostly managed at the supercomputing centres with very limited or non- existent engagement of the broader scientific and industrial community. A coordinated action in Europe with leadership from leading scientists, knowledgeable of HPC, is necessary."

"Action should be taken at EU level, in order to increase the amount of resources … and to assure a clear and fair model to fund them and access them. Important economies of scale could be obtained, making it less expensive to Member States to access advanced computing resources. PRACE needs a qualitative improvement in its organisation model."

"On the European level, HPC access is currently through PRACE and this should continue, but more resources are required as there is a great demand for these resources by European scientists. In order that European scientists remain competitive, an increase in European HPC infrastructure is required".

- Continuing in the current mode of fragmented and insufficient efforts, the EU is relegated against its global competitors (USA, China) in a field as strategic as supercomputing.[10]

This result is also confirmed by the top priority[11] identification by respondents of the need to set-up a coordinated approach for developing a leading HPC and big data ecosystem (hardware, software, applications, skills, services and interconnections) for the benefit of Europe's science and industry.

As can be seen in Figure 6, the position of the technology supply industry (93%), scientific users (91%), and computing centres (78%) is strongly in favour of taking measures at EU level going beyond the current actions. The position of industrial users, although also supporting action to be taken at EU level going beyond current actions (58%), is instead more moderate. This is consistent with the fact that 50% of industrial users have never applied for funding in Horizon 2020 or previous EU Research Framework Programmes (see section 8.2).

Except from a small minority among computing centres (6%), no one believes there should be no action at all at EU level.

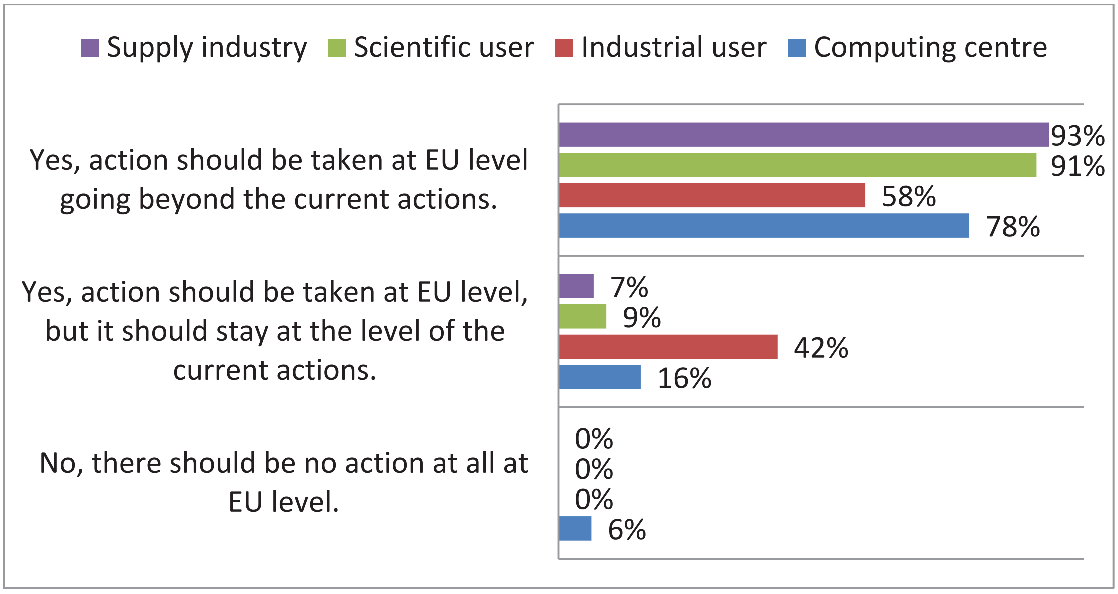

Figure 6 –Breakdown per group of respondents

6.5 Objectives of a future EU initiative on HPC

Respondents confirmed that the following actions rank among the main (>50% of responses) objectives of a future EU initiative on HPC:

- Establish a world-class HPC and Big Data ecosystem (79.3%);
- Support education and training in order to increase HPC skills in Europe (77.2%)

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[10] Example: "Focused operational and research high performance computing (as oppose to general computing) is one of the key tools of technological progress. US, Japan and China appreciate this quite well and invest heavily in all aspects of HPC. An organised holistic change in the European approach to, and funding of, HPC is required in order to stay competitive worldwide. Europe should aim at the HPC programme as seriously as at the satellite observing programme."

[11] Rate 4.4 on a scale between 1 (lowest importance) and 5 (highest importance)

- Stimulate the development and use of the best HPC and data intensive codes in today's and future most innovative scientific and industrial applications (76.1%);
- Set-up a coordinated research and innovation agenda for developing the next generation of HPC technologies and systems (75%);
- Deploy innovative, usable HPC services and competitive solutions satisfying the demands of users from science, industry (incl. SMEs) and the public sector (60.9%);
- Procure world class HPC and data infrastructures and make them widely accessible and available across Europe (56.5%).

This set of objectives – coordination of efforts, education & training, applications, HPC services to all stakeholders, widely accessible infrastructure – corresponds to the goals of the EuroHPC initiative.

When looking at the breakdown by group of respondents it appears that the following actions should be among the main objectives of a future EU initiative on HPC:

GROUP	MOST RELEVANT ACTION (% relative to the group)
Computing centres	Establish in Europe a world-class HPC and Big Data ecosystem (hardware, software, applications, skills, services and interconnections) (87.5%)
Scientific users	Stimulate the development and use of the best HPC and data intensive codes in today's and future most innovative scientific and industrial applications (78.8%)
Industrial users	Stimulate the development and use of the best HPC and data intensive codes in today's and future most innovative scientific and industrial applications (83.3%)
Technology supply industry	Establish in Europe a world-class HPC and Big Data ecosystem (hardware, software, applications, skills, services and interconnections) (86.7%)

The second most relevant actions identified by the groups of respondents are the following actions:

GROUP	SECOND MOST RELEVANT ACTION (% relative to the group)
Computing centres	Support education and training to increase HPC skills in Europe (84.4%)
Scientific users	Support education and training to increase HPC skills in Europe (75.8%)
Industrial users	Establish in Europe a world-class HPC and Big Data ecosystem (hardware, software, applications, skills, services and interconnections) (83.3%)
Technology supply industry	Support education and training to increase HPC skills in Europe (80%)

For all respondents, establishing a world-calls HPC ecosystem is among the most relevant objectives for a European HPC initiative, except for the scientific users. For the latter the development and use of applications and skills are more important. For most the education and training aspects are also among the top priorities.

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Annex 2 (Part 2)

6.6 Duration of a European HPC Initiative

Regarding the time-frame in which the future EU-initiative should run, a clear majority of respondents confirmed the need for an initiative that goes well into the next multi-annual financial framework (MFF), see Figure 7:

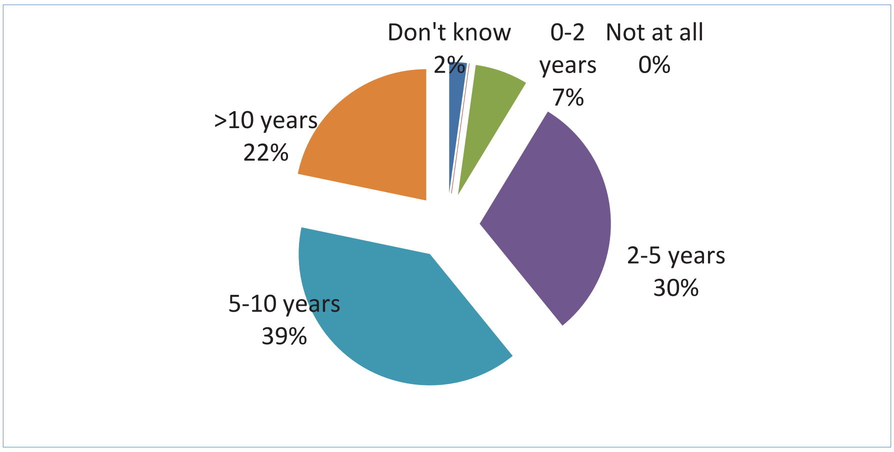

Figure 7 – Time-frame a future EU initiative on HPC should run

When looking at the different groups of respondents, a clear majority of each group confirmed the need for an initiative that expands beyond the last three years of Horizon 2020, as can be seen in Figure 8:

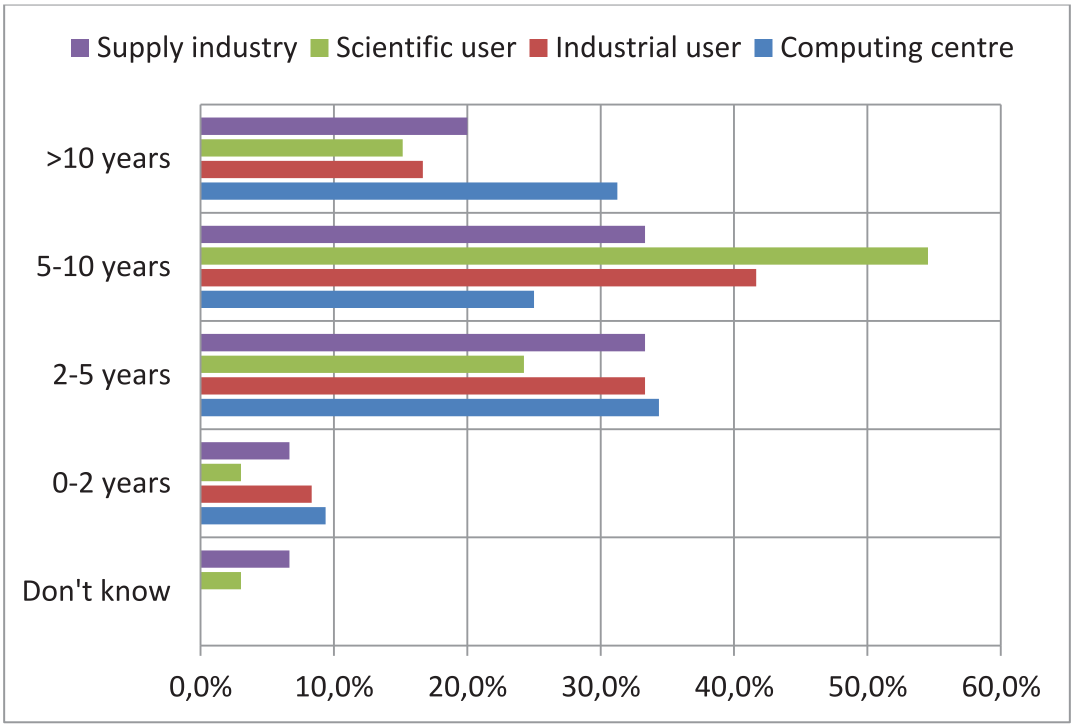

Figure 8 – Time-frame a future EU initiative on HPC should run

6.7 Improvements expected from a future EU initiative on HPC

Regarding improvements expected from a future EU initiative on HPC vis-à-vis the current situation, three main points emerged from the responses, indistinctly for all groups of respondents:

- First, an expectance of more EU-based technology with specific support to the EU hardware industry leading to the development of critical technologies within Europe.
- Second, the reduction of fragmentation, a better coordination of European HPC resources through the consolidation of the current programs into a single, clear and well-funded program aimed at building an exascale class system based on EU-developed technology.
- Third, the increase of competitiveness of European industry through a better involvement of SMEs in HPC.

6.8 Options to reach the objectives of a future EU initiative on HPC

Regarding the role of existing EU-funded HPC actions, such as PRACE, ETP4HPC and GEANT, in the future EU initiative on HPC, it was confirmed by respondents that existing actions:

- should be improved, especially PRACE[1], and
- collaborate closer, so that in a bigger picture provided by EuroHPC the existing actions should complement each other.[2]

As shown in Figure 9, the majority (>50%) of respondents proposed that participation in the new EU initiative on HPC should be constituted by *academia & research* (90.2%), *industry* (88.8%), *supercomputing centres* (87%), and *HPC intermediaries*, e.g. Centres of Excellence (57.6%).

[1] E.g. by strengthening its scientific oversight, by collaborating closer with industry, if possible.

[2] Examples:

"All these instruments have been developed under conditions that are no longer relevant."

"None of them existed before the advent of Big Data and now they are just adapting old structures to new problems. These instruments are in need for renovation and they must find a way to merge their efforts for the benefit of European science and not of the local HPC centres."

"It is very important that PRACE, GEANT and ETP4HPC with their own well-defined goals work together for achieving a sustainable EU HPC eco-system across Europe. As an example, PRACE supports users, however it needs to work very closely with GEANT to foresee how the future demands of users can be serviced through GEANT activities. Similarly through PRACE's input, ETP4HPC can better understand and define the future requirements of EU HPC users."

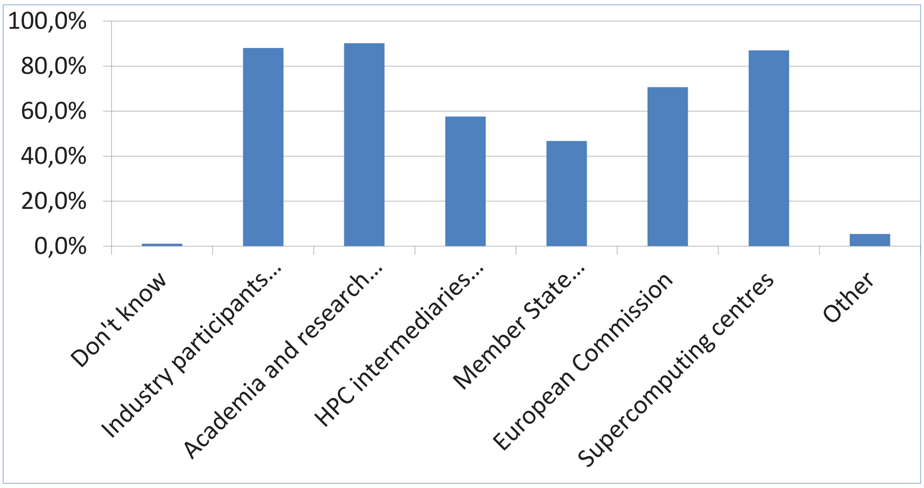

Figure 9 – Who should be part of a potential EU initiative on HPC?

Among those who declared to know how responsibilities in relation to the use of the exascale machines in the context of the new EU initiative on HPC should be distributed (59.8%) a recurrent idea was that HPC machines should be owned, be operated, and maintained by a consortium including, but not limited to, supercomputing centres, EU public infrastructures, and PRACE Tier-0 centres.

With respect to the usage and access conditions of the HPC machines, the allocation of computing time, and the decision criteria to allocate computing time, respondents' open-ended suggestions were less coherent and many scattered ideas were mentioned, such as the European Commission with the help of calls, a peer review process favouring the clear prioritization of usage, steering committees representing the owners of the machines, existing supercomputing centres, and management boards of public/private partnerships.

Figure 10 shows the breakdown relative to each group. As can be seen, the responses are rather uniform across the different groups of respondents.

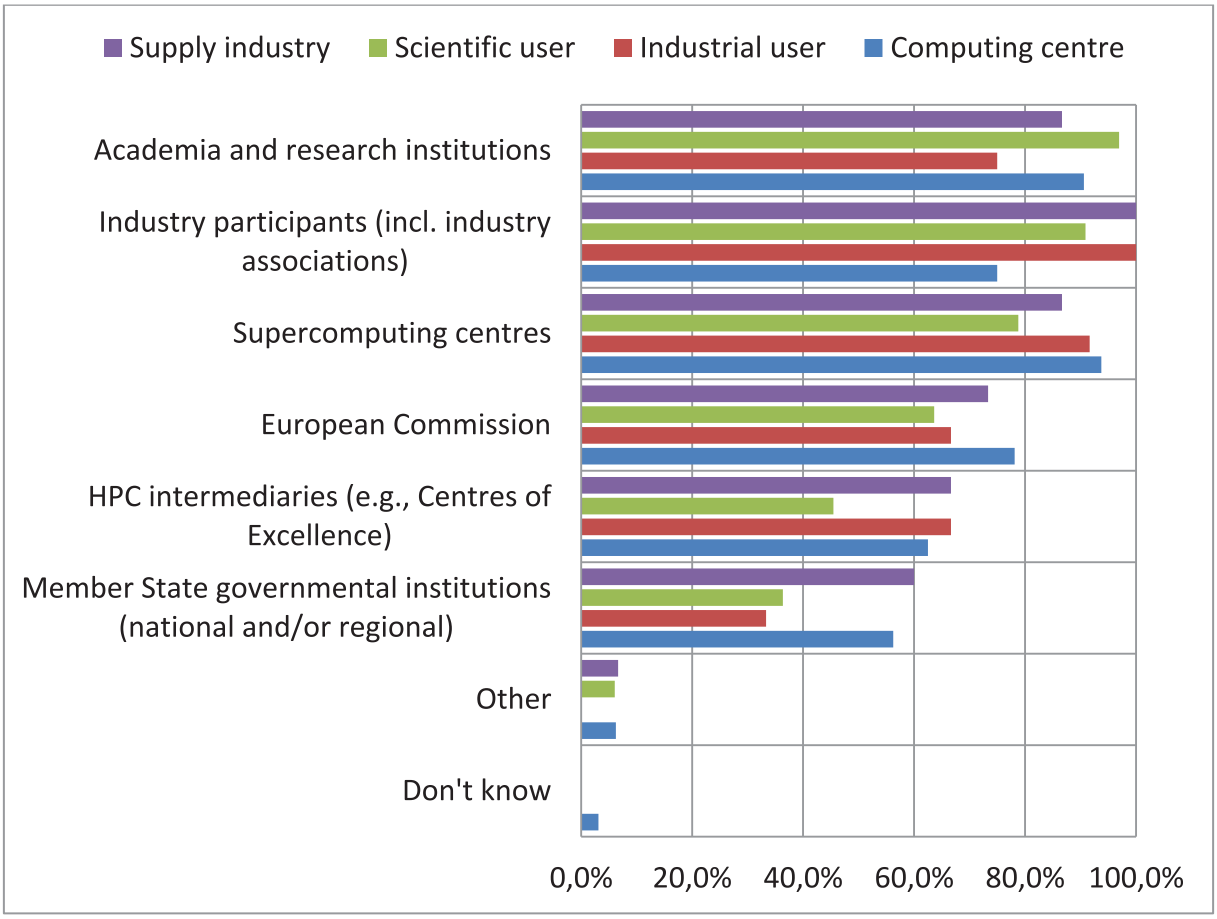

Figure 10 – Who should be part of a potential EU initiative on HPC?

Without surprise, each group identified itself as a key participant in the new potential EU initiative on HPC, indicating self-engagement and a strong will of each group to contribute to the initiative. Within each group the percentage of self-commitment was as follows: Technology supply industry (100%), industrial users (100%), scientific users (97%), and computing centres (93.8%).

Most interestingly, Figure 10 shows a strong consensus among the different groups of respondents that the key actors in a future European HPC Initiative should be the research organisations, industry, and the supercomputing centres. By importance, the next actor identified by all groups of respondents was the European Commission. In particular, for each group of respondents the European Commission should have priority over HPC intermediaries and over Member States in a potential EU initiative on HPC.

6.9 Expected impacts of a future EU initiative on HPC

The main desirable impact of such an initiative was expected to be on science and technology development (ranking 4.68/5). Expectations from the participants included:

- Underpinning the development of most emerging technologies and applications, from precision medicine and agriculture to deep learning,
- Development of new materials as well as medicine and healthcare, and
- Reduced economic losses thanks to better weather forecast or traffic forecast.

The second desirable impact (ranking 4.36/5) was expected to be on economy and growth, including competitiveness of Europe's industry. Expectations included:

- Development of more EU-based enterprises and support to digitisation of traditional EU industries,
- Job creation as HPC engineers are and will be needed,
- Development of sharper and more competitive products relying on massive optimisation.

Regarding impacts specific for the respondent's institution, responses included:

- Early access to state of the art HPC technologies stimulating more students in undertaking challenging projects with industry,
- Increased opportunities for R&D collaborations with SMEs, and
- Strengthening the own market position by using HPC as early as possible in the pre-development of products, making use of virtual prototypes and at the same time reducing costly experiments, and reducing waste.

The main desirable impact of such an initiative on a scale of importance between 1 and 5 (with 1=lowest importance and 5=highest) is reported on Figure 11 for each group of respondents.

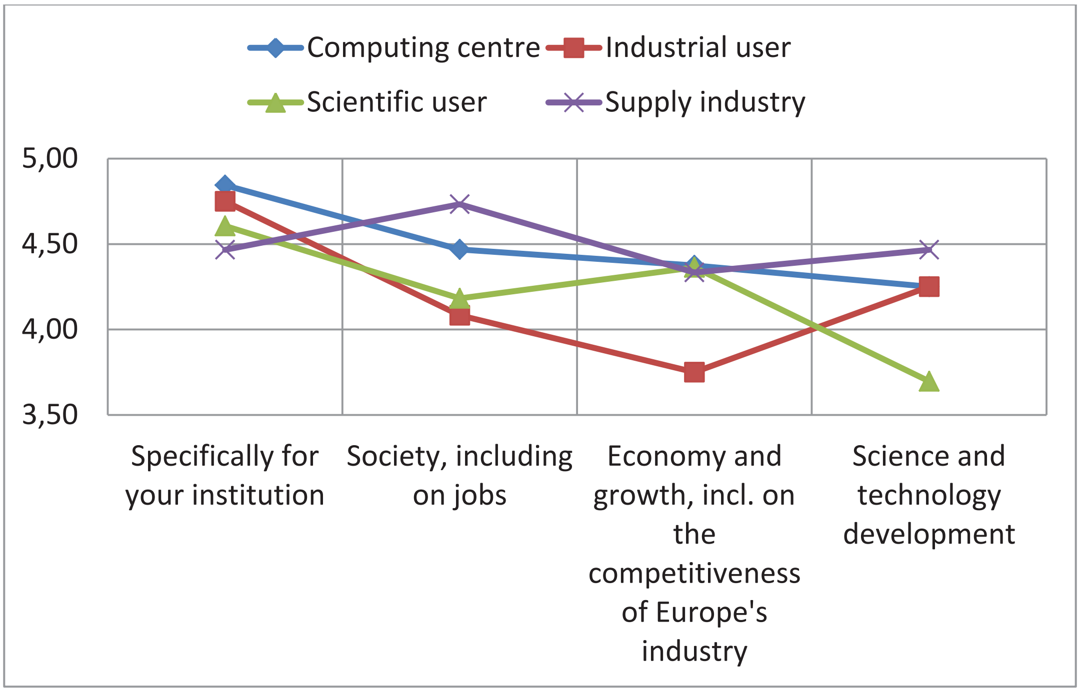

Figure 11 –What would be the desirable impacts from the future EU initiative on HPC?

Except for the technology supply industry group which expects the highest impact on society including on jobs (rating 4.73), all other groups expect the highest impact (rating > 4.5) specifically for their institutions.

1. Summary of the Responses to the Inception Impact Assessment Publication

The Inception Impact Assessment was published on the Commission's Better Regulation Website[3] and a feedback period was given from 3 August 2017 to 05 September 2017. Fifteen

[3] http://ec.europa.eu/info/law/better-regulation/initiatives/ares-2017-3896569_en

responses were received[14] (10 from Germany, 3 from UK, 1 from Spain, 1 from Netherlands) with the following main messages:

- four responses agreed to a new EU-wide initiative, and three of them explicitly favoured a Joint Undertaking as the most appropriate instrument;
- eight responses criticised the initiative as allegedly being promoted by the weapons manufacturing industry and sponsored by them;
- one response promoted the own consulting type of company as to be best place to play an active role in the future initiative;
- two responses criticised the initiative as creating either too much waste or as diverting money from help to developing countries.

However, all responses which discussed the issue in technical terms supported the new initiative. Three of them explicitly supported a Joint Undertaking as the best instrument.