2017 Progress Monitoring Report

H2020 contractual Public-Private Partnership on High-Performance Computing

EUROPEAN COMMISSION - DG CONNECT
ETP4HPC ASSOCIATION - WWW.ETP4HPC.EU

Contents

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EXECUTIVE SUMMARY

The objective of the European HPC strategy is to develop a competitive, complete European ecosystem, encompassing exascale HPC and the corresponding data infrastructure that will serve a large spectrum of users from scientists to industry (including SMEs) and the public sector. The ambition is also to strengthen the European HPC supply chain and to close the gap from research and development to the delivery and operation of exascale HPC systems co-designed between users and suppliers.

An HPC contractual Public Private Partnership (cPPP) between the European Commission and the European Technology Platform for High Performance Computing (ETP4HPC) was put in place in 2014 for this purpose, with EUR 700 million from the Horizon 2020 research and innovation programme, supporting HPC technologies and application R&D. In addition to the cPPP, the European Commission also invests in the PRACE HPC infrastructure (Partnership for Advanced Computing in Europe).

ETP4HPC Strategic Research Agendas (2013 and 2015 editions) were a main source for the definition of research priorities, and the official technical reference for these calls. Strategic Research Agendas are elaborated by ETP4HPC members, but also with other stakeholders and European or international associations or initiatives, such as BDVA, HiPEAC, BDEC, in particular. The 3rd edition (2017) has significantly increased the focus on Big Data requirements and related technological needs, all across the document and in its recommendations. ETP4HPC and BDVA collaborated via workshops and a dedicated joint task force for this purpose; a Memorandum of Understanding is being set up between the two associations to strengthen and sustain this relationship.

Although still in an early stage of implementation, since no project related to the HPC cPPP has yet finished, the first observations related to the main performance indicators are the following:

- *Mobilised private investments*: in direct R&I activities, it is estimated that the ecosystem effort (private side, understood as all research and private entities other than the EC) matches the direct public funding under Horizon 2020; in terms of specific leveraged investments, a five-fold effect in industrial effort per public Euro in the PPP is estimated.
- *New skills/jobs:* in the industrial sector, ca. 100 jobs were created from the programme projects, and an equivalent of at least 100 permanent FTEs is expected to remain after the end of the current projects. This is mostly in HPC technology – hardware, system, application software. More indirect and more important job creation effects in the various areas of HPC use are expected, but will require more time and efforts to be observed and measured. HPC projects that started in 2015 have been very actively reaching out with training events, organizing 45 workshops, 4 summer schools, 12 courses, 2 fora, and several open days, webinars, hackathons by the end of 2017.
- *Impact on SMEs:* compared with FP7 Framework Programme, the share of SME participation in HPC EU funded project has been significant under Horizon 2020. The SMEs also consider today H2020 projects as a building block for their R&I strategy: as of today, four of the "Top10" industrial beneficiaries in cPPP related calls are SMEs with a total funding of EUR 22 million.
- *Significant innovations:* HPC technology projects (FETHPC) and Centres of Excellence (CoEs) have so far supported the preparation of many innovative hardware and software building blocks for HPC solutions, as well as the evolution and improvement of many HPC applications. In terms of HPC platforms, we can already identify three architectural tracks that have been explored through groups of projects – Mont-Blanc for ARM-based low-power HPC architectures, DEEP for modular supercomputing architectures, EuroExa for

mixed ARM/FPGA solutions. The Mont-Blanc and DEEP series of projects have delivered and made available to user communities several successive prototypes, and their outcomes have been integrated in different commercial products.

In 2017 the European Commission launched the preparation of the EuroHPC Joint Undertaking, starting with a declaration signed by seven countries in March 2017 in Rome. More than twenty Members States have now joined, while EuroHPC has received a positive opinion by the European Parliament and will start operations in the coming months, once the Council adopts its regulation. This policy development is a crucial step for the EU's competitiveness and independence in the data economy. Today, European scientists and industry increasingly process their data outside the EU because their needs are not matched by the computation time or computer performance available in the EU. This lack of independence threatens privacy, data protection, commercial trade secrets, and ownership of data in particular for sensitive applications.

The EuroHPC Joint Undertaking is key to reach the overall objective of the European HPC strategy. It enables Member States to coordinate together with the Union their supercomputing strategies and investments. It pools Union and Member States resources to develop top-of-the-range exascale supercomputers for addressing extreme computing and big data applications, based on competitive European technology. Its objective is to acquire, build and deploy across Europe a world-class High-Performance Computing (HPC) infrastructure. It will also continue the research and innovation programme started under the HPC cPPP, to develop the technologies and machines (hardware) as well as the applications (software) that would run on these supercomputers.

The EU's contribution in EuroHPC will be around EUR 486 million for the years 2019-2020, matched by a similar amount from Member States and associated countries. Overall, around EUR 1 billion of public funding would be invested by 2020, and private members of the initiative would also add in kind contributions. This will bring the overall financial effort from the European Union well above the initially agreed level of EUR 700 million.

In addition, the Commission also implemented an important new call to establish a Framework Partnership Agreement on European low-power microprocessor technologies, in order to establish a stable and structured partnership between the EC and committed institutions and organisations. The "European Processor Initiative" (EPI) consortium was selected to co-design, develop and bring to the market a European low-power microprocessor, one of the core elements needed for the development of the European supercomputers with exascale capacity. Specific grant agreements will be signed in 2018 and 2020 with an overall EC contribution to the initiative expected to be around EUR 120 million.

In 2019-2020 new calls for proposals will be implemented, while EuroHPC will ramp up, coordinate the different aspects of the strategy and prepare their further development under Horizon Europe programme. The monitoring and impact assessment effort of the HPC programme will also be continued, building on the methodology and data collection already developed and adjusted since 2015. A significant fraction of the first series of R&D projects actually started in 2015 will finish in 2018-2019, progressively enabling the more precise observation of their outcomes and impact, which is mostly not immediate. The most difficult parts of the effort will remain the data collection from private companies, and will require specific further improvements and focus.

1. INTRODUCTION: THE HIGH-PERFORMANCE COMPUTING cPPP

High-Performance Computing (HPC) is a branch of computing dealing with technologies and methodologies for large-scale compute- and data-intensive applications - often simulation and modelling of science and engineering problems. It is a critical tool for understanding and responding to major scientific, industrial and societal challenges. As the problems modelled in computer simulations and decision support systems grow in size and complexity (to enable more detailed predictions and/or to cope with ever larger amounts of data or both), so do the demands on computational resources.

HPC mobilises densely integrated computing and storage hardware configurations, together with parallel programming. Deployed solutions may range from massively parallel extreme scale ones commissioned in very large infrastructures, to more compact and pervasive configurations. HPC is a generic enabler for more competitive research, industry, and economy in general when it comes to producing goods and services more efficiently, and has become indispensable to tackle societal challenges requiring large scale numerical approaches.

In many areas spanning from cosmology, material science, 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 has also a pivotal role in supporting the digital industrial revolution, which is deeply transforming traditional industries, how engineers collaborate and explore new designs and technical solutions. For example, in the automotive and aerospace industries, Computer Aided Engineering and design of new aircrafts and cars is carried out through large-scale simulation instead of or in addition to physical testing.

The contractual Public Private Partnership (PPP) on high-performance computing is investing EUR 700 million from the Horizon 2020 research and innovation programme with the objective to develop a competitive European ecosystem and exascale HPC and data infrastructure that will serve a large spectrum of users from scientists to industry (including SMEs) and the public sector. The ambition is also to strengthen the European HPC supply chain and to close the gap from research and development to the delivery and operation of exascale HPC systems co-designed between users and suppliers. With further resources beyond Horizon 2020 the ambition is to rank the EU among the world's top supercomputing powers by realising competitive exascale supercomputers around 2022/2023, based on EU technology, while promoting and stimulating the pervasive use of HPC at all scales and for a wide diversity of scientific and technical applications.

2. MAIN ACTIVITIES AND ACHIEVEMENTS DURING 2017

2.1. Implementation of calls for proposals evaluated in 2017

In 2017 the European Commission continued with the implementation of **three calls** for proposals to support the European HPC strategy (see Annex 5.1).

The **FETHPC-2017 call** included two topics addressing research and innovation actions and coordination and support actions. The former targeted the development of technological building blocks for exascale computing. In comparison to a similar call implemented in 2014, it addressed more specifically software aspects related to the exascale transition in the following areas:

a) High productivity programming environments for exascale
b) Exascale system software and management
c) Exascale I/O and storage in the presence of multiple tiers of data storage
d) Supercomputing for Extreme Data and emerging HPC use modes
e) Mathematics and algorithms for extreme scale HPC systems and applications working with extreme data

The last two areas were not explicitly proposed in previous calls and were new to the 2017 call. The number of proposals received in response to the call was 68. 11 proposals were selected to enter grant agreement preparation. All of the above areas were covered with 4 proposals in area a), 2 proposals in b), 1 proposal in c), 1 proposal in d) and 3 proposals in e).
A total of 541 participants (applicants) were involved in the 68 eligible proposals submitted for the call. 93 participants (i.e. 17.2 %) were involved in the 11 proposals considered for funding.

The second topic addressed 1) the coordination of the Exascale HPC strategy and International Collaboration, and 2) the Excellence in Exascale Computing Systems. In the first case the aim was to promote a joint community structuring and synchronisation; the further development and update of the Strategic Research Agenda for High Performance Computing and prepare the ground for targeted international research collaborations on specific aspects of the exascale challenges. In the second case the focus was to boost European HPC academic research excellence in future exascale-class computing cutting across all levels – hardware, architectures, programming, applications – and including specific actions to better structure the European academic HPC research, create stronger links with HPC providers and HPC users, attract venture capital, promote entrepreneurship and foster industry take-up.

The number of proposals received in response to the call was two. Both proposals were selected to enter grant agreement preparation.

The Commission implemented also an important **call to establish a Framework Partnership Agreement on European low-power microprocessor technologies**. This call represented the first step to translate the political ambition expressed in the Communication on the European Cloud Initiative[1]. There the Commission announced its aim to support, together with the EU Member States and European industry, the creation of a world-class European High Performance Computing (HPC) and Big Data ecosystem built on two exascale computing machines, which would rank in the first 3 places of the world. One of the specific objectives stated in the Communication is to "foster an HPC

[1] COM(2016) 178 final

ecosystem capable of developing new European technology such as low power HPC chips".

The objective of the Framework Partnership Agreement (FPA) is to establish a stable and structured partnership between the EC and the institutions and organisations that commit themselves to establish, maintain and implement a strategic research and innovation roadmap for building European low-power microprocessor technologies underpinning the build-up of future machines for exascale-class HPC, big data and emerging applications. Specific grant agreements will be signed in 2018[2] and 2020 with an overall EC contribution to the initiative expected to be around EUR 120 million.

The number of eligible proposals received in response to the call were two. 45 participants (applicants) were involved in the two eligible proposals submitted for the call. 23 participants (i.e. 51.1 %) are involved in the proposal retained.

The "European Processor Initiative" (EPI) consortium was selected to co-design, develop and bring to the market a European low-power microprocessor, one of the core elements needed for the development of the European supercomputers with exascale capacity. The main objectives of the EPI are to:

- Develop low-power processor technology to be included in a European (pre-) exascale system,
- Guarantee that a significant part of that technology is European,
- Ensure that the application areas of the technology are not limited only to HPC, but cover other areas such as the automotive sector or the data centres, thus ensuring the overall economic viability of the initiative.

Finally, the call on customized and low energy computing (including low power processor technologies) resulted in the selection of a project relevant to the HPC strategy and in particular supporting the FPA. The call had a wide scope addressing the development of a new generation of innovative, secure and reliable processors for systems based on highly parallel and heterogeneous architectures for very promising application areas, e.g. at the convergence between high performance computing, big data and deep learning. The selected "Mont-Blanc 2020" project has the ambition to initiate the development of a future low-power European processor for Exascale, which clearly relates to the objectives of EPI consortium and roadmap.

The evaluation of proposals for the above calls were carried out with the assistance of external experts and was monitored by observers.

2.2. Mobilisation of stakeholders, outreach, success stories

The European Commission significantly increased the outreach towards Member States in 2017. It intensively coordinated the preparation of the Digital Day in Rome on the 23rd of March[3]. On that occasion, Ministers from seven European countries (France, Germany, Italy, Luxembourg, Netherlands, Portugal and Spain) signed the EuroHPC declaration[4] to support the acquisition and deployment of next generation computing and data infrastructures across the EU. This world-class infrastructure would also support the European Open Science Cloud, which will offer Europe's 1.7 million researchers and 70

[2] SGA1 (first specific Special Grant Agreement) received its evaluation summary report end of June 2018

[3] https://ec.europa.eu/digital-single-market/en/digital-day

[4] https://ec.europa.eu/digital-single-market/en/news/eu-ministers-commit-digitising-europe-high-performance-computing-power

million science and technology professionals a virtual environment to store, share and re-use their data across disciplines and borders. Focusing initially on the scientific community, no matter where the users are located, the user base would be progressively be extended to industry and the public sector. Signatory countries agreed to establish a roadmap for the development of high-quality competitive European technology, the deployment of at least two pre-exascale supercomputers by 2020 and to reach full exascale performance by 2023.

Over the course of 2017, other countries joined the EuroHPC declaration bringing the count to 15 by February 2018[5]. This effort contributed considerably to the mobilisation and involvement of countries in EU-13, attracting 5 countries that are now actively participating.

After the signature of the declaration and for the rest of 2017, Member States in coordination with the European Commission prepared an implementation roadmap to deploy the European exascale supercomputing infrastructure. This roadmap addressed on one side the technical and operational requirements and the financial resources needed for acquiring such infrastructure. On the other side it identified appropriate legal and financial instruments for such acquisition.

As a result of the mobilisation of Member States in 2017, The Commission unveiled on the 11th of January 2018 its plans to invest jointly with the Member States through a new legal and funding structure – the EuroHPC Joint Undertaking (JU). The benefit of the HPC Joint Undertaking is that it will enable Member States to coordinate together with the Union their supercomputing strategies and investments. The EuroHPC JU will pool Union and Member States resources to develop top-of-the-range exascale supercomputers for processing big data, based on competitive European technology. Its objective is to acquire, build and deploy across Europe a world-class High-Performance Computing (HPC) infrastructure. It will also support a research and innovation programme to develop the technologies and machines (hardware) as well as the applications (software) that would run on these supercomputers.

The EU's contribution in the joint undertaking will be around EUR 486 million under the current Multiannual Financial Framework, matched by a similar amount from Member States and Associated Countries. Overall, around EUR 1 billion of public funding would be invested by 2020.

On its side ETP4HPC[6] has been steadily growing. As of December 2017, ETP4HPC had 86 members, of which 44 come from the private sector, including 28 SMEs. Amongst the new members are for instance ESI Group (a large European ISV in CAE/Virtual Prototyping), Infineon, a large European semiconductor company interested in embedded HPC (such as in automotive), as well as Verne Global (a SME providing data centre facilities). This shows that ETP4HPC is generating interest from a community that goes beyond the traditional HPC stakeholders. Efforts to engage more industrial partners and to attract a wider community are ongoing.

ETP4HPC strengthened its collaboration with Big Data Value Association (BDVA) cPPP and the European Network on High Performance and Embedded Architecture and Compilation (HiPEAC) and also started interaction with the Alliance for Internet of Things Innovation (AIOTI), to account for the changing HPC landscape: HPC applications are expected to require more and more highly efficient data analytics; embedded devices and

[5] By August 2018, 21 countries have signed the EuroHPC declaration.
[6] http://www.etp4hpc.eu/ETP4HPC-2017-annual-report/

other sensors will be other sources of massive data, new data analytics applications will require ever increasing computational resources and suited HPC systems.

The 3rd edition of the ETP4HPC Multi-Annual Roadmap (Strategic Research Agenda[7], issued in November 2017) benefitted from this momentum. The SRA was fed by the outcomes of different workshops with BDVA on extreme computing requirements of big data use cases. Other workshops bringing together application providers with technology providers, HPC centres and system integrators were also organised, exploring potential application for the Extreme Scale Demonstrators concept proposed in Work Programme 2018-2020, from both industrial and academic application standpoints. And application requirements were also collected and analysed from the Centres of Excellence in Computing Applications (CoEs) and PRACE Scientific Case 2017 update. These different actions were supported by the H2020-funded EXDCI CSA. This approach, linking the technology-focused vision to the needs of the applications, helps to make sure that future systems will efficiently contribute to tackle problems with societal impact.

Lastly, important and active bilateral or multilateral relationships have been established with other major non-European programmes or initiatives such as DoE in the USA, RIKEN in Japan. With EXDCI support, European HPC experts have been extremely active in the international BDEC initiative [and are now preparing its follow-up.

2.3. Outreach highlight

DGCNECT has developed a single point of access for all information about the EC HPC strategy, work programmes and other HPC-related news including events, blog posts, reports, and policies.[8]
ETP4HPC, the EXDCI support action, all FETHPC and CoE projects have strong focus on their dissemination activities which are complementary – ETP4HPC and EXDCI, together with PRACE, focus on ecosystem-level dissemination and networking support, whereas the projects promote their own specific scientific and technical activities and results.
EXDCI has had the opportunity to create a large annual pan-European HPC event, the "European HPC Summit Week", with a first edition in 2016 in Prague and a second in 2017 in Barcelona (Spain), gathering several hundred experts in HPC technology development, HPC infrastructures and HPC applications.[9] The 2018 edition is taking place in Ljubljana (Slovenia) in May 2018.

2.4. Governance

Two new regular cPPP Partnership Board (PB) meetings took place in 2017, in May and October, co-chaired by the EC and ETP4HPC Chair, with the participation of the 'private side' and of EC/DGCNECT representatives. After three years of ramping up, the HPC cPPP has now reached a stable configuration with the inclusion of the Centres of Excellence in Computing Applications (CoEs) in these bi-annual PB meetings - since 2015 - in addition to representatives from the ETP4HPC Steering Board; PRACE representatives are also invited.
ETP4HPC held one General Assembly in March 2017, to which all members of the association were invited, as well as PRACE, EC representatives and other guests.

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7 http://www.etp4hpc.eu/sra.html
8 https://ec.europa.eu/digital-single-market/en/high-performance-computing
9 https://exdci.eu/events/european-hpc-summit-week-2017

3. MONITORING OF THE OVERALL PROGRESS SINCE THE LAUNCH OF THE CPPP

3.1. Achievement of the goals of the cPPP

The build-up and creation of the Partnership gave new momentum to European HPC. This is reflected in the growing number of organisations joining the ETP4HPC, as well as through the response to the Calls for Proposals that were closed between 2014 and 2017, which allocated EUR 229.6 million in funding to 43 technical projects targeting technological blocks related to the Exascale goal - with the selected FETHPC projects mostly covering SRA topics and vision – plus 4 coordination and support actions – see Annex 5.1. This funding however is only 1/3 of the total amount initially planned for the HPC cPPP in the 2014-2020 period.

Let us note also that not all EUR 229.6 million of funding has been distributed yet – as of end of 2017 ca. EUR 180 million had been committed only for 33 projects (incl. 31 research projects and 2 coordination and support actions), and a lower fraction of this funding put in place and used by projects – especially those which started in 2017.

ETP4HPC members participating in cPPP related projects confirm the very important role of such funding – more than 40% of the respondents to a survey answer this enabled a new R&D direction never tried before, another 50% advanced an existing R&D initiative. And 80% admit they would have pursued the R&D initiative but on a more limited basis. Almost all are emphasising the collaboration opportunities offered by H2020 projects.

Annex 5.2 summarises the methodology used for the KPIs estimated in the next section. Annex 5.3 gives some extra highlights and quotes from H2020 HPC projects industrial participants, interviewed as explained in Annex 5.2.

3.2. Progress achieved on KPIs.

3.2.1. Mobilised private investments

At the beginning of the cPPP and via surveys amongst ETP4HPC's members, the annual investment in private HPC R&I funding was estimated to be in the range of EUR 165-210 million in HPC technologies and EUR 150-225 million in other HPC-related R&I. This gives a baseline and lower bound for the ecosystem engagement, regardless of the cPPP effect, which is already in the order of three times the average annual cPPP funding.

Regarding private-for-profit organisations investments directly related to the cPPP activities, the interviews revealed participating companies as a group made substantial in-kind contributions that included 73 full-time-equivalent (FTE) employees during the project lifetime. No project has come to an end yet: 50% will complete in the next 6 months after interview, 25% in the upcoming year and 25% in more than one year. The companies also report on additional contributions for infrastructure and software (for instance), however not in a precisely quantified way.

More substantial investment is planned after projects termination: the companies report on an aggregate EUR 132 million, to turn the project innovations into commercial products. This is for a sample of companies getting 62% of funding going to industry. With the same average effort from all other participating companies, the leverage factor is 5, compared to the EUR 43 million of H2020 funding going to industrial organizations in the observed period.

Higher and Secondary Education (HSE) and research Organisation (RO) institutes, get ca. 70% of the cPPP-related funding. Despite the 100% funding rate under H2020 rules (for RIA actions), a survey amongst ETP4HPC members revealed significant additional contributions during the project lifetime, which we estimate to be at least 25% of the funded total personnel cost (mostly related to higher indirect costs than the standard H2020 25% rate). Other extra contributions identified are related to additional personnel assigned to project-related effort (in-kind), use of equipment such as access to computing facilities, software licenses etc. However this latter category of contribution has not been precisely measured.

3.2.2. New skills and/or job profiles

One year ago, at the time FETHPC projects were roughly in the middle of their lifetime, the interviews revealed 61 jobs creations from the projects for 9 companies – the sample of companies and the percentage of overall funding assigned to them were comparable to this year. More than half of the interviewed companies were actually the same in 2017 and 2018. This figure has been updated to 73 this year - for 11 companies. Extrapolated from 62% to 100% of private companies receiving H2020 funding, an optimistic estimate would be ca. 115.These companies expect that after completion, the projects will produce 102 permanent FTEs. Again, this can be extrapolated to the subset of all private-for-profit participants in cPPP-related projects to ca. 165.

Analysts studies tend to confirm that most job creation related to advanced R&D happens after the R&D project is finished, especially when a commercial product is being prepared for and introduced into the market. But we could see already concrete effects during the projects lifetime, with a very positive consolidation and expansion of projects potential effects as they approach their completion. The job profiles are mostly in HPC technology: 30% in hardware development, 15% in system and 15% in application software development, 15% in storage and network - a mix of engineering and R&D.

Impact on jobs in the public research and academic area is more difficult to measure. An ETP4HPC survey towards its members, early 2018, revealed of the order of 150 new jobs related to the cPPP activities, created in 2017 in the public research sector (this figure stands for 33 organisations of various sizes). However it was difficult to tell whether the related positions were permanent. Research organisation tend to hire a significant number of people under doctoral or post-doctoral positions, or temporary research positions, in the context of R&I projects. Concerned job profiles are diverse, relating to R&D in hardware and software.

Eventually, an interesting indicator would be how the HPC applications, like those developed or optimised by the Centres of Excellence, contribute to job creations in companies using HPC. This was not in the scope of our current studies and would require other approaches and efforts. However, we can refer to Hyperion Research general studies where they are developing models linking use of HPC and ROI (return on investment)[10]. We consulted them on this question in 2017, and Hyperion Research evaluations of 160 HPC-enabled European projects – part of their more global study across several continents - showed that, on average, each euro invested in HPC was associated with EUR 588.7 in additional revenue, and EUR 47.1 in additional company profit or cost savings. In total, the 160 projects created 1,953 new full-time jobs, or about 12 jobs per project. We see no reason why projects more specifically related to the HPC applications in the scope of the

[10] http://www.hpcuserforum.com/ROI/

cPPP should significantly deviate from these orders or magnitude. Job profiles are rather experts in the development of codes or use of the codes in engineering and science.

3.2.3. Impact on SMEs

Since the start of FP7 Framework Programme, the share of SME participation in HPC EU funded project has been significantly improved. The SMEs have not only increased their participation in general, but also consider today H2020 projects as a building block of their R&I strategy: as of today, four of the "Top10" industrial beneficiaries in cPPP related calls are SMEs; SMEs get a total funding of EUR 22 million in the FETHPC programme. The strategic importance of H2020 for SMEs is also confirmed by the interviews: all SMEs consider H2020 funding as "extremely important for our future," and all say that it is "very important" for funding of this kind to remain available to industry in the future. One interviewee stated:

> "*We're an SME and have already begun investing in the product – it will be our flagship product and I estimate we will invest a million euros to get this to market."*
> And, as pointed out by another interviewee, the cPPP related funding is perceived as complementary to private funding:
>
> *"Private funding can be gotten for very focused, short-term things, but if you're trying to build a next-generation supercomputer, getting private funding is unlikely and if you get it, it will be short-term and for specific goals only, not for something that goes out to 2023-24. This public funding is essential for bigger, longer-horizon R&D initiatives that can advance Europe's global position in technology innovation."*

Five (5) out of eleven of the interviewed companies of our sample are SMEs and received approximately 50% of the cPPP-related R&I funding assigned to industrial organisations.

Different types of trajectories regarding SMEs were observed, not surprisingly:

- we saw several European HPC SMEs being acquired by large companies in 2016 (for example Nice was acquired by Amazon Web Services, and Allinea acquired by ARM)
- over the last 2-3 years, several startups joined ETP4HPC, not necessarily directly related to cPPP-related projects, but sometimes to FP7 projects
- for 2017, ETP4HPC members did not report any new start-ups, but some research organisations reported on 5 start-up projects (which should be launched in 2018) arising from H2020 funding in the domains of bio-technologies, aviation and visualisation.

3.2.4. Significant innovations

HPC technology projects (FETHPC) have so far supported the preparation of building blocks in different hardware or software areas recommended and documented in ETP4HPC Strategic Research Agendas (server architecture, network, storage, operating system, cluster resource management, programming environments and tools, algorithms etc.). The technologies produced by the projects should be used to build advanced HPC systems in order to validate the performance of the technologies applied and their market preparedness. ETP4HPC suggested the concept of Extreme-scale Demonstrators (EsDs) for this purpose[11]. In the meantime, some projects – actually groups of projects with strong co-design dimensions – have produced or will produce prototypes of full systems with significant innovation and already found paths to productisation and commercialisation:

[11] http://www.etp4hpc.eu/esds.html

- Mont-Blanc[12] : exploring ARM-based low-power HPC architectures since the end of FP7 with the Mont-Blanc1 and Mont-Blanc2 projects[13], Mont-Blanc3, their H2020 follow-up, produced different prototypes and made them available to user communities[14]. The latest Mont-Blanc3 Dibona prototype built by Atos started operation in Fall 2017. It is based on 64-bit ThunderX2 processors from Cavium®, relying on the ARM® v8 instruction set. The prototype leverages the Atos BullSequana X1000 infrastructure, including Direct Liquid Cooling – cooling with warm water. The blade model developed for the Mont-Blanc prototype has been productized and commercialized by Atos as part of its BullSequana X1000 range.
- DEEP[15]: the Modular Supercomputer Architecture developed in H2020 FETHPC DEEP-EST builds on the so-called Cluster-Booster architecture. It was first conceptualized and proven with prototypes in the DEEP project (DEEP and DEEP-ER were FP7 funded projects, running between 2011 and 2017[16]). It is a combination of a standard HPC Cluster and a tightly connected HPC Booster built of many-core processors, all together a heterogeneous HPC system supporting a broad portfolio of HPC and HPDA applications, coupling various compute modules through a high-speed network and operating them with a uniform system software and programming environment.
  The final DEEP prototype system consisted of a 128 node Eurotech Aurora Cluster and a 384 node Booster. In 2017 Juelich JSC's JURECA cluster was augmented with an Intel-based Booster leveraging the experience and results gained in the DEEP and DEEP-ER projects. At the end of 2017 the European providers Atos and ParTec were selected as industrial partners for the general-purpose Cluster Module to serve as Jülich's next supercomputer, starting with first production system module JUWELS, while the DEEP-EST project is extending the DEEP and DEEP-ER architectures, towards the more general Modular Supercomputer Architecture concept, by deploying a three-module hardware prototype.
- EuroExa[17]: originally the informal name for a group of FETHPC research projects - ExaNeSt, EcoScale and ExaNoDe, started in 2015 - EuroEXA co-design project was selected in 2016 and continues the previous projects effort with modular integration enabled by novel inter-die links and ARM-based processing systems together with FPGA acceleration for computational, networking and storage operations. EuroExa and the related projects involve several European SMEs.

A brochure listing all FETHPC (and CoE) projects can be found on the ETP4HPC website[18]. A more thorough analysis of the FETHPC projects hardware and software outcomes will require more time: such an effort is being started mid-2018 within the scope of the EXDCI2 coordination and support action (follow-up of EXDCI[19]). This study first targets the projects which started in 2015 and will be finished before the end of 2018. Some projects will continue for one year or more, whereas new FETHPC projects (on system co-design) started in 2016 are rather coming to their mid-term only, while the latest group of selected projects (software oriented) is only starting this year (see Annex for a more detailed reminder of the different calls relating to the cPPP). However the ending of a significant number of projects in 2018 will allow a first technical overview of the programme outcomes.

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[12] http://montblanc-project.eu
[13] http://www.exascale-projects.eu/EuroExaFinalBrochure_v1.0.pdf
[14] http://www.montblanc-project.eu/arm-based-platforms
[15] http://www.deep-projects.eu
[16] http://www.exascale-projects.eu/EuroExaFinalBrochure_v1.0.pdf
[17] https://euroexa.eu
[18] http://www.etp4hpc.eu/european-hpc-handbook.html
[19] https://exdci.eu

The Centres of Excellence (CoEs) were not scrutinised in detail for this report. We can however say CoEs stimulated and amplified the development, optimisation and scaling up of many community codes, libraries (incl. linear algebra), but also programming and performance analysis tool and methodologies. Areas covered by CoEs launched in 2015/2016 encompass materials science, renewable energies, weather and climate, computational medicine and biomolecular research, global systems science – as well as generic tools and methods for performance optimisation and productivity of applications. After an average 3-4 years of lifetime, CoEs started in 2015 will soon finish, and a second set of CoEs is about to be selected and funded in 2018, for a total funding of ca. EUR 72 million (vs. EUR 42 million for the first round in 2015).

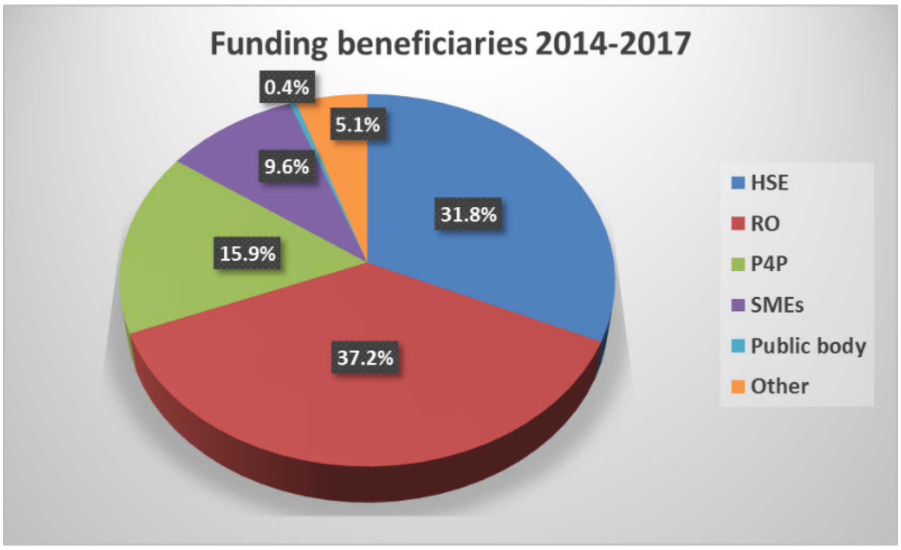
It is important to pint out that the focus of FETHPC projects is on pre-competitive, open research. This implies that most patents deriving from this research will occur after the completion of the projects; nevertheless, the industry participants (same interviewed sample as in previous sections) report they have already filed 10 patents during the lifetime of the projects.

Many ETP4HPC organisations (from industry as well as from research) are also represented and active in standard bodies, all of them being involved in FETHPC and/or CoE projects. These standard bodies are essentially concerned with parallel programming models or languages (MPI Forum, GASPI Forum, Fortran standardisation committee, OpenMP ARB), software frameworks for HPC (OpenHPC), file systems (EOFS, Lustre Centre of Excellence).

Standard body	**Participating ETP4HPC organisations**
MPI Forum	ATOS, BSC, EPCC, HLRS, CEA, INTEL, CRAY, IBM. INRIA. Forschungszentrum Jülich
OpenHPC	ARM, ATOS, BSC, CEA, CINECA, CRAY, INTEL, LRZ, PARTEC
EOFS	ATOS, BSC, CEA, DKRZ, Forschungszentrum Jülich, INTEL, LRZ, PARTEC, SEAGATE
OpenMP ARB	BSC, CRAY, EPCC, IBM, INTEL
GASPI Forum	Fraunhofer ITWM, KTH, LRZ
Fortran	NAG, LRZ, STFC

3.3. Evolution over the years

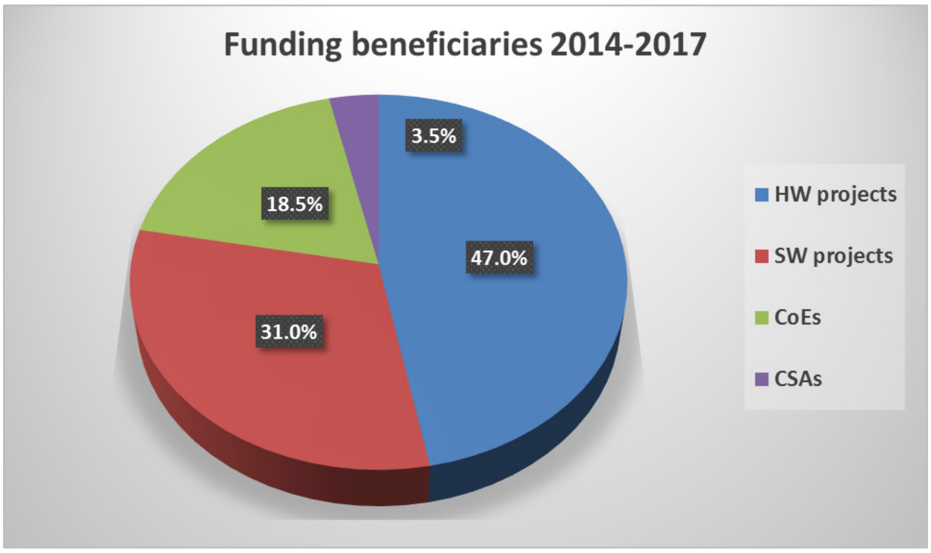
Below, the figures and tables summarize the distribution of the EUR 229.6 million of H2020 funding already allocated to projects implementing the HPC strategy. Since the start of the cPPP on HPC a majority of funding has been awarded to Higher and Secondary Education (HSE) and research Organisation (RO) institutes. The private-for-profit industry sector (P4P) and including SMEs, were the recipients of about one fourth of the funding, whereas other organizations (Other) and Public bodies received together 5.5%.



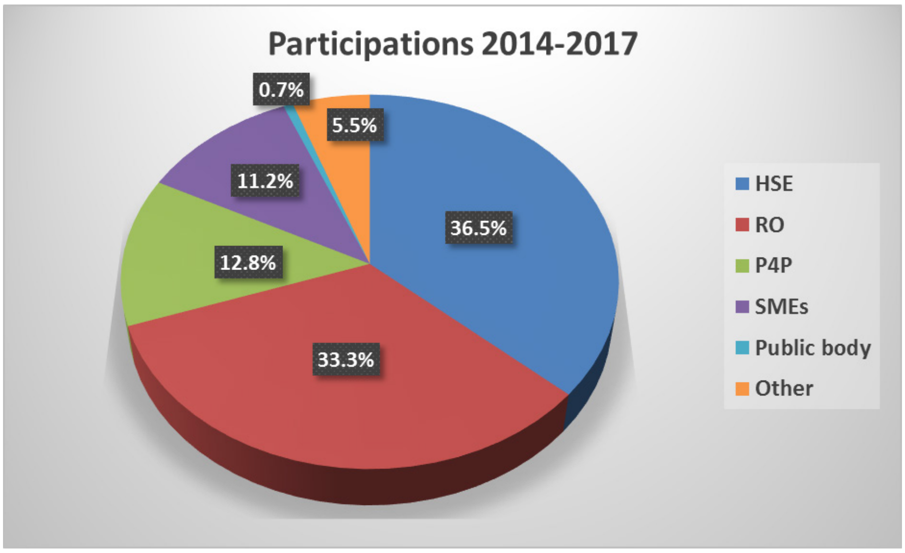
In order to clarify further the allocation of H2020 funding, the following table presents an analysis per type of project. The distinction made in the table between whether a project is classified as hardware (HW technology) or software (SW technology) depends on the call and subtopic to which it was submitted. Centres of Excellence (CoE) are mostly dealing with software but more (although not exclusively) at the application level, and are thus kept in a specific category – by contrast what we classify as SW is dealing with the 'software stack' going with the hardware to make up a HPC solution – a fully operational supercomputer.

Call reference	Subtopic(s)	Project type
FETHPC-1-2014	a (architectures)	HW
FETHPC-1-2014	b,c,d (system, tools, algorithms)	SW
FETHPC-2-2014	N/A	CSA
E-INFRA-5-2015	N/A	CoE
FETHPC-01-2016	N/A	HW
ICT-05-2017	N/A	HW
FETHPC-02-2017	a,b,c,d,e (system, tools, storage and I/O, data, algorithms)	SW
FETHPC-03-2017	N/A	CSA

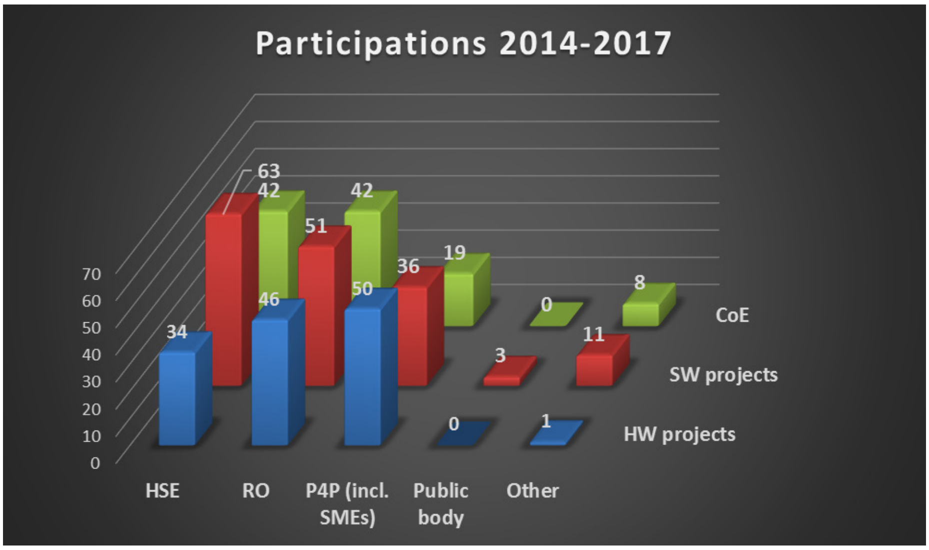
This methodology simplifies the actual picture, as in many cases the hardware and software aspects are interlinked through co-design in one project. However, at a first instance it allows us to break down the funding in the different areas, as this is an important aspect of the implementation of the HPC strategy. The picture that emerges is one where funding in HW and SW+CoE topics are very much evenly split. Calls in 2018 are expected to maintain this balance. Even the forthcoming low power processor project (EPI), clearly a hardware project meant to be strongly linked to the cPPP efforts, will encompass important software aspects, with clearly identified HPC co-design aspects.



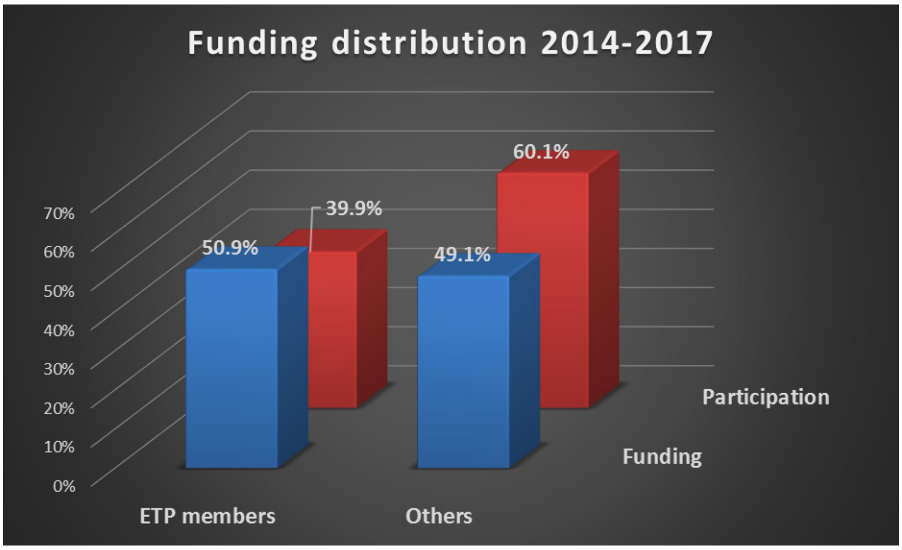
Participations by type of organization in the funded projects displayed in the next chart, broadly reflects the allocation of funding with small deviations in one direction or another.



More interestingly, the breakdown of participations in the different types of projects in the next chart presents a more detailed and informative view. In particular, it shows how HW projects involve more private-for-profit (P4P) organizations that are oriented towards creating innovations in this area, in line with our policy orientations to strengthen a European industrial supply chain. Higher and Secondary Education organizations are leading on the software development side, whether it is the middleware (typically targeted by SW projects) or closer to the applications (targeted by CoEs). The involvement of Research Organization (RO) is important in both and highlights their importance in effectively bridging both components in a hardware/software co-design approach.



An important facet of cPPPs is the openness. European industrial platforms play an important role in organizing the community around strategic priorities and European roadmaps. However their work should represent not only the interests of their members, but reflect the reality of a wider community. It is therefore important to monitor how H2020 funding is distributed among ETP4HPC members and non-members. The following chart does that for both funding and participation, showing that a majority of the beneficiaries are not members of the ETP4HPC and that the funding is almost exactly split in half between members and non-members.



4. OUTLOOK AND LESSONS LEARNT

Currently the regulation establishing the EuroHPC Joint Undertaking is expected to be approved in the Council of the European Union late September. The engagement with Member States at the political level will continue intensively in 2018. In addition, many working groups with representatives from Member States have already started studying several implementation and operational aspects of the future activities of the joint undertaking, which is foreseen to start before the end of 2018. Especially the establishment of adequate and timely procurement procedures will be critical to carry out the acquisition of pre-exascale HPC systems by 2020, an ambitious objective of the EuroHPC JU.

On a different front, several new calls for proposals related to the HPC strategy will be implemented during 2018. Many will be in the area of HPC applications such as the call for proposals on HPC Centres of Excellence, and HPC and Big Data enabled Large-scale Test-beds and Application. In addition, a call on the support to the governance of High Performance Computing Infrastructures will be implemented with the objective of establishing a communication platform for the dialogue of stakeholders involved in the implementation of the governance of HPC infrastructures across Europe. Last but not least, the consortium for the European Processor Initiative (EPI) will present a proposal for evaluation to implement the first stage of the research and industrial roadmap positively evaluated in 2017.

The feedback received from the experts that evaluated the cPPPs for the mid-term review have been carefully analysed and the cPPP on HPC will build on the lessons learnt during this process in order to improve its internal functioning and external communication and dissemination strategies. We have a data collection process and methodology, persistent and adjusted to the new KPI framework, but still showing shortcomings, of three main types. First, the difficulty of data collection especially from private companies is acknowledged by most cPPP private side associations. Our mitigation was to outsource part of this activity to specialised third parties. Second, we are at a stage where less than one third of the cPPP programme funding has been committed, and still less actually used by the different running projects and their partners. Lastly, it is also acknowledged some effects of the R&I funding will only become fully visible in a couple of years, and this latency will also exist for projects starting in 2018-2020, with a duration of three years or more per project.

5. ANNEXES

5.1. Operational statistics – calls for projects

Call reference	Call title		Closing date	Selected projects
FETHPC-1-2014	HPC Core Technologies, Programming Environments and Algorithms for Extreme Parallelism and Extreme Data Applications	RIA	25 November 2014	19
FETHPC-2-2014	HPC Ecosystem Development	CSA	25 November 2014	2
E-INFRA-5-2015	Centres of Excellence for computing applications	RIA	14 January 2015	9
FETHPC-01-2016	Co-design of HPC systems and applications	RIA	26 September 2016	2
ICT-05-2017	Customised and low energy computing (including Low power processor technologies)	RIA	25 April 2017	1
ICT-42-2017	Framework Partnership Agreement in European low-power microprocessor technologies	FPA	26 September 2017	1
FETHPC-02-2017	Transition to Exascale Computing	RIA	26 September 2017	11
FETHPC-03-2017	Exascale HPC ecosystem development	CSA	26 September 2017	2

History of cPPP related H2020 calls

# of H2020 calls implemented related to HPC	6
Avg. time-to-grant	219 days
Total H2020 funding committed	229.6 M€
# of running projects	33
# of projects to start in 2018	1 FPA + 11 RIA + 2 CSA
Projects coordinated by ETP members	20
Participating organisations	436
Unique participations	222
non-ETP members participations	62%
Industry (non-SME) participations	12.9%
SME participations	11.2%

Statistics on cPPP-related H2020 projects

5.2. Data sources and methodology

Over the years, different data sources have nourished the annual progress reports; some sources provide recurrent input, other more intermittent or demand-driven input. The main sources for current KPIs (data on 2017) were:

- data provided by the EC on the different calls
- ETP4HPC annual internal survey amongst ETP4HPC's members
- a more focussed survey for the private-for-profit (P4P) sector, outsourced to an external and independent analyst team.

Data provided by the EC on the different calls mostly relate to operational aspects of the programme and general statistics like categories of participants – ETP4HPC members vs. non-members); research organisation, academic organisations, industrial companies, SMEs.

ETP4HPC annual internal survey was sent to 89 organisations, out of which 37 answered it – not necessarily all questions. Only one industrial organisation participated in this survey, possibly because the complementary study with industrial partners, explained below, had been announced before the end of the survey, and private companies waited to focus on the latter one, guarantying more confidentiality and avoiding some redundancies in the questions. This ETP4HPC survey was thus considered as representative for the research and academic organisations only.

For the P4P sector, data were collected by the contractor via interviews along a pre-submitted questionnaire. Private companies would mostly not deliver any operational nor commercial data to ETP4HPC, the confidentiality constraints were managed by the contracted analyst, using a well-established protocol and non-disclosure agreement approach which was widely accepted by the interviewed organizations. Aggregated and anonymised data only have been delivered to ETP4HPC.

In order to get representative and focussed input regarding the KPIs, we selected 11 companies participating in FETHPC (and some CoE) projects. This sample represents the main industrial beneficiaries of the cPPP, amounting for 62% of the funding going to P4P industry sector, including SMEs. SMEs receive 54% of this share. The P4P sector receives ca. 25% of the whole cPPP-related R&I funding - the interviewed industry participants reported that together they received EUR 42.8 million in funding under the H2020 HPC programme.
The organisations interviewed are a mixture of SMEs and larger European or international companies; most are involved in more than one project. Private investment and skills/jobs KPI estimates primarily stem from this study; other sources are also used to elaborate on SME and Innovation KPIs.

NB: the 'public research' side of the so-called private side of the cPPP is estimated to contribute to private side investments as well, but to a limited extent. We estimate the extra effort can be an average 25% of the received R&I funding - in addition to the total Horizon 2020 funding (100% + 25% overhead). This is because the flat rate overhead may be lower than the actual overhead for many organisations, and because different in kind contributions may arise (incl. the use of computing resources, software licences etc.).

Data source	**2014**	**2015**	**2016**	**2017**
ETP4HPC internal survey	x	x	x	x
EXDCI survey (FETHPC+CoE projects)		x		
ETP4HPC Annual report	x	x	x	x
Analyst study (for profit organisations)			x	x
PRACE KPIs	x	x	x	x
EC H2020 stats	x	x	x	x
Public sources (internet, other reports and public registers)	x	x	x	x

5.3. Some extra facts and quotes from industrial partners interviewed on their H2020 project activity

Importance of H2020 funding

A large majority of industry participants (82%) rated the H2020 funding as "*extremely important for our future*." All the SMEs considered the funding extremely important. The two larger companies describing the funding as only "somewhat important" both explained that without the funding they would have pursued the research on a more limited basis without their own funding.

All our Horizon projects are RIAs, meaning EC provides all the money. We provide people time: 4-8 FTEs, plus 15-20 FTEs on related work. Our SME company has received EUR 10 million from VCs and will soon close a similar amount on top of this to commercialize this. We already have some commercial outcomes occurring as proofs-of-concept with top tier players.

H2020 funding has brought us lots of new learning and new technology tools. We've achieved quite a bit within this project. From our perspective, the learning and results have been more valuable than we ever expected.

The funding is important because it allows us to integrate technologies from various partners in the project. We have made significant advances. It's allowed us to do a co-design approach with software partners in ETP4HPC and customers. The level of cooperation and co-development is much deeper than in usual projects so we can much better understand applications requirements.

The H2020 Work Program is very important. It's important for investing in the future. The impact goes far beyond HPC, even for our small company, but HPC is where customers will first buy and test it. The program is really important because it promotes longer-term technology development rather than the short-term R&D companies are forced to focus on.

Grant programs like H2020 lets us hire people, bring them up to speed, and lower our operating risks as an SME European supplier.

The project gave us in-depth knowledge of the algorithms, through profiling and optimization. This will be very useful as we develop our next-generation product and future exascale supercomputers.

Our objective was to build a center of excellence and we could not have done it without this funding to involve research teams from all across Europe.

H2020 enables us to build the basis, targeting potential customers and so on.

It's absolutely critical because adapting the technology for exascale requires working closely with the European HPC community. The Work Program isn't just the money, it's even more importantly about bringing all the European players together to pursue a common goal that none of us could effectively pursue alone.

If the H2020 funding had not been available, all the industry participants would either not have pursued the research (55%) or would have been forced to pursue it on a more limited basis (45%). When asked about the consequences of pursuing the research on a more limited basis, participants in this category said that the research would have proceeded more slowly and with less ambitious goals. Both these consequences would have harmed the companies' ability to innovate and compete.

We would not have pursued this R&D initiative. As a business, we would have been more product focused and not have been able to afford this much R&D that really helps us as a smaller European supplier to jump ahead competitively. We'd have had to rely on our existing technology and knowledge.

We would have pursued this R&D initiative on a more limited basis – we may not have taken as much risk without the public funding, and we would have been slower and later in our R&D and the adaptation of our hardware to application needs wouldn't have been as deep.

We would have pursued this R&D initiative on a more limited basis and less effectively. It would have been delayed and more limited in scope. The Work Program funding has greatly accelerated the R&D.

Extra private investments and post-project perspectives

The additional money we will add is for post-project productization that will require significant effort, especially in quality assurance and certification, along with manufacturing readiness. We will add roughly 3-4 times what we received from the Horizon program.

By design, the project is 100% funded so we didn't add more money but we provided a system prototype that we plan to turn into a product. Our rough estimate to turn this into a product is 2 times the amount received from the H2020 program.

The project will create a prototype. After the project we will need to invest another 2 years and about EUR 10 million to harden the prototype to product status.

We're an SME and have already begun investing in the product – it will be our flagship product and I estimate we will invest a million euros to get this to market.

We expect to match the Horizon funding one-to-one or more in developing a product based on the project work.

All 10 positions created during the project will remain after the project. We also support start-up companies and if they succeed there would be great impact in job creation.

We expect the project to produce 4.5 FTEs for the post-project product development phase and 25-30 FTEs after productization.

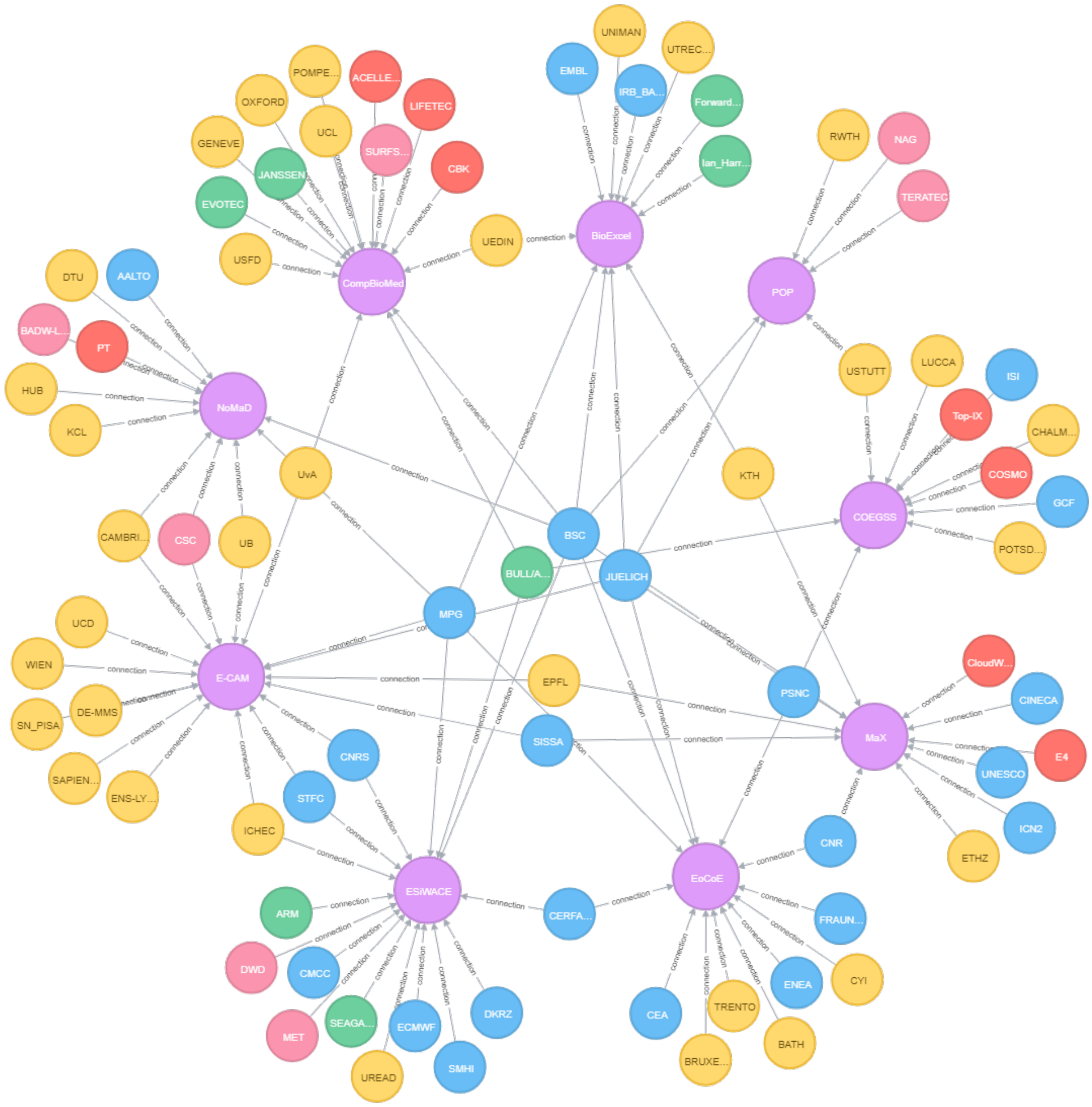
5.4. HPC Ecosystem

The following charts stem from a database of all FETHPC and CoE projects partners.

Selective graph visualisation of (project, partner) relationships reveal a number of interesting facts about the project consortia and the roles of different categories of partners in the ecosystem.

	Project
	HSE (Higher or Secondary Education Establishment)
	RO (Research Organisation)
	SME
	Private for Profit
	Other

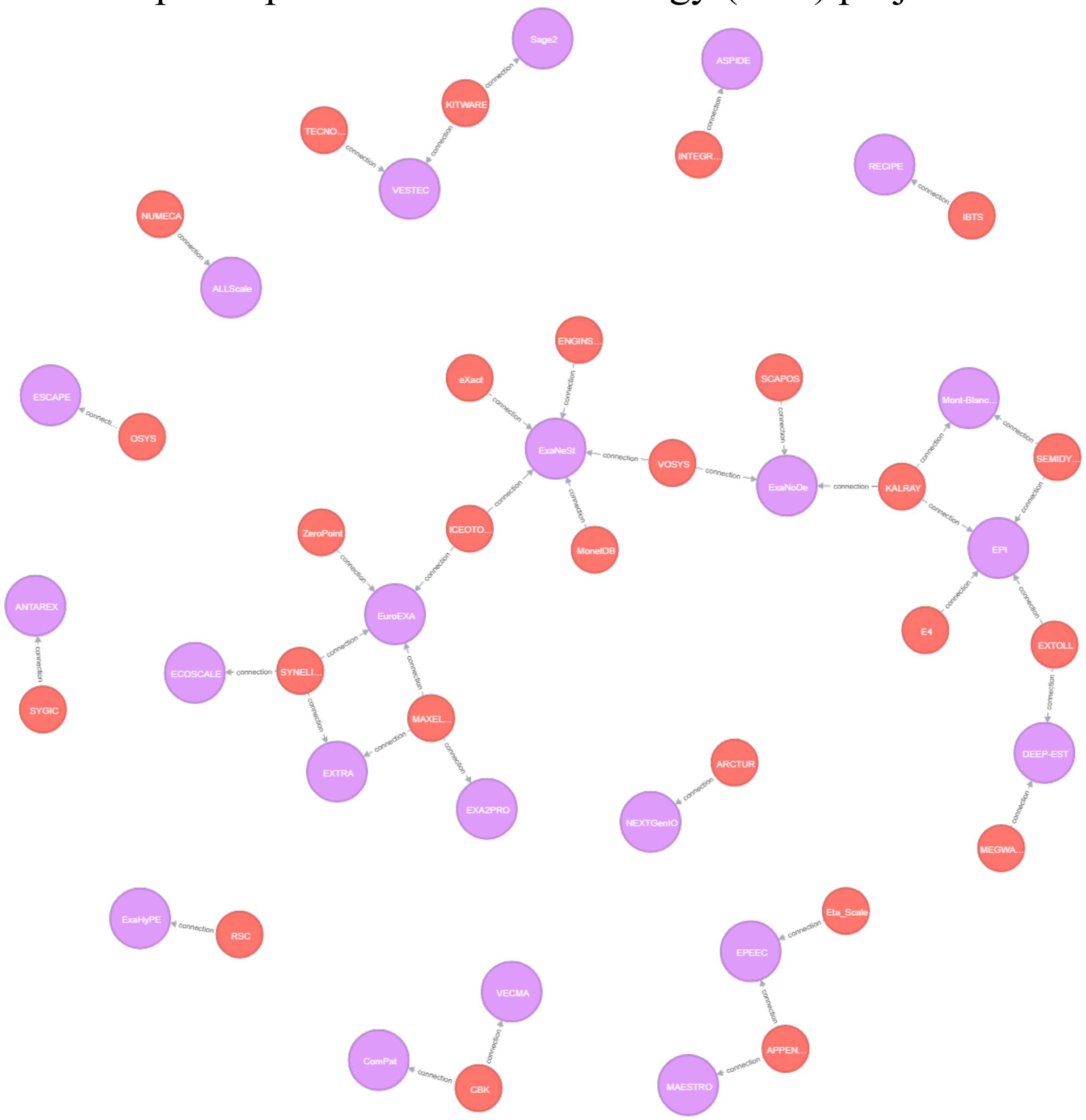
Centres of Excellence in HPC



Highlights:

- Key role of supercomputing centres for advancing codes in different application domains.
- Negligible overlap of communities within application areas (materials) or between them.
- Max Planck Gesellschaft (MPG) and Bull/ATOS involved in several application areas.
- Few SMEs participate in Centres of Excellence.

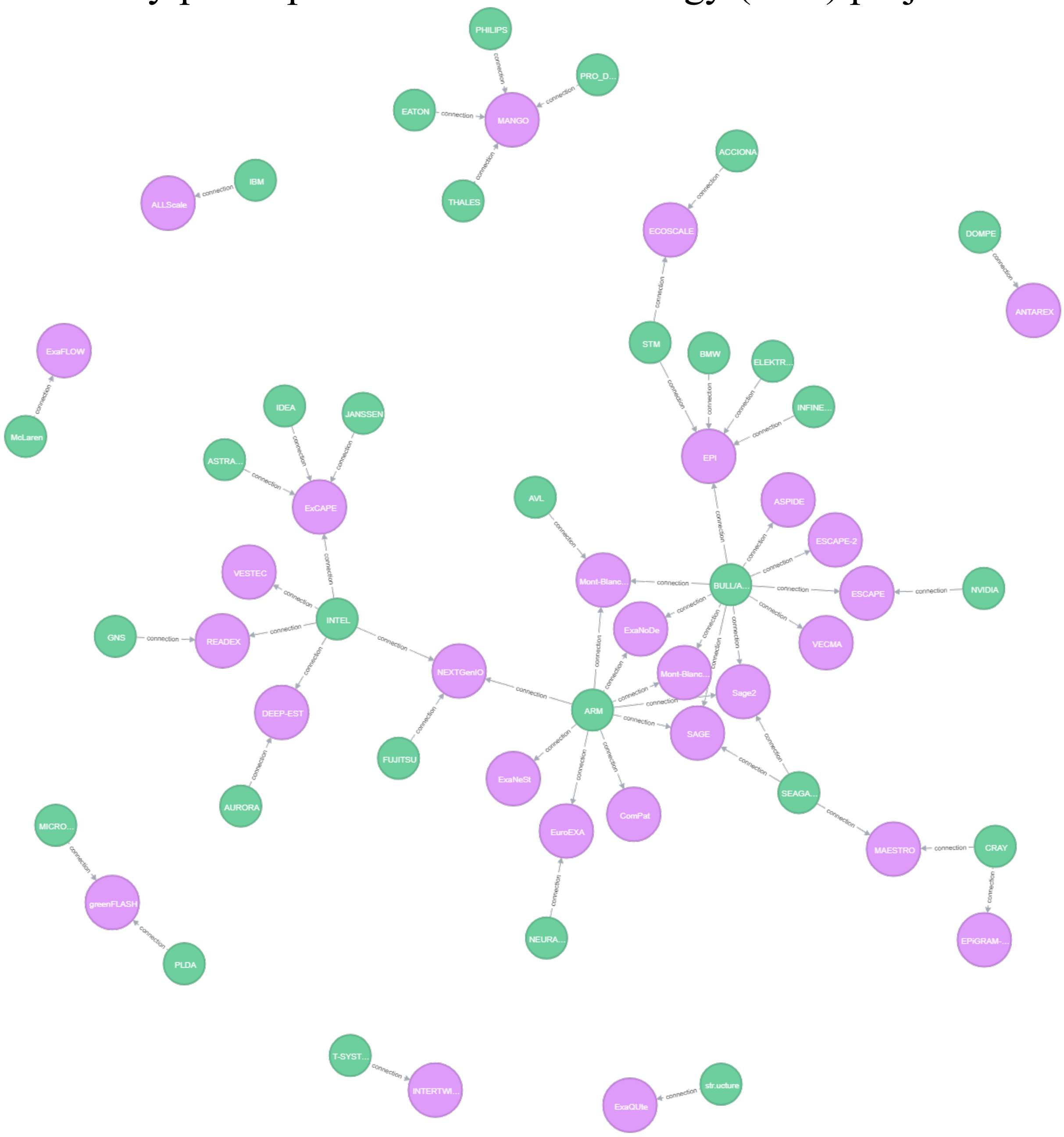
SME participation in HPC technology (FET) projects



Highlights:

- SMEs mostly engaging in one or two projects at a time.
- More than half of SME participation supported through four hardware projects: EPI, EuroExa, ExaNest, ExaNode.

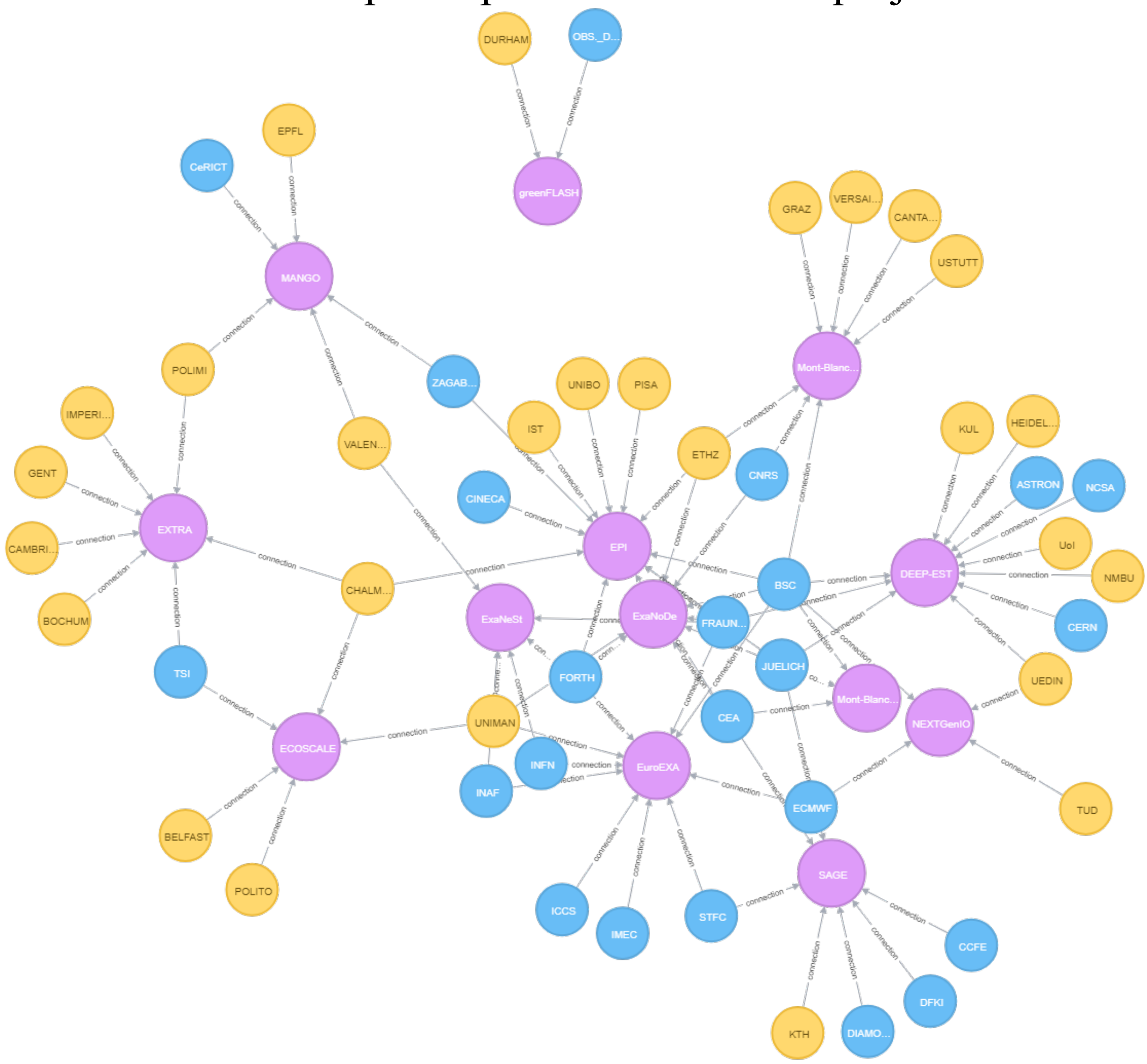
Industry participation in HPC technology (FET) projects



Highlights:

- Three clusters of projects revolving around three lead actors in HPC: Bull/ATOS, ARM/Allinea, Intel.
- Limited participation of other big HPC players like IBM, NVIDIA, Cray.
- EPI (low-power microprocessor), MANGO (architecture-level support for application customization) and ExCAPE (machines learning in HPC environment) are the three projects with most industry participation.

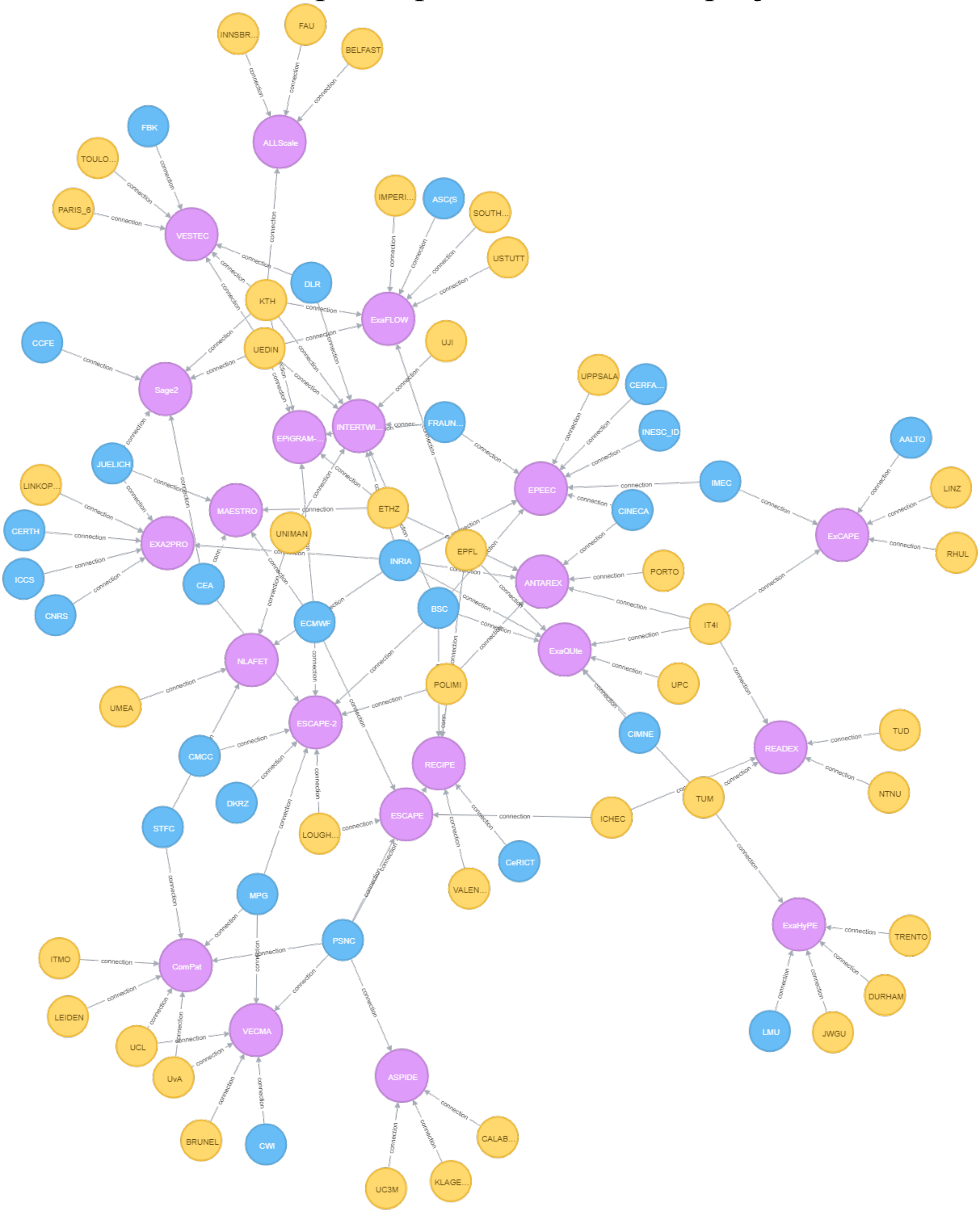
HSE and RO participation in hardware projects



Highlights:

- A number projects revolve around Research Organisations and Supercomputing Centres with 4 or more participations: BSC, Juelich, Fraunhofer, FORTH, CEA.
- Manchester University is the only Higher and Secondary Education Establishment participating in several hardware projects.

HSE and RO participation in software projects



Highlights:

- More distributed network compared to the one of hardware projects.
- More balanced participation of research organisations and universities.
- Features several actors with 4 or more participations in projects: INRIA, KTH, BSC, PSNC, IT4I, and Edinburgh University.

5.5. Selection of HPC cPPP related news articles in the European press

General public:

- EU hails new Airbus-size alliance for supercomputers, https://www.euractiv.com/section/digital/news/eu-hails-new-airbus-size-alliance-for-supercomputers/
- Europe sets sights on supercomputer future, http://www.euronews.com/2017/03/23/europe-sets-sights-on-supercomputer-future
- Europe puts 1bn euros into supercomputer research, https://www.bbc.co.uk/news/technology-42663027
- EU strebt bei Supercomputern in die erste Liga, http://www.spiegel.de/netzwelt/netzpolitik/supercomputer-eu-strebt-in-die-erste-liga-a-1147047.html
- Der Supercomputer-Plan der EU, https://www.sueddeutsche.de/digital/technologie-der-supercomputer-plan-der-eu-1.3821516
- Eine Milliarde Euro für einen europäischen Supercomputer, http://www.faz.net/aktuell/wirtschaft/diginomics/eine-milliarde-euro-fuer-einen-europaeischen-supercomputer-15386789.html
- Un supercalculateur européen est né à Rome, http://paperjam.lu/news/un-supercalculateur-europeen-est-ne-a-rome
- L'UE prévoit un milliard d'euros pour la prochaine génération de HPC en Europe, https://www.lemagit.fr/actualites/450433224/LUE-prevoit-un-milliard-deuros-pour-la-prochaine-generation-de-HPC-en-Europe
- Atos espère développer ses supercalculateurs grâce à un appel d'offres européen, https://www.lemonde.fr/economie/article/2018/01/15/atos-espere-developper-ses-supercalculateurs-grace-a-un-appel-d-offres-europeen_5241930_3234.html
- L'UE veut investir dans les superordinateurs http://www.lefigaro.fr/flash-eco/2018/01/11/97002-20180111FILWWW00116-l-ue-veut-investir-dans-les-superordinateurs.php
- La corsa ai supercomputer: avanti Usa e Cina, l'Europa arranca, https://www.wired.it/economia/business/2017/05/30/supercomputer-usa-cina-europa/
- Supercomputación frente a Trump, https://www.elperiodico.com/es/ciencia/20170705/la-ue-prima-la-supercomputacion-de-altas-prestaciones-con-eurohpc-6150085
- Bruselas quiere invertir 1.000 millones en el desarrollo de superordenadores europeos, http://www.europapress.es/ciencia/noticia-bruselas-quiere-invertir-1000-millones-desarrollo-superordenadores-europeos-20180111123605.html

Specialized audience beyond HPC:

- Supercomputing poised for a massive speed boost, https://www.nature.com/articles/d41586-017-07523-y
- Les supercalculateurs au régime sec, https://www.industrie-techno.com/les-supercalculateurs-au-regime-sec.49089
- Arriva il supercomputer europeo: l'UE lancia piano da 1 miliardo, http://www.meteoweb.eu/2018/01/arriva-il-supercomputer-europeo-lue-lancia-piano-da-1-miliardo/1029158/

5.6. KPI Part 1 - Common Priority Key Performance Indicators

	Key Performance Indicator (KPI)	Value in 2017	Baseline at the start of H2020 (latest available)	Target (for the cPPP) at the end of H2020	Comments
1	Mobilised Private Investments	Estimated leverage factor of 5 at the end of projects for industrial participants funding	Not defined	In leveraged investments, four-fold effect in industrial effort per pubic Euro in the PPP.	
2	New skills and/or job profiles	End of 2017: at least 73, and up to 115 direct jobs in s/w and h/w industry (30% in hardware development, 15 % in system and 15 % in application software development, 15% in storage and network) More than 150 direct jobs in research	Not defined	Direct jobs: 400 by 2017, and 1000 by 2020. Indirect jobs, 10000 in technology companies and 100000 in HPC end-users organisations by 2020	At this early stage of the PPP R&D funding use (1/3 of cPPP provisioned funding only has been committed, and many projects hare not finished yet), only direct job creations are estimated
3	Impact of a cPPP on SMEs	See section 3.2.3	Not defined	4 successful new SMEs in the PPP by 2017, and 10 by 2020	Four of the "Top10" industrial beneficiaries in cPPP related calls (FETHPC) are SMEs

4	Significant Innovations	Two main tracks of innovations emerging at system/solution level – see comments	Not defined		Mont-Blanc ARM-based low-power HPC architectures (from FP7 Mont-Blanc1&2 + H2020 Mont-Blanc3 projects)– several prototypes made available to scientific users; now a product commercialised by a European HPC vendor A first production setup of Modular Supercomputing Architecture - Cluster-Booster, from FP7 DEEP projects - in the process of being implemented at Juelich Supercomputing Centre (JUWELS system), concept being further expanded in H2020 DEEP-EST project

5.7. KPI Part 2 - Specific Key Performance Indicators for the cPPP

	KPI domain	Key Performance Indicator (KPI)	Value in 2017	Baseline at the start of H2020 (latest available)	Target (for the cPPP) at the end of H2020	Comments
1	Global market share of European HPC	HPC systems, components and tools based on technologies developed and built in Europe, volume (in generated income) of HPC technology exported from Europe (European HPC technology developers) to the rest of the world.	4.9% in 2016 N/E in 2017, but est. 4.9%	4.4% in 2013	Reach a global market share of at least 7.5% by 2017, and 12.5% in 2020	Source for values: IDC/Hyperion 2013 = 4.4% 2014 = 4.7% 2015 = 4.7% 2016 = 4.9% 2017 = (est.) 4.9%
2	HPC additional investments	The level of high-tech investment generated by the PPP, and the additional investments leveraged in the HPC value chain; relation to the investments made into European HPC companies by private investors and venture capital funds	See KPI 1 in Annex 5.6 KPI Part 1	No baseline	In direct R&I activities, matching the Community funding in the PPP (~700 million€ by 2020). In leveraged investments, four-fold effect in industrial effort per pubic Euro in the PPP.	
3	Jobs	Direct, sustainable jobs out of HPC research programmes recommended by the PPP, and indirect jobs in technology companies further downstream and in end-user organisations of HPC technologies and applications	See KPI 2 in Annex 5.6: KPI Part 1	No baseline	direct jobs: 400 by 2017, and 1000 by 2020. Indirect jobs, 10000 in technology companies and 100000 in HPC end-users organisations by 2020	
4	Innovation environment in HPC	European HPC start-ups (not just those arising from H2020 projects) Number of new SME start-up companies created out of HPC research programmes in the PPP	See comment => 0	No baseline	4 successful new SMEs in the PPP by 2017, and 10 by 2020	2 startups creation related to projects in FP7 & ICT advanced computing scope

		(only successful SMEs with a sustainable business) Unsuccessful HPC start-ups Growth of existing European HPC start-ups	 N/A N/A			
5	Research programme effectiveness and coverage	• Coverage of the R&I roadmap by calls topics • Number of co-ordinated calls launched • Number of responses to calls • Number of active research projects • Geographical coverage of project participation • Additional leverage and Impact in other related programmes (e.g. areas such as nano-electronics, photonics, microelectronics, software, storage in other parts of Horizon2020	• See sections 2.1 and 3.3 • 3 • 72 • 33 • All MSs except EE, LV, LT • Impact on application areas developed by CoEs and on microelectronics for the EPI project			2014-2017 calls reflect the SRA topics; the SRA is directly mentioned in the calls as detailed technical reference
6	Performance of HPC technologies developed	• Range of architectures available in Europe • Number of new prototypes made available per year via the PPP	• 6 • 1 per year			Projects concerned: NextGenIO, SAGE, Mango, Mont-Blanc, DEEP-EST, EuroEXA
7	People, education, training and skills development	Showing the European HPC knowledge base providing high-skilled HPC profiles and curricula developed in the PPP	45 workshops, 4 summer schools, 12 courses, 2 fora, several open days, webinars, hackathons			

8	HPC use	Use of the HPC technologies developed in academia and industry (in particular SMEs)	17 projects making available open source software packages			
9	HPC software ecosystem	Impact of software ecosystem (number of applications, number of users, etc.). Large scale scientific and industrial applications adapted to the next computing generation addressing key economic areas and societal challenges	CoEs and FETHPC use cases addressing 12 application areas with economic and societal relevance.			
10	Patent, inventions and contributions to standards in HPC by H2020 funded projects	Patent, direct contributions and activities leading to standardisation, and invention-submissions out of HPC research programmes recommended by the PPP	See KPI 1 & 2 in Annex 5.8: KPI Part 3		40 per year by 2017, 80 per year by 2020	
11	Efficiency, openness and transparency of the PPP consultation process	• Monitoring the number of participants contributing to the strategy and implementation workshops • Analysis of ETP4HPC members to provide evidence for representation of the HPC community • Monitoring of the decision making process during the consultation	ETP4HPC Strategic Research Agenda involved 200 experts ETP4HPC has grown to 86 members end of 2017, incl. 1/3 of EU SMEs; members are technology suppliers but also application owners, service providers, ISVs…			ETP4HPC SRAs elaboration also involved PRACE, Centres of Excellence, BDVA (Big Data Value Association) ETP4HPC membership: see http://www.etp4hpc.eu/membership.html and http://www.etp4hpc.eu/ETP4HPC-2017-annual-report/#section-3

12	Dissemination and awareness	Make HPC visible to the general public in Europe and to a broad range of stakeholders.	See section 2.3 and Annex 5.5			

5.8. KPI Part 3 - Contribution to Programme-Level KPIs

	Key Performance Indicator	Definition/Responding to question	Type of data required	Data	Baseline at the start of H2020	Target (for the cPPP) at the end of H2020	Comments
1	Patents		Number of patent applications Number of patents awarded	10 0	n.a. [new cPPP under H2020]	**H2020:** 3 patent applications per EUR 10 million funding	10 patents filed
2	Standardisation activities (project level) Contributions to new standards (PPP level)		Number of activities leading to standardisation Number of working items in European Standardisation Bodies Number of pre-normative research files – prEN - under consultation in ESBs	See report section 3.2.4		No target	Projects participants involved in 6 different HPC standardisation entities
3	Operational performance	Time-to-grant		219 days on average			6 calls, 47 projects granted (1 FPA, 42 RIA, 4 CSA)