Review Skills Gaps and Training Needs of SMEs

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1 Introduction

Contemporary supercomputers or HPC systems offer unprecedented computing power and their architectures are constantly evolving. The on-going challenge has always been to address the shortage of people with the relevant HPC skills to maximise efficiency and productivity, i.e. ensuring high returns on investment in HPC. This skills shortage has been well documented both in Europe [1] and in the US [2]. There is a clear recognition that HPC education and training are greatly needed and should be expanded to develop a larger cohort of HPC experts (e.g. researchers, software developers) who are able to advance the computational sciences in keeping pace with the latest hardware.

At the same time, industry and SMEs are increasingly relying on the power of supercomputers to invent innovative solutions, reduce cost and decrease time to market for products and services. Great strides have been made to facilitate HPC access and expertise for industry, e.g. PRACE, but the shortage of skills remains. For the SME sector, the shortage of HPC skills is particularly pronounced due to budget constraints in upskilling staff. Furthermore, there is a general lack of awareness of the potential benefits of utilising HPC technology.

This deliverable sets out to identify some of the training demands of SMEs (Section 2), and examine this in light of existing provision of HPC training in Europe (Section 3). We then identify areas where there are opportunities for SESAME Net WP6 when developing training material in the remainder of the project (Section 4).

2 Training demands of SMEs

In order to assess the needs of SMEs in terms of HPC training, we carried out two studies: (i) we surveyed 105 SMEs from 18 countries in the SESAME Net project (WP5, see [3]) where we asked questions on training demands and requirements, and (ii) we collated the opinions from HPC competency centres, who together had extensive experience in engaging and working with SMEs, as to what are perceived to be important topics for SME training.

2.1 Survey of SME training needs

In WP5, SESAME Net has devised a survey to capture the HPC demands of SMEs. This was disseminated extensively to SMEs by each competency centre and a total of 105 survey responses were obtained. One section of this survey was focused on training needs, in which five questions were posed; the raw results are provided in Appendix 6.1. After removal of blank/ambiguous responses (~10% of the feedback per question), the results can be summarised as follows:

- 70% of respondents are interested in information or training about possible applications and potentials of HPC technologies.

- 70% of respondents are willing to take advantage of HPC training tailored to their relevant business sector, although 20% of the 105 surveyed SMEs did not respond to this question.
- 76% of respondents are not aware of available HPC training courses or services in their local region.
- 42% of respondents indicate that their staff require training in HPC, with another 36% indicating uncertainty whether their staff require such training, i.e. only 22% of respondents indicate that their staff do not require HPC training.
- Out of those who has indicated that their staff require training, the topics that are of interest includes (in order of the level of demand):
  - code development and optimisation (70%)
  - introduction to HPC (68%)
  - application usage (65%)
  - administration of HPC infrastructure (55%)

While these results provide a rough overview of the training needs of SMEs through our survey, closer examination of these SMEs in how they respond to the five questions in combination can also reveal insights. These can be discussed in light of the following major observations.

2.1.1 Lack of awareness of available HPC training

This is clear from the 76% of respondents (69 SMEs out of 91 who provided valid responses) who are not aware of available HPC training courses or services. The lack of awareness is especially pronounced for the 31 SMEs who indicated uncertainty ("don't know") on whether their staff require HPC training, only 3 of them indicated knowledge about available HPC training courses, i.e. there are potentially many SMEs who do not know whether they require HPC training due to a lack of information. Among the 39 SMEs who indicated that HPC training is needed for their staff, only 28% of them are aware of available HPC courses locally and the majority of this cohort still indicate an interest in finding out more about potential HPC training. The overwhelming conclusion is that much needs to be done to disseminate availability of HPC training, as well as information about the potential of HPC technologies, to SMEs. SESAME Net is ideally positioned to provide this information.

2.1.2 Tailored training relevant to the sector

There is a general will for SMEs to take advantage of HPC training that are tailored to the relevant business sector, as reflected by 70% of respondents to the relevant survey question. The majority of SMEs who indicated no interest in tailored training have also indicated that their staff either do not require HPC training in the first place, or are unsure. This finding is very much consistent with experience of competency centres and feedback from personal interviews carried out [3], that many SMEs are heavily focused in developing specific solutions to their problems. Hence many SMEs are looking for training services that are highly specific to their solutions, or at least solutions within the same business sector.

2.2 Perceived skill gaps from HPC experts

While Section 2.1 provided some useful information about HPC training demands stemming from SMEs themselves, it is also important to obtain professional feedback from HPC experts and competency centres as to what are the perceived skill gaps in the SME sector. As highlighted previously, many SMEs are unaware about the potential and relevance of HPC technology and training, therefore such professional feedback is invaluable to guide the type and content of training courses that may be of most value and relevance for SMEs. Table 1 in Appendix 6.2 is a breakdown of the skills or knowledge gaps that are of most relevance to SMEs as identified by experts from 12 HPC competency centres in SESAME Net, the areas identified can be summarised into the following categories:

- **Fundamental HPC and parallel computing concepts** (e.g. basic parallelism and benefits, utilisation of HPC systems and environments).
- **Parallel programming and optimisation** (e.g. MPI, tools and techniques for parallel code development and optimisation).
- **Data-related skills in HPC** (e.g. "Big Data" in the context of HPC, computational statistics, data analysis beyond Excel).
- **Many-core technology** (e.g. programming for accelerator hardware such as GPUs, Intel Xeon Phi co-processors).
- **Large-scale simulations and modelling** (e.g. tools and techniques to deploy large-scale simulations on HPC systems, meshing and partitioning tools).
- **Application packages and services** (e.g. domain-specific packages such as those for engineering, ISV codes, applications as cloud services).
- **Software engineering** (e.g. tools and techniques to maintain software)
- **Command line interface, programming languages, compute architectures** (e.g. basic command line interfaces, Python, Fortran, basic hardware architectures).
- **Cloud computing** (e.g. HPC-cloud computing concepts and benefits)

The perceived SME skill gaps as highlighted by HPC experts are largely consistent with HPC training demands as identified by the SME survey (Section 2.1). Fundamental HPC and parallel programming concepts, code development and optimisation, as well as application usage (e.g. domain-specific codes) are all areas where both SMEs and the HPC community agree to be of relevance and are in significant demand for HPC training. However, the HPC competency centres have also highlighted several other areas where training should be offered to SMEs on topics such as data-related skills in HPC, many-core technology, large-scale simulations and modelling, software engineering and fundamental programming languages and computer architecture.

3 Provision of HPC training

This section examines the existing availability of HPC-related courses in Europe for SMEs. We look at the course offerings by HPC competency centres in SESAME Net (Section 3.1) as well as the provision of HPC courses at a wider European context such as those offered via PRACE and some of the challenges faced by training providers (Section 3.2).

3.1 Courses at HPC competency centres

The full list of courses offered by HPC competency centres in SESAME Net are presented in Table 2 in Appendix 6.3. These represent a total of 115 courses offered by 12 competency centres, who were also requested to provide an indication whether the content for each course was oriented towards (a) academia, (b) industry, or (c) both. While the content of 61% of the courses are targeted equally at both sectors, 32% are aimed towards academia with 7% of course targeted towards industry. Lastly, 46% of the courses on offer by the competency centres have been attended by staff from industry in the past, although the extent of participation was beyond the scope of our analysis.

Taken together, these courses cover a wide range of HPC topics from basic pre-requisite skills in programming, utilising HPC systems to intermediate (parallel programming, performance engineering) and advanced skills (advanced parallel programming, many-core technologies). The following are some observations from Table 2:

- Many of the partners offer introductory HPC courses covering access and basic usage of HPC systems, often managed by the same partners as a service (e.g. for the academic community). It is encouraging to see that many of these courses have been attended by industry personnel in the past. However, there may be room to build upon these courses to target SMEs and specific business sectors.
- As expected, the bulk of the courses are related to (both serial and parallel) programming on different compute architectures, and performance engineering tools and techniques. Many of these courses are targeted equally at both academic and industry audiences, with some evidence of participation from industry (30% of such courses).
- Eight centres offer courses on data analysis and data-intensive computing, which is emerging as a significant growth area of particular relevance to SMEs and industry in general. However, attendance by industry staff at these courses appears to be relatively limited.
- There appears to be a paucity of courses on system administration and the operation of small to large-scale HPC infrastructure, where such skills are of considerable demand (see Section 2.1). The “hands-on” nature of system administration work, and the lack of suitable training hardware resources, could act as barriers to developing and offering such courses.
- There are relatively small number of courses that focus on application packages (e.g. OpenFOAM), offered by only two of the partners. This type of content should be of significant interest to SMEs (see Section 2.1), although some of this type of

training may be available elsewhere (e.g. domain-specific organisations, developers of the application packages).

3.2 HPC training provision in Europe

In this section we discuss the wider landscape of HPC training in Europe, beyond the HPC competency centres of SESAME Net. Naturally, most if not all the HPC centres in Europe offer training services; some effort has been made to create a pan-European catalogue of HPC training providers in different European countries [4]. PRACE, established initially with a focus on providing access to European Tier-0 HPC resources, has also been ramping up its activities and investment in HPC training. Current PRACE projects organise and support about 70-80 HPC training events annually via its seasonal schools, on-demand training events and a network of six PRACE Advanced Training Centres; the latter providing the bulk of PRACE training offerings (see [5] and [6] for comprehensive reports of recent PRACE training courses, and [7] for current/upcoming courses).

The repertoire of HPC courses offered by PRACE covers a wide variety of skills and HPC-related topics, similar to those offered by HPC competency centres in SESAME Net; but the former also includes some advanced and specialised courses on cutting edge HPC programming paradigms and architectures used by the top tier of supercomputers. Yet PRACE also face challenges in terms of the level of industrial uptake of its training offerings. These challenges include the nature of the courses themselves (i.e. whether they represent a good fit for industry) but there are also dissemination, practical and legal issues.

3.2.1 Academic-industry training content

There is widespread belief that the course content of many courses are equally suitable for both academic and industry audiences (e.g. see Appendix 6.3), and that joint participation by both communities in the same courses would foster collaborations. While this is certainly true for some cases, the success of this approach in attracting industry or SME participation remains to be an open question. For example, SMEs tend to look for highly targeted training aligned with their solutions (Section 2.1.2), while the content of many HPC courses tend to be rather generic, aimed at researchers from many different backgrounds. A potential remedy for this may be variations of the same course content that are targeted at difference audiences, e.g. parallel programming courses that incorporates examples from different domains such as engineering, geoscience, material science, etc. Another challenge is the common reliance of SMEs on large, often commercial, application packages or solutions. While many HPC training providers are now offering courses on such applications (in some cases partnering with ISVs or the application developers), parallel code development courses continue to be the mainstay for training providers.

3.2.2 Dissemination

HPC training providers often have relative ease of access to disseminate training information for the academic community, many of whom may already have an ongoing relationship with said providers through academic access to HPC resources (e.g. a national HPC system). However, dissemination to industry, and in particular SMEs, requires considerable effort by the providers to build up client contacts. Here, national industry and/or SME networks can sometimes be useful dissemination channels.

3.2.3 Practical issues

As already highlighted previously, SMEs generally prefer highly targeted and local events but many have small budgets for travel. Logically more specialised courses attract fewer participants in a small area, hence it makes sense to open such courses to a wide geographic area in order to attain critical mass. But with limited travel budgets, mobility of SME participants to training courses can be a significant barrier for training uptake.

Another practical issue is the charging of fees for non-academic participation of courses provided by HPC centres. There are often rules and policies on charging models that vary from country to country. For example, some centres are obliged to charge fees to recover costs for non-academic attendees. Sometimes the fees involved may be too high for SMEs. In another example, HPC Wales received ESF funding to deliver training free of charge to individuals based within regional institutions/companies. As a result, their courses did attract significant numbers from Welsh SMEs. Similarly, some HPC centres are forbidden to charge fees for provision of HPC training. This diversity of charging models can be problematic for pan-European dissemination of HPC training courses for the SME sector.

4 Outlook for course material development in WP6

Having examined the training needs of SMEs (from both surveys and expert feedback) and existing provision of training courses, it is planned that SESAME Net WP6 will develop relevant training material for SMEs that fulfil some of the gaps between supply and demand. We have also compiled a list of course development ideas from competency centres in SESAME Net to increase relevance of HPC training to SMEs; these ideas can be categorised broadly into the topics in Sections 4.1.1 to 4.1.6 below, where we also discuss opportunities for WP6 to focus training material development efforts during M13-M24 of the SESAME Net project.

Our training material development activity will commence with a partners meeting to coordinate efforts focused on the areas discussed in Sections 4.1.1 to 4.1.6. In developing such material we will also seek guidance and collaboration from other European projects where relevant. For example, we will explore opportunities with the EXDCI (European Extreme Data & Computing Initiative) project [8], which has a training component to support HPC talent growth for the European job market. Here, we could assess the alignment of some of our material development efforts in code development and optimisation (Section 4.1.2) to European roadmaps for HPC technology and applications.

We will also explore collaborative opportunities with the H2020 EDISON project [9] that aims to establish data scientist as a new profession in support of e-infrastructures, which is particularly relevant to our efforts to develop material on HPC and Big Data (Section 4.1.3).

4.1.1 Introductory HPC Concepts and Benefits

This area should be of significant interest to many SMEs who would have interest in learning about key concepts and the potential application benefits of HPC technology (see Section 2.1). While there should be many examples of such courses provided by competency centres (Section 3.1) and beyond, we will compare the existing repertoire of material for partners to improve the content that would be targeted at SMEs; consistent with suggestions by competency centres in SESAME Net (Appendix 6.4). Such efforts will include relevant examples from different sectors that highlight the benefit of HPC utilisation and adoption, e.g. using material from other SESAME Network packages, e.g. case studies highlighting success stories from HPC adoption [10].

4.1.2 Code development and optimisation

This is an area where demand for training seems to be highest according to our survey of SMEs (Section 2.1). There should be an abundance of existing training material on this topic that would encompass serial/parallel programming on different HPC architectures (including many-core technologies) as well as performance engineering tools and techniques (Section 3.1). Hence we will review existing material and develop practical training examples that caters for different business sectors. As suggested by the competency centres (Appendix 6.4), there is also scope to incorporate material on more forward-looking technologies (e.g. MPI-3, getting the best out of the latest generation of accelerators, programming for exascale) in alignment with roadmaps for the European HPC ecosystem.

4.1.3 HPC and Big Data

This includes utilising HPC technology to process and analyse large volumes or streams of data as well as tools and techniques for data analysis (e.g. statistical modelling, machine learning). While this area was not included in the survey of SMEs, there is a general perception among competency centres that this area is of significant importance where skill gaps exists (Appendix 6.2) and courses are needed for SMEs (e.g. demonstration of how to create and use HPC environments in the cloud, see Appendix 6.4). Therefore we will develop material that showcases how HPC can be used to tackle Big Data problems. We will also explore opportunities with the EDISON project to analyse how our efforts would fit into their activities, which includes a model curriculum to foster a new generation of data scientists.

4.1.4 Engineering applications

In the engineering sector, SMEs are frequent users of HPC applications or packaged solutions and hence may require little to no in-house code development expertise. Such SMEs may benefit from training that focuses on usage of the applications, along with best practices and tools that will enable them to monitor and deploy jobs in a more efficient manner. There is considerable demand for such training (Section 2.1) and some availability of courses on the usage of engineering applications such as OpenFOAM (Appendix 6.3). But yet many HPC competency centres have highlighted the need for more engineering-related courses (e.g. OpenFOAM, best practices) to be developed for an SME audience (see Appendix 6.4). Hence we will look to develop material, in collaboration with the code developers where possible, that would cover best practices for optimal deployment and utilisation of engineering applications in a HPC environment.

4.1.5 HPC infrastructure administration

Training in this area is of less demand compared to other HPC topics in our survey (Section 2.1), but the paucity of training courses and material on HPC infrastructure administration (Section 3.1) deserves further investigation in WP6 for opportunities in developing training material. But as already highlighted, the hands-on nature of such courses, and the requirement of supporting physical hardware, can be significant barriers for training providers. One example of course material to be developed in this area, as suggested by PSNC (competency centre of SESAME Net), is on ways to optimise energy consumption at data centres via the use of different monitoring and energy management tools.

4.1.6 HPC-Cloud computing

While cloud computing has gained widespread popularity in the business sector, many SMEs are now often faced with different solutions to their problems (HPC vs Cloud vs hybrid HPC-cloud infrastructures). There are certainly opportunities for SESAME Net to develop material that would help SMEs understand how the different technologies can be utilised for different types of problems. Hence we will develop introductory material on how to use HPC environments in the cloud, as well as its use in specific domains such as bioinformatics, as suggested by different competency centres (Appendix 6.4).

5 Conclusions and next steps

In this deliverable we have carried out a review of HPC skills gaps and training needs of SMEs, in light of existing provision of HPC training in Europe. We analysed the feedback from a survey of 105 SMEs with regard to their needs on training, and identified some of the areas where there is considerable demand for training (e.g. HPC concepts and benefits, code development and optimisation, applications). This is combined with expert feedback from HPC competency centres to identify some of the skills gaps among SMEs. Then we

examined the existing supply of HPC training provided by competency centres in SESAME Net as well as on a wider European context (e.g. training provided by PRACE).

While there appears to be considerable overlap between the supply of courses with the demands of SMEs, there remains ample opportunities for WP6 to develop more SME-oriented course material, supported by a list of potential course developments proposed by partners. In preparation of the second phase of WP6 to achieve the objective to "develop SME-oriented training content", our efforts in M13-M24 will focus on the producing sets of training material on the following areas (discussed in Sections 4.1.1 to 4.1.6 above):

- Introduction to HPC concepts and benefits
- Code development and optimisation
- HPC and Big Data
- Engineering applications
- HPC infrastructure administration
- HPC-Cloud computing

While examining the supply and demand of courses, we have also identified significant dissemination and practical issues that may act as barriers for training uptake by SMEs. These issues will be communicated to other SESAME Net partners and work packages, where some of these issues can be addressed directly by the project, e.g. dissemination of HPC training information and the benefits of HPC to SMEs at SESAME Net events, and where best practices, e.g. models of training provision to SMEs, can be shared among partners in the network.

6 Appendix

6.1 SME Survey Responses – Training Section

Is your company interested in information or training about possible applications and potentials of HPC technologies?

Answer	Count	Percentage
Yes (A1)	63	60.00%
No (A2)	27	25.71%
No answer	15	14.29%
Not displayed	0	0.00%
TOTAL	105	100.00%

Would your company be willing to take advantage of HPC training tailored to the business sector of activity you operate in?

Answer	Count	Percentage
Yes (A1)	58	55.24%
No (A2)	25	23.81%
No answer	22	20.95%
Not displayed	0	0.00%
TOTAL	105	100.00%

Are you aware of available HPC training courses/ services in your region/country?

Answer	Count	Percentage
Yes (A1)	22	20.95%
No (A2)	69	65.71%
No answer	14	13.33%
Not displayed	0	0.00%
TOTAL	105	100.00%

Does your staff require training in the area of HPC?

Answer	Count	Percentage
Yes (A1)	40	38.10%
No (A2)	21	20.00%
Non Applicable/Don't know (A3)	35	33.33%
No answer	9	8.57%
Not displayed	0	0.00%
TOTAL	105	100.00%

What are the specific HPC areas in which your staff require training?

Answer	Count	Percentage
Introduction to HPC (SQ001)	27	25.71%
Infrastructure Admin (SQ002)	22	20.95%
Code development/ optimization (SQ003)	28	26.67%
Applications usage (e.g. ANSYS, Abaqus, OpenFOAM) (SQ004)	26	24.76%
Not displayed	65	61.90%
TOTAL	105	100.00%

6.2 Perceived SME skill gaps as identified by HPC competency centres

Fundamental HPC and parallel computing concepts
○ Understanding of the capabilities and limitations of parallelism. ○ Lack of knowledge about parallel technologies, both distributed and shared. Mainly the first one. MPI is completely unknown in many SMEs. ○ Introduction to HPC concept and capabilities. ○ Efficient usage of HPC resources (basic level). ○ Lack of knowledge about queue environments.
Data-related skills in HPC
○ Data and statistical analysis (beyond Excel). ○ Big Data software and tools for HPC environment. ○ Realistic expectation of 'Big Data' & 'The Cloud'. ○ Big Data on HPC. ○ Limited knowledge about Statistics, Big Data Technologies, Statistical Learning, Machine Learning, CAE algorithms and their possibilities. ○ DataFlow Computing Applications
Parallel programming and optimisation
○ Parallel programming. ○ Hybrid programming techniques. ○ How to use parallel filesystems as Lustre. ○ Optimisation of parallel code. ○ HPC developer tools in general (profiler, debugger, …). ○ Optimisation and parallelization of applications. ○ Basic node level optimisation concepts and techniques.
Many-core technology
○ The potential and limitations of many-core technologies. ○ Hardware accelerators (GPGPU, Phi). ○ Using accelerators (GPU, Intel Phi). ○ Multi core and many core technologies.

○ Programming for accelerators (MIC, GPU).
Large-scale simulations and modelling
○ Large scale simulations. ○ Mathematical modelling. ○ Multi-scale and multi-physics simulations. ○ Lack of knowledge about the possibilities to use remote centres to make simulations or analyse data. ○ Meshing and partitioning tools (Metis, Scotch, …). ○ Modelling with different ISV codes.
Application packages and services
○ Domain specific application usage. ○ Proprietary engineering software. ○ eScience Applications and Services. ○ Virtualization/containerisation techniques in HPC. ○ Lack of knowledge about visualisation tools.
Software engineering
○ Software engineering tools and techniques. ○ Software engineering tools and services. ○ Product life-cycle management.
Programming languages, compute hardware
○ Unix operating systems. ○ Using a command line interface (Linux). ○ Many SMEs do not want to use (initially) terminal access. They prefer browsers. ○ Python, which is included in many packages to control the simulation or to analyze data. ○ Working with legacy codes, e.g. Fortran. ○ Assembly language programming and compilers. ○ Microprocessor architecture and network devices.

Table 1. SME skill gaps as perceived by experts from HPC competency centres

6.3 HPC course provision by competency centres

Competence Centre	Category	Course Title	Duration	A	A&I	I	Prior industry participation
CESGA	Applications	Code Aster	3		*		Y
CESGA	Applications	ELMER	2		*		Y
CESGA	Applications	MaxFEM	2		*		
CESGA	Applications	OpenFOAM	3		*		Y
VSC	Applications	OpenFOAM	2		*		Y
CESGA	Big Data & data-intensive computing	CESGA Big Data service	1		*		
IT4I	Big Data & data-intensive computing	Hadoop	2		*		
RBI	Big Data & data-intensive computing	Data Flow Computing - FPGA accelerator	1		*		
SCAI	Big Data & data-intensive computing	Big Data (Architecture, Basic analytics, introduction)	3		*		Y
VSC	Big Data & data-intensive computing	Big Data with Hadoop-on-demand	0.5		*		Y
CESGA	Cloud computing	Opennebula practical workshop	1	*			
VU	Cloud computing	Cloud Computing Intro	1			*	Y
VU	Cloud computing	Private Clouds	2			*	Y
VU	Cloud computing	Public Clouds	2			*	Y
HPC Wales	Command line interface	Using HPC Wales via the command line	0.5		*		Y
ICHEC	Command line interface	Introduction to Linux	2		*		Y
PSNC	Command line interface	Linux - bash and managing of processes	4	*			

Competence Centre	Category	Course Title	Duration	A	A&I	I	Prior industry participation
VSC	Command line interface	Linux introduction	1	*			
VU	Command line interface	Linux and scripting	4	*			
HPC Wales	Computer architecture	Introduction to computer architecture	0.5		*		
VU	Computer architecture	Computer architecture	4	*			
ICHEC	Data analysis	Introduction to R	2		*		
PSNC	Data analysis	Introduction to statistics with R	8	*			
VSC	Data analysis	Introduction to R	2				
VU	Data analysis	Statistics with R	4	*			
GRNET	Fundamental HPC & parallel computing	Introduction to HPC Access Policies - National - PRACE	0.5		*		Y
GRNET	Fundamental HPC & parallel computing	Introduction to HPC GRNET's systems	1		*		Y
HPC Wales	Fundamental HPC & parallel computing	Introduction to HPC	0.5		*		Y
HPC Wales	Fundamental HPC & parallel computing	Sector-specific uses of HPC	0.5		*		Y
HPC Wales	Fundamental HPC & parallel computing	Thinking in parallel	1		*		Y
ICHEC	Fundamental HPC & parallel computing	Introduction to HPC and ICHEC systems	1	*			
IICT-BAS	Fundamental HPC & parallel computing	Access to HPC infrastructure, software and libraries	1		*		Y
PSNC	Fundamental HPC & parallel computing	Introduction to HPC systems	5	*			
UVT	Fundamental HPC & parallel computing	Introduction to parallel algorithms	4		*		Y
UVT	Fundamental HPC & parallel computing	Introduction to parallel systems	4		*		Y
UVT	Fundamental HPC & parallel computing	Using HPC center facilities	1		*		Y
VSC	Fundamental HPC & parallel computing	HPC introduction	1		*		Y
IT4I	Large-scale simulations	SeisMIC - Seismic Simulation on Current and Future Supercomputers	1	*			
CESGA	Many-core programming	Introduction to CUDA	2	*			
GRNET	Many-core programming	Overview of many-core technologies	0.5	*			
HPC Wales	Many-core programming	Introduction to CUDA	2		*		Y
ICHEC	Many-core programming	Introduction to CUDA	3		*		Y
ICHEC	Many-core programming	Overview of many-core technologies	0.5			*	Y
IICT-BAS	Many-core programming	Introduction to GPGPU computing	1		*		
IICT-BAS	Many-core programming	Introduction to programming for Xeon Phi accelerators	1		*		Y
IT4I	Many-core programming	Intel MIC Programming Workshop	2		*		
IT4I	Many-core programming	Intel® Xeon Phi™ User's Group Workshop and Tutorials	3.5		*		
PSNC	Many-core programming	Parallel programming using CUDA	6	*			
SCAI	Many-core programming	Cuda training	2		*		Y
UVT	Many-core programming	Parallel programming using CUDA	4		*		Y
GRNET	Numerical libraries	Scientific Libraries Usage	0.5		*		Y
HPC Wales	Numerical libraries	Libraries	1		*		
IT4I	Numerical libraries	PETSc Tutorial	2	*			
CESGA	Parallel programming	Introduction to MPI parallel programming	4	*			Y
CESGA	Parallel programming	Parallel programming using OpenMP directives	4	*			Y
GRNET	Parallel programming	Introduction to MPI	0.5	*			
GRNET	Parallel programming	Introduction to OpenMP	0.5	*			
HPC Wales	Parallel programming	Advanced parallel programming using MPI	1		*		
HPC Wales	Parallel programming	Advanced parallel programming using OpenMP	1		*		
HPC Wales	Parallel programming	Hybrid programming	1		*		
HPC Wales	Parallel programming	Parallel programming using MPI	2		*		Y
HPC Wales	Parallel programming	Parallel programming using OpenMP	2		*		Y
ICHEC	Parallel programming	Introduction to MPI	2		*		
ICHEC	Parallel programming	Introduction to OpenMP	1		*		
IICT-BAS	Parallel programming	Advanced OpenMP programming	1		*		
IICT-BAS	Parallel programming	Introduction to parallel programming	1		*		
IT4I	Parallel programming	Advanced OpenMP	2		*		

Competence Centre	Category	Course Title	Duration	A	A&I	I	Prior industry participation
IT4I	Parallel programming	Parallel programming in modern Fortran	2	*			
IT4I	Parallel programming	Parallel Programming with MPI	2		*		
IT4I	Parallel programming	PGAS Parallel Programming in UPC	1		*		
RBI	Parallel programming	Hybrid HPC computing	1		*		
UVT	Parallel programming	Parallel programming using MPI	6		*		Y
UVT	Parallel programming	Parallel programming using OpenMP	4		*		Y
VSC	Parallel programming	Introduction to multithreading and OpenMP	2				
VSC	Parallel programming	Message Passing Interface (MPI)	1		*		
VU	Parallel programming	Parallel programming	4	*			
CESGA	Performance engineering	Introduction to vectorizing applications	2		*		
GRNET	Performance engineering	Benchmarking	0.5	*			
GRNET	Performance engineering	Code optimization and profiling techniques (gprof, Scalasca, Vtune)	0.5		*		Y
HPC Wales	Performance engineering	Debugging, profiling and optimising parallel codes in a cluster environment	1		*		
HPC Wales	Performance engineering	Debugging, profiling and optimising serial codes in a cluster environment	2	*			
IICT-BAS	Performance engineering	Advanced application porting and optimisation	2		*		Y
IICT-BAS	Performance engineering	Advanced MPI programming and optimisation	2	*			
IT4I	Performance engineering	Kaira-prototyping of MPI applications	1	*			
PSNC	Performance engineering	Intel Tools for building, debugging and profiling HPC applications	9	*			
PSNC	Performance engineering	Parallel Programming: memory usage optimisation	4	*			
SCAI	Performance engineering	Intel Tools (together with Intel)	1		*		Y
VSC	Performance engineering	Node-level performance engineering	2		*		Y
CESGA	Programming languages	Fortran 90 programming	3	*			Y
CESGA	Programming languages	Python programing	3		*		
CESGA	Programming languages	Shell scripting simple	3		*		
HPC Wales	Programming languages	Introduction to C/C++	2		*		Y
HPC Wales	Programming languages	Introduction to Fortran	2		*		Y
HPC Wales	Programming languages	Scripting languages	1	*			
ICHEC	Programming languages	Introduction to Modern Fortran	3		*		
ICHEC	Programming languages	Scientific programming concepts	4	*			
PSNC	Programming languages	Introduction to secure coding in Python/Django	5	*			
VSC	Programming languages	Matlab	6				
VSC	Programming languages	Migrating old to modern Fortran code	1				
VSC	Programming languages	Modern Fortran	0.5				
VSC	Programming languages	Python course	2				
VSC	Programming languages	Python for data processing	2	*			
HPC Wales	Scientific visualisation	Visualisation	1		*		Y
IT4I	Scientific visualisation	Scientific visualization with COVISE	2		*		
CESGA	Software engineering	Compiling, running and optimizing scientific applications	2		*		Y
HPC Wales	Software engineering	Software engineering in a cluster environment	1	*			
ICHEC	Software engineering	Software engineering for scientists	3	*			
IT4I	Software engineering	Allinea Tools Workshop	1		*		
VSC	Software engineering	Debugging techniques	0.5	*			
VSC	Software engineering	Version control with git	0.5	*			
ICHEC	System administration	Fundamentals of network and system administration	9			*	Y
ICHEC	System administration	HPC systems operations and management	9			*	Y
ICHEC	System administration	HPC technology and administration	9			*	Y

Table 2. List of courses offered by HPC competency centres including title, category, duration, orientation (A for academic focused, A&I for courses that are equally focused for academia and industry, I for industry focused), and whether a course has been provided to industry participants before.

6.4 Course development suggestions from competency centres

Category	Potential course	Comments
Big Data	Big Data, Machine Learning, Deep Learning algorithms. An introduction.	Introduction to the basic algorithms for Big Data and Machine Learning
Big Data	High performance data analysis	Utilising HPC systems for tackling large data processing and analysis problems
Big Data	HPC-style processing of Big Data	Demonstrate HPC-specific tools and techniques for Big Data analysis
Cloud	Bioinformatics workshop	HPC and Cloud service in Bioinformatics applications
Cloud	How to create and use SaaS in HPC	Demonstration of QCG middleware and science gateways
Cloud	HPC in the Cloud	Demonstrate how to create and use HPC environments in the Cloud
Engineering	Best practices in using HPC for engineering applications	Examples of using HPC in the design of new materials, meteorology, remote sensing, digital heritage
Engineering	Engineering applications in a HPC environment	Introduction to running engineering simulation packages in a HPC environment
Engineering	OpenFOAM advanced	Advanced tools for OpenFOAM
Engineering	OpenFOAM basic	Introduction to OpenFOAM
Engineering	PLM	Management of CAD and CAE results using PLM
Engineering	Verification and validation of CAE software	Techniques to validate CAE software.
HPC	High performance computing for small and medium enterprises	Introduction to HPC technology and potential application in SME sector.
HPC	High performance computing forum	Introduction to HPC technology and potential application in SME sector.
HPC	Overview of HPC, applications and benefits	Key HPC concepts, then expand on industry use cases, outcome and benefits (less focus on academic applications)
Infrastructure	How to optimize energy consumption in your data center	Introduction to various monitoring and energy management tools used at PSNC data center
Many-core	Advanced topics in programming and optimisation for Xeon Phi	Covering specific tools and techniques for reaching optimal performance using Intel Xeon Phi accelerators
Many-core	Overview of many-core technologies & outlook	Covering different types of accelerators, how they are used for different types of problems, outlook (e.g. ecosystem)
Many-core	Programming CUDA	CUDA for beginners
Parallel Programming	Advanced MPI Programming	MPI-3 and MPI-X
Parallel Programming	Advanced topics in MPI programming	Latest changes in the MPI standard implementations
Parallel Programming	Hybrid MPI and OpenMP	

Parallel Programming	Parallel programming in the exascale race	Introduction to the problems raised by the future exascale system, current approaches and open questions
Performance engineering	Application performance tuning and scalability analysis	Covering tools and software for performance tuning, techniques for scalability analysis and optimisation
Performance engineering	How to reduce the response time of my code	Introduction to multi-core and GPU programming
Python	Python for simulation and analytics	Introduction to Python and to the modules for data analytics and simulation
Simulations	Meshing and partitioning	
Simulations	Multi-scale and multi-physics simulations	Coupling of multiple models or multiple physical phenomena in a single simulation
Software eng	developer tools for HPC	
Visualisation	Data Visualization	Using visualization tools and new kind of graphics to represent big Data and CAE results

Table 3. Suggested course materials for development by SESAME Net WP6 as proposed by competency centres

References

[1] "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020". IDC final report of the HPC study for the DG Information Society of the European Commission

[2] "Council on Competitiveness and USC-ISI Broad Study of Desktop Technical Computing End Users and HPC"

[3] SESAME Net project deliverable D5.1: "SME Demands and Needs".

[4] HPC Training Courses in Europe @ HLRS, https://www.hlrs.de/training/hpc-eu/

[5] PRACE-3IP Deliverable 4.5: "Final Report on Training Activities". http://www.prace-ri.eu/IMG/pdf/D4.5_3ip.pdf

[6] PRACE-4IP Deliverable 4.1: "Interim PRACE Training Report". http://www.prace-ri.eu/IMG/pdf/D4.1_4ip.pdf

[7] PRACE Training Portal, http://www.training.prace-ri.eu/

[8] EXDCI project web site: https://www.exdci.eu/

[9] EDISON project web site: http://edison-project.eu/

[10] SESAME Net Deliverable 3.1: "Best Practice guidelines for HPC in industry and in particular to SMEs".