Research & Innovation Policy Exchange Platform

EU-ASEAN High Performance Computing (HPC) Study

Expert Mapping of ASEAN policy orientations and related HPC research infrastructures

Independent
Expert
Report

Research and Innovation

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Expert Mapping of ASEAN policy orientations and related HPC research infrastructures

European Commission
Directorate-General for Research and Innovation
Directorate F — Global Approach and International Cooperation in Research and Innovation
Unit F.2 - International Cooperation II (Asia, Africa, Middle East & External Relations)
Contact Pierrick Fillon-Ashida
Email *Pierrick.Fillon@ec.europa.eu*
RTD-PUBLICATIONS@ec.europa.eu
European Commission
B-1049 Brussels

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Synthesis Report

EU-ASEAN High Performance Computing (HPC) Study
Expert Mapping of ASEAN policy orientations and related HPC research infrastructures

ASEAN-EU Research and Innovation Policy Exchange Platform

Supported by the Enhanced Regional EU-ASEAN Dialogue Instrument (E-READI)

Edited by: Dr. S. Varrette (EU) and Dr. I. F. Sulaiman (ASEAN)
Contact: sebastien.varrette@gmail.com

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Approvals

This report was reviewed for approval during the 2nd EU-ASEAN HPC Coordination Group meeting held in Luxembourg on Nov. 29-30; 2019. Approvals from both the ASEAN HPC Task Force and EU (i.e. EC DG RTD and E-READI) representatives were provided at that occasion, requesting the addition of a brief historical notes (received on May 17, 2020) embedded in the current (and final) version.

Disclaimer

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Mission of the European Union to ASEAN

Menara Astra, 38th Floor
Jl. Jend Sudirman Kav 5-6
Jakarta 10220, Indonesia
+62 (21) 2554 6200
mission-asean@eeas.europa.eu
MISSION-ASEAN-EREADI-CONCEPTS@eeas.europa.eu

ASEAN Secretariat

70A Jl. Sisingamangaraja
Jakarta 12110, Indonesia
+62 (21) 726 2991
ereadi@asean.org

This study was prepared by Dr. Sébastien Varrette (EU) and Dr. Idris F. Sulaiman (ASEAN), HPC experts and consultants for the European Commission on behalf of the E-READI program.

Historical notes depicting the past collaboration on Grid computing and HPC between EU and Asian/Southeast Asian Countries (Section 1.B) were generously prepared by Dr. Suhaimi Napis, from the Universiti Putra Malaysia.

List of Acronyms

Below is an extensive List of Acronyms used in this document.

A3I	Asian Internet Interconnection Initiatives
AMSs	Association of Southeast Asian Nations Member States
APAN	Asia-Pacific Advanced Network
APGI	Asia Pacific Grid Initiative
ASEAN	Association of Southeast Asian Nations
A*CRC	A*STAR Computational Resource Centre (Singapore)
A*STAR	Agency for Science, Technology and Research (Singapore)
ASCG	Academia Sinica Grid Computing (Taiwan)
ASTI	Advanced Science and Technology Institute (Philippines)
BD	Big Data
BDEC2	Big Data and Extreme-scale Computing 2 (EU)
BioExcel-2	Centre of Excellence for Computational Biomolecular Research (EU)
BMKG	Meteorological, Climatological and Geophysical Agency (Indonesia)
CFD	Computational Fluid Dynamics
ChEESE	Centre of Excellence for Exascale and Solid Earth (EU)
CoE	Centres of Excellence for Computing Applications
CompBioMed2	Centre of Excellence in Computational Biomedicine (EU)
COST	ASEAN Committee on Science and Technology
cPPP	contractual Public-Private Partnership
DC	Data Centre
DLC	Direct Liquid Cooling
DOST	Department of Science and Technology (Philippines)
EC	European Commission
ENES	European Network for Earth System modelling
EoCoE-II	Energy Oriented Center of Excellence Phase II (EU)
ERASMUS	EuRopean Community Action Scheme for the Mobility of University Students
ESiWACE2	Centre of Excellence in Simulation of Weather and Climate in Europe Phase 2 (EU)
ETP4HPC	European Technology Platform for High Performance Computing
EU	European Union
Eurolab-4-HPC2	Foundations of a European Research Center of Excellence in High Performance Computing Systems
EXCELLERAT	Centre of Excellence for Engineering Applications (EU)
EXDCI	European Extreme Data and Computing Initiative
FET	Future and Emerging Technologies
FET-HPC	Future and Emerging Technologies – HPC
FocusCoE	Concerted action for the European HPC CoEs (EU)
GDPR	EU General Data Protection Regulation
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
H2020	Horizon 2020 – The EC Research and Innovation Programme in Europe
HiDALGO	HPC and Big Data Technologies for Global Challenges (EU)
HiPEAC	European Network on High Performance and Embedded Architecture

	and Compilation
HUST	Hanoi University of Science and Technology (Vietnam)
HPC	High Performance Computing
HPC-Europa3	Pan-European Research Infrastructure on High Performance Computing 3
HTC	High Throughput Computing
IADA	Institute of Applied Data Analytics (Brunei Darussalam)
ICT	Information and Communication Technologies
IHPC	Institute of High Performance Computing (Singapore)
IS-ENES	Infrastructure for the European Network of Earth System Modelling
KOL	Key Opinion Leaders of the ASEAN HPC Task Force
LAPAN	National Institute for Aeronautics and Space Research (Indonesia)
MaX2	Materials design at the Exascale 2 (EU)
ML	Machine Learning
mmREN	Myanmar Research & Education Network (Myanmar)
MoEYS	Ministry of Education, Youth and Sport (Cambodia)
MOOC	Massive Open Online Course
MPT	Ministry of Posts and Telecommunications (Cambodia)
MRC	Mekong River Commission (Cambodia, Laos, Thailand and Vietnam)
MSS	Meteorological Service Singapore
NECTEC	National Electronic and Computer Technology Center (Thailand)
NSCC	National SuperComputing Centre (Singapore)
NSTDA	National Science and Technology Development Agency (Thailand)
NSTI	National Science and Technology Infrastructure (Thailand)
P2O/LIPI	Research Centre for Informatics, Institute of Science (Indonesia)
PAGASA	National Meteorological and Hydrological Services (Philippines)
POP2	Performance Optimisation and Productivity 2 (EU)
PREGINET	Philippine Research, Education and Government Information Network (Philippines)
PHOpenIX	Philippine Open Internet Exchange (Philippines)
PRIMAVERA	Process-based climate simulation: Advances in high-resolution modelling and European climate risk assessment
PTC	PRACE Training Centre
PRACE	Partnership for Advanced Computing in Europe
PU	Perdana University (Malaysia)
REN	Research and Education Network
RJMS	Resource and Job Management System
RCI/LIPI	Research Centre for Informatics, Institute of Science (Indonesia)
RCO/LIPI	Research Centre for Oceanography, Institute of Science (Indonesia)
SC	The International Conference for High Performance Computing, Networking, Storage and Analysis
SHAPE	SME HPC Adoption Programme in Europe
SingAREN	Singapore Advanced Research and Education Network

SME	Small and Medium Enterprise
TARA	Thailand's Advanced Research Accelerator
TCEI	Technology Computer and Electronic Institute (Lao PDR)
TEIN	Trans-Eurasia Information Network
UBD	Universiti Brunei Darussalam
UCC	Universities' Computer Center (Myanmar)
UCSY	University of Computer Studies, Yangon (Myanmar)
UPM	Universiti Putra Malaysia
US	United States
UTeM	Universiti Teknikal Malaysia, Melaka (Malacca)
UTM	Universiti Teknologi Malaysia
VAST	Vietnam Academy of Science and Technology
VNSC	Vietnam National Space Centre
VNU	Vietnam National University
WCRP	Grand Science Challenges of the World Climate Research Programme (EU)
xMOOC	extended Massively Open Online Course
XSEDE	Extreme Science and Engineering Discovery Environment

Chapter 1 : Introduction

High Performance Computing (HPC) is a strategic tool for competitive science. Having been used for more than 30 years in climate research, numerical weather prediction, particle and astrophysics, earth sciences and chemistry, HPC is now a cornerstone of all scientific fields from biology, life sciences and health, energy, geosciences, high-fidelity combustion, materials science, to social sciences, and humanities. In industry, HPC is widely used in oil & gas exploration, aeronautics, automotive, and finance, and is now becoming crucial for ensuring personalized medicine, developing nano-technologies, or enabling the development and the management of renewable energies. Initially the preserve of large companies, HPC is now used in all domains, and is becoming a tool of growing importance for supporting public rational decision making by simulating scenarios and allocating urgent computing resources in the case of natural hazards (extreme events such as earthquakes, thunderstorms, flooding or evacuations), a thematic common with several ASEAN countries, industrial risks (rupture of a dam, failure of a power-plant, spills), biological risks (diffusion of pandemics) or (cyber)terrorism attacks.

In parallel, data is being produced at astronomical speed and if properly collected and analysed, data can drive policy. The world in 2012 was already creating 2.5 quintillion (that's 2,500,000,000,000,000,000) bytes of data. The Big Data concept then was defined as "*data sets that grow so large that they are nearly impossible to work with using traditional database management tools, but yet offer a powerful tool when married with strategic use*"[1]. Since then there is continued growth of global data use stemming from increased use of images, video, social media, GPS with the smartphone revolution. Added to this Internet-of-Things (IoT) related signals from various monitoring devices, interactive content, online gaming, "nowcasting", "data exhaust" and other forms of data harvesting[2] that in 2016 it was declared that 90 percent of data today has been created in the last two years[3]. Furthermore, it was estimated that by 2020 the amount of data would grow to 44 zettabytes. It was also projected that in 2017, developing economies would overtake developed economies in creating data. In 2017, it was projected that "*in 2025 the world will create and replicate 163 zettabytes of data, representing a tenfold rise from the amount of data created in 2016*"[4].

Every country in the world is facing these challenges. To address them within the Association of Southeast Asian Nations (ASEAN) countries, several initiatives were conducted to enhance the internal cooperation within the consortium. Indeed, The ASEAN economies as a collection of emerging and frontier market economies are evaluating and acquiring advanced information and communication technologies (ICT) as competitive platforms for socio-economic benefit. One of the advanced technologies to deal with such data 'tsunami' is High Performance Computing (HPC). HPC acquisition is an indicator of national strategies to accelerate scientific discovery, engineering science, and innovation, along with focus on societal and economic benefit. ASEAN governments are strategizing on how best to incentivize the use of

[1] http://blog.aicpa.org/2012/07/big-data-presents-big-opportunities-for-firms-and-cfos.html

[2] "Nowcasting" and "data exhaust" data harvesting is the use of daily data by-product of our online and mobile use activities, see Douglas Broderick "Data matters for development, democratization" Jakarta Post, 10 October 2016, and Margaret Rouse, "Data Exhaust", WhatIs.com, April 2015. Available at https://whatis.techtarget.com/definition/data-exhaust.

[3] https://www.mediapost.com/publications/article/291358/90-of-todays-data-created-in-two-years.html

[4] David Reinsel, John Gantz and John Rydning, "Data Age 2025: The Evolution of Data to Life-Critical", IDC White Paper, April 2017.

HPC for public good and have implementation activities to become HPC-focused member states in recent years. Those ASEAN Member States (AMSs) that have already been investing in advanced computing to enhance their economies and to strengthen the path from knowledge to value creation are now in the vanguard of AMSs to engage the corporate community in HPC for economic competitiveness. Their activities will be closely followed by others as they consider overall optimisation of HPC use.

A. EU-ASEAN Cooperation on Science and Technology under E-READI

Scientific cooperation is part of the partnership between the Association of Southeast Asian Nations (ASEAN) and the European Union (EU) since the 16th ASEAN-EU Ministerial Meeting held in Nuremberg, Germany in 2007.

ASEAN Science and Technology institutional set-up is structured under the ASEAN Committee on Science and Technology (COST) with its various Subcommittees. ASEAN COST developed the ASEAN Plan of Action on Science, Technology and Innovation (APASTI) 2016-2025, the strategic backbone for the further cross-border development of integrated Science, Technology and Innovation initiatives. This document lays out the principles and strategic activities for regional research and innovation policy.

Collaborative regional Science and Technology activities are developed mainly through the ongoing EU-ASEAN Dialogue on Science and Technology that takes place at regular intervals at Senior Official level between the ASEAN Committee of Science and Technology (COST) and the EU represented by the European Commission Directorate General for Research and Innovation (EC DG RTD). The latest meeting, the 8th ASEAN-EU Senior Officials Dialogue (Cebu, the Philippines, October 2018), was held back to back with the 10th ASEAN Ministerial Meeting on Science and Technology that endorsed its conclusions[5]. The 22nd EU-ASEAN ministerial meeting held in Brussels on 21 January 2019 welcomed the outcome of the 8th ASEAN-EU Dialogue on Science and Technology[6].

In parallel, the Enhanced Regional EU-ASEAN Dialogue Instrument (E-READI), funded by the EU, is a development cooperation program that facilitates dialogue forums between the EU and ASEAN in priority policy areas of joint interest across all three ASEAN Community pillars (Political and Security, Economic and Socio-Cultural). Drawing on relevant EU regional integration experience, the E-READI policy dialogue facility further strengthens both the ASEAN regional integration as well as the overall ASEAN-EU partnership.

The ASEAN COST (COST-74) meeting held in Chiang Mai, Thailand, 8-11 May 2018, approved a concept note to expand and enhance the ASEAN-EU policy cooperation in Science and Technology through E-READI.

The E-READI intervention in the Science and Technology area has identified priorities for support namely the establishment of the ASEAN-EU Research and Innovation Policy Exchange Platform. The ASEAN-EU Research and Innovation Policy Exchange Platform – appreciated by both the 8th ASEAN-EU Senior Officials Dialogue on Science and Technology and the 22nd EU-ASEAN ministerial meeting - is proposed to be a long-term and continuous support measure and detailed activity planning tool for Region-to-Region cooperation on an expert working level on the one hand, and exchange between working level and policy level on the other hand. Its establishment aims at facilitating policy exchange, alignment, learning, networking and planning

[5] https://asean.org/storage/2018/10/Final-JMS-of-IAMMST.pdf

[6] https://www.consilium.europa.eu/en/press/press-releases/2019/01/21/joint-statement-of-the-22nd-eu-asean-ministerial-meeting/pdf

between the two Regions, initially in the domains of Talent Mobility and Research Infrastructures, including HPC.

ASEAN has plans to define a shared HPC capacity in addition to the existing HPC developments performed locally or at a national level (a survey of the existing facilities and HPC capabilities is actually proposed in this report). The objectives of such a shared HPC infrastructure in ASEAN are multiple and pertain to build Regional HPC capacities; deepening digital connectivity; encouraging innovation and overcome high entry barrier of HPC by optimising resources and cost sharing and creating opportunities for talents in ASEAN.

COST has recently formalised the establishment of the HPC Task Force (HPCTF) composed of Key Opinion Leaders (KOLs) of the ASEAN Member States. The ASEAN HPCTF has been mandated by COST to develop the recommended configuration regarding requirements, computational demands, hardware and software of an HPC shared facility, and targets to present the findings by the next COST meeting expected to take place in Indonesia in June 2019. The HPCTF had their first meeting on September 2018 and agreed that there is a need for a shared ASEAN HPC facility to enable seamless access to a shared ASEAN facility and to create opportunities for growth of technological capabilities in all ASEAN Member States. Moreover, there is a gap in the current technological capacities in the field of HPC amongst the ASEAN Member States, and it made recommendations in the following key areas to bridge the gap, namely: policy and governance; enhancement of HPC capacities in the ASEAN Member States as well as community awareness; enhanced ASEAN Member States' network infrastructure. Areas for possible ASEAN-EU cooperation where identified: governance; human capital/capacity development; awareness for policymakers.

The EU Member States have supported HPC with national or regional research and innovation policies, and with national public procurement of HPC systems. They have also successfully coordinated access to national supercomputing and data management resources and services at the European level. This has enabled high-impact scientific discovery and engineering research and development, with the EU-supported PRACE (Partnership for Advanced Computing in Europe) initiative[7], and GEANT programme[8]. In 2013, the European Commission signed a contractual public-private partnership with the industry association ETP4HPC, with the objective of working together under Horizon 2020 on a European Research and Innovation roadmap to develop the next generation of HPC technologies. In March 2017 it launched the EuroHPC declaration – an agreement in which the signatory countries commit to work together with each other and with the European Commission to acquire, build and deploy an integrated world-class HPC infrastructure that would rank among the world's top three. By now 22 European countries have signed the declaration. As the next step, the Commission proposed in January 2018 to invest jointly with the Member States €1 billion in world-class European supercomputers through a new legal and funding structure – the EuroHPC Joint Undertaking. The Council has endorsed the Commission's proposal, and the Joint Undertaking has started its work. So far 25 European countries have confirmed their commitment to the ambitious project.

[7] http://www.prace-ri.eu
[8] https://www.geant.org

B. Brief History of Collaboration Between EU and Asian/Southeast Asian Countries on Grid and High-Performance Computing

Note: this sub-section was courtesy provided by **Dr. Suhaimi Napis** (Universiti Putra Malaysia/SIFULAN Malaysian Access Federation) and briefly reviews a selected set of past projects illustrating successful collaborations between the European Union and Asian or ASEAN Countries on Grid Computing and HPC.

Academia Sinica Grid Computing (ASGC) of Taiwan was established to join the international collaborations centered at CERN in Europe to build distributed computing infrastructure for e-Science in 2005. In support of its missions to develop advanced distributed research infrastructure based on requirements from multiple disciplinary research applications and in order to strengthen the global e-Infrastructure ecosystem, ASGC took the Tier-1 Center responsibility and has been participating to many international e-Science collaborations together with Asian partners since 2006, such as Enabling Grid for E-SciencE (EGEE)[9], EGI-Inspire, EGI-Engage or EOSC-Hub – these projects, etc.

More specifically, as a leader of the EGEE Asia Federation, ASGC is acting as a center of Grid infrastructure and e-Science research and application in Taiwan and the host for Asia Pacific Regional Operation Center (APROC) services to Asia Pacific Worldwide LHC Computing Grid (WLCG)/EGEE sites. APROC provides deployment support to facilitate Grid expansion, maximizes the availability of Grid services and supports Asia Pacific Federation beginning with South Korea and Taiwan (2006-2008) followed by Australia, Japan, South Korea and Taiwan (2008-2010). ASGC was instrumental in extending EGEE activities to Southeast Asian Countries through a parallel project called **EUAsiaGrid**[10]. EUAsiaGrid drew on the experiences of European initiatives within a wide range of applications of interest to Asian scientific communities made up of biologists, astrophysicists, chemists, experts on disaster mitigation and social sciences. It has seen the involvement of Australia, Brunei, India, Indonesia, Malaysia, Philippine, Singapore, Taiwan, Thailand and Vietnam between 2008 to 2010 (see below). At that time, ASGC was supporting 21 EGEE sites in 8 countries in the Asia Pacific region including the Southeast Asian countries providing production infrastructure in excess of 3,500 CPU Cores, 2 PB diskspace and 3.5 Millions KSI2K-hours. This distributed computing facility across Asia was running several key e-Science applications across a wide range of domains:

- High Energy Physics: WLCG, CDF, Belle
- Bioinformatics: mpiBLAST-g2
- Biomedicine: Distributing AutoDock tasks on the Grid using DIANE
- Digital Archive: Data Grid for Taiwan's National Digital Archives Program (NDAP) Long-term preservation
- Atmospheric Science
- Earth Sciences: SeisGrid, GeoGrid for data management and hazards mitigation
- Ecology Research and Monitoring: EcoGrid BioPortal
- Humanity and Social Sciences
    - General HPC Services

[9] https://eu-egee-org.web.cern.ch.
See also https://indico.cern.ch/event/23084/sessions/136144/attachments/382710/532374/ASIA.pdf

[10] https://ec.europa.eu/programmes/horizon2020/en/news/asian-grid-builds-european-experience-further-international-research
See also https://indico.in2p3.fr/event/2116/contributions/23047/attachments/18714/22823/FARGETTA_EUASIA_PROJECT.pdf

- Agriculture
- e-Science Application Development Platform (GAP)

The Asia Pacific Federation was central to the success of the EUAsiaGrid Project as collaborators have already built good relations with the CERN Large Hadron Collider (LHC) initiative and the associated middleware in use on these platforms. The EUAsiaGrid project was able to connect researchers in different countries in Southeast Asia with their counterparts in Europe. In particular, partner institutions from Brunei, Indonesia, Malaysia, The Philippines, Thailand and Vietnam participated in the project (Singapore dropped out of the project due to bureaucratic delay in signing the Grant Agreement). Security and trust aspects, initially key issues, were overcame by establishing "grid certificate authorities" in several countries including Malaysia and Thailand. In all cases, one good example of the outcome of the project was the *South China Sea tsunami warning system*. The computing grid was allowing locally recorded data to be shared between Taiwan, the Philippines and Vietnam. Another outcome example was the large-scale drug screening application focusing on diseases that pharmaceutical companies have overlooked, such as dengue fever, an infectious tropical disease. In this context, many countries in Asia provided resources for the screening, and the results were published for public use. In addition, the computing grid has also been used for social migration, climate and cultural heritage initiatives. After receiving excellent review by the European Commission, EUAsiaGrid Project was officially ended on June 30th, 2010.

Riding on the successes of EUAsiaGrid, the EU-Asia collaborative partnership continued under a new project called **EGI-InSPIRE**[11] (Integrated Sustainable Pan-European Infrastructure for Researchers in Europe). Started on May 1st, 2010 for 48 months *i.e.,* until 2014, the EGI-InSPIRE project was a collaborative effort involving more than 50 institutions in over 40 countries with a mission to establish a sustainable European Grid Infrastructure (EGI). Moreover, the project has 9 unfunded partners from the Asia Pacific region that were organised into an informal Asia Pacific Grid Initiative (APGI). The APGI is led by ASGC which serves as the liaison between the EGI-InSPIRE Project Office and APGI partners, and represents them in the EGI-InSPIRE Project Management Board. Southeast Asian partner institutions from Indonesia, Malaysia, The Philippines, Singapore, and Thailand participated in the project in various roles:

- Asian Science and Technology Institute (ASTI) of The Philippines continued with its activities on High Performance Computing with virtualization of the clusters using the OpenNebula platform and continuing collaborations under Philippine eScience Grid (PSciGrid) Program.
- The Institut Teknologi Bandung (ITB) of Indonesia continued to provide computing and GPU clusters to support the Weather Forecast and Computational Chemistry research groups. The integration of these resources into EGI continued alongside further activity in Desktop Grids.
- The NECTEC/NSTDA of Thailand focused on contributing to the "Thailand National e-Science Infrastructure Consortium" project[12] which was a five year national eInfrastructure for e-Science project. This project used Virtual Organisations (VO) to manage application areas relying on the gLite middleware.
- Universiti Putra Malaysia (UPM) of Malaysia continued to carry out tasks established in the EUAsiaGrid Project and worked on the development of grid sites for all universities to be certified within EGI, while exploring the potential of cloud resources. The Malaysian Identity Management and Access Management

[11] https://wiki.egi.eu/wiki/EGI-InSPIRE:Main_Page. EGI-InSPIRE EGI-MS117-final work of the Asia-Pacific Region: https://documents.egi.eu/document/1067
[12] http://www.e-science.in.th

(MyIFAM) has been formally accepted as a Member of APGridPMA and IGTF and thus approved to be Malaysia's National CA.

After a brief period of non-activity for about one year of proposal preparation, a project called Disaster Mitigation Competence Centre (DMCC[13]) was approved under **EGI-enGAGE**[14] (Engaging the EGI Community towards an Open Science Commons) for the time-period 2015-2017. The Disaster Mitigation Competence Centre (DMCC) of the EGI-Engage project involved design, development and support of customized IT services for the support of climate and disaster mitigation research. Partner institutions were Academia Sinica, Taiwan (Leading Partner, represented by the ASGC Centre (ASGC), Institute Teknologi Bandung (ITB), Indonesia, Universiti Putra Malaysia (UPM), Malaysia, Advanced Science and Technology Institute (ASTI), The Philippines and Thailand National Electronics and Computer Technology Centre (NECTEC), Thailand. The case studies were Typhoon Haiyan (2013), Malaysia Flood (2014-2015) and Forest Fire Dust Transportation (2015). DMCC collaboration has been extended to broader Asia countries with more various disaster types, supported the formation of Disaster Mitigation Working Group at Asia Pacific Advanced Network (APAN) which has 17 Asian country members in January 2016 and build up a new collaboration paradigm between EGI and APAN. Later, DMCC enlarged the collaborations to include India, Nepal, Sri Lanka and South Korea with new case studies of different disaster types in different places were initiated upon extending collaboration to additional countries and continue under a new project called DMCC+ within EOSC-Hub[15] (European Open Science Cloud) and Deeper Understanding of Natural Disaster (UND) – Instrumental for Disaster Mitigation[16]. In this context, services to conduct disaster mitigation simulations were provided by the Tsunami Wave Propagation Simulation Portal iCOMCOT[17], the Weather Simulation Portal gWRF[18] and the Advanced Visualization facility to be integrated with the target cases by Leibniz Supercomputing Centre (LRZ), Munich, Germany. The DMCC+ project is currently still ongoing.

C. Scope and objective of the EU-ASEAN HPC Study

Following the past successful collaboration, the ASEAN HPCTF has expressed interest to exchange and cooperate with the EU and EU experts due to their experience in regional resources' sharing in Europe, their training capacities, and their experiences with applications for computing capacities. The HPCTF also expressed interest in exploring possibilities of E-READI support. Subsequently, under the first E-READI Annual Work Plan, on HPC it was planned to:

1. Conduct the mapping of policy orientations and identification of ASEAN HPC capacity and related research infrastructures;
2. Support the ASEAN HPC Taskforce meeting and EU-ASEAN experts' exchange towards the organisation of resource sharing and access to HPC services at a regional level and between EU and ASEAN.

[13] https://wiki.egi.eu/wiki/Competence_centre_Disaster_Mitigation
[14] https://www.egi.eu/tag/egi-engage/. See also https://cordis.europa.eu/project/id/654142
[15] https://www.eosc-hub.eu/. See also https://www.eosc-hub.eu/research-communities/disaster-mitigation-competence-centre-plus-dmcc
[16] Regional Collaboration on Disaster Mitigation: https://apan.net/meetings/apan45/files/13/13-01-02-01.pdf
[17] http://icomcot.twgrid.org
[18] https://gwrf.twgrid.org/

The present report is a concrete outcome supporting the above objectives through an expert mapping study of ASEAN policy orientations and related HPC research infrastructures. Conducted by two mandated experts (one for EU, one for ASEAN), the work entails consolidating information on each AMS on multiple topics covering both the mapping and research strategies, which includes:

- **Identifying of the target group for the interviews** (operators of Research Infrastructures and the relevant national authorities engaged in International cooperation) able to provide the accurate information.
- **Performing an in-depth study of ASEAN HPC capacity as well as its ecosystems** for example: existing Research Infrastructures in each AMS, national platform strategy, the point of contacts, application benefits, human capital workforce, available knowledge and skills, career development, regional common interest, etc.
- **Performing a Cross Analysis with EU pools of information and seek shared interests for collaboration and regional resources sharing.** Due to the gap of technology advancement between EU and ASEAN, the objective is to look for a value proposition that benefits both rather than matching the amount of the same thing.
- **Propose options and strategies to go forward based on the shared interest of mutual benefit between the two regions**.

The present study aims at delivering a per sector approach of potential HPC use, underlying the specificity of the EU-ASEAN links (e.g. biodiversity, bioinformatics, oceans, water, seismology, scientific data, HPC etc.), to facilitate the possibility of setting an EU-ASEAN joint-roadmap with joint activities and mechanisms.

D. Methodological approach

The organization of the work leading to the present report was initiated during the First EU-ASEAN HPC Coordination Group Meeting which was organised back-to-back with the second ASEAN HPCTF meeting and within the second Asia Super Computing Conference 2019 (SCAsia'19)[19] on 14 and 15 march, 2019, an event which took place at the Suntec Singapore Convention and Exhibition Centre in Singapore.

This meeting served as an inaugural platform for dialogue between ASEAN and EU on HPC. Both ASEAN and EU counterparts presented their respective HPC roadmaps, capacities, expertise and priorities. The EU shared experiences on the computational power applied in support to research, and the exchange recommended the next steps in the Region-to-Region collaboration on HPC. Finally, the methodology of the proposed study on policy orientations was presented and relied on the following axis:

1. Design of a relatively detailed online survey[20] which has the purpose of collecting past, current and planned computing requirements, governance expectations and application area expertise within the representative countries and divisions of the ASEAN countries. The objective is of course not to redo an academic exercise already performed within the ASEAN HPC Task force, but rather to understand the conditions and the eventual existing gap enabling the promotion of long-term collaboration with EU of mutual benefit for all parties. This survey is structured in 9 sections:
   a. Introduction
   b. Contact and Organisation Details (6 questions)
   c. HPC/Research Computing Centre Profile (11 questions)

[19] https://www.sc-asia.org/
[20] See Appendix B

d. Technical Characteristics of your Computing / HPC facility (if any) (67 questions)
e. Software and Application Domain Needs (10 questions)
f. Staff and Support services (15 questions)
g. Training (8 questions)
h. Policy and Governance for Regional HPC Resource Sharing (11 questions)
i. Miscellaneous (5 questions)

2. Combine the collection of information from the survey with selected site visits by the E-READI experts to consolidate the in-depth study of ASEAN HPC capacity and policy mapping study. Apart from the leading HPC centers of the ASEAN region recommended by the ASEAN HPCTF chairs and co-chairs, emerging AMS having a strong HPC development strategy was also considered important to investigate further and were also visited.
3. From the identified joint priority application areas, investigation on the EU groups matching the selected domain was of course one of the expected outcomes of the mapping study and were conducted. Of prime importance for the present report was also to not only summarize the existing programs, training framework and funding environment but also to associate each of these elements with a single point of contact person able to later answer specific need request.
4. Perform the synthesis of the collected information in a single document (i.e. the present report) meant to circulate among the AMS to collect their feedback and comments.

This approach was presented by the European and ASEAN experts mandated to conduct the study during the 1st EU-ASEAN HPC Coordination Group Meeting. It was agreed by the present participants, *i.e.,* the senior KOLs of the ASEAN HPC Task Force, the key representatives of the EC DG RTD, of the EU Mission to ASEAN, and the work was performed over 4 months' time period (i.e from March to June 2019).

E. Organization of the document

This document is structured as follows:

- Chapter **2** on page 19 offers an overview of the international HPC landscape in the Exascale race, covering (very briefly) the general HPC strategies defined in US, China, Japan and Australia.
- The European HPC strategy being at the heart of the collaboration framework with ASEAN, the Chapter **3** on page 21 is dedicated to it and permits to review:
  - The European HPC Ecosystem and the projects tied to its three pillars (infrastructure, Technologies and Applications)
  - PRACE, the EuroHPC Joint Undertaking (JU) and the supporting Tier-0 facilities (present and incoming)
  - The EU Centres of Excellence in Computing Applications, as essential drivers for the foreseen collaboration with ASEAN Member states and the associated research centres.
  - The list of other European HPC projects open for International collaborations
- Chapter **4** (page 36) is dedicated to the analysis of ASEAN HPC capabilities, related research infrastructures and domain expertise. This analysis is structured to summarize the situation of each individual AMS with, in each case, a synthetic analysis of the existing HPC capacity as well as the list of the reference institutes tied to HPC activities.
- Chapter **5** on page 65 depicts the EU-ASEAN past links and current collaborations, allowing to identify the best approaches meant to consolidate these collaborations in the framework of this study

- The analysis of the identified joint priority application areas and potential synergies is conducted in the Chapter **6** on page 72. This aims at reinforcing the standing EU-ASEAN Dialogue on Science and Technology in these areas by reviewing:
    - The detailed list of software required to be provided and covered to satisfy the ASEAN HPC user community. Apart from allowing to raise priority awareness on deployment requirement within a shared HPC facility, such a list is strategic for the foreseen training aspects.
    - The application domains with societal impact matching AMS priority and interest for a collaboration within E-READI
- Chapter **7** on page 82 expounds the cross analysis performed with EU pools of resources as regards Training and Human capacity development program which were indicated as strategic to enhance the collaboration with ASEAN countries. This chapter reviews the existing provision of HPC training in Europe, identify the future training needs of the HPC community among the AMS, and produce recommendations based on the resulting gap analysis
- Chapter **8** on page 93 is dedicated to the suggested Policy and Governance for the design of a Regional HPC Resource Sharing at the origin of this study.
- Chapter **9** on page 111 expounds the cross analysis performed with EU pools of resources as regards Staff and Support services.

Finally, the Chapter **10** concludes the document and offers perspectives for further developments.

Chapter 2 : Overview of the international HPC landscape in the Exascale race[21]

This chapter propose a very short overview of the HPC strategic developments performed in US, China, Japan and Australia.

A. HPC Strategy in US

In US, the leading supercomputing program have been run by the Department of Energy (DOE) for several decades. Since about ten years, the Leadership Computing Facilities in Oak Ridge (OLCF) and Argonne (ANL) operate systems that aggressively explore new architectures at extreme scale. OLCF and the facility at Lawrence Livermore National Laboratory (LLNL) regularly deploy supercomputers that take the top spots in terms of peak floating-point performance. The leadership computing systems at OLCF and ANL are open and intended for extreme-scale computing applications, like the Tier-0 systems of PRACE in Europe. In addition, capacity resources similar to the PRACE Tier-1 systems are operated by the National Energy Research Supercomputing Centre (NERSC) at Lawrence Berkeley National Laboratory (LBNL), as well as the supercomputing facility of Los Alamos National Laboratory (LANL). Each time new supercomputers are introduced by these facilities, they appear in the top ten of the Top500 list[22]. The National Science Foundation (NSF) operates a Track 1 system, similar to PRACE's Tier-0 systems, to support its programs – this system is currently operated at the National centre for Supercomputing Applications (NCSA) at the University of Illinois, and its successor will be installed at the Texas Advanced Computing centre (TACC) in Austin. The NSF Track 1 system and the programmatic systems of DOE are of comparable performance and will reach pre-exascale levels by 2020.

B. HPC Strategy in China

China operates a very large network of capacity systems that serve researchers at universities, its national academy of sciences, as well at other state funded research labs. The most visible supercomputers, however, are China's version of leadership-class systems. They have stunned the global supercomputing community with performance, and with the fact that they are built with Chinese technologies (in particular at the level of processors, accelerators and interconnects). These supercomputers are regularly competing for the top spots with the leading US systems in terms of peak floating-point performance.

C. HPC Strategy in Japan

While China and the USA are competing to build the first sustained exaflops systems early next decade, Japan is taking an entirely different approach to leadership class computing. At Riken's Centre for Computational Sciences (CCS), the country operates its national leadership supercomputer, the K Computer. This system only briefly took the top spot in terms of peak floating-point performance in 2011; however, it has until recently outperformed every other supercomputer on the planet with its memory performance. As a result, applications from all domains run very efficiently. The post-K Computer will be deployed in the early 2020s. It will not match its US and Chinese counterparts in terms of peak floating-point performance, but very likely it will

[21] See also "*PRACE in the EuroHPC Era*" White Paper, Dec. 2018. http://www.prace-ri.eu/IMG/pdf/PRACE-role-in-the-EuroHPC-era-FINAL-proof.pdf

[22] https://www.top500.org/lists/

outperform its rivals in sustained application performance. Besides the leadership system at Riken's CCS, Japan maintains a network of capacity computing systems at various universities and national research centres. It had the first top-10 supercomputer dedicated to machine learning applications.

D. HPC Strategy in Australia

The Australian HPC competitiveness position improved considerably in the last three years as the two premier petascale HPC and data facilities the National Computational Infrastructure (NCI) at the Australian National University, Canberra and the Pawsey Supercomputing Centre in Western Australia received further funding support from the Australian Government. In early 2018, it was announced that a new program worth A$70 million will commence to replace NCI's aging supercomputer, the Raijin which was ranked 70th globally starting with the installation of a Lenovo cluster supported by the National Collaborative Research Infrastructure Strategy (NCRIS) Agility Fund. Additional investments of a Cray XC50 trial system is further enhanced with additional storage and data expertise was to follow which will integrate compute with the essential advance data management and services. In May 2018, the Australian Government announced another A$70 million funding for the sister HPC facility, the Pawsey. At the same time, the Government made a commitment to sustained capital and operational funding for other parts of the inter-connected national research infrastructure.[23]

Focused engagement and collaboration in joint planning to map out optimal strategies to advance Australia's research infrastructure capabilities has been carried out by the two Tier 1 HPC facilities – NCI and Pawsey Supercomputing facilities as well as by several major parts of the HPC community. The NCI has impact as diverse as HPC and data analytics, genomics and health, data science more broadly, materials, cellular and tissue imaging, nano-fabrication, geoscience and climate and weather. While the Pawsey HPC facilities is all about enabling leading-edge and innovative science that underpin the activities of the radio astronomy community and the development of the Square Kilometer Array (SKA) precursors including doubling the size of the Murchison Widefield Array (MWA). At the same time, Pawsey has been broadening their support of research across Earth science, medical science, engineering, chemistry, agriculture and more. The planning process of the two HPCs are guided by the National Research Infrastructure Roadmap and both continue to broaden their horizons and partnerships with national and international partners including in the US, Japan, Singapore and the EU. In April 2018, NCI Associate Director (Systems and Technology) Allan Williams present a keynote lecture on "HPC in Australia" at the European PRACE Days HPC Conference. In addition, the two Australian HPC representatives participated in the International Supercomputing Conference 2018 in Frankfurt, Germany and in the Supercomputer Asia 2019 in Singapore. As HPC matures in Australia as a pivotal part of the research landscape, the two Tier 1 HPC facilities will continue to drive world-leading research that adds great value to Australia's and the global partners' economy and future.[24]

E. HPC strategy in EU and ASEAN Member states

The situation of EU and ASEAN countries are detailed in the following chapters.

[23] NCI Australia – Annual Report 2017-2018: *World-Class High-End Computing Services for Australian Research and Innovation, National Computational Infrastructure*, Canberra, 2018.
[24] Pawsey Supercomputing Centre – Annual Report 2017-2018*: A World of Difference, Connecting Australia's HPC*, 2018.

Chapter 3 : Overview of the European HPC Strategy

Over the last decades, High Performance Computing (HPC) systems has become an essential driver for the progress of scientific discovery as all scientific disciplines are becoming computational today. In parallel, the increased availability and usability of these infrastructures has been identified as a strategic resource for the global competitiveness of all countries. All economic sectors are increasingly relying on the available computing facilities and associated data analytics capabilities to invent innovative solutions with improved accuracy and quality, while reducing development cost and decreasing time to market for products and services[25]. Overall, mastering advanced computing technologies from hardware to software, including for emerging domains as Big Data analytics or Artificial Intelligence, has become essential for innovation, growth and jobs. Australia, China, Japan, the US and EU are making huge investment to sustain the continuous development and deployment of new computing technologies with increased performance on priority application domains.

The European HPC Strategy was first defined by the European Commission in a publication entitled: "*High Performance Computing: Europe's place in a Global Race*"[26] issued in 2012. It recognizes the need for EU to compete for leadership in HPC systems, a necessity driven both by the need to address societal and scientific grand challenges more effectively, such as early detection and treatment of diseases like Alzheimer's, deciphering the human brain, forecasting climate evolution, or preventing and managing large-scale catastrophes, and by the needs of industry to innovate in products and services.

The European HPC Ecosystem aims to develop world-class HPC technologies, platforms and applications, leading to exascale systems and their advanced use, thus creating jobs, new products and more efficient companies as well as enabling scientific discoveries.

For the European Commission, HPC needs an EU-level policy to optimise national and European investments, addressing the entire HPC ecosystem. Therefore, its HPC Strategy[27] as adopted in 2012 and implemented in the biggest EU Research and Innovation program called Horizon 2020[28]. Of particular interest for strengthening EU-ASEAN collaborations, the definition of this Horizon 2020 Work Program is subjected to evolution allowing for newly funded international activities. For instance, one of the most recent revision (adopted on July 24, 2018 by the EC) included new calls for Future Emerging Technologies (FET) activities in High Performance Computing (HPC) strengthening international cooperation with South America (in particular Argentina). Part of the recommendation of this report involves the definition of supporting instruments for ASEAN collaborations.

[25] As per IDC (International Data Corporation) Studies "A Strategic Agenda for European Leadership in Supercomputing: HPC 2020" and "Financing a Software Infrastructure for Highly Parallelised Codes", 97% of the industrial companies that employ HPC consider it indispensable for their ability to innovate, compete, and survive.

[26] EC Communication, "*High Performance Computing: Europe's place in a Global Race", Feb. 2012,* https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2012:0045:FIN:EN:PDF

[27] http://ec.europa.eu/digital-agenda/en/high-performance-computing-hpc

[28] https://ec.europa.eu/programmes/horizon2020/en/h2020-section/high-performance-computing-hpc. It is worth to note that the Commission is working on a proposal for the framework program that will succeed Horizon 2020. This will be done as part of the EU's proposal for the next 7-year EU budget in Multi-Annual Financial Framework (MFF).

A. The European HPC Ecosystem

The EC strategy on HPC activities stipulates the need for the balanced development of the European HPC Eco-system based on three pillars:

1. **HPC Infrastructure**, represented by PRACE (Partnership for Advanced Computing in Europe)[29] and GEANT[30]. The EuroHPC Joint Undertaking (JU) is also now playing a key role at this level as it will be described in the section I.B. PRACE is the European HPC infrastructure for science - it runs calls for academic projects to be executed in its network of supercomputing resources across Europe. It also runs an HPC program for SMEs called SHAPE[31] - SME HPC Adoption Programme in Europe. GEANT interconnects Europe's national research and education networking (NREN) organisations with an award-winning high bandwidth, high speed and highly resilient pan-European backbone – connecting Europe's researchers, academics and students to each other, and linking them to over half the countries in the world.
2. **HPC Technology**, represented by ETP4HPC (the European HPC Technology Platform)[32] and the European Processor Initiative (EPI). ETP4HPC is a HPC industry-led think tank which aims to build a world-class HPC Supply Chain and increase the global market share of European HPC vendors. It serves as advisory board, just like BDVA (Big Data Value Association)[33]. EPI gets together 23 partners from 10 European countries, with the aim to bring to the market a low power microprocessor. It gathers experts from the HPC research community, the major supercomputing centres, and the computing and silicon industry as well as the potential scientific and industrial users. Through a co-design approach, it will design and develop the first European HPC Systems on Chip and accelerators. Both elements will be implemented and validated in a prototype system that will become the basis for a full Exascale machine based on European technology.
3. **Application expertise**, represented by the Centres of Excellence of Computing Applications (CoEs - see list below in the section I.C) and several projects,

These three pillars are building the **European HPC Ecosystem**, illustrated in the below Figure **1.** Contact details (completed with EuroHPC JU – see Section I.B) are summarised in the below Table **1**.

Table 1: Contact list for the main projects tied to the European HPC Ecosystem pillars

EuroHPC JU **EuroHPC Joint Undertaking**	**Anders Dam Jensens** anders.jensen@eurohpc-ju.europa.eu
• *Website* : https://eurohpc-ju.europa.eu/	
PRACE **Partnership for Advanced Computing in Europe**	**Serge Bogaert** S.Bogaerts@staff.prace-ri.eu
• *Website* : http://prace-ri.eu/	
GEANT **EU Network for scientific excellence, research, education and innovation**	**Erik Huizer** erik.huizer@geant.org

[29] http://www.prace-ri.eu/
[30] https://www.geant.org
[31] See http://www.prace-ri.eu/hpc-access/shape-programme/
[32] See https://www.etp4hpc.eu
[33] See http://www.bdva.eu/

- *Website* : https://www.geant.org

ETP4HPC **European Technology Platform (ETP) in the area of HPC**	**Jean-Pierre Panziera** jean-pierre.panziera@atos.net

- *Website* : https://www.etp4hpc.eu/

EPI **European Processor Initiative**	**Jean-Marc Denis** jean-marc.2.denis@atos.net

- *Website* : https://www.european-processor-initiative.eu/

EXDCI-2 **European Exterme Data & Computing Initiative 2 (2018-2020)**	**Serge Bogaerts** pers@chalmers.se

- *Website* : https://exdci.eu
- *Coordinating Organization:* PRACE
- Support the road-mapping, strategy-making and performance-monitoring activities of the ecosystem

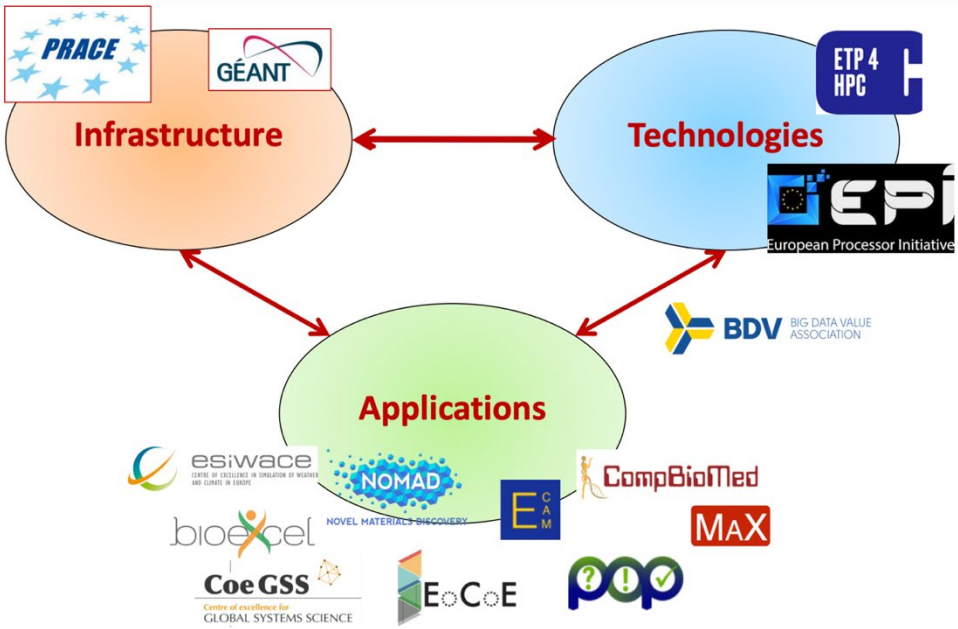


Figure 1:The three pillars of the European HPC Ecosystem. [Source: European commission, ETP4HPC]

The Technology and the Applications pillar of the ecosystem form a contractual Public-Private Partnership (cPPP)[34] with the European Commission (EC), which monitors the implementation of the European HPC strategy. It serves as a forum in which the stakeholders involved have an opportunity to discuss this process with the EC and exchange mutual commitments. In practice, EC operates through "*calls*" for proposals

[34] https://ec.europa.eu/digital-single-market/en/high-performance-computing-contractual-public-private-partnership-hpc-cppp

for projects in the area of HPC technology and applications -- a total of €700 million has been committed to these developments within the EC Horizon 2020 program. In particular, the **FET-HPC** (Future and Emerging Technologies – HPC)[35] program of the EC supports the development of European HPC technology while the EINFRA calls include the operation of the Centres of Excellence in Computing Applications. The separately funded European Extreme Data and Computing Initiative (EXDCI)[36] project coordinates the implementation of the European HPC strategy.

The EU Member States have thus supported HPC with national or regional research and innovation policies, and with national public procurement of HPC systems. They have also successfully coordinated access to national supercomputing and data management resources and services at the European level. This has enabled high-impact scientific discovery and engineering research and development; an experience EU is wishing to share with ASEAN Member States to avoid the potential pitfalls such a collaboration between different countries having competing objectives can bring.

B. The EuroHPC Joint Undertaking (JU)

The EC Strategy on HPC has seen a significative upgrade in 2018. Constating that the computing and data needs of European scientists and industry did not match the computation capabilities available in the EU since no EU supercomputer is present in the global top 10[37], and none of the existing ones depend on non-European technology, a situation which may create problems related to privacy, data protection, commercial trade secrets or ownership of data. Acknowledging also that Europe consumes about 29% of HPC resources worldwide today, while the EU industry provides only ~5% of such resources, EU response to the above was to invest together in an ambitious supercomputing infrastructure strategy. More precisely, the EC plans to develop and reinforce the European high-performance computing and data processing capabilities to achieve exascale capabilities by 2022-2023 and post-exascale facilities by 2026 or 2027. The EuroHPC Joint Undertaking[38] operational since Nov. 2018 (and foreseen to at least 2026) from Luxembourg provides mechanisms to implement this strategy: a joint procurement framework, EU-level coordination and the pooling of financing, networking of national capacities and deployment of technology when it becomes available. The EuroHPC JU is a legal funding entity which relies on the initial co-investment with 28 Participating States and the EC for a total of about 1 billion € with regards the period 2019-2020, out of which EUR 486 million come from the actions already planned by the Commission in Horizon 2020 and Connecting Europe Facility (CEF) programs in the current Multiannual Financial Framework (MFF). An additional ~422 million € will be contributed by private or industrial players in the form of in-kind contributions to the JU activities. Concretely in terms of supercomputer acquisitions, the EuroHPC JU has launched in February 2019 two calls for hosting entities i.e. countries meant to host EuroHPC supercomputers:

- A call for Precursors to exascale systems (*i.e.* with at least 150 PFlops computing capacity), which received 3 consortium candidates (from Finland (CSC), Italy () and Spain (BCS))

[35] See Horizon 2020 Work Program 2018-2020 http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-fet_en.pdf. FET activities in general consist of 3 lines of activities: FET Open, FET Proactive and FET Flagships.
[36] https://exdci.eu/
[37] As per Top500 rank of supercomputer in the world – see http://top500.org
[38] https://eurohpc-ju.europa.eu/

- A call for petascale systems (*i.e.* between 2 and 100 Pflops), which received 5 candidatures (Czech Republic, Luxembourg, Portugal, Slovenia and Bulgaria)

The decision for the hosting entities was officialised on June 7, 2019 and acknowledged the funding of all candidatures[39]. This shall provide a total computing capacity within the EuroHPC JU Hosting entities of 976,54 PFlops (aggregated performance). As of July 2021, 7 procurement contracts were signed and under implementation for a total value of ~360 M€. One procurement (Mare Nostrum 5) had to be relaunched. In addition to the EuroHPC supercomputing infrastructure, and taking into account the existing PRACE Tier-0 system (accounting for a total of 111 PFlops aggregated peak performance), that means that the scientists and researchers from all over the world (in particular ASEAN) will have the possibility (under conditions) for free access to the EU computing systems listed in the Table 2 for open research (*i.e.* with publication of results).

Table 2: List of EU Tier-0 systems

	System	Location	System Characteristics
PRACE	**Hazel Hen** **Gauss Centre for Supercomputing (GSC), HLRS**	Germany (Stuttgart)	Cray XC40 system 7.42 PFlops (7712 nodes) Xeon E5-2680v3 12C 2.5GHz Aries interconnect
	JOLIOT Curie **Très Grand Centre de Calcul (TGCC)** **GENCI**	France (Paris)	Atos/BULL Sequana X1000 9,38 PFlops (2484 mixed nodes) Intel KNL accelerators, Xeon Platinum 8168 24C 2.7GHz, Mellanox EDR interconnect
	JUWELS **Julich Supercomputing Center (JSC)**	Germany (Jülich)	Atos/BULL Sequana X1000 9,89 PFlops (2575 mixed nodes) Xeon Platinum 8168 24C 2.7GHz, Mellanox EDR InfiniBand
	MARCONI **CINECA**	Italy (Bologna)	Lenovo SD530/S720AP 10,38 PFlops (4104 mixed nodes) Intel KNL (Phi 7250 68C) accelerators Intel Omni-Path interconnect
	MareNostrum **Barcelona Supercomputing Center (BCS)**	Spain (Barcelona)	Lenovo SD530, 10,296 PFlops (3456 nodes) Xeon Platinum 8160 24C 2.1GHz, Intel Omni-Path interconnect
	Piz Daint **ETH Zurich/CSCS (Swiss National Supercomputing Centre)**	Switzerland (Zürich)	Cray XC50 27 PFlops (4400 mixed nodes) Xeon E5-2690v3 12C 2.6GHz, NVIDIA Tesla P100 accelerators Aries interconnect
	SuperMUC-NG **Leibniz Supercomputing Centre (Leibniz-Rechenzentrum, LRZ)**	Germany (Munich)	Lenovo ThinkSystem SD530 26,87 PFlops (6480 mixed nodes) Xeon Platinum 8174 24C 3.1GHz Intel Omni-Path interconnect
TOTAL Aggregated computing capacity (PRACE):		**111,24 PFlops**	
	System	**Location**	**System Characteristics**
EuroHPC Pre-exascal	**EuroHPC Pre-exascale system * LUMI - CSC (Finnish IT Center for Science)** http://www.csc.fi	Finland (Kajaani)	HPE Cray EX 375 PFlops ** Planned deployment: 2021-2022* *LUMI-C (Nov21), LUMI-G (Mar22)*

[39] http://europa.eu/rapid/press-release_IP-19-2868_en.htm

	EuroHPC Pre-exascale system * Mare Nostrum 5 (MN5) Barcelona Supercomputing Center (BCS)	Spain (Barcelona)	Vendor: n/a (Consortium/ 4 partners) 200 PFlops ** Planned deployment: 2022-2023*
	EuroHPC Pre-exascale system * Leonardo CINECA	Italy (Bologna)	Atos/BULL Sequana XH2000 249.5 PFlops ** Planned deployment: 2022*
EuroHPC Petascale (between 2 and 100 Pflops)	**EuroHPC Petascale system * Karolina IT4Innovations National Supercomputing Centre**	Czech Republic (Ostrava)	HPE Apollo 9.4 Pflops (827 mixed nodes) AMD Epyc, Nvidia A100 accelerators IB HDR interconnect
	EuroHPC Petascale system * MeluXina LuxProvide S.A.	Luxembourg (Bissen)	Atos/BULL Sequana XH2000 12.8 PFlops (824 mixed nodes) AMD Epyc, Nvidia A100 accelerators IB HDR interconnect
	EuroHPC Petascale system * Deucalion Fundação para a Ciência e a Tecnologia	Portugal (Barco)	Fujitsu FX700 7.2 PFlops ** Planned deployment: Dec 2021*
	EuroHPC Petascale system * Vega (izum) Institute of Information Science	Slovenia (Maribor)	Atos/BULL Sequana XH2000 6.9 Pflops (960 mixed nodes) AMD Epyc, Nvidia A100 accelerators IB HDR interconnect
	EuroHPC Petascale system * Discoverer Petascale Supercomputing Consortium (PetaSC) Bulgaria	Bulgaria (Sofia)	Atos/BULL Sequana XH2000 4.5 Pflops (376 nodes) AMD Epyc
TOTAL Aggregated computing capacity (EuroHPC, by 2022, excl. Exascale systems):		**865,3 PFlops**	

As will be highlighted later, EuroHPC and PRACE supercomputer access is granted through a rigorous peer review process. Industrial users with headquarters or large R&D activity in Europe can also apply for open R&D projects and must undergo the same review. Access is provided via calls for Project Access (regular access to a research infrastructure), for Preparatory Access (to enable proposal preparation), and for SHAPE, (the SME HPC Adoption Programme) and later to the EuroHPC Center of Competence (pending funding decision in progress) in Europe.

In all cases, the next steps planned within the EuroHPC JU involve the deployment of 2 Exascale systems by 2022/2023 (following a call for hosting entity), of a post-exascale infrastructure by 2027. Also, the federation of HPC infrastructures at European level consolidating the experience of PRACE is foreseen, as well as the release of a hybrid HPC/Quantum infrastructure. A summary of the European HPC funding effort is proposed in the Figure **2**.

It is quite interesting to note that this funding effort was significantly increased with updated committed contributions since 2019:

- The EuroHPC Budget for the time period 2019-2020 was finally set as follows:
  - 2019: 198.4 M€
  - 2020: 287.6 M€
- Then the European Commission has announced in December 2020 a new Digital Europe Framework[40] program with a budget of 7.5 billion€ to accelerate the recovery and drive the digital transformation of Europe. It is part of the next long-term EU budget that will fund projects from 2021-2027. It will provide funding for projects in five crucial areas: supercomputing, artificial intelligence,

[40] https://digital-strategy.ec.europa.eu/en/activities/digital-programme

cybersecurity, advanced digital skills, and ensuring the wide use of digital technologies across the economy and society. On the first priority, the program aims to build up and strengthen the EU's supercomputing and data processing capacities, helping EU to reach exascale supercomputing by 2022/2023 and post-exascale capabilities by 2026/2027.

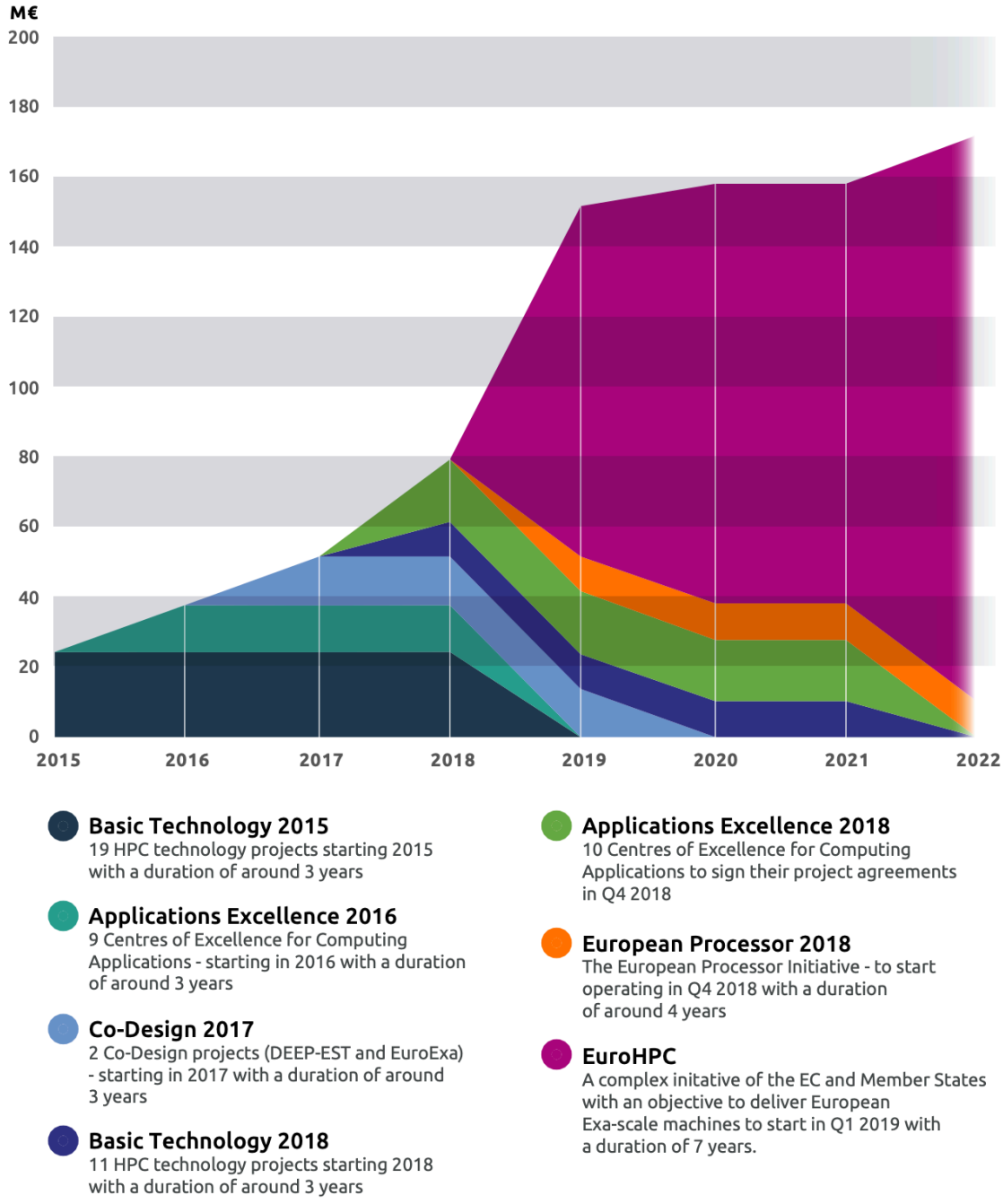


Figure 2: Summary of the EU HPC funding efforts [Source: ETP4HPC Handbook 2018]

C. Centres of Excellence in Computing Applications (CoEs)

The **Centres of Excellence in Computing Applications** (CoEs) represent the European Application expertise and are essential drivers for the foreseen collaboration with ASEAN Member states and the associated research centers. Ten new Centres of Excellence (CoEs) for computing applications were selected following the recent EC call under e-Infrastructures (operational since 2018). They will help strengthen Europe's leadership in HPC applications and cover important areas, providing services such as: developing, optimising (including if needed re-design) and scaling HPC application codes towards peta and exascale computing; testing, validating and maintaining codes and managing the associated data; quality assurance; co-design of hardware, software and codes; consultancy to industry and SMEs; research in HPC applications; and addressing the skills gap in computational science.

A detailed list and description of the Centres of Excellence in Computing Applications CoEs is available in the European High Performance Computing Handbook 2018[41]. An up-to-date view can be obtained from the COE website[42]. The Table 3 below provides a short summary meant for facilitating the mapping collaboration strategy with ASEAN partners.

Table 3: List of EU Centres of Excellence in computing applications CoEs (2018-)

BioExcel-2 **Centre of Excellence for Computational Biomolecular Research**	**Prof. Laure Erwin** erwinl@pdc.kth.se

• *Website* : **https://bioexcel.eu/**
• *Coordinating Organization*: KTH Royal Institute of Technology, Sweden (+ 12 other partners)
• *Main HPC-accelerated domain fields expertise*:
  ○ Bioinformatics
  ○ High-end computing for Biomolecular modelling and simulations
• *Main Objectives*:
  ○ Improving the performance and scalability of major simulation packages (Ex: Gromacs)
  ○ Competence-building among both academia and industry through extensive training programs and promotion of best practices	

ChEESE **Centre of Excellence for Exascale and Solid Earth**	**Arnau Folch** arnau.folch@bsc.es

• *Website* : **https://cheese-coe.eu/**
• *Coordinating Organization*: Barcelona Supercomputing Centre, Spain (+ 13 other partners)
• *Main HPC-accelerated domain fields expertise*:
  ○ Computational seismology
  ○ Magneto-hydrodynamics, Physical volcanology, tsunamis, and data analysis and predictive techniques for earthquake and volcano monitoring
• *Main objectives:*
  ○ preparation of 10 Community flagship European codes for the upcoming pre-Exascale (2020) and Exascale (2022) supercomputers.
  ○ Example of Pilots demonstrators: Urgent seismic simulation, "Faster than real-time Tsunami Simulations", High resolution volvanic plume simulation, physic-	

[41] See https://www.etp4hpc.eu/pujades/files/ETP4HPC_Handbook_2018_web_20181210.pdf
[42] https://www.hpccoe.eu/

based tsunami-earthquake interactions, Probabilistic Tsunami Forecast (PTF) for early-warning and rapid post event assessment…

CompBioMed2 **Centre of Excellence in Computational Biomedicine**	**Emily Lumley** e.lumley@ucl.ac.uk

- *Website* : **https://www.compbiomed.eu/**
- *Coordinating Organization*: University College London, UK (+ 14 other partners)
- *Main HPC-accelerated domain fields expertise*:
  - Computational Biomedicine
  - Predictive models of health and disease

EoCoE-II **Energy Oriented Center of Excellence Phase II**	**Edouard Audit** contact@eocoe.eu

- *Website* : **https://www.eocoe.eu/**
- *Coordinating Organization*: CEA – Maison de la Simulation, France (+ 17 other partners)
- *Main HPC-accelerated domain fields expertise*:
  - Meteorology for Energy
  - Material Science
  - Computational Simulation (Water, fusion and Wind)
- *Main objectives*:
  - simulate a wind power plant to optimize its production,
  - predict the wind directions and speed over complex terrain,
  - use our high-end numerical tools to determine the properties of new materials for photo-voltaic power panels, or for batteries and super-capacitors,
  - monitor and improve the performance of your code using the unique methodology we have developed

ESiWACE2 **Centre of Excellence in Simulation of Weather and Climate in Europe Phase 2**	**Joachim Biercamp** esiwace@lists.dkrz.de

- *Website* : **https://www.esiwace.eu/**
- *Coordinating Organization*: Deutsches Klimarechenzentrum (DKRZ) (+ 19 other partners)
- *Main HPC-accelerated domain fields expertise*:
  - Weather Prediction, Climate modeling
  - Global Earth system modelling
- *Main objectives*:
  - Cutting Edge Resolution in Earth system modelling
  - Establish and watch new technologies for the community
  - HPC services to prepare the weather and climate community for the pre-exascale
  - Data Handling (post-processing, analytics and visualization) at Scale
  - Community engagement and Training

EXCELLERAT **Centre of Excellence for Engineering Applications**	**Dr.-Ing. Bastian Koller** koller@hlrs.de

- *Website* : **https://www.excellerat.eu**

- *Coordinating Organization*: Universität Stuttgart (HLRS), Germany (+ 12 other partners)
- *Main HPC-accelerated domain fields expertise*:
  - Manufacturing
  - Automotive
  - Energy
  - Aerospace
- *Main objectives*:
  - Provide the HPC and engineering community with easy access to relevant services and knowledge, including to niche applications development and offered hardware
  - Support the community with targeted training and networking activities
  - Strengthen European competitiveness in the domain of HPC driven engineering through excellent research in the areas of developing, scaling and optimizing applications
  - Apply innovative engineering solutions enabled by HPC technologies to real world problems
  - Facilitate technology transfer from academia to industry

FocusCoE **Concerted action for the European HPC CoEs**	**Dr. Guy Londsdale** guy.lonsdale@scapos.com

- *Website* : **https://www.focus-coe.eu/**
- *Coordinating Organization*: Scapos AG, Germany (+ 10 other partners)
- *Main objective:*
  - Platform for the CoEs to coordinate strategic directions and collaboration through support services in relation to training, industrial outreach and promotion of their services to potential users.

HiDALGO **HPC and Big Data Technologies for Global Challenges**	**Francisco Javier Nieto** francisco.nieto@atos.net

- *Website* : **https://hidalgo-project.eu**
- *Coordinating Organization*: Atos, Spain (+ 12 other partners)
- *Main HPC-accelerated domain fields expertise*:
  - Modeling of refugee movements and human migration modelling
  - Control system of urban traffic based on high resolution and real time modeling of urban air pollution
  - Social network modeling
- *Main scientific objectives*:
  - Algorithmic and technological challenges for data-centric-computation
  - Developement and implementation for strong and weak coupling mechanisms
  - Introduction of AI assisted workflows to improve application lifecycle handling
  - Integration of real-world sensor data into the simulation execution

MaX 2 **Materials design at the Exascale - 2**	**Prof. Elisa Molinari** elisa.molinari@max-centre.eu

- *Website* : **http://www.max-centre.eu/**
- *Coordinating Organization*: CNR Nano, Modena, Italy (+ 13 other partners)
- *Main HPC-accelerated domain fields expertise*:
  - Materials modelling, simulations, discovery and design
- Main objectives:
  - supports developers and end users of advanced applications in the field of materials, enabling works at the frontiers of the current and future HPC and HTC technologies

- enabling the exascale transition in the materials domain

NOMAD **Novel Materials Discovery Center Of Excellence**	**Prof. Dr. Matthias Scheffler** **scheffler@fhi-berlin.mpg.de**

- *Website* : **https://www.nomad-coe.eu/**
- *Coordinating Organization*: FHI, Berlin, Germany (+ 11 other partners)
- *Main HPC-accelerated domain fields expertise*:
  - Computational Material sciences

PerMedCOE **Centre of Excellence in Personalised Medicine**	**Prof. Dr. Matthias Scheffler** **scheffler@fhi-berlin.mpg.de**

- *Website* : **https://permedcoe.eu/**
- *Coordinating Organization*: BCS, Barcelona, Spain (+ 11 other partners)
- *Main HPC-accelerated domain fields expertise*:
  - Life Sciences, Personalised Medicine (PerMed)
- Main objectives:
  - develop a sustainable roadmap to scale-up the essential software for the cell-level simulation to the new European HPC/Exascale systems
  - provide an efficient and sustainable entry point to the HPC/Exascale-upgraded methodology to translate omics analyses into actionable models of cellular functions of medical relevance

POP 2 **Performance Optimisation and Productivity 2**	**Judith Gimenez** **judit.gimenez@bsc.es**

- *Website* : **https://pop-coe.eu/**
- *Coordinating Organization*: BCS (Barcelone Supercomputing Center, Spain (+ 7 other partners)
- *Main HPC services provided*:
  - Parallel Application Performance Assessment (combining performance audit and performance plan
  - Proof of concept
  - Training
- *Main Objectives*:
  - provides performance optimisation and productivity services for academic and industrial code
  - the services are free of charge to organisations / SMEs / ISVs / companies in the EU

D. Other European HPC projects open for international collaborations

The EC encourages international collaboration between the communities in order to reach the critical mass at the European level and leverage developments with other teams around the world. This is achieved by international visibility, establishing contacts with world leading HPC ecosystems, and increasing the European impact on standards. In this context, **several other HPC projects**, shortlisted in the below Table 4, **are important for AMS as they are open for international collaborations and can fund Short Term Collaboration Visits**.

Table 4: List of other European HPC projects open for international collaborations.

BDEC2 **Big Data and Extreme-scale Computing 2**	**Thomas Hahn** President@core.bdva.eu
• *Website* : https://www.exascale.org/bdec/	
HiPEAC **High Performance and Embedded Architecture and Compilation**	**Koen De Bosschere** coordinator@hipeac.net
• *Website* : https://www.hipeac.net/	
Eurolab-4-HPC 2 **Foundations of a European Research Center of Excellence in High Performance Computing Systems**	**Per Stenström** pers@chalmers.se
• *Website* : https://www.eurolab4hpc.eu/ • *Coordinating Organization:* Chalmers University of Technology • **Funding grants for Short Term Collaboration Grants for HPC**	
HPC-Europa3 **Pan-European Research Infrastructure on High Performance Computing 3**	**Debora Testi** d.testi@cineca.it
• *Website* : http://www.hpc-europa.eu/ • **Funding calls for Short Term Collaboration Grants for HPC**	

Among these projects:

- The mission of HiPEAC, the European Network on High Performance and Embedded Architecture and Compilation[43], is to steer and increase European research in the area of HPC and embedded computing systems, and stimulate co-operation between academia and industry, as well as between computer architects and tool builders. HiPEAC runs the ACACES (Advanced Computer Architecture and Compilation for High Performance and Embedded Systems) summer school[44] mentionned in the Chapter **7**. This one-week summer school aims to disseminate advanced scientific knowledge and promote international contact among scientists from academia and industry – the next edition (ACACES 2019)[45] being held on July 14-20, 2019 in Fiuggi, Italy.
- The Eurolab4HPC[46] project has the bold overall goal to strengthen academic research excellence and innovation in HPC in Europe. Of particular interest for AMS is the fact that this project can fund Short Term Collaboration Visits via regular calls. For instance, the **2nd Eurolab4HPC Call for Short Term Collaboration Grants for HPC**[47] **is due for July 1st 2019**. Each visit typically lasts 3 months and needs to end by 31 March 2020. The objective of the instrument is to foster tight integration among research teams from multiple communities working across all levels: hardware, architectures, programming and applications. Each proposal should contain representatives from multiple research communities across the whole system stack (in this case for AMS: one of the EU HPC centers or CoE), including strong commitment from the user communities. The grants will provide funding for short cross-discipline visits, targeted at PhD students, post-doctoral researchers and academics to work on a

[43] https://www.hipeac.net/
[44] https://www.hipeac.net/events/#/acaces/
[45] http://acaces.hipeac.net/2019/
[46] https://www.eurolab4hpc.eu/
[47] https://www.eurolab4hpc.eu/calls/2019/collaboration/8/2nd-call-for-short-term-collaboration-grants-for-hpc/

common project in different layers of the compute stack. Funding is available for independent small studies and benchmarking activities to capture requirements, metrics and opportunities to improve the platforms and technologies. A short-term collaboration grant has a maximum budget of 5 000 EUR and will be paid as a daily allowance of 55 EUR for max. 91 days. Half of the Eurolab4HPC grant will be paid upon receival of a grant agreement signed by the grantee, the host and home institution. The second half of the grant will be paid upon submission of a public summary of the activity that will be published on the Eurolab4HPC website. Final documents need to be submitted by 15 April 2020.

- **The HPC-Europa-3**[48] **project** (Pan-European Research Infrastructure on High Performance Computing) **permits to fund Transnational Access research visits**, which offered to researchers of postgraduate level and above the opportunity to carry out a collaborative visit to a host research group in a EU country, working in a similar field, while benefitting from the HPC facilities at one of the EU centres. Some of the participants of the program already had considerable HPC experience, but many were novice HPC users or complete beginners. The Transnational Access programmes therefore offered a unique opportunity for many new HPC users to gain hands-on experience of some of Europe's most powerful HPC facilities (Tier-0 listed in the
- Table 2, and other Tier-1 systems). In short, the programme offers a unique combination of both training and research opportunities, with relatively low barriers to participation. While training was not a primary objective of the Transnational Access visits, it was clearly one of the major outcomes of most visits, and for some it represented a very useful first step into the world of HPC. **Normally restricted to EU candidates, it was confirmed to be open for AMS candidatures in the future**.

The below Figure **3** (extracted from 2018 Handbook of European HPC Projects[49]) synthetizes the EU HPC ecosystem, the CoEs and the HPC-related projects.

[48] http://www.hpc-europa.eu/
[49] https://www.etp4hpc.eu/european-hpc-handbook.html

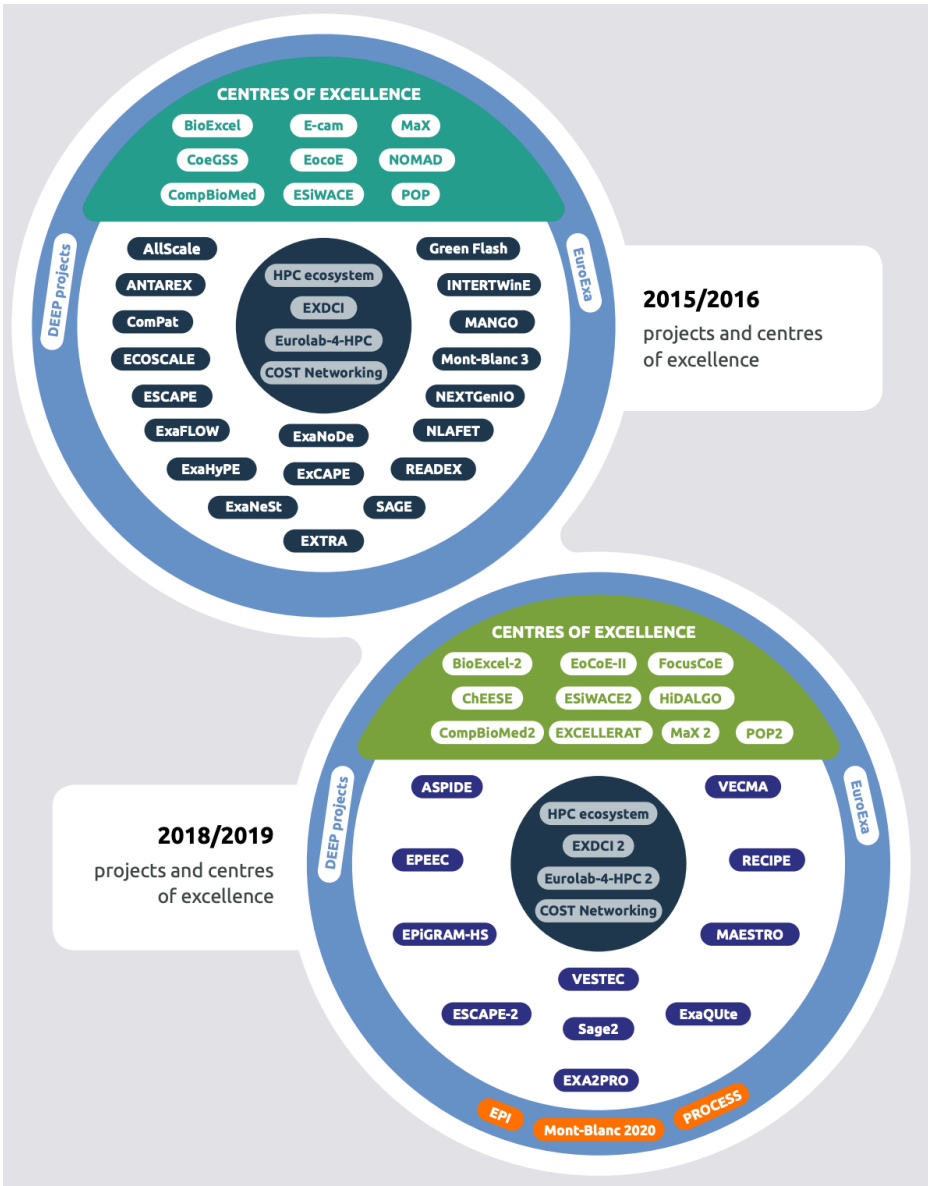


Figure 3: Summary of the EU Exascale Projects [Source: ETP4HPC Handbook 2018]

Finally, a potential EU-ASEAN synergy with regards the Climate and Earth Sciences domain involves the European climate community which is represented by the European Network for Earth System Modelling (ENES)[50]. Since, numerical weather prediction and climate modelling require more computing power, it is a driver for further HPC developments and is thus open for international collaboration (some of the AMSs being already part of collaboration programs).

Otherwise, an overview of the collaborations within HPC weather and climate projects funded by the EC is depicted in the Figure **4**.

[50] https://portal.enes.org/

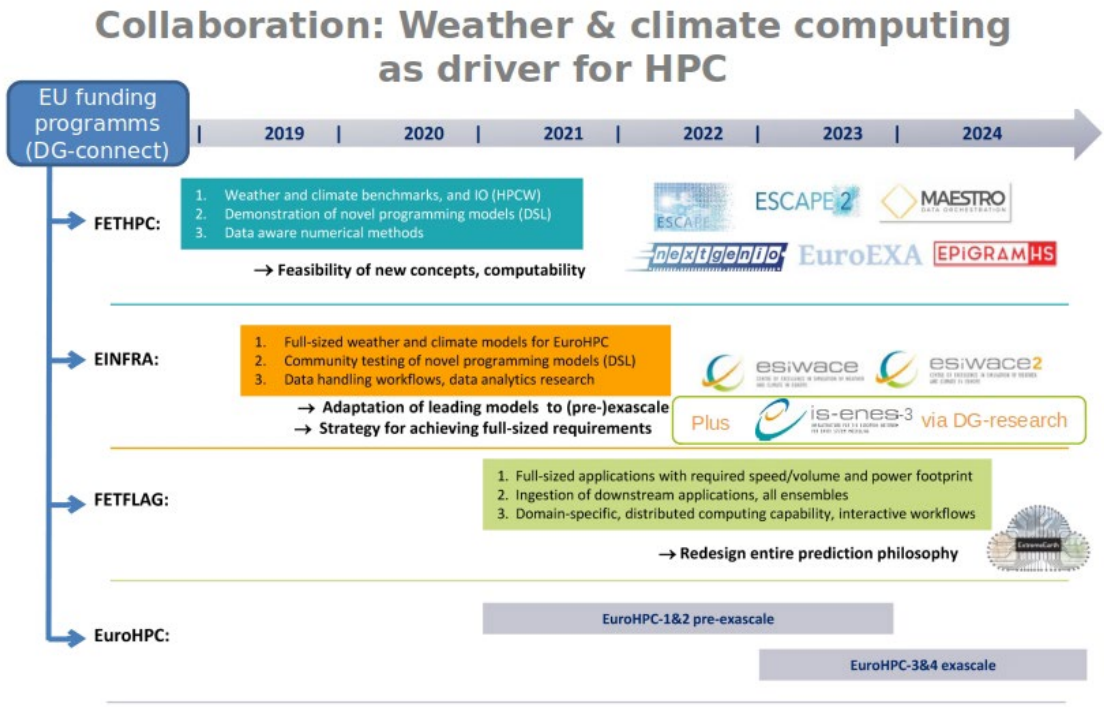


Figure 4: Collaborations of HPC weather and climate projects funded by the EC [Source: Joachim Biercamp, ESIWACE CoE meeting, Dec 2018].

Chapter 4 : Analysis of ASEAN HPC capabilities, related research infrastructures & domain expertise

As mentioned in the **Chapter 1.D** while reviewing the methodological method, a **relatively detailed online survey**[51] was prepared in order to gain a deeper insight in past, current and planned computing requirements, governance expectations and application area expertise within the representative countries and divisions of the ASEAN countries.

18 answers were collected from the online survey and permitted to cover inputs from 8 AMS. In addition, online and face to face meetings were organised to support and validate the accuracy of the collected answers to ensure a fair and representative situation is reported. As depicted in Figure **5**, in terms of working segment, the profile of the contacted organization clearly tends toward research (76,9%) and/or academic (53,8%) centers , most of them being state-funded organizations (61,5%).

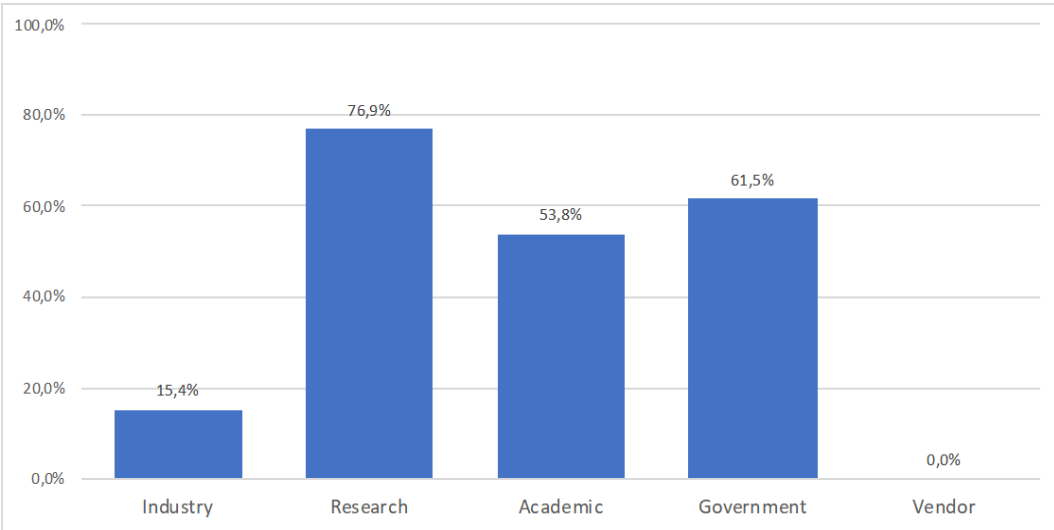


Figure 5: Working segment of the consulted ASEAN organizations

Also, a majority of the collected answers comes from HPC/Research computing Centre operating a local Tier-2 HPC facility as can be seen in the Figure **6**.

The domain fields represented in the interviewed organization accelerated by their HPC facility or aimed for HPC-based developments are displayed in the Figure **7**. As can be seen, this list reveals a wide set of expertise represented within the AMS, with (like in Europe) a clear emphasis on Machine learning and big data analytics.

[51] See Appendix B

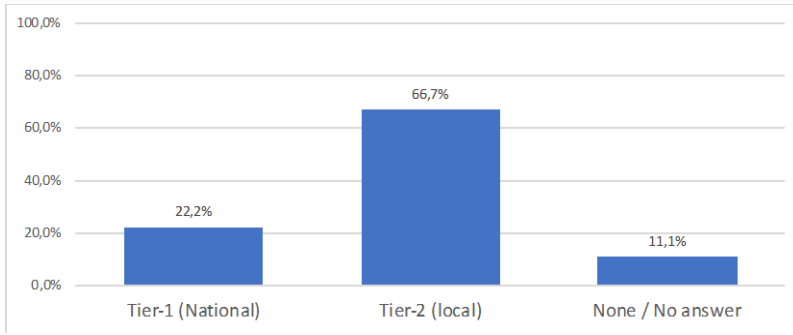


Figure 6: Type of HPC/Research computing centre represented in the collected answers

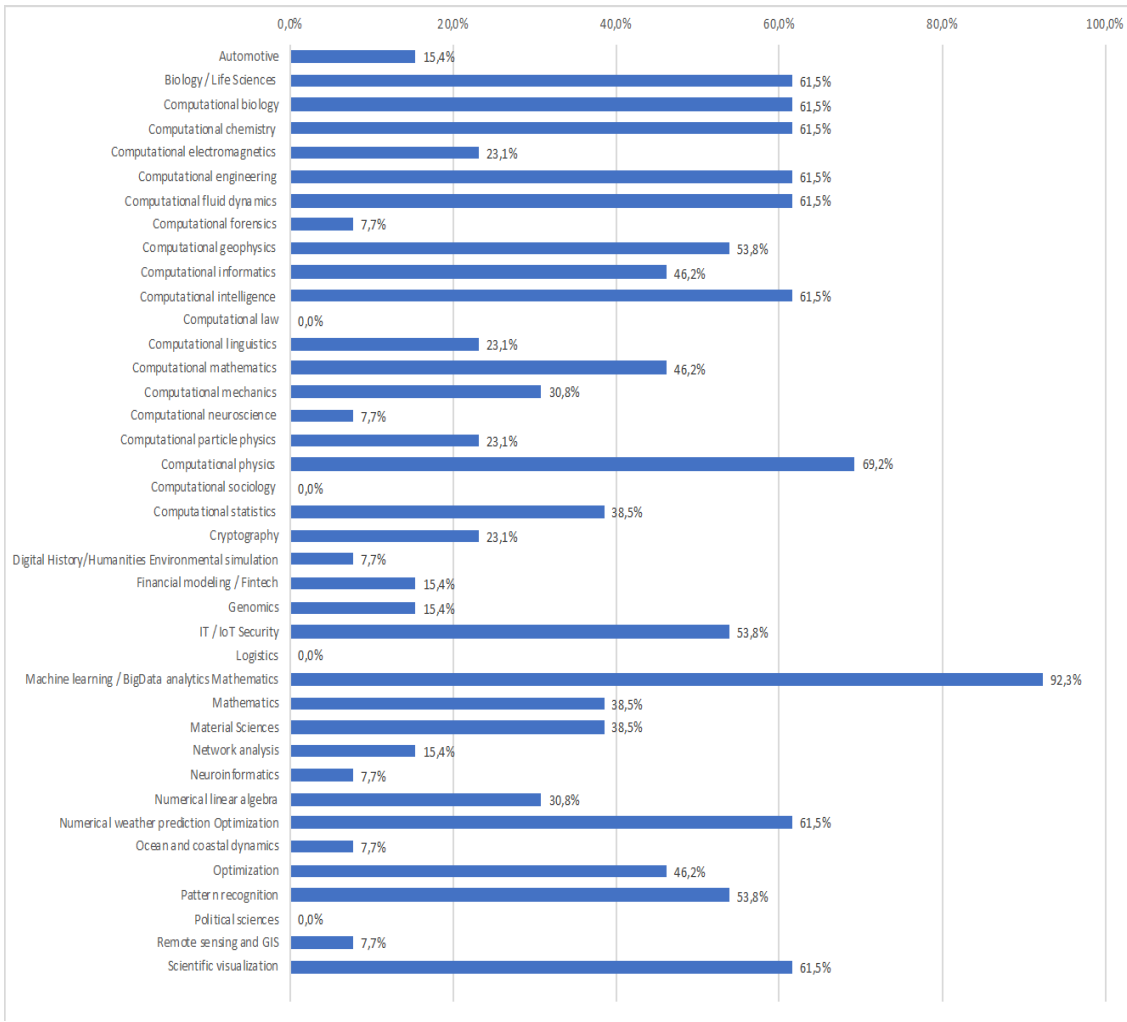


Figure 7: Domain fields accelerated by the local HPC facility or aimed for HPC-based developments within the interviewed organization

More interesting, the situation of the majority of the HPC user community within the ASEAN institutes is summarised in the Figure **8**.

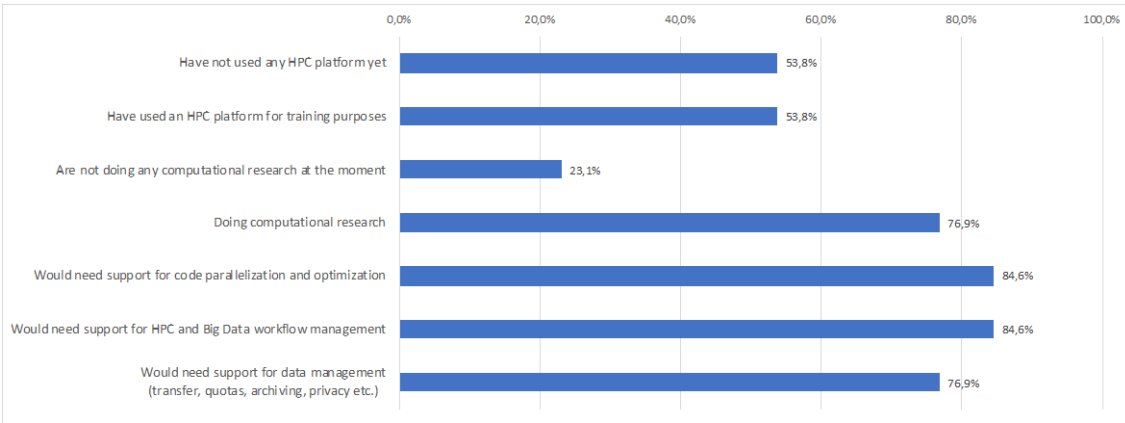


Figure 8: Situation of the majority of the HPC user community within the interviewed ASEAN organisations

As can be seen, and this should drive also the collaboration with EU centres, the majority of the ASEAN HPC users:

- Are doing computational research (76,9%)
- Would need support for code parallelization and optimization (84,6%)
- Would need support for HPC and Big Data workflow management (84,6%)
- Would need support for data management (transfer, quotas, archiving, privacy etc.) (76,9%)

The next sections detail for each AMS (listed in alphabetical order) the identified HPC capabilities, related research infrastructures and domain expertise that came out to consolidate the in-depth study of ASEAN HPC capacity and policy mapping study.

A. Brunei Darussalam, the Nation of

HPC in Brunei is mainly represented within the ASEAN HPC Task Force by the Institute of Applied Data Analytics (IADA)[52], a research center under the Universiti Brunei Darussalam (UBD), which received its primary funding from Brunei Government and reports to the Ministry of Education. This centre is specialised to the delivery of computing services in a specific application domain, i.e. Weather and Climate Modeling, Flood forecasting & Wind Energy (from past projects). To that end, **IADA** has a separate HPC facility from the main UBD Campus-wide Computing Facility. The characteristics of this facility are presented in the Table **5**.

Table 5: Characteristics of the surveyed HPC Facilities in Brunei Darussalama

Brunei Darussalama	IADA (2010-)
HPC Facility Category	**Tier-2 (local)** Tier-1 desired if Brunei government policy
Total Computing Capacity	**14 TFlops**
#nodes	1024 nodes
Processor architecture	POWER (**BlueGene/P**) (PowerPC 450 @ 850MHz)
Accelerators	None
Storage capacity [TB]	56 (+180TB on Tape archives)
Storage Filesystem(s)	GPFS/SpectrumScale
Interconnect	10G Ethernet
Network Topology	Torus
RJMS	Bluegene Navigator
Node Provisioning	IBM Platform HPC
Main Operating System	n/a
User Software Environment	IBM Fortran and C compilers for Bluegene
Core HPC Management Team [FTE]	n/a
Regional Network Connectivity to EU	n/a Currently not connected to the TEIN Network.
Server room Power and Cooling capacity [kW]	40

Domain expertise tied to HPC in IADA is mainly targeted toward Weather and Climate modelling but covers of course other fields accelerated by the local HPC facility or aimed for HPC-based development, as summarized in the below Table **6**.

Table 6: Contact list and domain expertise for the main HPC-related institute in Brunei Darussalama

Brunei Darussalama

[52] https://expert.ubd.edu.bn/iada

Institute of Applied Data Analytics (IADA), Universiti Brunei Darussalam (UBD)	Ass. Prof. Abdul Ghani Haji Naim ghani.naim@ubd.edu.bn

- *Website* : **https://expert.ubd.edu.bn/iada**
- *Main HPC-accelerated domain fields expertise*:
  - Environmental simulation (Flood forecasting & Wind Energy),
  - IT / IoT Security
  - Machine learning / BigData analytics
  - Numerical weather prediction / Weather and Climate modelling
  - Pattern recognition and Scientific visualization

B. Cambodia, Kingdom of

Investing in the HPC technologies for most developing countries means a considerable effort to mobilise resources and in laying the groundwork for HPC human capital and network infrastructure development, for industry engagement with HPC, and for public sector use of HPC – all of which can bring about substantial benefits for national strategic goals. One US Office of Science 2016 study that analyses the impact of HPC suggested that HPC-driven solutions returned hundreds of times the revenue per dollar spent and over 40 times the profit. Behind these numbers are he extreme compute and network performance of HPC[53]. For example, when say an HPC has over 9 Terabits-per-second of bandwidth with 130 nano-seconds of latency port-to-port, HPC solutions easily transforms complex workloads into competitive advantages. Many smaller developing countries such as Cambodia, Laos and other AMSs are exploring to define their scientific and business needs, problem areas and their demanding compute workloads, and overall IT solution requirements in their journey to select a high-performance cluster options. HPC power on the order of tens-of-thousands of cores interconnected via high-performance network and working together with other HPCs might be the most useful outcome to provide scientific and business solutions to agricultural, environmental, economic and other problems facing the country.

While continuing to research and develop HPC technology and human resources, Cambodia's journey toward HPC acquisition appears to be focused on building the communication network called Cambodia Research Education Network (CamREN) which was established I 2012 under the Ministry of Education, Youth and Sport (MoEYS). The Institute of Technology of Cambodia (ITC) has been selected as the hub centre of CamREN (and most likely institute to host HPC). CamREN now has more then 40 institutional members with link capacit of 100mbps for data centre and 25 mbps for members. The network facilitates more 20 online courses and has increasing other educational resources such as e-library, research resources, video conferencing and others. CamREN is connected to TEIN-3 through VinaREN (Vietnam) to HUB network in Hong Kong (45 mbps), to ThaiREN (400 mbps), HUB link to Singapore. Moving forward, CamREN has been developing a Roadmap as outline in Table **7** below.

Table 7: Cambodia's CamREN Roadmap (2012 to beyond 2020)

Cambodia/Khmer	
Timeline	**Activities**

[53] https://www.energy.gov/science/office-science

2012 – 2015: Activate Services & Members	• Review on initiative members • Review on NOC and priority services • Decision maker meeting • Workshop / training for operational team
2016-2019: Expand Member	• Connect data Centre to research Centre members • Provide common services to members • Capacity Building (leadership & developer) in advanced level • Assist e-learning operations, techniques, and online development
2020 – Beyond: Further Development of HUB and Gateway for HEI's	• Update Link Capacity locally and Internationally • Provide more services on educational and research areas • Increase CamREN's members widely • Test the sustainable model for CamREN

C. Indonesia, Republic of

The last five years has been an exciting period as Indonesia is experiencing a growth in the use of HPCs to tackle big challenges in fields such as climate and atmospheric modelling including intensive use of satellite data, geoscience, material science, bio-informatics, molecular dynamics, material modelling, machine learning, cryptography, computational fluid, radiation simulation and others. In two key institutions have concrete plans for new HPC acquisitions. As indications suggest that the National Planning Agency, the Ministry of Environment and Forestry as well as the Ministry of the Higher Education have approved the acquisition of new HPC facilities as part of the national strategy to accelerate scientific discoveries in two areas namely climate, meteorology and biophysics related fields (Meteorological, Climatetology & Geophysical Agency (English translation) - **BMKG**) as well as for greater innovation in bio-informatics and molecular dynamics related fields (Research Centre for Informatics, Indonesian Institute of Science - **P2I-LIPI**). In this brief review, the cases for more intensive use of HPCs by two other institutions is also reported, namely by the National Institute for Aeronautics and Space Research (**LAPAN**) in the domain fields of climate modelling and more advance techniques in using remote sensing or Earth observations (including atmospheric data use for early disaster warning), in aviation or specifically aircraft aerodynamics simulation, in micro satellite and rocket technology designs and by Research Centre for Oceanography, Institute of Science (**P2O-LIPI**) in the domains of ocean dynamics and coastal environmental simulation, climate and numerical weather modelling, scientific visualisation and other related fields.

The collected information reflecting the characteristics of the existing HPC Facilities in Indonesia are proposed in the Table **8**.

Table 8: Characteristics of the surveyed HPC Facilities in Indonesia.

Indonesia	BMKG (2019-)	P2I/LIPI (2019-)*	LAPAN Bandung (2019)*
HPC Facility Category	**Tier-2 (local)** No Tier-1 desired	**Tier-2 (local)** No Tier-1 desired	**Tier-2 (local)**
Total Computing Capacity	**15 TFlops** Acquisition in 2019-20 for	**n/a**	**n/a**

	1.2 Pflops for operational and 100 Tflops for research		
#nodes	92 (2506 cores)	100 (2864 cores)	38 (2432 cores)
Processor architecture	x86_64 (AMD, intel)	x86_64 (intel)	X86_64 (AMD)
Accelerators	None	10 NVIDIA Tesla P100 16 Nvidia Tesla M2075	None
Storage capacity [TB]	750	3752	800
Storage Filesystem(s)	NFS, [Scale-out] NAS (OneFS)	NFS, Lustre, HDFS	n/a
Interconnect	Infiniband (IB) QDR, 1G Ethernet, 10G Ethernet	Infiniband (IB) QDR, 10G Ethernet, 40G Ethernet	Mellanox Infiniband QDR (40Gbps)
Network Topology	Fat-Tree/Clos Network, Random, Mesh	Fat-Tree/Clos Network	n/a
RJMS	Slurm	Slurm, PBS Pro	n/a
Node Provisioning			
Main Operating System	n/a	Rocks Cluster	n/a
User Software Environment	FOSS (Free and Open Source Software): GNU Compiler Collection, LLVM Clang, etc., Intel Parallel Studio XE, PGI compilers and tools	FOSS, GNU Compiler Collection, LLVM Clang	FOSS, GNU Compiler Collection, LLVM Clang, etc. Intel Parallel Studio XE
Core HPC Management Team [FTE]	2	5	n/a
Regional Network Connectivity to EU	n/a	n/a	n/a
Server room Power and Cooling capacity [kW]	n/a	100 kW	n/a

Domain expertise tied to HPC and data analytics in Indonesia is widespread. The below Table **9** lists for each identified centres (including contact details) domain fields in process of being accelerated by the introduction of an added HPC facility within 1-2 year or aimed for HPC-based developments in the next 3-5 years.

Table 9: Contact list and domain expertise for the main institutes in Indonesia identified as dependent on HPC facilities

Indonesia	
Meteorological, Climatetology & Geophysical Agency (BMKG)	Dr. Dwikorita Karnawati dwiko@bmkg.go.id

• *Website* : **http://www.bmkg.go.id/?lang=EN**
• *Main HPC-accelerated domain fields expertise*
  ○ Numerical weather prediction
  ○ Climate modelling	

Research Centre for Informatics, Institute of Sciences (P2I-LIPI)	Dr. Rifki Sadikin MKom, Head of HPC Lab Rifki.sadikin@lipi.go.id

• *Website* : **http://grid.lipi.go.id/**
• *Main HPC-accelerated domain fields expertise*:
  ○ Bio-informatics
  ○ Climate modelling & weather prediction	

- Computational Fluid and Molecular Dynamics
- Cryptography
- Material Sciences
- Machine Learning
- Radiation Simulation

National Institute for Aeronautics and Space Research (LAPAN)	Mr. Chusnul Tri Judianto, Head of ICT Centre/Division chusnul.tri@lapan.go.id

- *Website* : **http://www.psta.lapan.go.id**
- *Main HPC-accelerated domain fields expertise*:
  - Computational chemistry, engineering, fluid dynamics, particle physics and geophysics
  - Satellite payload analysis
  - Remote sensing
  - Speech and Object Identification

Research Centre for Oceanography, Institute of Science (P2O-LIPI)	Dr. Dirhamsyah M.A. dirhamsyah@lipi.go.id

- *Website* : **http://www.oceanografi.lipi.go.id**
- *Main HPC-accelerated domain fields expertise*:
  - Numerical weather prediction
  - Climate modelling

In what follows, the specificities, HPC capacities, expectations, and needs of these institutes are investigated as well as their ecosystems (existing Research Infrastructures, national platform strategy, available knowledge and skills and regional common interest.

- **Meteorological, Climatetology & Geophysical Agency (BMKG)[54]:** Initially established by the Dutch East Indies government in 1841, the organisation has evolved to become a premier Indonesian non-departmental government agency for the three domain areas of meteorology, climatology and geophysics. Since 1986 the BMKG, has run a Tropical Cyclone Warning Centre (TCWC) within their headquarters in Jakarta. At the start of the 2010-11 season, TCWC Jakarta's area of responsibility was then extended out to include the region from the Equator to 10°S between 125°E and 141°E. Given the diverse field coverage expected from BMKG and with the motto of providing "safe and fast service" with broad coverage in the world's largest archipelagic country, the BMKG has considerable demands on its ICT infrastructure for production operational and research works that relate to the wide scope of work above. Further, specifically with respect to climate, earthquake and tsunami warning requirements, the current system which can deal with tsunami in 2 minutes needs to be improved to 1 minute respond from sensor signals. Hence, currently BMKG is planning the procurement of a peta-scale HPC so that they can speed up their earthquake and tsunami response.

- **Research Centre for Informatics, Institute of Sciences (RCI/P2I-LIPI):** The RCI was established in June 5, 2001 and previously called the Center for Research and Development of Informatics and Computer Science which was established on January 13, 1986. The RCI consists of three Research and Development Centres (1. Telecommunications, Strategic Electronics, Components and Materials (Research Center for Telkom-LIPI); 2. Informatics and Computer Science (Inkom LIPI Research Center); 3. Electricity and Mechatronics (Puslitbang Telimek-LIPI)) and one Technical Implementation Unit (TIU), known as the Center for National Engineering Laboratory (UPT Center LEN

[54] http://www.bmkg.go.id/?lang=EN

LIPI). As it will be detailed in the **Chapter 5.A.2**, RCI features some of the Monitoring Agents using a Large Integrated Service Infrastructure (MonALISA)[55] nodes involved on the Grid analysis system of the ALICE (A Large Ion Collider Experiment) project, currently being built at CERN, Geneva (Switzerland))[56]. Part of European Data Grid, this is the main existing collaboration within RCI with an EU institution and one rack is dedicated for this activity.
HPC Second-generation outreach of P2I-LIPI services including Machine Learning and Deep Learning as well as other routine activities. Since 2015, RCI has been conducting annual Regional School of HPC (RSHPC). This workshop is aimed at increasing HPC use by all researchers within the overarching Institute of Sciences (LIPI) involving academics, students as well as other interested parties with national and international expert speakers.

Dissemination of all HPC research output is also one mission of RCI, using Universal Data Logger[57] as well as facilitating scientific and professional visits to disseminate the results of all research activities. In December 2019, the RCI has obtained the Government approval to start a tender process to supply new investment for a Petascale HPC asset to be commissioned in 2020 to focus on Bio-Informatics and Medical related use complete with a new building. However, the RCI management stated that the success of this exciting new procurement will depend upon their HPC human capital development as well as increasing academic and public sector use of HPC and industry engagement with their new HPC.

- **National Institute for Aeronautics and Space Research (LAPAN):** LAPAN is a non-ministry Indonesian Government institution active in the field of aerospace research and development and its utilisation. It was established in 1963 with four main areas of focus namely remote sensing, aerospace technology, space science, and aerospace policy. The enormous range of LAPAN activities is distributed among three subdivisions (Aviation Technology, Remote Sensing and Space & Aerospace Science) in addition to the Agency's Secretariat. Since 2015, the Center for Aeronautics and Information Technology and Standards (PUSTISPAN) was separated from the Secretariat's HRD and External Relations Bureau. It became an independent center that has the authority to carry out technology development and IT services throughout LAPAN. In 2017, PUSTISPAN was renamed the Center for Aviation Information and Communication Technology and Antariksa (PUSTIKPAN) with the responsibility supporting the LAPAN R&D facilities in 23 different locations throughout Indonesia. It runs a Data Center with two Disaster Recovery Centres (DRC) but the ***HPC is run by LAPAN's Bandung Space Center*** which is the office of the Deputy of Space and Aerospace Sciences LAPAN, consisting of the Space Science Center and the Center for Atmospheric Science and Technology. The Director of PUSTIKPAN however, admits that HPC facilities in Bandung is due for a refresh to improve its climate and atmospheric modelling (that has been using both growing satellite and drone data), and improve Aviation and Aircraft aerodynamics simulation, Atmospheric data for early disaster warning, Micro satellite and rocket technology.

  In addition, the aeronautics design activities are due for an upgrade and new HPC tool and HRD training are part of LAPAN's top priorities.

- **Research Centre for Oceanography, Institute of Sciences (RCO/RCI-LIPI).** The Research Center of Oceanographic began in 1905 when the Colonial Government of Dutch Indies established the Fish Station (Visscherij Station) was established in the central fish market (Pasar Ikan) of Batavia (now Jakarta). From this early beginning this institution was established the aim of conducting

[55] http://alimonitor.cern.ch/map.jsp
[56] https://home.cern/
[57] http://unidalog.informatika.lipi.go.id/

marine research to explore the marine resources of important economic value still stays with the institution. In the course of time, the institution has changed its name several times and fast forward to 2001, it became part of the Institute of Sciences (LIPI) and it became known as the Research Center for Oceanology (P2O-LIPI) under the auspices of LIPI's Deputy of Earth Sciences. Briefly, the scope of its research work covers the following:

- Research Collaboration: The RCO has been opened to establish maritime research cooperation with other agencies, both within the country and from abroad. Cooperation is stated in the form of MOU (Memorandum of Understanding) or other cooperation agreements.
- Laboratory Services to Stakeholders, both individuals, private companies, government institutions, educational institutions and others cover the fields of physics, chemistry, biology and marine geology.
- Special online and physical library services (online catalog menu) with collections about marine science, you can see the collections that we have through the.
- Providing apprenticeship and internship opportunities for final year graduates and post-graduates in laboratories or different fields within the Research Center.

  Conceptualise and manage strategic climate and environmental projects. One outstanding example is the Coral Reef Rehabilitation and Management Program-Coral Triangle Initiative (COREMAP-CTI)[58], which aims in general to strengthen the capacity of institutions in conserving and managing coral reef ecosystems and its resources. It also aims to empower coastal communities to sustainably manage their coral reefs and associated ecosystems, and through such efforts, enhance the welfare of these communities. The principal physical objects focus has been on conserving and enhancing the development of coral reefs, mangrove and seagrass. Note that RCO/P2O-LIPI is the "data guardian" of 2 key objects of interest (coral reefs and seagrass) while BIG has a coordination role for the data use, while the Ministry of Maritime and Fishery (KKPM) might be the "data guardian" for mangrove eco-system and BIG appears to play a coordinating role – the nature of these relationships relating to key data stewardship and the tremendous HPC opportunities therein, warrants further investigation.[59]

E. Lao PDR

In Lao PDR, the Technology Computer and Electronic Institute (TCEI)[60] depending on the Ministry of Science and Technology is mandated to handle issues related to HPC, which is a relatively new priority for the country, in particular to seek for technology to work in the area of weather forecast, water management and artificial intelligence. **TCEI has currently no HPC facility but is mandated to facilitate and**

[58] The COREMAP-CTI project is sponsored by the Government of Indonesia (i.e. Directorate General of Marine, Coastal, Small Island of Ministry of Marine Affairs and Fisheries (DGMCSI/MMAF). The project has been supported by Ministry of Fishery and Marine Affairs (KKP.go.id), Ministry of Agriculture & Land Administration (BPN), Ministry of Tourism (KEMENPAR), Police-Water and Air Division (KORPOLAIRUD), Ministry of Justice (KEJAKSAAN) and the Geospatial Information Agency (BIG). Some of the others are: The Asian Development Bank (ADB), United States Agency for International Development (USAID-Asia), US Department of Commerce- National Oceanic and Atmospheric Administration (NOAA), Coral Triangle Support Partnership (CTSP), The Nature Conservancy (TNC), Conservation International (CI), World Wildlife Fund (WWF), WorldFish (WF), Wetland International (WI), Coral Triangle Atlas (CTA), Mangrove Research and Development Centres (LPPM-IPB-Bogor) and various research and community support centres (LPPM) at various universities

[59] http://www.beritasatu.com/iptek/348768-lipi-jadi-wali-data-ekosistem-terumbu-karang-dan-padang-lamun.html

[60] http://tcei.most.gov.la and https://www.most.gov.la/

coordinate access to HPC facilities for other research agencies. Contact details are proposed in the below Table **10**.

Table 10: Contact list and domain expertise for the projected HPC-related institute in Lao PDR

Lao PDR	
Technology Computer and Electronic (TCEI)	Saysongkham Phanouvong sphanouvong@gmail.com

- *Website* : **http://tcei.most.gov.la**
- **No HPC facility yet**
- *Main HPC domain fields foreseen*:
  - Environmental simulation
  - Machine learning / BigData analytics
  - Numerical weather prediction / Water resource simulations
  - Optimization

Domain expertise tied to HPC in which TCEI wish to focus on corresponds to Early warning system and Water Management, which are the keys priority area that the LAO PDR's government focus on in its National Scio-Economic Development Plan.

F. Malaysia, Federation of

HPC development in Malaysia was closely linked with the development of the National Grid Computing Initiative (GGCI) which started in 2006. It was initially targeted to be a shared distributed computing resources (SDCR) deployed at several locations throughout the country with a similar facility to be run by a Grid Operations Centre and all sites are connected via Malaysian Research & Education Network (MYREN). However, it eventually emerged more as an access to HPC services rather than a truly SDCR as it focused on Grid application users with nearly no access for Grid core technology developers.[61] It was further claimed that: "*EUAsiaGrid has contributed greatly towards the next phase of Grid development and in particular gave Malaysian scientists and institutions a better understanding of a truly SDCR, and emphasise the importance of federated certificates with certificate issuance to users that must be adhered to*". In 2007, **MIMOS Berhad** (or incorporated) *i.e.* Malaysia's national applied research and development centre under the purview of the Ministry of Science, Technology and Innovation (MOSTI). The company was founded as the Malaysian Institute of Microelectronic Systems in 1985 with the aim of pioneeing innovative and communication technologies for commercialisation aimed at growing globally competitive indignenous industries. Its research, development and commercialisation focuses on nine technology clusters namely Advanced Informatics, Advanced Information Security, Advanced Analysis and Modelling, Green Technology, Grid Computing, Knowledge Technology, Micro Systems & MEMS, Nano Electronics and Wireless Communications. MIMOS Berhad has been established as a key enabler of national wealth by spearheading globally competitive technology and adopted the role of a facilitator, allowing virtual researchers access to technology resources beyond their individual buying capacity. Hence, an investment was made in creating a world-class, low risk HPC infrastructure with resources spanning from the MIMOS Technology Park, to Kulim High Tech Park to various local Malaysian universities. The resulting grid of close to 1,000 cores or high-performance CPUs, collectively called **KnowledgeGrid Malaysia (KGrid)**, is designed to deliver reliable, cost-effective supercomputing power to scientists and research teams from local and global universities and organisations, in a bid to assist them in addressing some of the toughest, most pressing societal and technological challenges. It is further claimed that: "NGCI is now able to contribute and share computing resources with partners with a federated certificate authority (Academia Sinica Grid Computing *Certification Authority*-ASGCCA), and work has begun to establish a Malaysia certificate authority. **NGCI will follow closely EGI especially on middleware**[62] and promote trust and encourage sharing for example by implementing VOMS or GridShib Digital Certificates and developing policies for harmonisation of Raw and Clean Data computing from various disciplines." (p. 19). Furthermore, Kgrid covers various key research areas such as AgriGRID for precision farming, BioGRID (Dbrain) for dementia studies, VLSI GRD for integrated circuit design (FRGA) for green motion controller and AutomotiveGRID for full efficient concepts in automobiles.

[61] Francois Grey and Simon C. Lin "Malaysia" in Simon C. Lin and Eric Yen (ed.) "Data Driven e-Science: Use Cases and Successful Applications of Distributed Computing", Proceedings of Asia Federation Report on International Symposium on Grid Computing (ISGC), Springer, Kuala Lumpur, 2011, p. 18. This book compiles procedures from ISGC 2010, The International Symposium on Grid Computing that was held at Academia Sinica, Taipei, Taiwan, March, 2010. The 2010 symposium brought together prestigious scientists and engineers worldwide to exchange ideas, present challenges/solutions and to discuss new topics in the field of Grid Computing.

[62] The EGI Foundation (also known as EGI.eu) coordinates the EGI infrastructure on behalf of the participants of the EGI Council: national e-infrastructures and European Intergovernmental Research Organisations (EIROs). https://www.egi.eu/about/egi-council/

In practice, the main institutes tied to HPC in Malaysia are the Universiti Putra Malaysia (UPM), the Universiti Teknologi Malaysia (UTM) and the Perdana University (PU).

- Universiti Putra Malaysia (UPM), formerly known as Universiti Pertanian Malaysia was founded in 1971 through the merger of Faculty of Agriculture, University Malaya and Agriculture College in Serdang. The first three founder faculties were Faculty of Agriculture, Faculty of Forestry and Faculty of Veterinary Medicine and Animal Science. It has more than 12000 students and the focus on research is very high.
- Universiti Teknologi Malaysia (UTM) HPC was established to create public computing grid to cater to projects that can benefit all stakeholders especially Malaysian and UTM students. The infrastructure is used to facilitate the familiarisation and deployment of GRID best practise and to "take lead in activities aimed to ensure high percentage of use, acculturation and awareness".[63] UTM claims a global network through MOUs with partners in Algeria (University of Bejaia-HPC Project-Software: abinit), Indonesia (Univ. Syah Kuala, Aceh and Institut Teknologi Sepuluh November) and Malaysia (MY HPC Project with Universiti Teknologi Pahang, Proton Automotive, Universiti Tun Hussein Onn Malaysia (UTHM) and Universiti Teknikal Malaysia Melaka).

Other institutes are reporting HPC activities in Malaysia. For instance:

- Universiti Sains Malaysia (USM) was established as the second university in the country in 1969. It claims to be a pioneering, transdisciplinary research intensive university and offers courses ranging from Natural Sciences, Applied Sciences, Medical and Health Sciences, Pharmaceutical Sciences to Building Science and Technology, Social Sciences, Humanities, and Education. In 2007, USM was recognised by the Ministry of Higher Education Malaysia (MOHE) as a Research Intensive University. Some of the key activities tied to HPC performed within USM in line with the E-READI HPC Project are: EU-Asia Grid Resource Contributor, National Academic Grid Resource Contributor and PRAGMA Member. Within its organisation, USM has an extensive HPC training programme involving HDFS, MapReduce, Cassandra, Hive Parallel and Distributed Processing, R programming once per semester or twice per year.
- The Medical Molecular Biology Institute (MMBI) at the Universiti Kebangsaan Malaysia (UKM) offers the use of HPC technology focuses on analysis of "big data" connected with the Malaysian Cohort project and various multi-omics projects being conducted in MMBI to focus on the application of Next Generation Sequencing (NGS) technologies that produces large volumes of genomics data every year at lower cost. This ever-growing volume of big data allows more and more new functional genes and variants being discovered at a fast pace.

In general, Malaysian researchers have for a long time recognized the importance of HPCs and Grid computing. Examples of HPC configurations within Malaysian universities are seen in Table **11** below.

[63] https://hpc.utm.my/index.php/2015/05/18/about-myutm-hpc/

Table 11: Characteristics of the surveyed HPC Facilities in Malaysia

Malaysia	INSPEM (UPM)	UMBI-HPC (UKM)	UTM-HPC
HPC Facility Category	**Tier-2 (local)**	**Tier-2 (local)**	**Tier-2 (local)**
Total Computing Capacity	**n/a**	**n/a**	**67,8 GFlops**
#nodes	40 nodes	30 nodes (1500 cores)	25 nodes (264 cores)
Processor architecture	x86_64 (intel)	x86_64 (intel)	x86_64 (intel, AMD)
Accelerators	None	Intel Xeon Phi (KNL)	None
Storage capacity [TB]	50	~1 PB	51
Storage Filesystem(s)	Lustre, NFS	n/a	n/a
Interconnect	IB EDR and 1GbE	IB FDR, 10GbE	IB, Myrinet
Network Topology	Star	n/a	n/a
RJMS	Torque / Moab	Slurm	PBS
Node Provisioning	xCat (Extreme Cloud Administration Toolkit)	OpenHPC/Warewulf	n/a
Main Operating System	n/a	CentOS 7.3	n/a
User Software Environment	FOSS (Free and Open Source Software): GNU Compiler Collection, LLVM Clang, etc. provided by Environment Module	FOSS (Free and Open Source Software): GNU Compiler Collection, LLVM Clang, etc. provided by Environment Module	FOSS (Free and Open Source Software).
Core HPC Management Team [FTE]	n/a	n/a	n/a
Regional Network Connectivity to EU	UPM and UTM are connected to the TEIN Network via MYREN (shared bandwidth)	n/a	UPM and UTM are connected to the TEIN Network via MYREN (shared bandwidth)
Server room Power and Cooling capacity [kW]	n/a	n/a	n/a

Contact details are proposed in the below Table **12**.

Table 12: Contact list and domain expertise for the main institutes in Malaysia identified as dependent on HPC facilities

Malaysia	
Universiti Putra Malaysia (UPM) **Institute for Mathematical Research**	Suhaimi Napis suhaimi@upm.my
• *Website* : **https://inspem.upm.edu.my/perkhidmatan/pengkomputeran_berprestasi_tinggi_hpc-10139?L=en** • *Main HPC-accelerated domain fields expertise*: ○ Computational statistics and Data science ○ Computational Fluid Dynamics, Molecular dynamics ○ Bioinformatics ○ Computational Chemistry & Computational Physics	
Universiti Kebangsaan Malaysia (UKM) **UKM Molecular Biology Institute (UMBI)**	Professor Datuk Dr. A. Rahman A. Jamal rahmanj@ppukm.ukm.edu.my
• *Website* : **http://www.ukm.my/umbi/news/high-performance-computing-hpc-umbi-providing-researchers-computing-power-big-data-analytics/** • *Main HPC-accelerated domain fields expertise*: ○ System Bio-medicine ○ Next Generation Sequencing	
Universiti Kebangsaan Malaysia (UTM) **Centre for Information and Communication Technology (CICT)**	Aslinda Binti Mohamed Aris aslinda@utm.my
• *Website* : **http://hpc.utm.my/** • *Main HPC-accelerated domain fields expertise*: ○ Computational Fluid Dynamics, Molecular dynamics ○ Mathematics, statistical computing	

Note: The Ministry of Energy, Science & Technology, Climate Change is still awaiting instructions from the government on further update on Malaysia's strategy regarding HPCs. At the time of writing this report, and the best of our knowledge, no official mandate has been delivered to take this strategy forward.

G. Myanmar, Republic of the Union of

In 1971, Universities' Computer Center (UCC) was funded to provide computer training to Universities and Government employees. In 1988, it was established as an Institute of Computer Science and Technology (ICST) and the Institute was changed to the University of Computer Studies, Yangon (UCSY) on 1st July 1998.

The University of Computer Studies, Yangon (UCSY) is leading institution in Myanmar under the Ministry of Education. UCSY is to conduct teaching and research in various branches of computer science, computer technology, and information technology. To meet the growing need for general and advanced computer education in Myanmar, the university currently offers both undergraduate and postgraduate degrees. UCSY is the Hub University of Myanmar Research & Education Network (mmREN) and it connected to Trans Eurasia Information Network (TEIN) in 2018.

UCSY is structured with 4 faculties:

- Faculty of Computer Systems and Technologies
- Faculty of Computer Science

- Faculty of Information Science
- Faculty of Computing

3 departments:

- Department of Language
- Department of Natural Science
- Department of Information Technology Supporting and Maintenance

Universities' Computer Center (UIT) was funded in 1971 to provide computer training to Universities and government employees. It depends on the Yangon University which itself depends on the country's Ministry of Education. It changed into the Institute of Computer Science and Technology (ICST) in 1988 to finally become on 1st July, 1998 , the University of Computer Studies, Yangon (UCSY). Separately established on 3rd December,2012, as the Center of Excellence, it was officially renamed as the University of Information Technology (UIT) since 1st April, 2015. It features 5 faculties, and there are seven research laboratories under each Faculty, for instance (among others):

- Data Center for Cloud Computing Lab,
- Human Computer Interaction and Natural Language Processing Lab
- Software Systems Development Lab
- Mobile and Wireless Systems Development Lab
- Software Testing Lab
- Micro controller and Embedded Systems Lab
- Digital Systems Design Lab
- Networking and Network Security Lab
- Physics Lab

Contact information are provided in the below Table **13**.

Table 13: Contact list and domain expertise for the projected HPC-related institute in Myanmar

Myanmar	
University of Information Technology (UIT)	Mie Mie Thet Thwin miemiethetthwin@ucsy.edu.mm
• *Website* : http://www.uit.edu.mm/	

UIT provides a bachelor program dedicated to High Performance Computing (HPC)[64]. However, no information could be collected on the potential HPC facility in place (if any).

H. Philippines, Republic of

Established in 1987 by virtue of Executive Order No. 128, the Advanced Science and Technology Institute (ASTI)[65] is an agency of the Department of Science and Technology (DOST) mandated to undertake research and development activities in the advanced fields of information and communication technology and electronics. Since the 1990s, the DOST-ASTI has undertaken numerous projects in network technologies and High Performance Computing, including pioneering efforts in open source software, IPv6, VoIP, establishing a local Internet exchange and a globally-connected research and education network. ASTI-developed products ranging from

[64] http://www.uit.edu.mm/HPC.html
[65] https://asti.dost.gov.ph/

electronic data acquisition, embedded and enterprise software, biomedical devices and environmental monitoring systems have been successfully deployed - supporting nationwide initiatives in public health, e-governance, education and disaster risk management - including the underlying nationwide infrastructure of over 1,500 sensors and weather stations for Project Noah. Recently, the DOST-ASTI launched a multi-mission ground control station for multiple satellites, including the Philippines' first microsatellite, Diwata-1.

In all cases, ASTI is the only institution in the country that maintains and offers HPC services for scientific research on a national scale (see the current characteristics in the Table **14**). In practice, these services are powered by PREGINET and PHOpenIX as backbone provider, and COARE.

- PREGINET[66], the country's only Research and Education Network (REN) that interconnects academic, research, and government institutions, and has links to international RENs such as the Asia-Pacific Advanced Network (APAN), the Asian Internet Interconnection Initiatives (AI3), and the Trans-Eurasia Information Network 3 (TEIN3).
- PHOpenIX[67], the only Exchange in the Philippine Internet industry operated by a neutral institution that allows the exchanges of Internet traffic in a free-market environment among local internet and data service providers.
- COARE[68] (Computing and Archiving Research Environment) is the main HPC facility. Its details are proposed in the below
- A cloud service (based on OpenStack) is offered, and recently, a second site has been opened for these services, composed of Compute Node, Block Storage, Object Storage, Network Node.

A third site meant to host a new HPC facility is also scheduled for deployment. The three existing sites are connected by a 10 Gbps.

Table 14: Characteristics of the surveyed HPC Facility in Philippines

Philippines	ASTI COARE (2014-)
HPC Facility Category	**Tier-1 (national)**
Total Computing Capacity	**n/a**
#nodes	n/a nodes (3696 cores)
Processor architecture	x86_64 (intel)
Accelerators	28480 CUDA core NVidia Tesla K80, NVidia Tesla P40
Storage capacity [TB]	2801

[66] Philippine Research, Education and Government Information Network. http://pregi.net/
[67] Philippine Open Internet Exchange. http://phopenix.net/
[68] https://asti.dost.gov.ph/projects/coare/

Storage Filesystem(s)	Lustre, GlusterFS, Nimble, Ceph
Interconnect	n/a
Network Topology	n/a
RJMS	Slurm
Node Provisioning	n/a
Main Operating System	n/a
User Software Environment	n/a
Core HPC Management Team [FTE]	n/a
Regional Network Connectivity to EU	TEIN
Server room Power and Cooling capacity [kW]	n/a

Contact details are proposed in the below Table **15**.

In terms of notable activities tied to HPC performed within ASTI, one can cite the EUAsiaGrid[69] and the UND Project (spearheaded by EGI and Acedemia Sinica).

[69] Towards a common e-Science infrastrcucture for the European and Asian Grids. https://cordis.europa.eu/project/rcn/87303/factsheet/en

Table 15: Contact list and domain expertise for the main institute in Philippines identified as dependent on HPC facilities

Philippines	
Advanced Science and Technology Institute (ASTI)	Peter Antonio M. Banzon peterb@asti.dost.gov.ph

- *Website* : https://asti.dost.gov.ph/
- *Main HPC-accelerated domain fields expertise*:
  - Biology / Life Sciences, in particular rice genomics
  - Computational chemistry, engineering, geophysics and physics
  - Computational statistics and Scientific visualization
  - Environmental simulation
  - Machine learning / BigData analytics
  - Numerical weather prediction

I. Singapore, Republic of

The interest of Singapore toward a national ICT strategy dates back from the 80's and permitted to offer to the country a fast and dense broadband infrastructure enabling for a competitive boost to the economy. Supercomputing was quickly identified as another vital component of the country's ICT strategy.

Setup in 1988, the Advanced Computation Centre (ACC) was Singapore's first supercomputing bureau, offering HPC resources to the researchers belonging to the National University of Singapore (NUS)[70], the Nanyang Technology University (NTU)[71], or within public sector agencies as well as private enterprises.
Facing troubles to attract industry users, the ACC morphed into a new organization called the National Supercomputing Research Center (NSRC) on 1992 where industry collaboration was a key mission. The focus was not only laid to resource sharing but also to training with the setup of a computational science program at NUS and the creation of a computation science department in 1997. Later on (in 1998), the NSRC and the Centre for Computational Mechanics merge to form the Institute of High Performance Computing (IHPC), an applied research lab involving around 120 computational scientists and engineers developing new tools and supercomputing-based solutions in collaboration with organizations including businesses. It was set up jointly by the NUS and the National Science and Technology Board (NSTB), which also provided the funding. Established in 1991 with the primary mission to advance the economy and improve lives by growing the knowledge-intensive biomedical, research, scientific and engineering fields, NSTB is known since 2002 as the Agency for Science, Technology and Research (A*STAR)[72].

In all cases, the intent was for IHPC to centralize all Singapore's supercomputing under one roof. However, while it initially prevented the fragmentation of these resources, this concept faded as the local tertiary institutions and various organisations installed supercomputing systems and commodity HPC clusters as, among other reasons, they became more affordable. For this reason, the **A*STAR Computational Resource Centre (A*CRC)**[73] was created as a supercomputing technical arm to centralise the management of the scattered supercomputing resources for A*STAR research community. Formed by the HPC unit of the IHPC and the system, storage, network and data centre team of one of the Biomedical Research Council (BMRC) research entities (the Bioinformatics Institute BII), A*CRC

[70] http://nus.edu.sg/
[71] https://www.ntu.edu.sg
[72] https://www.a-star.edu.sg
[73] https://www.a-star.edu.sg/acrc

immediately inherited for 10 small HPC clusters, totaling 10 TFlops computing capacity (which was still considered as quite powerful in 2007), and aimed at providing supercomputing services for the numerous A*STAR's research institutions (which account over 20 at that time). It also took care of the organization of several supercomputing conferences, and special bootcamps and HPC-related training (in particular for undergraduates).

A list of the current HPC resources managed by A*CRC can be found on their website[74]. The Table **16** below reflects the current global performances (**around 500 TFlops**) and characteristics of the systems managed by the organisation.
Support within A*CRC is composed by 25 staff members divided into 6 teams:
Operation Team, HPC System Team, HPC Research & Scientific Support Team, Network Team,
Storage and Cloud Service Team and the Service Management Team.

Recognizing that the computational power provided was not enough for Singapore, A*STAR took the lead in 2011 to convince the two universities (NUS and NTU) to co-invest with the government for a shared national facility. The discussions continued and the plans for a national HPC centre progressed over years, leading to the approval and establishment of the **National Supercomputing Centre Singapore (NSCC)**[75] in 2015. Its stackholders are the A*STAR, NTU, NUS and the Singapore University of Technology and Design (SUTD)[76] and its budget over three years was set to S$98 million.

NSCC aims to support the high-performance science and engineering computing needs for academic, research and industry communities in Singapore. The general vision is to democratise access to supercomputing with the ambition to support Singapore's R&D initiatives, attract industrial research collaborations and enhance Singapore's research capabilities. NSCC provides access to the **1 PFlop system** called **A**dvanced **S**upercomputer for **P**etascale **I**nnovation **R**esearch and **E**nterprise (or Aspire 1), unveiled in 2016 and those details are provided in the Table **16**. The facility is linked by high bandwidth multi-gigabit networks to provide high speed access to users everywhere locally (especially to the three universities) or globally. The regional network connectivity is provided by SingAREN (Singapore Advanced Research and Education Network)[77]. Additionnaly, NSCC co-funded with STAR-N International Links to connect Singapore to Established HPC Centres worldwide, but also to Singapore as a Strategic Hub in the region.

[74] https://www.a-star.edu.sg/acrc/Services/High-Performance-Computing-Systems
[75] https://www.nscc.sg
[76] https://www.sutd.edu.sg
[77] https://www.singaren.net.sg

Table 16: Characteristics of the main HPC facilities surveyed in Singapore

Singapore	NSCC Aspire I (2016-)	A*CRC
HPC Facility Category	**Tier-1 (national)**	**Tier-2 (local)**
Total Computing Capacity	**1010 TFlops**	**500 TFlops**
#nodes	1288 nodes (Fujitsu) (31000 cores)	700 nodes (Fujitsu, SGI, IBM)
Processor architecture	x86_64 (intel)	x86_64 and POWER (intel) and PowerPC
Accelerators	128 nodes feat. NVidia Tesla K40, 6 DGX-1 (each with 8 Tesla v100)	None
Storage capacity [TB]	13 PB (I/O bandwidth up to 500GB/s)	2.5 PB
Storage Filesystem(s)	GPFS, Lustre File Systems, NFS	GPFS, Lustre File Systems, NFS, BeeGFS
Interconnect	IB EDR	IB FDR, EDR {1,10,40,100} GbE
Network Topology	Fat Tree	Fat-Tree Torus and Hypercube
RJMS	PBS Pro	Slurm, PBS Pro, Platform LSF
Node Provisioning	Bright Cluster Management	xCat (Extreme Cloud Administration Toolkit) Bright Cluster Management
Main Operating System	n/a	Redhat, CentOS, Scientific Linux
User Software Environment	FOSS (Free and Open Source Software): GNU Compiler Collection, LLVM Clang, etc. Intel Parallel Studio XE All via Environment Module	FOSS (Free and Open Source Software): GNU Compiler Collection, LLVM Clang, etc. Intel Parallel Studio XE All via Environment Module/LMod
Core HPC Management Team [FTE]	5 (Fujitsu) + 10	25
Regional Network Connectivity to EU	TEIN	100 Gb TEIN
Server room Power and Cooling capacity [kW]	400m^2, 1 MW, chilled water rear door heat exchange, dry cooler, CRAC units	250kW

Contact details for the involved HPC institutes in Singapore are proposed in the below Table **17**.

NSCC supercomputer is already almost fully utilized and the next phase of the project (NSCC 2) has been already launched – a dedicated significant budget was announced during the last SCAsia'19 event. Yet the form and final capacity is still under discussions.

Table 17: Contact list and domain expertise for the main institutes in Singapore identified as providing HPC services facilities

Singapore	
National Supercomputing Centre (NSCC)	Prof. Tan Tin Wee tinwee@nscc.sg

• *Website* : https://www.nscc.sg/
• *Main HPC-accelerated domain fields expertise (across NSTDA affiliated research institutes)*:
  ○ Material Sciences, Finite Element analysis, Computational fluid dynamics, Molecular dynamics
  ○ Bioinformatics, Precision Medicine
  ○ Density functional theory
  ○ AI / Data analytics, Natural language processing
  ○ Advanced Manufacturing	

A*STAR Computational Resource Centre (A*CRC)	Tay Kheng Tiong, PhD kttay@acrc.a-star.edu.sg

• *Website* : https://www.a-star.edu.sg/acrc/
• *Main HPC-accelerated domain fields expertise*:
  ○ Biology and Bioinformatics
  ○ Chemistry and Molecular Modeling
  ○ Physics and Material Science
  ○ Mathematical, Statistical and Other Utilities
  ○ Software Development
  ○ Engineering	

Meteorological Service Singapore (MSS) **Centre for Climate Research Singapore (CCRS)**	Prof Erland Källén erland_kallen@nea.gov.sg
• *Website* : https://www.a-star.edu.sg/acrc/ • *Main HPC-accelerated domain fields expertise*: ○ Weather Research and Forecasting (WRF)	

In all cases, Singapore is one of the main leader in supercomputing in the ASEAN region because of its early and sustained development efforts in the domain coupling strong support from agencies with tight links to outstanding research institutes.

As part of the policymakers strategy to make Singapore a technology hub across AMSs, the aim to play a larger role in advancing supercomputing capabilities in the ASEAN region through the project developed within the ASIAN HPC Task Force – see also the Chapter **8**.

J. Thailand, Kingdom of

HPC in Thailand is increasingly more active, driven by new demand on data science, AI, IoT sustained by increased government spending in R&D. In Thailand, the reference centre leading the HPC strategy development is the National Electronics and Computer Technology Center (NECTEC)[78] established in 1986 under the Ministry of Science, Technology and Energy (the former name of Ministry of Science and Technology). On 30 December 1991, following the enactment of the Science and Technology Development Act of 1991, NECTEC was transformed into a national technology center under the National Science and Technology Development Agency (NSTDA), Ministry of Science and Technology. Apart from NECTEC, the following other research institutes are affiliated with NSTDA: the National Center for Genetic Engineering and Biotechnology (BIOTEC)[79], the National Metal and Materials Technology Center (MTEC)[80] and the National Nanotechnology Center (NANOTEC)[81]. At present, NECTEC is a statutory government organization with its main responsibilities of under taking, supporting and promoting the research and development of electronics and computer technologies. NECTEC also provides linkage between research communities and industries through the established industrial clusters and programmes.

Located in Thailand Science Park, the NSTDA Supercomputer Center (ThaiSC)[82], founded in 2018, was designated in Jan. 2019 as a National Science and Technology Infrastructure (NSTI) to provide cutting-edge HPC and data analytics (DA) research and service to the R&D community within Thailand. As such, it corresponds to a *Tier-1* National HPC/Research Computing Centre according to EU nomenclature. Annual operational budget & investment plan is approved by internal supervision board on National S&T Infrastructure. The supporting HPC facility, delivered in Jan. 2019 and called TARA follows a modular approach for the computing nodes (*i.e.* featuring regular, GPU/accelerated and large-memory computing nodes). The currently reported characteristics of ThaiSC are depicted in the Table **18** below.

Note: Short term extension of the ThaiSC facility are scheduled dedicated for AI workflows, adding several DGX-1 compute nodes, each featuring 8 Nvidia V100 GPGPU accelerators per nodes.

Other research institutes are operating an HPC facility to serve their local services (and can thus be categorized as Tier-2 local HPC/Research Computing Centre according to EU nomenclature), in particular:

- The Hydro and Agro Informatics Institute (HAII)[83], established in 2004 under NSTDA, which hosts since 2012 the National Hydroinformatics and Climate Data Center (NHC/ThaiWATER)[84] created after the major flooding happening in Thailand in 2011. Designed for Early warning and real time decision making, this centre aims at integrating technology for data analysis and flood management.
- The Thai Meteorological Department (TMD)[85] have been running the Weather Research and Forecasting (WRF) Model and was made fully operational in October 2017.

Table 18: Characteristics of the surveyed HPC Facilities in Thailand

[78] https://www.nectec.or.th/en/
[79] http://www.biotec.or.th/en/
[80] https://www.mtec.or.th/en/
[81] https://www2.nanotec.or.th/en/
[82] https://www.nectec.or.th/en/research/nccpi/nccpi-thaisc.html
[83] https://www.hii.or.th/haii/
[84] http://www.thaiwater.net
[85] https://www.tmd.go.th/en/

Thailand	ThaiSC Tara cluster (2019-)	HAII / NHC (2019-)*	TMD (2017-)*
HPC Facility Category	**Tier-1 (national)**	**Tier-2 (local)**	**Tier-2 (local)**
Total Computing Capacity	**531,6 TFlops**	**39.3 TFlops (estimated)**	**228 TFlops**
#nodes	75	60	192
Processor architecture	x86_64 (intel, Skylake)	x86_64 (intel)	X86_64 (intel)
Accelerators	28 NVIDIA Tesla (218,4 GPU TFlops)	None	n/a
Storage capacity [TB]	750	280	3000
Storage Filesystem(s)	GPFS/SpectrumScale	Lustre	n/a
Interconnect	IB EDR 100 GBps	IB	n/a
Network Topology	Fat Tree	n/a	n/a
RJMS	Slurm	n/a	n/a
Node provisioning	xCat (Extreme Cloud Administration Toolkit)	n/a	n/a
Main Operating System	CentOS 7	Rocks Cluster	n/a
User Software Environment	EasyBuild + LMod	n/a	n/a
Core HPC Management Team [FTE]	8	n/a	n/a
Regional Network Connectivity to EU	Asi@Connect / TEIN 10Gbps		
Server room Power and Cooling capacity [kW]	140 kW (N+N), 97.5 m^2	n/a	n/a

**: estimative numbers based on public information.*

Domain expertise tied to HPC and data analytics in Thailand is widespread. The below Table **19** lists for each identified centres (including contact details) domain fields accelerated by an HPC facility or aimed for HPC-based developments.

In term of collaboration platforms around HPC and BD activities, the Thai National e-science infrastructure consortium (E-science)[86] could be the consortium consolidating research collaboration with external partners. Founded in 2011 with 8 member institutes, the consortium uses the concept of Virtual Organization (VO) to allocate computing resources. This approach could be extended. Existing collaboration with EU already exists, in particular on High Energy Physics with CERN[87] (through the ALICE project, part of European Data Grid).

In all cases, through its current HPC computing capacities and associated strategy, Thailand stands as a major player aiming to play with Singapore a larger role in advancing supercomputing capabilities in the ASEAN region through the project developed within the ASIAN HPC Task Force – more details are provided in the Chapter **8**.

[86] http://www.e-science.in.th
[87] https://home.cern/

Table 19: Contact list and domain expertise for the main institutes in Thailand identified as dependent or providing services on HPC facilities

Thailand	
NSTDA Supercomputer Center (ThaiSC), National Electronics and Computer Technology Center (NECTEC)	Piyawut Srichaikul piyawut.srichaikul@nectec.or.th
• *Website* : https://www.nectec.or.th/en/research/nccpi/nccpi-thaisc.html • *Main HPC-accelerated domain fields expertise (across NSTDA affiliated research institutes)*: ○ Material Sciences, Finite Element analysis, Computational fluid dynamics, Molecular dynamics ○ Bioinformatics ○ Numerical weather prediction / Water resource simulations ○ Density functional theory ○ AI / Data analytics, Natural language processing	
Hydro and Agro Informatics Institute (HAII) National Hydroinformatics and Climate Data Center (NHC)	Royol Chitradon royol@haii.or.th
• *Website* : https://www.haii.or.th / http://www.thaiwater.net • *Main HPC-accelerated domain fields expertise*: ○ Hydro-informatics, Water resource simulations ○ Numerical weather prediction (incl. air pollution)	
Thai Meteorological Department (TMD)	Phuwieng Prakhammintara phuwieng@yahoo.com
• *Website* : https://www.tmd.go.th/en/ • *Main HPC-accelerated domain fields expertise*: ○ Weather Research and Forecasting (WRF)	
National e-science infrastructure consortium (e-Science)	Chalee Vorakiulpipat chalee.vorakulpipat@nectec.or.th
• *Website* : http://www.e-science.in.th • *Main HPC-accelerated domain fields expertise*: ○ High Energy Physics ○ Computational science and engineering, ○ Water resource simulations ○ Energy and environmental, Climate change	

K. Vietnam, Socialist Republic of

Vietnam like China its neighbour to the north, has been rapidly developing its supercomputing infrastructure and expertise over the past 15 years. There are four locations where HPCs have been operating within the state funded universities and research institutions:

- Within the **Vietnam National University (VNU)**[88], University of Science (UOS) where, in August 2005, the Centre for HPC at VNU was established (initially with LINUX 1350 and AIX 1600 systems) with the assistance from World Bank Higher Education Project with the following mission:
  - To support scientific research with the HPC technology in order to deal with large data sets and complex problems;
  - To provide training high quality human resources, advance scientific methods such as parallel computing and grid analysis;
  - to advance innovations based on advance computing and "big data" within various fields of science and technology in Vietnam.

  Several scientific domains or research field are accelerated by HPC within VNU, in particular with regards the development of Geographical Information Systems (GIS) with application to Tam Dao National Park resources, weather forecasting, coastal 3D hydrodynamic models and calculations for Quang Ninh and Tonkin Gulf waters, development of law enforcement software for forest protection in Quang Nam which was funded by the World Wildlife Fund or development of software for agricultural land and garbage in Duy Tien district, Ha Nam province. Since early days of HPC development at VNU-UOS, there have been engaged in HPC training to its own students as well as about 20 students per session from various other universities such Hanoi University of Science and Technology, Hanoi Pedagogical University, Electricity University, Dong Thap University of Education, Institute of Cryptographic Engineering and others.
  The VNU Center for HPC has developed various international relationships with HPC centres in the US, Germany, Japan, China, Canada, Taiwan, Singapore, Australia, and others. Two memorandums of understanding on cooperation on HPC collaboration were signed with the Interdisciplinary Center for Scientific Calculation of the University of Heidelberg University, Germany and the Old Dominion University. USA (more on international collaboration later below in section V below). Since 2004, scientist exchanges have been conducted with HPC centres in Malaysia, Singapore, China, Taiwan and Germany.

- **Hanoi University of Science and Technology (HUST)**[89], which host three HPC clusters (ICCMS, BKPARAM, RAPID, released respectively in 2011, 2013 and 2017) as outlined in the Table 20. The application areas that have been the focus of research exploiting these resources has been very diverse (including generic domains listed in the Table 21). Recently there is a considerable focus on climate change research beyond Numerical Weather Prediction (NWP) to use more advance techniques for dealing with remote sensing data, exploration of new kinds of plants for food consumption that can withstand greater climate variation for both government agencies as well as for the private sector (i.e. the VIN Group[90]). The latter are also sponsoring AI projects to analyse medical images and bio-informatics research that support the agricultural sector. The relatively small cluster at HUST are housed within the main library building of the university with only standard room cooling facilities.

[88] https://vnu.edu.vn/eng/
[89] https://en.hust.edu.vn/
[90] https://vingroup.net

- **Ho Chi Minh University of Technology (HCMUT)**[91]**.** Renamed as HCMUT in October 1976 while initially established in November 1957 as the Pho Tho National Institute of Technology, it is now one of the largest institution of its kind that has 27,000 students. HCMUT hosts a local Tier-2 HPC facilities which appear to be one of the fastest with 70 Tflops of total computing capacity. The HPC Lab within HCMUT was established in 2013 with substantial support from international IT companies (such as Intel HP Enterprise and Nvidia) with a 10-year plan (2013-2022) to focus initially on traffic analysis, urban flooding, bid data analytics and AI. One of the unique and specific features of the HPC Lab at HCMUT is the ITS Lab designed to analyse the current state of the traffic in Ho Chi Minh in real-time (Automatic vehicle detection and counting, Security and Law Enforcement (*e.g*. automatic license plate extraction) to allow for optimized motorbike and bus routing avoiding traffic congestion. Other initiatives make use of the HPC facility within HCMUT, for instance to apply reconfigurable computing for Internet security and low-power wireless water quality monitoring system, to allow for IoT-based flood/fire data collection within smart farm design or for air quality monitoring system. Smart cities and Industry 4.0 in Ho Chi Minh City applications are also generating a significant usage of the HPC facility. HCMUT is also involved in close collaboration with VNU in a number of areas with regards the usage of the HPC Lab at HCMUT, for instance:
    - Material Science for the design of novel Highly Functional Materials involving organic chemistry (and thus makes use of HPC software such as VASP, Quantum Expresso).
    - Computational Fluid Dynamics, with regards the optimisation of turbines/wings, targeting noise reduction around Ho Chi Minh city buildings through OpenFOAM modelling.
    - Climate research, for the prediction and simulation of flooding in Ho Chi Minh city, or the salinization analysis of the Mekong Delta (using software such as TELEMAC-MASCARET[92], WRF or SWAN)
    - Computer Vision & Big Data Analysis for Motobike Routing, Congestion Detection, GPS data analysis and Face Recognition

- The **Vietnam National Space Centre (VNSC)**[93] was established on September 2011 under the Vietnam Academy of Science and Technology (VAST)[94] by the Government of Vietnam with the goal to manage, and implement the Vietnamese space related projects as part of the "Strategy on Research into and Applications of Aerospace Technology" (2006-2020) which aims to make Vietnam more competitive in the region. In this context, VNSC is tasked with the following objectives:
    - building and completing the legal and regulatory framework for the research and application of space technology;
    - building the infrastructure for space technology
    - enable scientific research of space technology and apply it to remote sensing (i.e. satellite earth observations), Geographic Information System (GIS) and Global Navigation Satellite System (GNSS).

A review of the surveyed HPC configurations in Vietnam is proposed in the Table **20**.

[91] http://www.hcmut.edu.vn/en
[92] http://www.opentelemac.org/
[93] https://vnsc.org.vn/en/
[94] http://www.vast.ac.vn/en/

Table 20: Characteristics of the surveyed HPC Facilities in Vietnam

Vietnam	HUST (2011, 2013, 2017)	HCMUT (2013-)	VNSC
HPC Facility Category	**Tier-2 (local)**	**Tier-2 (local)**	**Tier-2 (local)**
Total Computing Capacity	**26 TFlops**	**70 TFlops (estimated)**	**2 TFlops**
#nodes	60	26	9
Processor architecture	x86_64 (intel, Skylake)	x86_64 (intel)	n/a
Accelerators	1 NVIDIA Tesla	48 Xeon Phi (KNL) 4 NVIDIA Tesla	n/a
Storage capacity [TB]	500	100	200
Storage Filesystem(s)	NFS	NFS, Lustre	NFS
Interconnect	IB FDR, EDR 1 GbE	IB FDR, 1GbE	10 GbE
Network Topology	Fat Tree	Fat Tree	Mesh
RJMS	Torque/Moab	PBS Pro	Slurm
Node provisioning	n/a	n/a	n/a
Main Operating System	n/a	n/a	n/a
User Software Environment	FOSS (Free and Open Source Software): GNU Compiler Collection, LLVM Clang, etc., Intel Parallel Studio XE	FOSS (Free and Open Source Software): GNU Compiler Collection, LLVM Clang, etc., Intel Parallel Studio XE	FOSS
Core HPC Management Team [FTE]	n/a	2	n/a
Regional Network Connectivity to EU	100 Mbps to VinaREIN then 1 Gbps to TEIN		
Server room Power and Cooling capacity [kW]	50 kW	n/a	n/a

Contact details for the main organisations involved in HPC activities are proposed in the Table 21.

Due to the high investment and running cost of HPC resources and the lack of supporting capability, there is almost no sharing policy in HPC centres in Vietnam (with one exception of HCMUT and VNU). While currently there is no Tier-1 HPC centre in Vietnam, HCMUT expresses a clear aspiration to become one as such while both HUST and VAST suggest that they may consider this possibility. While the realisation of such aspiration would require a great effort and investment from the government, the possibility for a Tier-1 status might be greater in the case of HCMUT which has already extensive collaboration with the private sector. Nevertheless, in all cases, such aspiration would be more possible if all of these Vietnam centres make greater investments in the human resources to design and maintaining a Tier-1 HPC centre.

Table 21: Contact list and domain expertise for the main institutes in Vietnam identified as dependent or providing services on HPC facilities

Vietnam	
Hanoi University of Science and Technology (HUST)	Dr. Nguyen Huu Duc duc.nguyenhuu@hust.edu.vn
• *Website* : **https://en.hust.edu.vn/** • *Main HPC-accelerated domain fields expertise (across NSTDA affiliated research institutes)*: ○ Computational biology ○ Computational chemistry and fluid dynamics ○ Computational mechanics, ○ Computational physics, ○ Cryptography ○ Environmental simulation, ○ Financial modelling / Fintech, IT / IoT Security, Machine Learning / BigData analytics ○ Material Sciences, ○ Numerical weather prediction (NWP), ○ Optimization, ○ Pattern recognition and Scientific	
Ho Chi Minh University of Technology (HCMUT)	Prof. Nam Thuoi namthoai@hcmut.edu.vn
• *Website* : http://www.hcmut.edu.vn/en • *Main HPC-accelerated domain fields expertise*: ○ Bio-informatics (Genome Analysis), Computational biology, ○ Computational chemistry, engineering and physics, ○ Computational fluid dynamics (e.g. aircraft aerodynamics simulations, Optimisation of turbines/wings, etc.) ○ Computational linguistics ○ Environmental simulation (Flooding, Salination in Mekong Delta, Simulation of airflow around HCMC buildings) ○ IT / IoT Security ○ Machine learning / Big Data analytics ○ Pattern recognition, ○ Transport modelling (GPS data analysis, Motorbike routing and traffic congestion detection ○ Hydro-informatics, Water resource simulations ○ Numerical weather prediction (incl. air pollution)	
Vietnam National Space Centre (VNSC)	Assoc. Prof. Pham Anh Tuan patuan@vnsc.org.vn
• *Website* : **https://vnsc.org.vn/en/** • *Main HPC-accelerated domain fields expertise*: ○ Aerospace ○ Earth simulation ○ Computational fluid dynamics	

Chapter 5 : EU-ASEAN Past Links and Current Collaborations

To accelerate innovation and development of HPC use, various "models" of past of current collaboration could be explored to provide some highlights on what, who and where some institutions manage to implement their collaboration efforts.

In the section A, a selected set of use cases offers relevant "cases of interests" snapshots that have some novel elements worth interesting for consolidated support from the partnered EU institutes, eventually as an outcome of the present study.

Then the section B exhibits multilateral and bilateral past or current collaborations between ASEAN and EU Institutions for some of the AMS.

A. Selected set of collaborative projects

1. ERASMUS+KA2 Strategic Partnerships

The current ERASMUS+ KA2 Strategic Partnerships Project (2018-21)[95] is proposing a project aiming of developing researches on Cloud computing in environmental science and promoting education in Southeast Asia countries. Called MONTUS (Master On New Technologies Using Services), this project inherits from the achievements and extends the developments performed within the TORUS (Toward an Open Resource Upon Service) project from 2015 to 2018. The budget of 1M€ (financed by the European Union in the framework of Erasmus + Capacity Building) is allocated and the project gathers 12 universities both in the EU and the neighbouring Southeast Asia countries:

- University of Toulouse 2 Jean Jaures (France)
- International School of Information Processing Sciences (EISTI) - Pau (France)
- University of Ferrara (Italy),
- University Brussels Vrije (Belgien)
- Vietnam National University (VNU) – Hanoï (Vietnam)
- Nong Lam university of Ho Chi Minh City (Vietnam)
- Asian Institute of Technology (AIT) – Pathumthani (Thailand)
- Walailak University - Nakhon Si Thammarat (Thailand)
- Two Cambodian institution in Phnom Penh: the Royal University of Fine Art and the Institute of Technology of Cambodia.

In total, 60 permanent members are working for MONTUS during three years with height workshops scheduled alternatively in Europe and in Asia.

The principal objective is to develop a Master Training Program around Cloud computing of environmental data processing and the ITC will also obtain equipment platform (value to about 120k€) and capacity building in HPC. MONTUS started from the observation that Cloud Computing (CC) is a paradigm too recent – although dating back from the 2000s – to be fully operational in most environmental science disciplines that need it to cope with Big Data challenge / Artificial Intelligence. The realities in Southeast Asia suggest that the environment must be prioritized and this project aims at facilitating learning and deployment best practices from each other institutions.

[95] https://eacea.ec.europa.eu/erasmus-plus/actions/key-action-2-cooperation-for-innovation-and-exchange-good-practices_en

2. ALICE and MonALISA (A Distributed Monitoring Service Architecture) projects

ALICE (A Large Ion Collider Experiment) is one of the four LHC (Large Hadron Collider)[96] experiments, currently being built at CERN, Geneva (Switzerland) which currently collect data at a rate of up to 2PB per year and is expected to run for 20 years while generating more than 10^9 data files per year in more than 50 locations worldwide. These data are aiming to be analyzed by thousands of scientists from hundreds of geographically distributed institutes, implying a highly distributed data flow exploiting the Grid Computing paradigm. As mentioned in the **Chapter 4.C**, the Research Centre for Informatics (RCI) in Indonesia features some of the Monitoring Agents using a Large Integrated Service Infrastructure (MonALISA) nodes involved on the ALICE Grid analysis system allowing for computing jobs (controlled by an intelligent workload management system) to be scheduled on the geographically distributed resources.

Analysis jobs are sent to the sites where the data are located, thus minimizing the network traffic. Both batch and interactive jobs are fully supported. The latter are spawned on remote computing elements and report the results back to the user's workstation.

The RCI is one of the two centres involved in this project within the ASEAN region (with SUT in Thailand). It is worth to note that only a few sites exists within the Asia-Pacific region (see Figure 9 below).

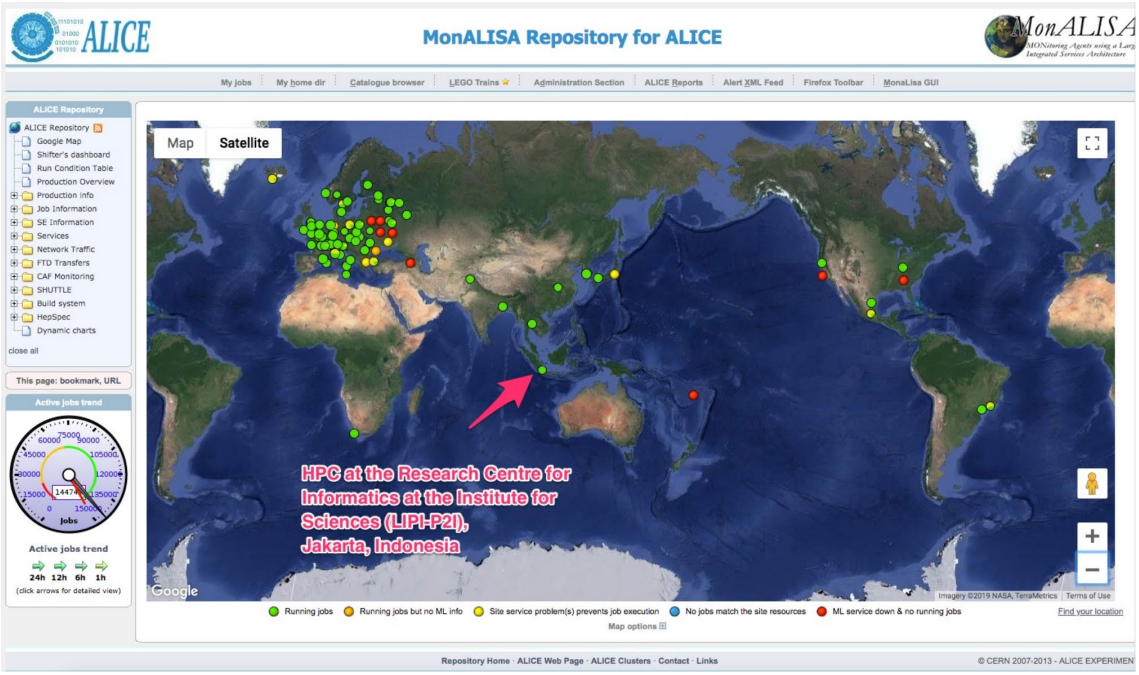


Figure 9: Status of the Global Network of MonALISA Repository for ALICE (based in CERN, Switzerland)

[96] https://home.cern/science/accelerators/large-hadron-collider

3. Identity Federation, Grid Infra & European Open Science

Since 1990s, the benefits of HPC and Grid computing have been recognized by most of the AMSs. The precedent section mentioned one of the distributed computing analyzing platform involving Indonesia and Thailand. Other examples can be found in Singapore for instance.

In Malaysia, a distributed grid infrastructure was developed by 5 Malaysian universities (UPM, UM, UTM, USM and UUM – see **Chapter 4.F**) under the umbrella of a Virtual Organisation called the Academic Grid Malaysia (AGM). Some of these universities have been participated in the EUAsia Grid Project where resources at the AGM received jobs from international partners and vice versa. The AGM continues to operate until today but clusters at all sites are "independent" of each other. More recently, a federated cloud including HPCs that caters for general and specific purpose computing resources came out of the AGM for science and engineering research, animation rendering, and Big Data (among other domains). This federated cloud includes the identity and trust framework called SIFULAN[97] (Malaysian Access Federation). It is hoped that this framework will lead to a greater spirit of sharing and become an important component towards large data transfer between Data Centres hosting HPC and storage, especially within the ASEAN region.

At this level, another Federated Identity Management System is well established among the AMS while dedicated for Singapore's research and education (R&E) community: the Singapore Access Federation (SGAF)[98] operated by SinAREN.

In the developed shared ASEAN HPC facility (see **Chapter 8**), it would be important to inter-connect these identity federation systems. One model that could be applied is developed within the Open Science Data Cloud (OSDC)[99]. An EU-ASEAN collaboration could also integrate and/or benefit from the experience gained within the Authentication and Authorisation for Research and Collaboration (AARC)[100] initiative which was first launched in May 2015 to address the increased need for federated access and for authentication and authorisation mechanisms by research and EU e-Infrastructures.

4. Early Warning Natural Disasters

In the past the World Meteorological organization (WMO)[101] focused its activities on early warning prevention for countries to collaborate around Regional Areas (RA).

Among them, the Region V (South-West Pacific) covers the vast expanse of the South-West Pacific Ocean but also includes adjacent oceanic areas north of the Equator as well as eastern parts of the Indian Ocean. The countries that comprise the Regional Association are diverse in many respects: culturally, economically, biologically, geographically and climatologically. It has seen many collaboration activities which have taken place already in the form of training and public education. It could serve as a framework for EU-ASEAN collaboration, given that Singapore, Thailand (and possibly Indonesia which will join in 2020) possess Petascale-level HPC facilities as well as established centers designed for Early warning and real time decision making. For instance, in Thailand, the HAII hosts the National Hydroinformatics and Climate Data Center (NHC/ThaiWATER)[102] created soon after the major flooding happening in Thailand in 2011 (see also **Chapter 4.J**). There is a

[97] https://sifulan.my/
[98] https://www.singaren.net.sg/SGAF
[99] https://www.opensciencedatacloud.org
[100] https://aarc-project.eu
[101] https://public.wmo.int/en
[102] http://www.thaiwater.net

great deal of possibility that ASEAN's metereology bureaus (such as Indonesia's BMKG and Philippines' PAGASA, among others) could form a working group to start information exchange programs aiming at integrating technology for data analysis and flood management, with the collaboration of the European Centre for Medium-Range Weather Forecasts (ECMWF) products.

5. Open Data Cube

As mentioned earlier, Open Data Cube (ODC)[103] is an Open Source Geospatial Data Management and Analysis Software project that seeks to increase the value and impact of global Earth observation satellite data by providing an open and freely accessible exploitation architecture. It also aim at fostering a community to develop, sustain, and grow the technology and the breadth and depth of its applications for societal benefit.

In order to the manage the Remote Sensing data from various satellite sources, the Vietnam National Space Centre (VNSC – see also **Chapter 4.K**) has developed the Vietnam Data Cube (VDC)[104] and a team structure based on the ODC framework which is supported by the Committee on Earth Observation Satellites (CEOS), USGS, Australian Geoscience Data Cube (AGDC) and others to improve data access, data preparation, and efficient analyses to support user applications in HPC or other environments. In particular, this is supported by the VNSC HPC facility reviewed in the Table **20**.

VNSC plans to share the VDC resource with the AMSs within the Mekong River Commission (Cambodia, Laos, Thailand) as well as other AMSs. In conclusion, remote sensing data as a whole might be an attractive case study for E-READI HPC to consider as it small enough to be manageable in an HPC sense, and large enough to make a difference (synching data and coordinated compute across ASEAN countries). Clearly the VNSC perspective is keen to share such resources such as the VDC and its methodology (e.g., depending on future requirements or opportunities for integration across ASEAN). If not to related to VDC specifically, it appears that VNSC will appreciate greater collaboration for advanced HPC activities across university, government or industry sectors with other AMSs and with EU institutions. Note that VNSC on behalf of Vietnam Academy of Science and Technology will take the Chair and host the international meeting of the Committee on Earth Observations Satellites (CEOS) conference in October 2019 where some of the above developments including possibilities of resource sharing will be discussed.

[103] https://www.opendatacube.org/
[104] http://datacube.vn/

B. Example of Multilateral and Bilateral Past/Current Collaborations between ASEAN and EU Institutions

The survey and the performed interviews permitted to highlight collaboration cases and past links which might involve either multi- or bi-lateral partners across EU and **some of the AMS (4 out of 10)**. The below Table **22** summarises these findings – information for the AMS not covered could not be obtained at the time of writing.

Table 22: Example of a few Multilateral and Bilateral Past/Current Collaborations between ASEAN and EU Institutions

Cambodia, Kingdom of		
Institutions / Organisation	**PRIOR LINKS to EU***	**CURRENT collaborations with EU & non-EU / Domain area(s)**
Institute of Technology of Cambodia (ITC)	• Past assistance in exchanges and loan of teaching staff from University of Namur, Belgium	• ITC participate in one Erasmus+ KA2 project (2018-21) through the MONTUS project - see **Chapter 5.A.1** 1M€ (financed by the European Union in the framework of Erasmus + Capacity Building) is allocated and the project gathers 12 universities both in the EU and the neighbouring Southeast Asia countries
Indonesia, Republic of		
Institutions / Organisation	**PRIOR LINKS to EU***	**CURRENT collaborations with EU & non-EU / Domain area(s)**
Meteorological, Climatetological & Geophysical Agency (BMKG)	• Many EU multilateral links through the World Meteorology Organisation (WMO) including all Asia workshops in India	• Links with WMO is on going relationship, setting up theTraining Centre for WMO Regional Area Group V (Australasia including the South Pacific Islands) on Seismology, Tsunami & Inundation System (see **Chapter 5.A.4**)
Research Centre for Informatics, Indonesian Institute of Science (P2I-LIPI)	• Staff members – Trained in Austria & the Netherlands; • Graduates from non-EU: Japan, Taiwan, the US	• Monitoring Agents using a Large Integrated Service Infrastructure (MonALISA) within the ALICE project (involving rack sharing with EU Institution with CERN, Geneva (Switzerland) - see **Chapter 5.A.2** • Training HPC Skill with ICT Section, Absus Salam Int'l Centre for Theoretical Physics / ICTP, Trieste Italy • Hosting month full training session with Prof. Axel Kohlmeyer, ICTP and VP-HPC at Temple Univ, PA-USA and others; Visits to Riken University HPC Centre, Japan; Lars Goerigk, University of Melbourne on Theoretical Quantum Chemistry including Quantum Refinement, Development of Computational Methods and Computational Materials Science

National Institute for Aeronautics and Space Research (LAPAN)	• Many EU multilateral links through the Committee on Earth Observation Satellites (CEOS) and Group on Earth Observations / GEO. • Indonesia (represented by LAPAN) was leading in Sub-Committee on Space Technology and Application of ASEAN COST, now Interim Chairman is Malaysia	• Links with CEOS is still on-going • Collaboration with Technische Universitat Berlin (Prof. Udo Renner) to develop LAPAN-TUBSAT micro satellite/rocket technology and staff currently completing PhDs programs there. Strong interest for HPC applications in Atmospheric data for early disaster warning, Aviation Aircraft aerodynamics simulation, Remote Sensing/Earth Observations. Asia-Pacific Space Cooperation Organization (APSCO) based in PR China has provided PhD and Masters scholarships to 11 students from Indonesia. • LAPAN has MoU's on various collaboration activities with other national bodies (BMKG and others) and international partners such as TerraMaris-UK, JAXA-Japan, US-NOAH and Australian institutions (BOM and CSIRO/Open Data Cube).
Malaysia, Kingdom of		
Institutions / Organisation	**PRIOR LINKS to EU***	**CURRENT collaborations with EU & non-EU / Domain area(s)**
Universiti Putra Malaysia (UPM)	• Bioinformatics (including gene sequencing), Energy, buildings, traffic and smart city simulations collaborations with Prof. Dr. Suhaimi Napis Ph.D., Durham University, United Kingdom	• Academic Grid Malaysia (AGM) – see see **Chapter 5.A.3**
Centre for AI & Robotics, Universiti Teknologi Malaysia (UTM)	• Dr. Danapalasingam Ph.D. (Aalborg University, Denmark)	• As above
Universiti Teknikal Malaysia (UTeM), Melaka	• Postdoctoral Fellow-Forschungszentrum Juelich & Mineral Resources Flagship-CSIRO/AU, PhD-Institute for Geoinformatics, University of Muenster, Researcher-British Telecommunication PLC, Malaysian Research Centre	• As above
University Perdana, Putrajaya	• Grid Computing infrastructure • EUAsia Grid Project	• As above
Universiti Sains Malaysia (USM)	• Prof Chan PhD. (Computer Science), Université de Franche-Comté, France	• As above

Vietnam, Socialist Republic of		
Institutions / Organisation	**PRIOR LINKS to EU***	**CURRENT collaborations with EU & non-EU / Domain area(s)**
Vietnam National Space Centre (VNSC)	• On going collaboration with France's National Centre for Space Studies / CNES & Netherlands Space Office / NSO	• VNSC to host and chair CEOS October 2019, EU participation in workshop and conference
Ho Chi Mihn City University of Technology (HCMUT)	• Education: Johannes Kepler Universitat Linz, Doctor of Phil.-PhD, Computer Science; Other members of the Faculty education backgrounds: Germany and Austria	• Germany Institute of Computer Science LMU-Ludwig Maximilians Universitat Munchen, Liebniz Computing Centre (LCC-Supercomputer) and Department for Informatics at the Leibniz Recher Zentrum (Leibniz Research Centre) of the Bavarian Academy of Sciences (BAdW). ○ Contact: Prof. Dr. med. Dieter Kranzlmüller, Head, LCC.

**: including past research experience and student placements in the EU*.

Chapter 6 : Analysis of the identified joint priority application areas

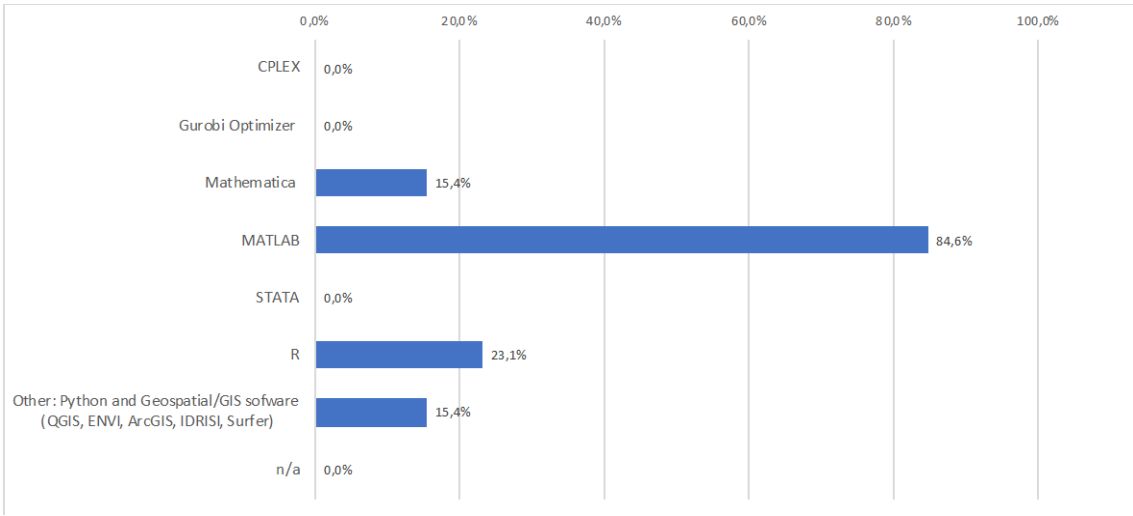
The in-depth analysis of the ASEAN HPC capacities and expectations are axed around priority application areas of common interest from AMS. At the heart of these developments, it is crucial to highlight the supporting software that are either already used within the HPC development among the identified HPC centers, or that are foreseen for the future developments. The survey permitted to analyze in an exhaustive and throughout way the list these software that are required to be provided (either on the foreseen shared HPC facility, or within the collaborative EU HPC centers) to satisfy the ASEAN HPC user community.

The next section (**Chapter 6.A**) provide the consolidated statistics on these application classified per application domain. Apart from allowing to raise priority awareness on deployment requirement within the ASEAN shared HPC facility, such a list is also important for the training aspects tacked in the **Chapter 7** to better target the application software trainings.

Then, the joint priority areas with societal impact matching AMS priority and interest for a collaboration within E-READI are reviewed in the **Chapter 6.B**. EU Projects that could sustain and support these collaborations are also listed for each sectoral area.

A. Software and Application Domain Needs

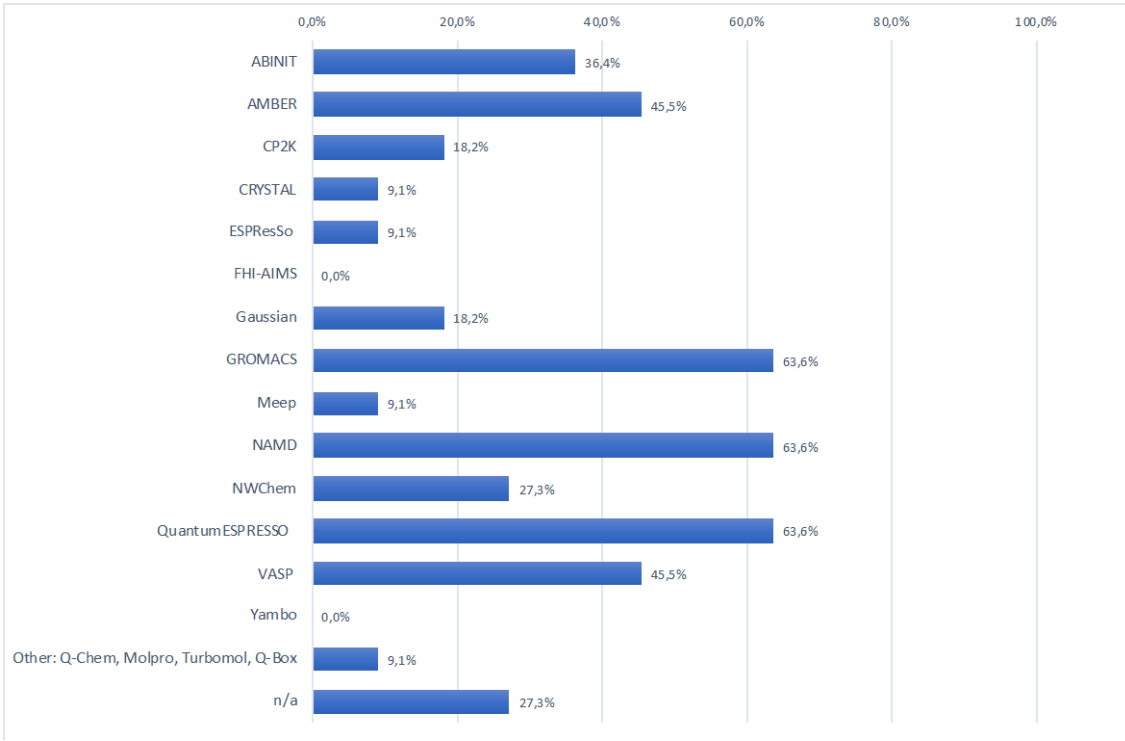
1. Mathematics, Statistics & Optimisation Software



As can be seen, only 4 applications (and in particular MATLAB[105] (commercial) and R[106]) are worth to provide within a shared ASEAN HPC facility to satisfy the needs for Mathematics, Statistics & Optimisation software. The case of Python (and for instance the numpy[107] package) and R is interesting – In EU centers, more and more mathematical workflows tend to rely on these popular programming environments to favor open-source alternatives to the commercial applications MATLAB and Mathematica.

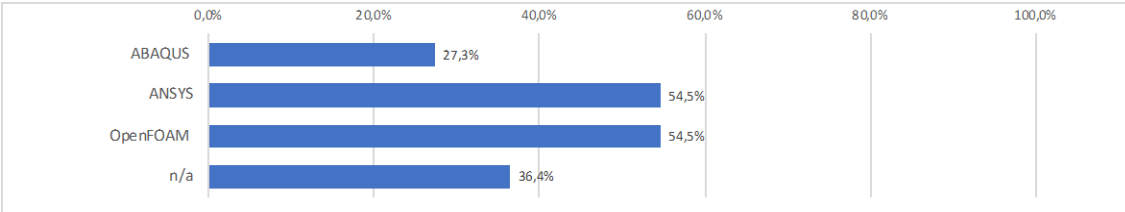
[105] https://mathworks.com/
[106] https://www.r-project.org/
[107] https://www.numpy.org/

2. Physics and Chemistry Software



In terms of physics and chemistry applications, the classical reference software (such as GROMACS[108], NAMD[109], QuantumExpresso[110], VASP[111], AMBER[112] etc.) are expected.

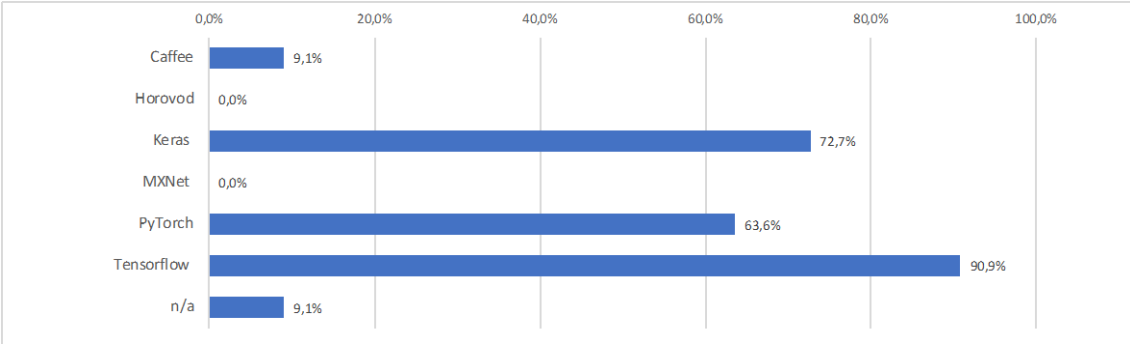
3. Computational Engineering Software - CAD, CAE and CFD Software



Again, the notable reference software (such as the commercial ANSYS[113] or ABAQUS[114], or the open-source OpenFOAM[115] package) are required.

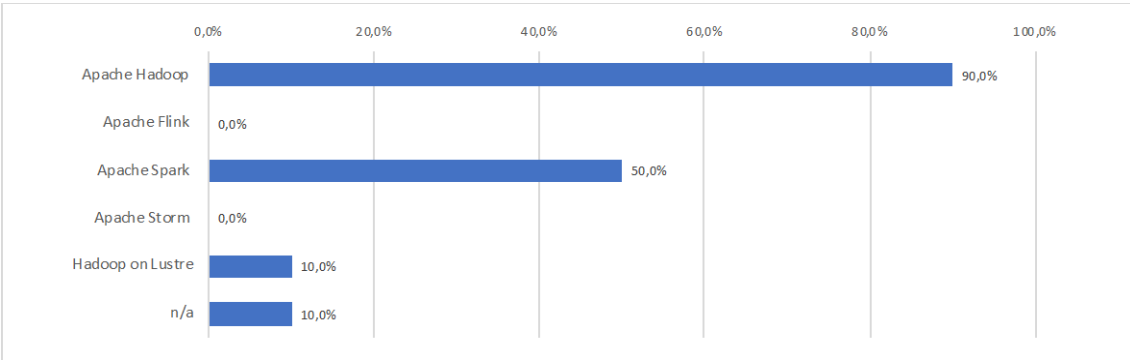
[108] http://www.gromacs.org/
[109] http://www.ks.uiuc.edu/Research/namd/
[110] https://www.quantum-espresso.org/
[111] https://www.vasp.at/
[112] http://ambermd.org/
[113] https://www.ansys.com
[114] https://www.3ds.com/fr/produits-et-services/simulia/produits/abaqus/
[115] https://www.openfoam.com

4. AI, Deep and Machine Learning Software



AI and Deep Learning are critical and are nowadays unavoidable in the HPC landscape. ASEAN user community needs are no different at this level and will need the delivery of the usual popular frameworks, in particular the open-source Tensorflow[116], Keras[117] and Pytorch[118] environments.

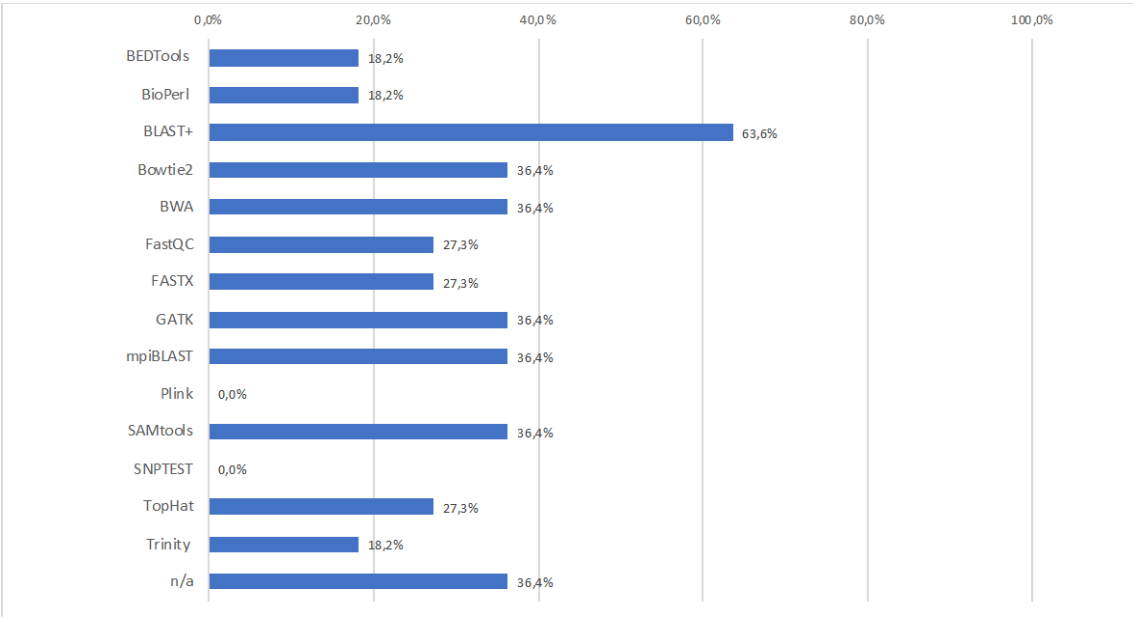
5. Big Data Analytics Software



ASEAN development for Big Data analytics are still relying on either the seminal Apache Hadoop[119] batch processing framework, or more recent hybrid (i.e. batch and stream processing) Apache Spark[120]. Other classical tools such as Tableau are also foreseen.

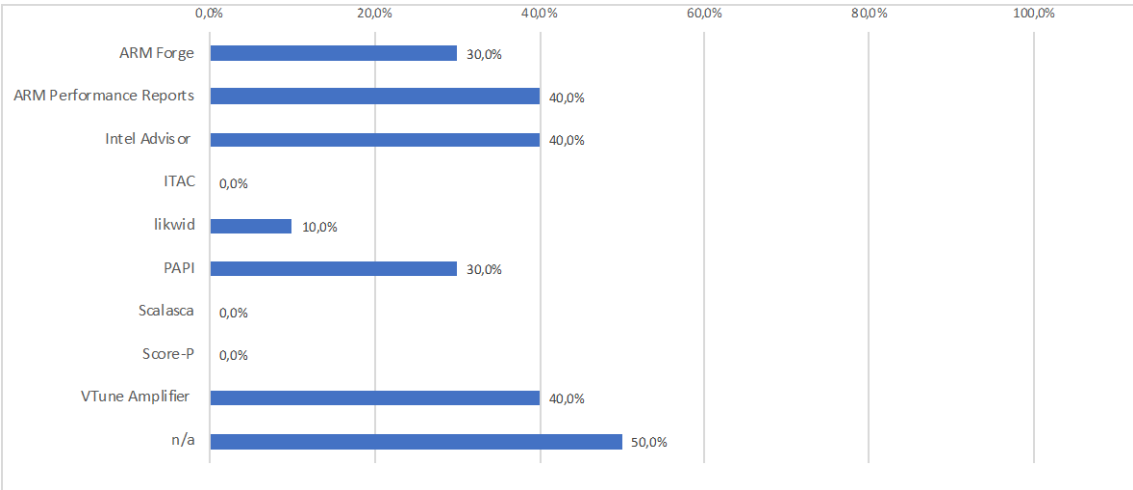
[116] https://www.tensorflow.org
[117] https://keras.io
[118] https://pytorch.org
[119] https://hadoop.apache.org
[120] https://spark.apache.org

6. Life Sciences Software



Bio-informatics (including gene sequencing) being one of the identified priorities, the associated software such as Blast+[121], Bowtie2[122] etc. are required. The widespread list of software is quite common and is also representative of similar usage in EU HPC centers, thus facilitating the potential synergies.

7. Performance tools

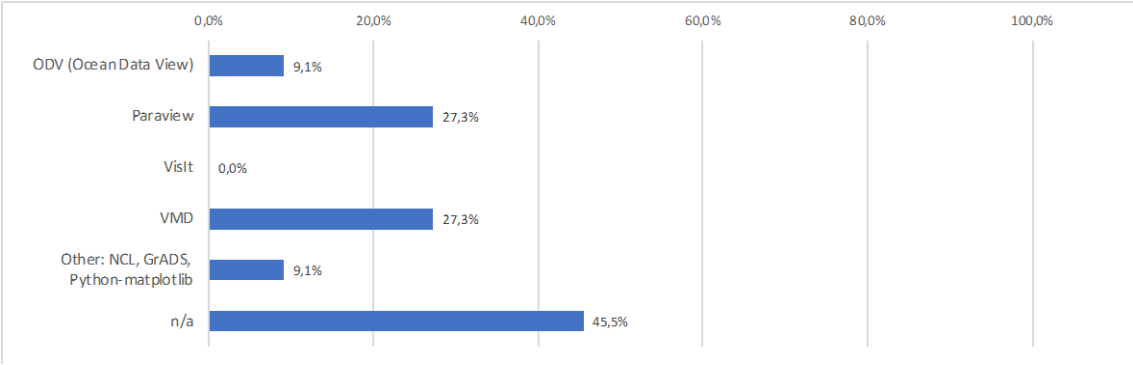


Performance engineering over the developed code base, especially when it involves scalable parallel code (which is common in most of the priority domains such as Climate and earth sciences (incl. Climate Projections), Hydro-informatics etc.) assumes the availability of performance and profiling tools. It seems that most of the proposed tools were actually not known or available (see 50% of the 'n/a' answers),

[121] https://blast.ncbi.nlm.nih.gov
[122] http://bowtie-bio.sourceforge.net/bowtie2/

a gap for which the foreseen trainings and deployment should focus on since such tools can help to achieve significant speedup on the delivered code.

8. Visualization



Visualization software are key for the treatment of numerical simulations at the heart of ASEAN priority areas (for instance tied to Climate and earth sciences, hydro-informatics, Early-warning of Geophysical events etc.). All tools exhibited within the collected answers to the survey, in particular the reference Paraview[123] (open-source) or VMD (Visual Molecular Dynamics)[124] software, but also ODV (Ocean Data View)[125], NCL[126], GrADS (Grid Analysis and Display System)[127] or simply the Python matplotlib[128] library are required.

9. Containers

The type of Container technologies currently supported on the surveyed HPC facility is depicted in the below Figure **10**. In nearly half of the cases, none are supported, which opens perspective for collaboration with EU HPC sites where the support for containers (especially Singularity) is more widespread.

In all cases, when containers are supported, Docker[129] despite its associated security issues and relative irrelevance for HPC workflows remains the container technology of choice. In some cases, this is due to a compliance with an existing HPC provider – for instance Nvidia provides its own version of Docker which should be used on some of its platfoms. Surprisingly, alternatives to Docker (yet compliant with Docker images generations) and designed for HPC workflows (being user defined software containers that are used as reference nowadays in large-scale HPC facilities) such as Singularity[130], Shifter[131] or CharliCloud[132] are hardly or not supported.

[123] https://www.paraview.org
[124] https://www.ks.uiuc.edu/Research/vmd
[125] https://odv.awi.de
[126] https://www.ncl.ucar.edu
[127] http://cola.gmu.edu/grads
[128] https://matplotlib.org
[129] https://www.docker.com/
[130] https://sylabs.io/singularity/
[131] https://github.com/NERSC/shifter
[132] https://hpc.github.io/charliecloud/

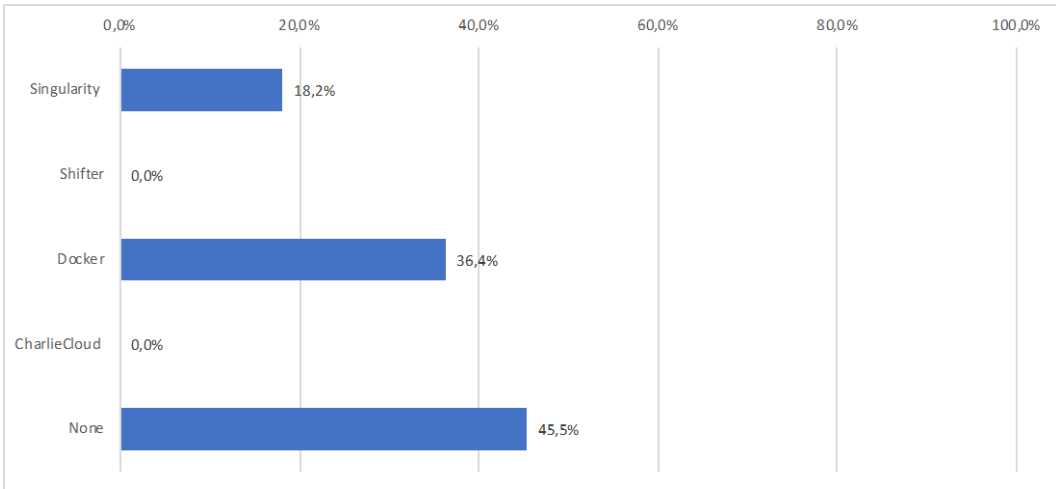


Figure 10: Type of container technologies currently supported on the surveyed HPC facility

B. Sectoral and joint priority areas with societal impact matching AMS priority and interest for a collaboration within E-READI

The previous section permitted to exergue the multiple "basic" bricks which are required in terms of supporting software package by ASEAN HPC user community. Those software are used in multiple application domains, however to sustain a successful enhanced collaboration in the context of the EU-ASEAN HPC coordination group, it is clear that there is a **need to focus on a subset of sectoral entry point and joint priority areas having a significant societal impact among all AMS**, thus matching not only the ASEAN priority and interest, but also the expertise of the EU Center of Excellence (CoEs) and associated programs (such as ECMWF) within the E-READI mapping study for the initial domain of cooperation. Identifying these priority areas was the subject of several questions within the survey, and the identified sectoral domains that come out of the survey and the face-to-face meetings are depicted in the Figure **11**.

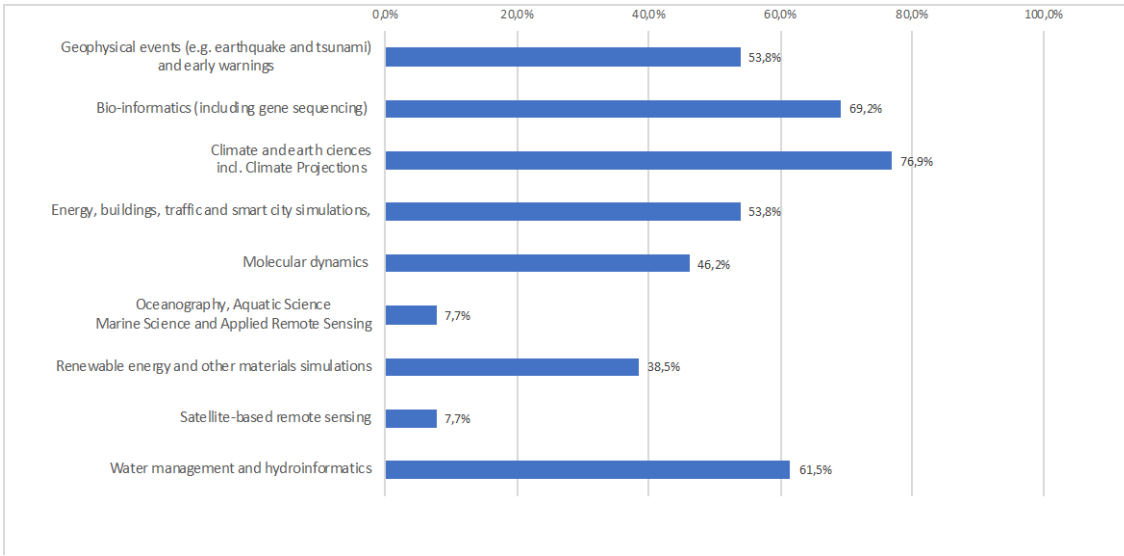


Figure 11: List of application areas having a significant societal impact which match AMS priority and interest for a collaboration within E-READI

The following sub-sections exhibits for each of the identified application area reported in the above figure and the potential synergies based in the ASEAN expectations that would be recommended to enhance the development of an EU-ASEAN collaboration within these domains.

1. Climate and Earth Sciences

This includes also several subdomains (in alphabetical order), such as:

- Modelisation and extreme weather forecasting for Geophysical seismic events (e.g. earthquake, flooding and tsunami) and their early warnings systems
- Oceanography, Aquatic Science, Marine Science and the related Applied Remote Sensing platforms. In particular, there is an expressed wish for strengthening the AMS capacity on ocean and coastal dynamics modelling.
- Precision Agriculture and Satellite-based remote sensing.
- Seasonal climate modelling
- Water management and hydro-informatics

For all these domains, there is a wish to access to big dataset of satellite imagery and geospatial data as well as the associated processing tools. To that end, it would be of interest to **establish within the ASEAN region a Copernicus Open Access Hub** (previously known as Sentinels Scientific Data Hub) which provides complete, free and open access to Sentinel-1, Sentinel-2, Sentinel-3 and Sentinel-5P user products, starting from the In-Orbit Commissioning Review (IOCR). Having such a mirroring access point within the AMSs would facilitate the fast and efficient access to these data.

Beside the **ESiWACE2** CoE projects (see **Chapter 3.C**), adaption of leading weather and climate models on (pre-)exascale systems of interest for ASEAN to catch up are provided by the following projects:

- Infrastructure for the European Network of Earth System Modelling (**IS-ENES**)[133] projects of the distributed e-infrastructure of models, model data and metadata of ENES (see **Chapter 3.D**). It gathers together the European modelling community working on understanding and predicting climate variability and change.
- The Coupled Model Intercomparison Project phase 6 (**CMIP6**)[134], an international endeavour to better understand past, present and future climate changes. It referes to the Grand Science Challenges of the World Climate Research Programme (**WCRP**).
- Process-based climate simulation: Advances in high-resolution modelling and European climate risk assessment (PRIMAVERA)[135], which develop a new generation of advanced and well-evaluated high-resolution global climate models, ccapable of simulating and predicting regional climate with unprecedented fidelity, for the benefit of governments, business and society in general.
- The Performance Optimisation and Productivity (**POP2**) and the Energy oriented (**EoCoE-II**) CoEs (see **Chapter 3.C**).
- The Centre of Excellence for Exascale and Solid Earth (**ChEESE**) and the pilot demonstrator developed in this context (see **Chapter 3.C**: Urgent seismic simulation, "Faster than real-time Tsunami Simulations", High resolution volvanic plume simulation, physic-based tsunami-earthquake interactions, Probabilistic Tsunami Forecast (PTF) for early-warning and rapid post event assessment…)
- The (old as now completed) Centre of Excellence for Global System Science (**CoEGSS**)[136] which aims at empowering the community of analysts addressing global challenges through high-performance computing and data analysis could

[133] https://is.enes.org
[134] https://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip6
[135] https://www.primavera-h2020.eu
[136] http://coegss.eu

be also a source of contacts (even if most are currently re-dispatched within the **HiDALGO**[137] CoE (HPC and Big Data Technologies for Global Challenges).

2. Bio-informatics (including gene sequencing)

This would involve the following sub-domains clearly expressed as priority in this case:

- Computational Chemistry
- Gene sequencing
- Molecular Modelling

At this level, EU-ASEAN collaboration could be provided through the following projects (detailed in **Chapter 3.C**):

- The **Centre of Excellence in Computational Biomedicine** (**CompBioMed2**)[138], especially for the collaborative development performed around the predictive models of health and disease;
- The **Centre of Excellence for Computational Biomolecular Research** (**BioExcel-2**)[139], which aims at Improving the performance and scalability of major simulation packages for this domain (such as Gromacs) to enhance the competence-building among both academia and industry through extensive training programs and promotion of best practices

3. Material Science and Computational Chemistry

In this case, the reported priorities involve the following fields:

- Renewable energy and other materials simulations
- Efficiency of turbines and development of new materials for higher solar energy efficiency

In particular, EU-ASEAN collaboration could be provided in these domains through the following projects (detailed in **Chapter 3.C**):

- The CoE for **Materials design at the Exascale** (**MaX 2**)[140] which provides support for developers and end users of advanced applications in the field of materials, enabling works at the frontiers of the current and future HPC and HTC technologies. The objective to enable the exascale transition in the materials domain could serve also ASEAN interests.
- The **Energy Oriented Center of Excellence (EoCoE-II)**[141] which aims (among other objectives) to use our high-end numerical tools to determine the properties of new materials for photo-voltaic power panels, or for batteries and super-capacitors.
- The Performance Optimisation and Productivity (**POP2**) CoEs could be also useful to support the development in the ASEAN region with performance audit.

[137] https://hidalgo-project.eu/
[138] https://www.compbiomed.eu
[139] https://bioexcel.eu/
[140] http://www.max-centre.eu/
[141] https://www.eocoe.eu/

4. Energy, buildings, traffic and smart city simulations.

This subject was not really anticipated at the beginning of this analysis; however, the survey reported a clear interest for some of the AMSs toward these domains, more specifically to tackle the following subjects:

- Smart city development through land-based environment analysis for transport, traffic flows and congestion mitigation in real time.
- Built Environment (Building Twinning, Heat Island, etc.) planning, typically using information extracted from applied remote sensing (both based on Earth Observations from Satellites and/or from Air-borne Drone devices) and the application of platforms such as Open Data Cube (ODC)[142], an Open Source Geospatial Data Management and Analysis Software project that helps you harness the power of multiple satellite data sets (such as from the European Space Agency's Sentinel satellite). For example, the ASEAN implementation for this methodology could combine several sources of satellite data as found in the Vietnam Data Cube.

Developments in these domains within a consolidated EU-ASEAN collaboration could rely on the following projects:

- The **StarDust**[143] project, which aims at developing intelligent solutions for energy, mobility and ICT integrated in cities together with innovative business models, to serve as blueprints for replication across Europe and abroad.
- The European Innovation Partnership on Smart Cities and Communities (EIP-SCC) and the **IRIS** project[144] which brings together cities, industry and citizens to improve urban life through more sustainable integrated solutions, including applied innovation, better planning, a more participatory approach, higher energy efficiency, better transport solutions, intelligent use of Information and Communication Technologies (ICT).
- The Centre of Excellence for Engineering Applications (**EXCELLERAT**)[145] and the HPC and Big Data Technologies for Global Challenges CoE (**HiDALGO**)[146], which contribute to the development of a control system of urban traffic based on high resolution and real time modeling of urban air pollution (see **Chapter 3.C**):

[142] https://www.opendatacube.org/
[143] https://stardustproject.eu/
[144] https://irissmartcities.eu/
[145] https://www.excellerat.eu
[146] https://hidalgo-project.eu

Chapter 7 : Cross Analysis with EU pools for Training

In an increasing number of areas of academic research, industry, commerce and government, large-scale computational approaches are used for simulation and increased productivity in research and innovation. However, the shortage of personnel with expertise in HPC skills is still a barrier to increasing the uptake of HPC in academia and industry, and this has been identified as a major risk both in Europe and within the ASEAN Member states. In part, this is due to the insufficient provision of HPC training courses at all levels and across all sectors, a situation which have been handled in Europe through several programs, most of them orchestrated by PRACE.

This section aims to review the existing provision of HPC training in Europe, identify the future training needs of the HPC community among the AMS, and produce recommendations based on the resulting gap analysis.

A. Priority domains to tackle during user-oriented training sessions

The survey permitted to review the topics and expert domains in which the interviewed institutes report a missing expertise in the delivery of the training, or at least a need for having these identified domains covered in a training. This is illustrated in the Figure 12. As can be seen, the most sensitive domains where dedicated sessions by external experts are expected are tied to the following sujects:

- Containers technologies and integration in HPC workflows (81,8%)
- Data management, expecially backup strategies (81,8%)
- Security aspects (data privacy etc.) (72,7%), where obviously the EU expertise and feedback on the management of the EU General Data Protection Regulation (GDPR)[147] i.e. the most important change in data privacy regulation in 20 years, is seen as crucial
- Parallel programming (63,6%), incl. accelerator programming (72,7%)
- Configuration and Operational management of HPC systems and workflows (63,6%)
- MATLAB and Statistical programming (R etc.) (63,6% and
- Visualization

It is worth to note that most existing EU trainings listed in the section Chapter 7.C are designed to cover all the identified subjects in continuous training events provided within reference EU centers by EU experts in these domains.

[147] https://eugdpr.org

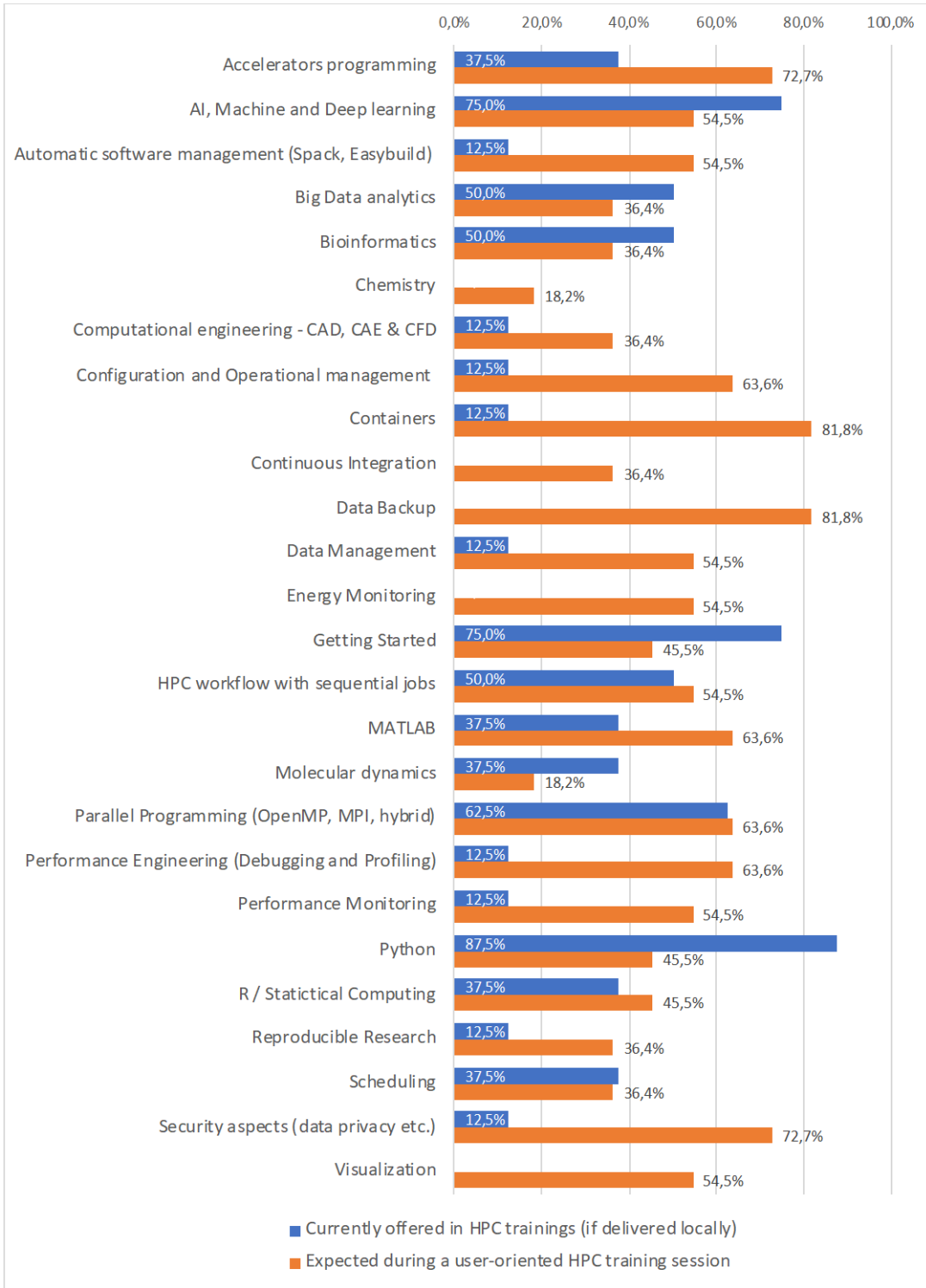


Figure 12: Current vs. expected subject to be tackled during user-oriented training sessions.

B. Priority domains to tackle during HPC-staff oriented training sessions

Of course, the HPC staff is more inclined to participate to training sessions dedicated to other specific domains typically tied to the operation management of HPC facilities, where of course the expert training offered in the framework of PRACE are seen as a priority.

The subjects identified as strategic at this level are listed below:

- Configuration management (Puppet, Ansible),
- Node provisioning (xCat....),
- RJMS (Slurm…),
- Interconnect and Network (Infiniband...), Network management (CISCO...)
- Parallel and distributed File Systems (in particular SpectrumScale/GPFS and Lustre)
- Management of Kubernetes cluster for HPC services provisioning
- Continious integration (Gitlab pipelines, Jenkins…)

This type of training is relatively specific, and should be organized with the EuroHPC/PRACE Tier-0 and Tier-1 system, or in combination with the **major international supercomputing conferences** (SC, ISC and/or SCAsia). Indeed, these events attract attendees from around the world, bringing together hardware and software vendors, staff from HPC centres, application developers, scientists and more. In addition to the exhibition aspect of the events, there are **tutorials, workshops and Birds-of-a-Feather sessions (BoFs), which would be an excellent framework for exchanging information and knowledge on these subjects**. Due to the large number of attendees at these events, HPC stakeholders have an unequalled opportunity to provide training sessions for a varied audience with whom they may not otherwise come into contact

C. Overview of the HPC training delivered in Europe

EU HPC training consists of a continuum of learning resources as varied as the community it addresses. It includes general courses covering the underlying concepts and methodologies of HPC, and courses on HPC-specific technologies (e.g. a specific national service) or programming models and applications (e.g. MPI or OpenMP). Courses may be short intensive courses (typically from one day to a week long), longer fulltime courses (such as a Master's course), or an integral part of a bigger course (e.g. a module within an undergraduate degree). They may be taught face-to-face, or – increasingly – online, in the form of video tutorials, webinars, or MOOCs (Massive Open Online Courses). Online courses may be synchronous (followed in real-time), or asynchronous (e.g. self-paced tutorials). There is also a large amount of documentation freely available online, including course slides, video recordings, and interactive exercises.

1. Overview of short-term, intensive training opportunities in Europe

PRACE, the Partnership for Advanced Computing is probably the principal European coordinator of intensive HPC training courses. PRACE training activities range from 1-hour webinars to the 2-month Summer of HPC program.

Most PRACE trainings are delivered by the PRACE Training Centres (PTCs)[148] via short face-to-face training courses (typically lasting 2-5 days). With approximately **100 training events each year**, the ten PRACE Training Centres (PTCs) which are summarized in the below Table **23** have established a state-of-the-art curriculum for training in HPC and scientific computing of interest for ASEAN partners.

Table 23: Overview of the PRACE Training Centres

PRACE Training Centres (PTCs)		Primary Contact
Czech Republic	IT4Innovations[149] – National Supercomputing Center VSB Technical University of Ostrava	Dr. Vít Vondrák vit.vondrak@vsb.cz
Finland	CSC[150] - IT Center for Science Ltd	Dr. Janne Ignatus janne.ignatius@csc.fi
France	Maison de la Simulation[151]	Edouard Audit edouard.audit@cea.fr
Germany	GCS - Gauss Centre for Supercomputing[152]	Michael M. Resch resch@hlrs.de
Greece	GRNET – Greek Research and Technology Network[153]	Ognjen Prnjat oprnjat@admin.grnet.gr
Ireland	ICHEC – Irish Centre for High-End Computing[154]	Jean-Christophe Deplat j-c.desplat@ichec.ie
Italy	CINECA - Consorzio Interuniversitario[155]	Sanzio Bassini s.bassini@cineca.it
Spain	BCS - Barcelona Supercomputing Center[156]	Fabrizio Gagliardi fgagliar@bsccns.onmicrosoft.com
The Netherlands	SURFsara[157]	Peter Michielse peter.michielse@inter.nl.net
UK	EPCC at the University of Edinburgh[158]	Mark Parsons m.parsons@epcc.ed.ac.uk

The following figure map (extracted from the PRACE website) depicts the location of the PTC centers throughout Europe.

[148] http://www.prace-ri.eu/ptcs
[149] https://www.it4i.cz/?lang=en
[150] https://www.csc.fi/
[151] http://www.maisondelasimulation.fr/
[152] http://www.gauss-centre.eu/gauss-centre/EN/Home/home_node.html
[153] https://grnet.gr/en/
[154] https://www.ichec.ie
[155] https://www.cineca.it/en
[156] https://www.bsc.es/
[157] https://www.surf.nl/en/about-surf/subsidiaries/surfsara/
[158] https://www.epcc.ed.ac.uk

PTCs carry out and coordinate training and education activities that enable both European academic researchers and European industry to utilise the computational infrastructure available through PRACE and provide top-class education and training opportunities for computational scientists in Europe.

PTC training events are advertised on the following pages :

https://events.prace-ri.eu/category/2/

PRACE runs also 3-4 seasonal schools[159] each year. These week-long training courses usually focus on a specific domain or area of HPC programming. They take place all

[159] http://www.prace-ri.eu/prace-seasonal-schools/

around Europe, but are mainly held in non-PTC countries in order to complement the PTC activities.

PRACE Seasonal Schools are advertised on the following page :

https://events.prace-ri.eu/category/6/

Note that PRACE, together with XSEDE[160], RIKEN[161] and SciNet[162] jointly organises the International HPC Summer School on HPC Challenges in Computational Sciences[163], an annual one-week summer school which takes place alternately in Europe and the USA.

In order to widen the reach of the courses as much as possible and provide the best opportunities for AMS, the below list depicts the **incoming EU HPC-related Trainings events (in addition to the regular events listed in the above link):**

- PRACE Summer of HPC 2019[164], July 1-6; Bologna, Italy. This program offers two-month student placements at HPC centres across Europe for senior undergraduates and early postgraduates. The programme attracts a slightly different demographic from the other PRACE training activities, as it targets younger researchers who often have not previously used or even considered the use of HPC facilities. Aimed for EU candidates, it is a priori not opened for ASEAN, nevertheless the format of this training framework could be a source of inspiration for organizing a similar type of program within AMS HPC centres.
- ACACES, "HiPEAC Summer School"[165], 14-20 July 2019, Fiuggi, Italy
- EUDAT Trainings[166]
- The HPC University[167] is a virtual organisation of mainly US-based partners, but which includes PRACE and the Cyprus Institute. It seeks to provide a cohesive, persistent, and sustainable on-line environment for training materials in all HPC computing environments
- TeSS: ELIXIR's Training Portal[168] (Life sciences training resources)
- Jülich Supercomputing Centre HPC training[169], featuring scheduled events untils Nov. 2019
- Uni.lu HPC Workshop[170], Nov. 2019

Of course, short training courses and internship-style training are available and are part of the mission of EU FETHPC projects and Centres of Excellence (see section Chapter 72 below).

Courses are open to all researchers in Europe, are free of charge to academics, and are usually given in English, the default of the European research

[160] Extreme Science and Engineering Discovery Environment (XSEDE) - https://www.xsede.org/
[161] http://www.riken.jp/en/
[162] SciNet is Canada's largest supercomputer centre, providing Canadian researchers with computational resources, training, and expertise necessary to perform their research on scales not previously possible in Canada. https://www.scinethpc.ca/
[163] http://www.ihpcss.org/
[164] https://events.prace-ri.eu/event/845/
[165] http://acaces.hipeac.net/2019/
[166] https://www.eudat.eu/training
[167] http://hpcuniversity.org
[168] https://tess.elixir-europe.org/
[169] https://www.fz-juelich.de/ias/jsc/EN/Expertise/Workshops/Courses/courses_node.html
[170] https://hpc.uni.lu/education/hpcschool

community. **Access to the trainings for ASEAN staff and researchers is still possible and is tied to local arrangement and agreement**.

Online Training

The PRACE training portal[171] contains an extensive archive of training resources, such as video tutorials and material from courses, including slides as well as video recordings and / or topic specific exercises where these are available. The increased number of visits to the training portal and registered users demonstrate that the demand for online training resources is growing significantly.

PRACE aims to intensify online training offerings by providing MOOCs (Massive Open Online Courses)[172], and is currently proposing 4 courses. The joint development of such MOOCs is of course a very important concrete collaboration direction for EU and ASEAN.

Overall, all types of HPC-related training/exchange are expected to be offered by E-READI to develop the policy framework for HPC development, as reported in the Figure 13.

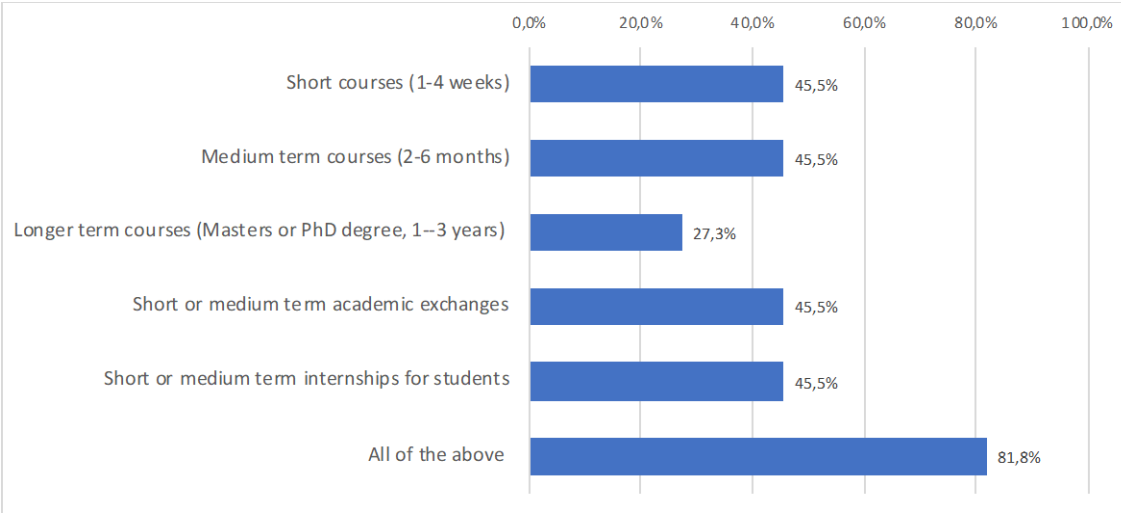


Figure 13: Type of HPC-related training/exchange expected to be offered by E-READI to develop the policy framework for HPC development

[171] http://www.prace-ri.eu/trainings/
[172] https://www.futurelearn.com/partners/prace

2. Other short training courses and internship-style training

Some of the EC-funded FET-HPC projects and EU Centres of Excellence (CoE) offer training in their specific areas of research as part of their core activities. See the Chapter 3.I.C for the list of existing CoEs with their respective points of contacts.

Examples of such trainings include:

- BioExcel-2[173], like ComBioMed[174], which provides training in HPC for Life Science research, including several webinars and training events. For instance, the BioExcel Summer School on Biomolecular Simulations 2019 will be held the Science and Technology Park of Sardinia in Pula from in July 2019.
- ChEESE trainings[175] on Exascale and Solid Earth. For instance, the 2nd ExaHyPE User Workshop (a open source simulation engine to solve systems of hyperbolic equation systems) will be held in July 2019
- EoCOE-II offers a series of workshop trainings[176] on several domains tied to energy technology modelling
- Of prime importance for AMS, ESiWAVE-II offers a series of trainings[177] on pre-exascale HPC software engineering, methods and tools for engineers and scientists in the domain of weather and climate. IN the same vein, ECMWF learning framework[178] has an extensive education and training programme to assist EU Member States and Co-operating States (thus including ASEAN) in the training of scientists in numerical weather forecasting, and in making use of the ECMWF forecast products.
- Excellerat trainings[179], while outdated, are provided through both class room-based courses and online courses related to the efficient use of HPC resources that combine lectures with hands-on exercises
- MaX[180] offers integrated training and education in the field of HPC developments and in the computational materials science domain.
- POP[181], the Centre of Excellence in Performance Optimisation and Productivity, provides training on parallel programming in general as well as on specific performance tools, analysis methods and optimization techniques

[173] https://bioexcel.eu/services/training/
[174] https://www.compbiomed.eu/training-3/
[175] https://cheese-coe.eu/events/training
[176] https://www.eocoe.eu/workshopstrainings
[177] https://www.esiwace.eu/services/trainings
[178] https://www.ecmwf.int/en/learning
[179] https://www.excellerat.eu/wp/training/
[180] http://www.max-centre.eu/training-and-education/
[181] https://pop-coe.eu/further-information/learning-material

D. Feedback on the general training strategy within AMS

Funding a training program between ASEAN AMS and EU around HPC is definitively possible but would need the clear support from EU as can be seen in the Figure **14**.

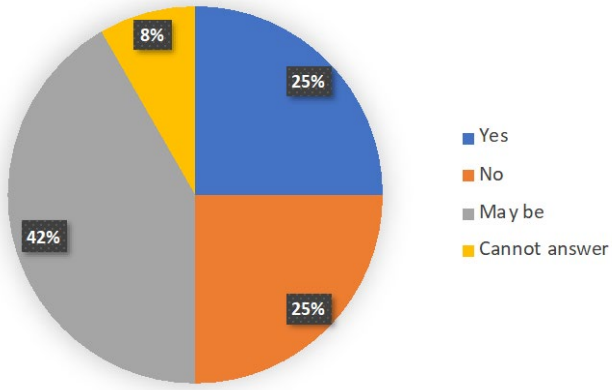


Figure 14: Capacity of the interviewed organisations to jointly fund a training program between ASEAN AMS and EU around HPC.

In all cases, there is also a clear wish to **contribute to improved training strategies to reach, support and upskill the HPC professionals and HPC researchers-users (particularly how to generate and engage new users across ASEAN) with HPC tools and management skills.** This could take the form of an increase in the number of face-to-face and or flexible learning (combined FTF and online) training offered in ASEAN and/or in EU as well as the development of online training modules and portal.

In line with the above identified gaps in the available training domains, all AMS clearly expressed their interest to:

- **Access to incoming PRACE Training Centers (PTCs) events**, especially for trainings tied to applications dealing with seismic, climatology, meteorology, geophysics and remote sensing (or satellite earth observations)
- **Access to European Centre for Medium-Range Weather Forecasts (ECMWF) trainings** (see above)[182]**,** especially on use and Intepretation of ECMWF products.

[182] https://www.ecmwf.int/en/learning

E. Human capacity development program

One question was linked to the **interest for a human capacity development program specifically through EU-ASEAN consortium exchange around HPC** (similar to the EU Erasmus Program). As expected, a large majority of the collected answers were positive on this subject – see below Figure **15**.

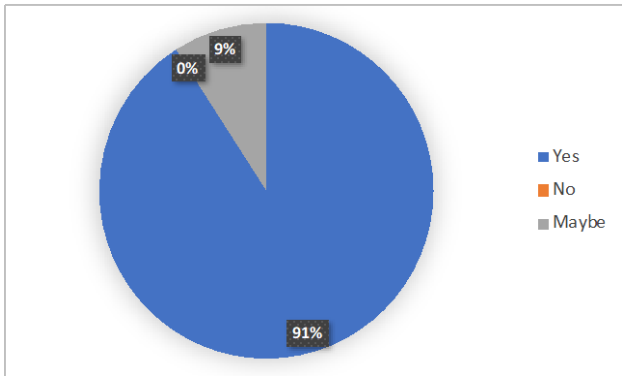


Figure 15: Interest for a human capacity development program specifically through EU-ASEAN consortium exchange around HPC.

In terms of certifications, there is a strong interest to promote and **contribute to the joint definition of recognized/approved HPC training and certificates** as depicted in the below Figure **16**.

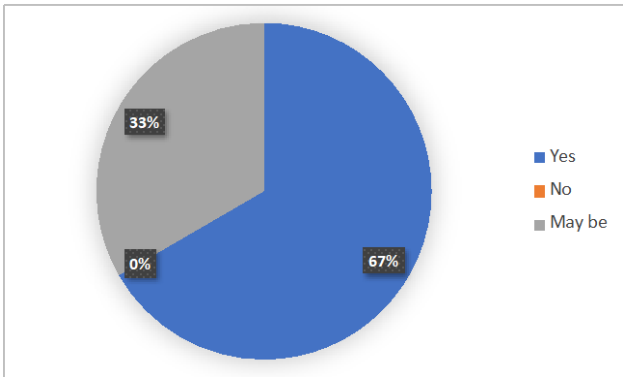


Figure 16: Interest to promote and contribute to recognised HPC training and certificates

The **format** which would be supported for such HPC training and certificates includes **shared/joint Master with HPC specialization** (operational management, DC), **joint MBA on HPC management** (DC, staff, procurement, HPC Operator). Several EU Universities are already delivering this type of master program, for instance in France (Reims or Paris)[183], UK (Edinburgh)[184] or in Italy (Trieste)[185] and could be a source of inspiration at this level. Most courses have both a set of compulsory courses, to give a broad-based foundation in HPC and data science, and a range of optional courses, which give students a chance to tailor their studies towards their particular interests. Further, some courses allow students to take a number of credits from other relevant courses offered by different departments of their institute. The

[183] Master "Calcul Haute Performance Simulation" (CHPS) - http://www.chps.uvsq.fr
[184] EPCC MSc in High Performance Computing - http://www.epcc.ed.ac.uk/msc
[185] Master in High Performance Computing (MHPC) - https://www.mhpc.it

range of Master's projects available for students gives a feel for the variety of work to which HPC can be applied and we could imagine projects highlighting EU-ASEAN collaboration (typically on a joint subject tackle on the facilities of both ends). Industry-based projects can be a great opportunity to have hands-on experience of a real-world project and to gain a variety of practical, transferable skills from the workplace environment.

The case of HPC training for undergraduates is more problematic. As reported in the EXDCI HPC Training Roadmap 2017[186], there is currently a general lack of HPC training in undergraduate curricula, even when HPC centres are located within universities. Often those designing and teaching the undergraduate curricula do not have contact with or awareness of the HPC centres, whose local users are more focused on research. This could be a source of joint development that could benefit for both EU and ASEAN HPC partners.

[186] See https://exdci.eu/sites/default/files/public/files/d5.4_training_roadmap.pdf

Chapter 8 : Suggested Policy and Governance for Regional HPC Resource Sharing

Under the first E-READI Annual Work Plan, on HPC it was also planned to support the ASEAN HPC Taskforce meeting and EU- ASEAN experts' exchange towards the organization of resource sharing and access to HPC services at a regional level and between EU and ASEAN.

Indeed, a large majority of the consulted center reported an interested in accessing an inter-state regional (Tier-0) HPC/Research Computing Centre, as depicted in the Figure **17**.

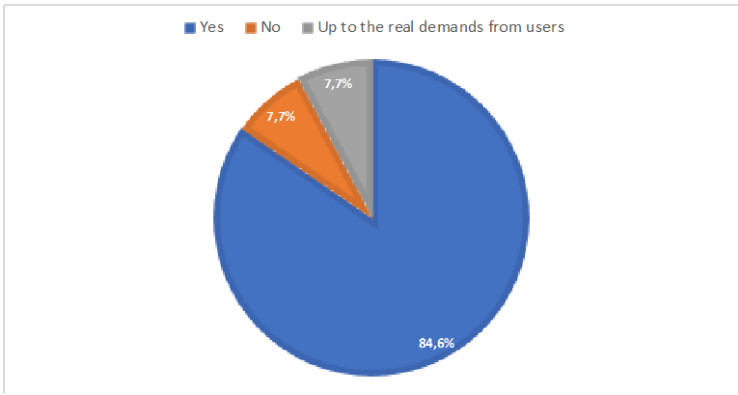


Figure 17: Reported interest in accessing an inter-state regional (Tier-0) HPC/Research Computing Centre

The objective of a shared HPC infrastructure in ASEAN are multiple and pertain to build Regional HPC capacities; deepening digital connectivity; encouraging innovation and overcome high entry barrier of HPC by optimizing resources and cost sharing and creating opportunities for talents in ASEAN.

Such a shared facility can exist under different governance models which are listed in the next section.

A. Governance Model

We can basically suggest two governance models for the definition of a shard HPC facility within the ASEAN region:

1. **Governance Model 1 (distributed, hierarchical, similar to PRACE):** One approach for the governance of regional HPC resource sharing is to have a set a (identified) National (Tier-1) Computing Center and/or regional (Tier-0) Supercomputing center with joint agreement and trusted delegation to enable access to externals to the local resources (up to a certain fraction of the computing capacity).
2. **Governance Model 2 (centralized):** this approach consists in promoting a single regional (Tier0) Supercomputing centralizing the management of all accesses.

Europe has of course the experience (quite unique in the world) with regards the first model which present the advantage to maintain the sovereignty of the national platforms. In this case, and from the analysis performed in the **Chapter 4** we could have imagined a specification depicted in the Figure **18**. The driving forces for the HPC resources would be in this case the existing national HPC centers (above 1 PFlops). From the current situation, this would involve Singapore (with NSCC) and

Thailand (with ThaiSC). With regards the anticipated developments for this year or up to 2020, this could also involve Indonesia and Malaysia. The other AMS would contribute in this case with local login nodes allowed to submit jobs and transfer data toward the federated HPC infrastructure, thus outsourcing the execution onto the shared HPC facility.

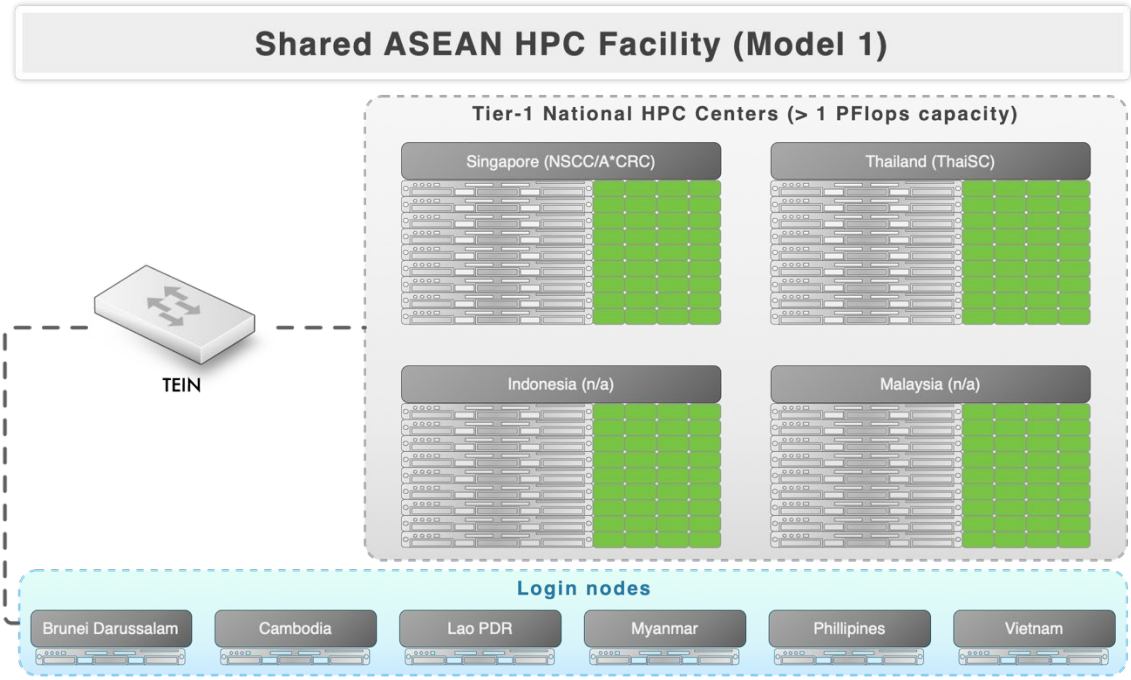


Figure 18: Distributed model for the shared ASEAN HPC facility

These login nodes are local servers benefitting from a dedicated interconnection toward the shared HPC facility. Eventually, they could be attached to a local computational power (typically below 100 TFlops) to allow for local pre and/or post analysis duties (for instance to apply pseudo anonymization on the outsourced data analysis).

The second (centralized) model could take the form depicted in the Figure **19** where Singapore is ready to provide the HPC resources within a dedicated Tier-0 regional system, and all the other AMS would host local login nodes allowing to submit jobs to this system, thus outsourcing the execution onto this facility.

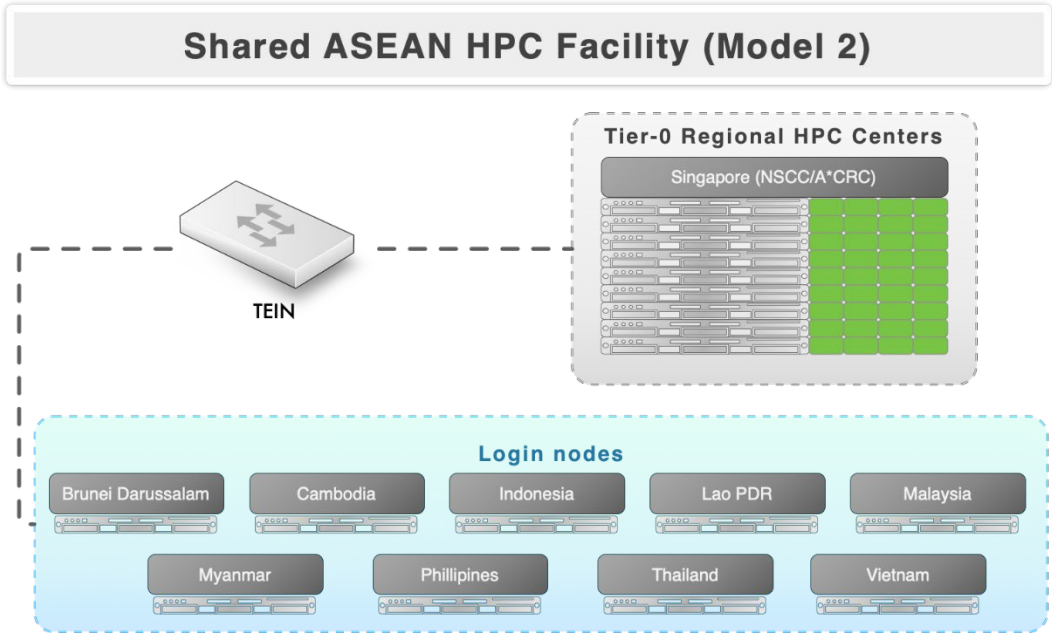


Figure 19: Centralized model for the shared ASEAN HPC facility

1. Partial SWOT analysis of the models

Thanks to the survey and the performed interviews, it was possible to collect the feedback from the AMS with regards each model and the conditions expected to reach a consensus on one or the other. While it does not allow to perform a complete SWOT (Strengths, Weaknesses, Opportunities, and Threats) analyses for each model, it still permits to report the perceived advantages and drawbacks of each model.

First of all, **both models are seen as stimulator** for local development and enhance synergies, enabling a more efficient HPC usage that would allow:

- To leverage on the expertise, data sharing and capacity sharing
- A better understanding, learning, and HPC support of benefit for the STI, which bring significant economic value and social impact.
- To create an ecosystem within the nations or ASEAN regions targeting scientists, researchers, funding agency, high level policy maker, and productive sectors.
- Higher availability and access to (more than existing) HPC resources for AMS scientists within their reach of supporting mechanisms, policy, and budget.

Potentially, both models are considered to allow for a fair and sensible service model.

Model 1 (distributed) is seen as the most flexible approach. While this model allows for confidential data and simulation to be performed locally while outsourcing public data analysis, this distributed model raises a general security concern upon outsourced computations. A common consensus is that only specific data related to the agreed (amongst all AMS) research areas should be accessed and shared, yet this probably highlights a general reluctance to share on the same platform jobs emanating from both local and remote actors. Such a consideration would favor the Model 2 which present the advantage to centralise the expertise and resources for solving large problem. In particular, it does not require expertise on local system support which could be of interest for AMS not having enough HPC staff or capacity locally.

In all cases, **several barriers were foreseen** to allow for HPC resource sharing across research Institutes within AMS in both models. As per survey, the following elements prevent the implementation and success of an shared ASEAN HPC facility:

1. *Inadequate amount of HPC core management team*, career development and incentives to use the shared facility
2. *Un-appealing business model*. In particular, the following criteria would be key failing factors:
   - High Cap-ex and (shared) Op-ex
   - Price of the cost-recovery formula for all participating institutions to use the HPC resources
3. *Instability of political situation*, hence affecting the volatile S&T Infrastructure investment and policy
4. *Lack of expertise to support the use of HPC facilities*
5. ***Information security, data privacy***. In particular, data can't be moved easily between AMS due to certain data protection policy.
   - Model 1 raises a common concern with the fact that there should be a way to ensure that only specific data related to the agreed (amongst all AMS) research areas would be accessed and shared.
6. S&T infrastructure in almost all AMS are built with government subsidy and taxpayer money. They already are scarce to serve each nation's demands. As a consequence*, mutual sharing could be difficult to justify*.
7. Network backbone infrastructure between the AMS as well as within domestic network can be a bottleneck for efficient data transfer

All these arguments are pertinent and are addressed differently depending on the deployment model considered. A risk mitigation strategy for the identified weaknesses for each model is proposed in the below Table **24**.

Table 24: Risk mitigation strategy for the identified weakness for a shared HPC facility

	Weakness	Strategy Model 1 (distributed)	Strategy Model 2 (centralized)

1	*Inadequate amount of HPC core management team*	• Federation of the expert HPC core management team of the contributing centers
		  ○ Involves team from 2 to 4 expert national center
		  ○ Involves international (EU) / vendor support
			• Expert HPC core management team already in place and daily address national HPC needs thus is able to serve regional needs
			• Other teams from other HPC national center could be involved with the appropriate incentives and cost model

2	*Un-appealing business model*	• Free access for interactive and best-effort usage (prototype design) • Free access over computing shares for users belonging to HPC resources providers (up to a certain usage) threshold then pay-per-use	

		• Fair-share model with increased sharing ratio for business/local users • Free access/no overhead pay-per-use for academic usage • Price/cost model below public cloud market offering • Delegate commercial application licensing cost to the end user if possible	
3	*Instability of political situation*	• Ensure AMS contributors to HPC resource are supported by national strategy and with a stable regime	
4	*Lack of expertise to support the use of HPC facilities*	• ITIL best practices for centralised IT service management • Distributed support team involving senior HPC experts and domain specialist across AMS. Consider extension to international support from reference HPC centers (EU etc.) • Responsibility matrix (RACI Responsible, Accountable, Consulted, Informed) to allocate clear roles within the operations and management staff, including roles within issue resolution processes	
5	*Information security, data privacy*	• General Data Protection Regulation (GDPR)-inspired policies for data and privacy • Data Protection Officer (DPO) to help risks evaluation • Support for automatic assessment of pseudonymised or anonymised data. • SLA and scheduling policy for exclusive access to allocated resources with on-demand cleanup procedure • EUDAT Collaborative Data Infrastructure or similar • Continuous monitoring and ACL enforcement • Continuous Infrastructure audit / pen testing	
6	*Mutual sharing could be difficult to justify*	• TCO and cost model demonstrating savings when compared to individual development • Success story and policy makers involvement • Use cases matching national priorities	n/a
7	*Network backbone infrastructure between the AMS*	• Consolidation of TEIN network	

2. Funding Model consensus

The **expected funding model** was also covered in the survey and discussed during the interviews. It permitted to report the common expectation which seem mandatory to receive a consensus agreement across all AMS (especially the ones not contributing to a significant amount of HPC resources)

- Access is granted under the general conditions of an ASEAN cooperation framework
- **Limited basic tier access free of charge** with default storage and cpu hours **for learning and training purposes**
- **Project based access** to granted storage and compute time based on a resource allocation process on **scientific merit, justified collaborative research on priority areas or direct fee-paying model**
    - This would involve a Scientific Steering Committee (SSC) as done in PRACE, in this case involving domain experts from all AMS. The presence of external international experts (from EU etc.) is also frequently mentioned and considered an asset
    - The cost model for fees should be competitive with public cloud providers offerings.
- **Initial CAPEX investment** (as well as future technology refresh) should be financed **from external funding agencies** e.g. COSTI, ASEAN Dialogue Partners, etc
- **Partial cost recovery on OPEX expenses** should come **from yearly contributions by participating organisations and AMS** (as done in PRACE)

The ASEAN HPC Task Force has also worked on their own vision for the shared HPC facility (see Figure **28** on page 109). In particular, Singapore is willing to consider the second approach (Model 2) for a fast-start toward democratizing HPC access to all authorized HPC-using researchers in ASEAN Member States, with a plan to evolve it to a distributed hierarchical approach as other AMS develop their internal HPC ecosystem. There seems to be a consensus toward this solution, and EU is the right partner to bring its expertise on concretizing this effort.

B. Shared HPC facility system specifications

The shared facility will serve a large variety of complex, data-driven computational workloads. Its design should be forward-looking, responding to the emerging convergence of simulation, modelling, data analytics and AI. Details on the precised processor architecture or exact computing / storage capacity would be out of the scope of this report, yet it is possible to report from the survey and the performed interviews the expected characteristics (outside the featured software largely covered in the **Chapter 6.A**) of the shared ASEAN HPC facility.

1. Modularity

A modular setup is expected to cover all needs, typically composed by the following modules:

- A **regular cluster** module, comprising computing nodes with dual (as traditionally featured), high core density CPUs providing the base computational capability for the widest range of applications
- An **accelerator** module**,** composed primarily of computing nodes with a dense set of GPU-AI accelerators targeting high speed-up of GPU-enabled applications and AI/Deep Learning-oriented workflows. Visualization nodes are also typically included as part of this module.
- A **large memory** module could be considered, featuring computing nodes with multiple high-core density CPUs and a large live memory capacity (for instance over 3 TB RAM/node), meant for in-memory processing of huge data sets.
- A **cloud** module would be of interest for several AMS, consisting of a significant number of virtualisation hosts; its primary purpose is to meet the need for cross-computational job persistence with project-lifetime databases and APIs.

Such a configuration is reflecting the current situation across the ASEAN HPC sites, as depicted in the below Figure **20**.

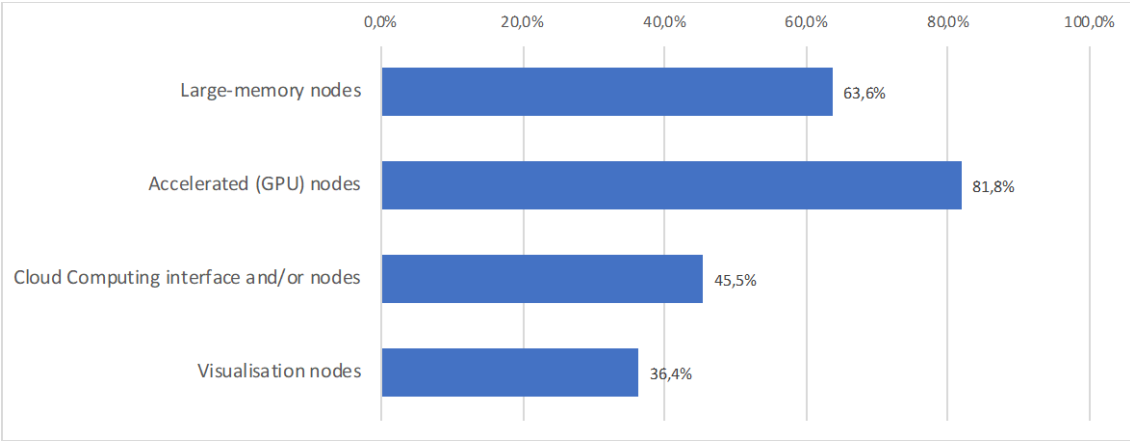


Figure 20: Featured specialized nodes within the surveyed ASEAN HPC facilities

2. Fast Local Interconnect

High Performance Computing (HPC) encompasses advanced computation over parallel processing, enabling faster execution of highly compute intensive tasks. The execution time of a given simulation depends upon many factors, such as the number of CPU/GPU cores and their utilisation factor and the interconnect performance,

efficiency, and scalability. HPC interconnect technologies can be nowadays divided into three categories: Ethernet, InfiniBand, and vendor specific interconnects.

Whatever technology is selected, it is advised to enable adaptive routing and congestion management over a scalable topology.

3. Operational Management

This includes (1) configuration management, the (2) node provisioning and (3) the workload management systems. Things are easier in the Model 2 (centralized) as the technological choices for these three components are controlled by a single entity managing and operating the main system. For the distributed model (Model 1), it is advised to reach a consensus on the deployed tools.

The current situation among the existing ASEAN HPC facility is now reported for these elements:

- Configuration in large-scale systems requires automated tools that facilitate the deployment and management of production services based on repetitive and error-prone system administration tasks, while minimizing the effort of the technical staff maintaining these resources. The two most popular and reference frameworks in this domain are Puppet[187] and Ansible[188]. Both share the similar concepts of reusable shared recipes (called modules or playbooks depending on the framework) that can be combined and customized to define the way a certain resource or service is expected to be configured and run. Yet, as can be seen in the Figure **21**, none of these tools are currently used (except Puppet in a few case). So the selected technology remains opened.

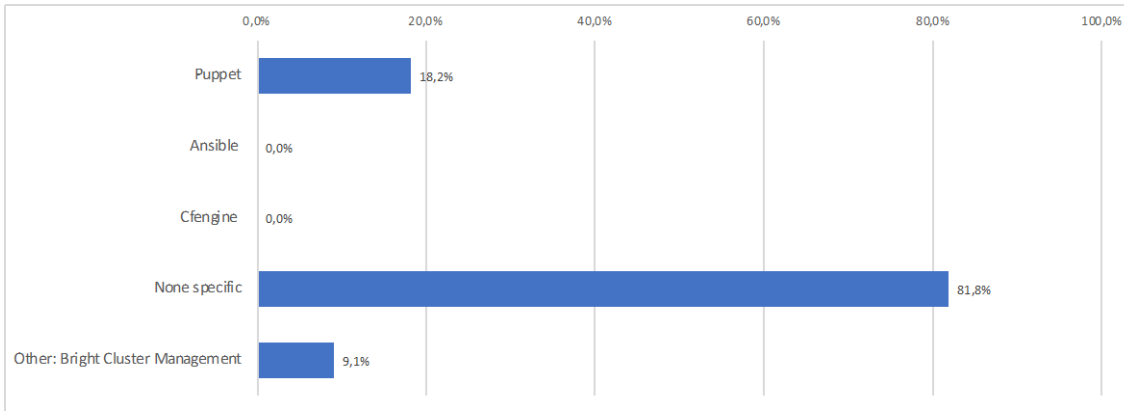


Figure 21: Type of configuration management tools in use within the surveyed HPC facilities

- The management of large-scale HPC facilities assumes the availability of scalable provisioning tools, especially as regards the automated deployment of the many computing nodes that compose a supercomputer. At this level, several tools are traditionally used in leadership HPC Centers:
  - xCat[189];
  - Bright Cluster Manager[190];

[187] https://puppet.com/
[188] https://www.ansible.com/
[189] Extreme Cloud Administration Toolkit - http://xcat.org/
[190] https://www.brightcomputing.com/documentation

- IBM Spectrum LSF Suites[191];
- Warewulf3[192], also used within the community-driven OpenHPC[193] project.
- Of less frequent usage, Kickstart, Cobbler[194] or FAI[195] are also used.
  Overall, these tools are meant to cover part or all of the below features:
- Discover the hardware servers;
- Execute remote system management;
- Provision operating systems on physical or virtual machines, either in disk-based (stateful) or diskless (stateless) mode;
- Install and configure user applications;
- Perform parallel system management tasks.
  The current situation (as depicted in the Figure **22**) is more heterogeneous within the existing ASEAN HPC centers, which could raise concerns when sharing the expertise and HPC staff to support the managed resources within a shared facility.

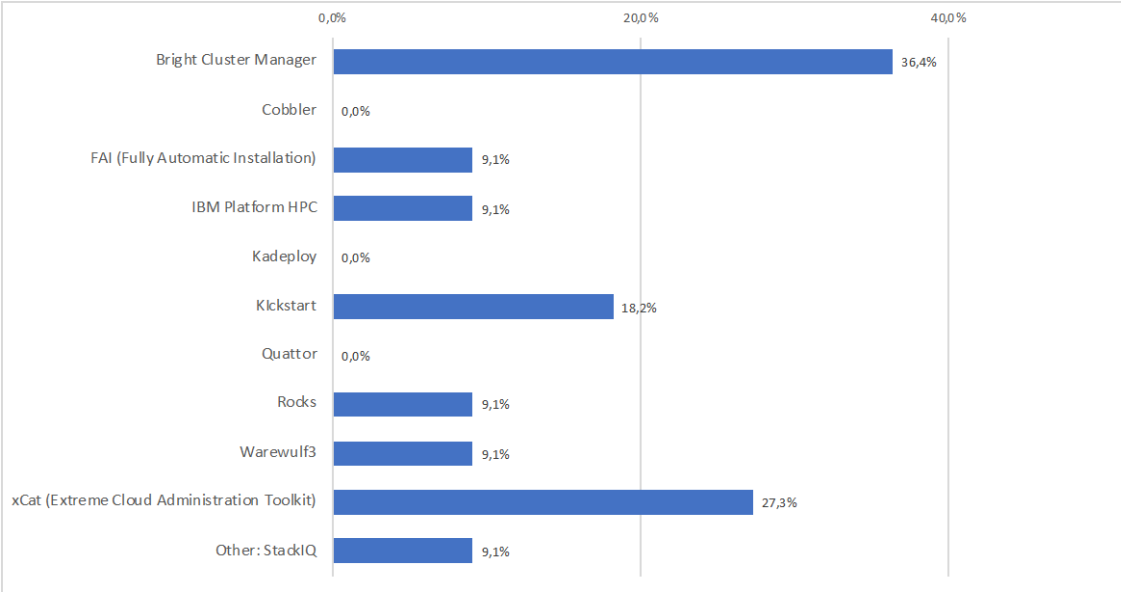


Figure 22: Type of Node Provisioning tools in use within the surveyed HPC facilities

- The selection of the workload management system is also quite sensitive. The current situation among the existing facilities is proposed in the Figure **23**.
  Among the possible choices, we could only suggest favoring Slurm[196] (already in place in half of the considered HPC centers across the AMS) as it is used in top-class supercomputers worldwide due to being highly performant, configurable and extensible, with fault tolerance features throughout its architecture, enabling high availability. It has been designed for scalability, shown to operate systems with over 10 million cores (the Sunway TaihuLight system. Many software packages and frameworks integrate natively with Slurm ranging from MPI implementations to toolkits for Big Data analytics.

[191] https://www.ibm.com/sg-en/marketplace/hpc-workload-management
[192] http://warewulf.lbl.gov/
[193] https://openhpc.community/
[194] https://cobbler.github.io/
[195] Fully Automatic Installation - https://fai-project.org/
[196] https://slurm.schedmd.com/

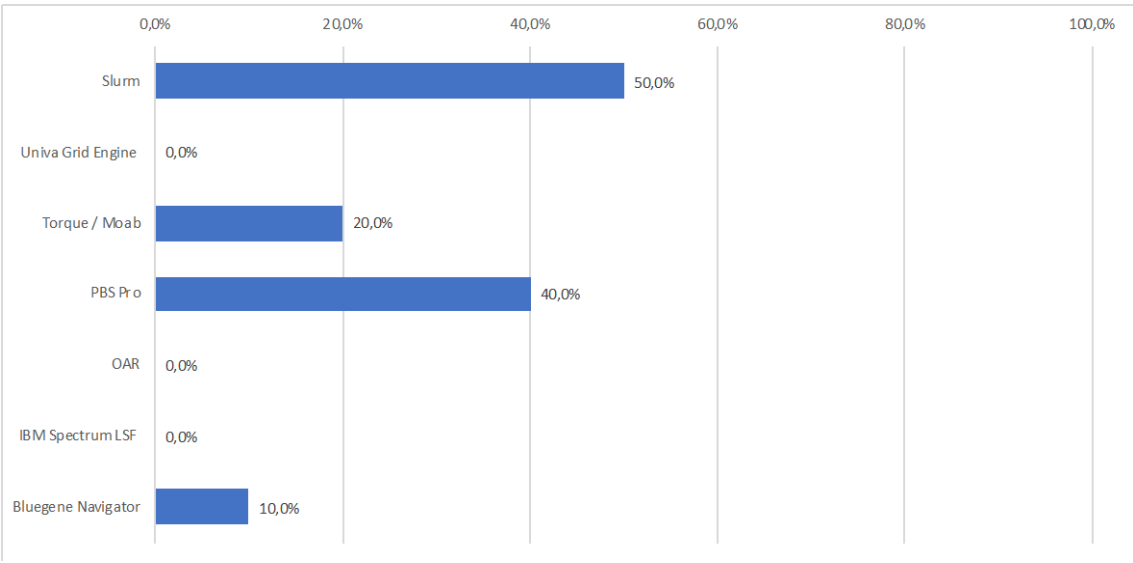


Figure 23: Type of RJMS (Resource and Job Management System) in use within the surveyed HPC facilities

4. Issue Management

While better covered in the **Chapter 9**, issue management remain a key aspect enabling a successful experience with the foreseen shared HPC facility. At this level, we could only suggest applying ITIL[197] best practices for IT service management in order to manage, resolve and communicate issues.

As a technical support base, the operation and management team of the shared facility should provide the following systems:

- A user-oriented service desk tool such as Atlassian Jira[198];
- An operations team project management tool such as GitLab[199];
- An operational status communication tool such as Cachet[200].

5. Energy Efficiency Aspects

Even prior to the 21th century, there was an awareness on the importance of energy efficiency in management strategies for HPC facilities. By the second decade, the awareness that improvements in energy efficient design and operations of data centres can bring significant reduction of the overall energy consumption and therefore operational costs is much more widespread coupled with a better understanding of the trade-offs involved in using energy-efficient strategies by many HPC operators and users mainly in the EU and other developed countries. The evidence that such awareness is now widespread globally became apparent with the integration of the Green500 project with TOP500 list (the global list of fastest 500 HPCs) in November 2007 at SC07, following nearly a decade of collaboration between the two projects. The Green500 list ranks the top 500 supercomputers in the world by energy efficiency. The focus of performance-at-any-cost computer operations has

[197] https://wiki.en.it-processmaps.com/index.php/IT_Service_Continuity_Management
[198] http://www.atlassian.com/software/jira/service-desk
[199] http://docs.gitlab.com/ee/user/project/issues
[200] http://cachethq.io

led to the emergence of supercomputers that consume vast amounts of electrical power and produce so much heat that large cooling facilities must be constructed to ensure proper performance. To address this trend, the Green500 list puts a premium on energy-efficient performance for sustainable supercomputing. The Green500 rank supercomputers compared by performance-per-watt and also uses the performance numbers by the Linpack benchmark[201]. In order to understand the patterns of energy efficiency practice in HPC facilities in the ASEAN sites, the survey questionnaire asks three questions to respondents as follows:

1. The type of cooling technology available in the Data center – as can be seen in the Figure **24**, a majority of the interviewed site are relying on the reference Airflow-based cooling. A few sites (mainly in Singapore) are already using cutting-edge cooling infrastructures allowing for higher computing density and a higher energy efficiency, i.e. based on Direct Liquid Cooling (DLC) technologies or with Water doors (i.e. using a cooling late and frame heat exchanger rather than cooling water from chiller plant). It is clear that DLC type of cooling technology is expected to be democratized across the AMSs, at least for the countries which envision the hosting of Tier-1 (national) HPC facilities. **This could be done with the support and return of experience of EU HPC sites which are deploying these approaches for a few years within their Tier-0 systems**.

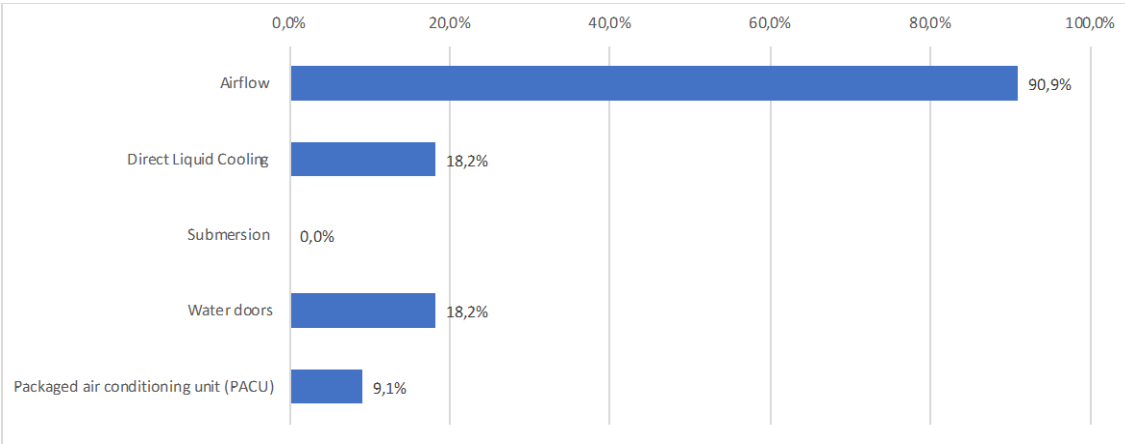


Figure 24: Type of cooling technology available on the interviewed sites hosting an HPC facility

2. the identification of energy management procedures outlined in the center (see Figure **25**), which includes:

- Benchmark (or review full system operation and efficiency) on a regular monitoring e.g. electric power meters, chilled water flow meters, and temperature sensors for nearly half of the sites (45,5%)
- Regularly measure the Power Utilization Effectiveness (PUE) of the total infrastructure, also for close to half of the sites
- Cooling and Electrical Distribution Efficiency.
- Train/Raise awareness and train HPC Staff about the financial and environmental impact of energy savings as well as latest energy management best practices and tools. Only a few sites implement this option which means that this could be of interest for collaborative trainings with EU sites already proposing this methodology within their HPC teams.
    - Eventually, a Thermal-Topology-aware job scheduling policy (featured in PBSPro for instance) can be implemented (this is the case in one site),

[201] https://www.top500.org/green500/

which involves 6540 sensors real-time monitoring allowing to depict live PUE computation

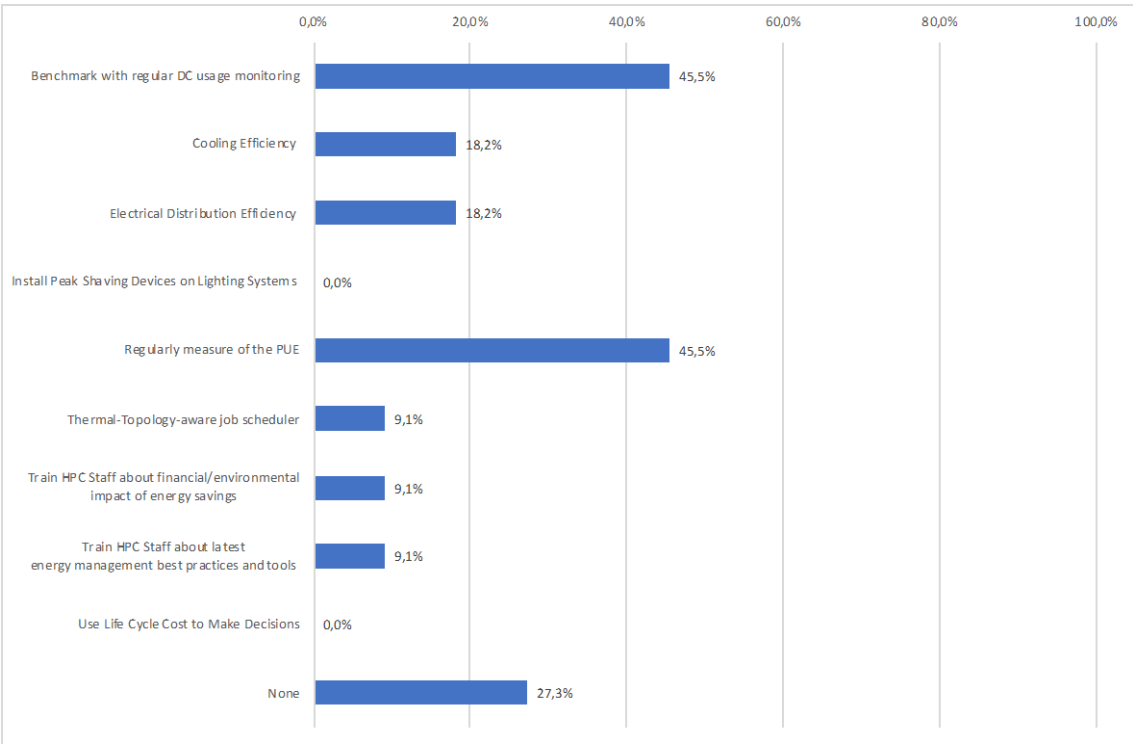


Figure 25: type of energy efficiency management procedures available in the interviewed HPC sites

3. the identification of willingness to create a Team to improve data centre energy efficiency by reducing potential communication gaps between their IT and Facilities management within the HPC Cluster. As can be seen in the Figure **26**, given that in above over 90% respondents either would like to engagement into this type of improvement within their Data Centre (DC) and/or might be thinking of this type of activity, then there is a strong case for either introducing a more automated energy management software (such as DC Information Management or DCIM) for whole of DC IT and/or just the HPC building facilities. Using such a software, the HPC staff can auto-generates accurate IT compute and infrastructure monitoring and their inter-dependence diagram making HPC DC management as a whole faster, user-friendly and more accurate.

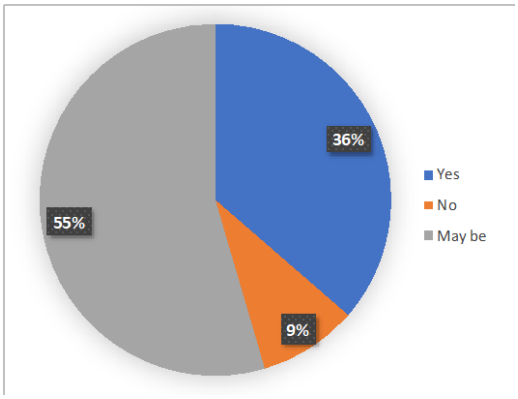


Figure 26: Willingness to create a dedicated team to improve data centre energy efficiency by reducing potential communication gaps between the IT and Facilities management

More energy efficiency gains can be achieved if a great deal of attention is paid at the design stage of a data centre and having the data centre achieving to compliance to standards (such as ANSI/TIA-942 compliant, Uptime Institute TIER ranking or others) which will bring not only operational cost savings but also recognition by users and other stakeholders. Again, this could be done with the support and return of experience of EU HPC sites which are deploying these approaches for a few years within its Tier-0 systems.

6. Data Management

Inspired by the EUDAT Collaborative Data Infrastructure[202], a European e-infrastructure of integrated data services and resources to support research, where European researchers and practitioners from any research discipline can preserve, find, access, and process data in a trusted environment, the AMS could benefit from this experience for the management (preservation, sharing, publication, discovery, access, tagging, data management plans, training, etc.) of data flows between the AMS HPC sites, in collaborative large-scale projects.

Similarly to the identified collaboration opportunities and services between PRACE and EUDAT, E-READI can support the following challenges:

- Data lifecycle coverage to support AMS users to cover the entire data lifecycle from creating, processing, analysing, to preserving data.
- Consolidating in collaboration with TEIN and GEANT the seamless access to the data infrastructure
- Data management training as part of the foreseen training courses

7. Access policy and allocation procedure

Access from users, coming from other partnered AMS (contributing or not to the local pool of HPC resources), should be granted according to the rules and procedures approved by an ASEAN cooperation framework.

At this level, we can report (for inspiration) the current procedure in place within PRACE, which provides HPC resources to researchers and scientists from academia

[202] https://eudat.eu/

and industry through **Preparatory Access (code scaling and optimisation) and/or through Project Access (large-scale, computationally intensive projects)** at European level. The call for proposals for project access opens twice a year when the call for proposals for preparatory access is a continuously open call with cut-off dates every three months. Proposals have to be submitted online and are being reviewed by selected independent (external) reviewers which must be internationally recognised experts in their field, normally scientists at Associate or Full Professor level and at least two years beyond the postdoctoral level. Emphasis on interdisciplinary scientists with a demonstrated track-record in HPC is encouraged. After the technical and scientific review steps the proposals, reviews and replies from the applicants are ranked by the Access Committee (AC) according to scientific and technical excellence in a Resource Allocation Session (RAS). This is the base for the allocation of resources to proposals by the Board of Directors (BoD). The Access Committee is composed of eminent scientists from across the remit of the PRACE scientific applications.

The overall process is supervised by the PRACE **Scientific Steering Committee (SSC)**.

This Peer Review Process has proven as effective and efficient with the goal to select and award the best scientific proposals. It is based on the following principles:

- *Transparency*: The peer review process is transparent and clear to all stakeholders in PRACE including funding agencies of all member countries and users from research institutions and industry.
- *Fairness*: Proposals are evaluated on merit and potential high impact on European and international science and economy.
- *No parallel assessment*: The PRACE peer review process builds on the experiences and best practices of national and international institutions and constitutes a centralised peer review exercise recognised by all PRACE partner countries and scientific communities.
- *Reviews are done by experts* in the scientific field of the proposal, with no declared conflict of interest, based on criteria published in the PRACE Calls for Proposals and with a periodic reshuffling of reviewer's appointments.
- *Confidentiality*: Proposals will be treated with the needed confidentiality by PRACE staff and reviewers. The identities of the peer reviewers shall not be disclosed.
- *Right to reply* to technical and scientific evaluations.

For these reasons, **AMS are encouraged to apply a similar approach within the shared ASEAN HPC facility**.

C. Connectivity aspects between the AMS and toward EU and the GEANT network

Asi@Connect[203] provides dedicated high-capacity internet connectivity for research and education communities across Asia-Pacific. Operating at speeds of up to 10 Gbps, it currently interconnects universities and research centres in 21 countries/economies across the region. It also connects to the 50 million European researchers and academics served by the GÉANT network[204] and supports collaborative programmes in areas such as Earth observation, disaster warning, climate research, food security, delivery of e-health and e-learning.

Asi@Connect marks the 4th phase of EU funding to the Trans-Eurasia Information Network (TEIN) program which was launched as an Asia-Europe Meeting (ASEM) initiative in 2001; it successfully established a regional research and education internet network (TEIN) from scratch in 2004 and progressively expanded its geographical footprint over the years. During this new phase, greater emphasis will be placed on delivering the project with increased involvement of additional partners within the Asia-Pacific R&E community.

The current project phase, Asi@Connect, is a 60-month project which started on 1 September 2016. The project is jointly funded by the European Union and Asian partners and is managed by TEIN*CC (TEIN*Cooperation Center) based in Seoul, Korea. The Korean Government, the Ministry of Science and ICT, supports the project and TEIN*CC. Seoul Metropolitan City Government has contributed the TEIN*Cooperation Center office, facilities and property management costs.

Building on previous TEIN programme project phases, Asi@Connect also aligns to and interacts with other regional R&E network projects and organisations in other parts of the world, in particular:

- GÉANT (Europe)
- APAN (Asia-Pacific)
- EUMEDCONNECT (Eastern Mediterranean)
- RedCLARA (Latin America)
- CAREN (Central Asia)
- AfricaConnect2 / WACREN / UbuntuNet / ASREN(Africa)
- ASREN (Middle East)
- Internet2 / ESNET / CANARIE (North America)

The current network map is depicted on the Figure **27**.[205] The online (and up-to-date) version of this map can be found on the following url: http://www.tein.asia/sub/?mc=2030. As can be seen, Singapore is clearly a central hub allowing for the efficient connection among the AMS and toward EU and the Geant network. Yet the current state of this backbone remains quite heterogeneous and limited in the connection speed offered for the different partners, including across the AMS. For instance, some countries within the ASEAN region only benefit from 1GbE connections (Indonesia, Thailand, Malaysia…) or even below: Laos is only reachable within this backbone through Thailand and a 100Mbps link. In this context, interconnection links toward the shared ASEAN HPC facility (whichever model is retained) will be problematic as it would not be sufficient to sustain the heavy data exchanges foreseen in HPC workload tied to the identified priority areas (see **Chapter 6**). It is worth to note that this was also identified by the ASEAN HPC Task force, as

[203] http://www.tein.asia/sub/?mc=1010
[204] https://www.geant.org/
[205] Also available on http://www.tein.asia/sub/?mc=2030

depicted in the Figure **28** depicting the projected configuration. Note that the correctness of the links (and associated capacity) reported could not be checked.

To sustain the development of a shared HPC facility, it is thus required to consolidate the TEIN network (especially the connectivity links below 10 Gbps capacity) as well as the interconnect toward the GEANT network.

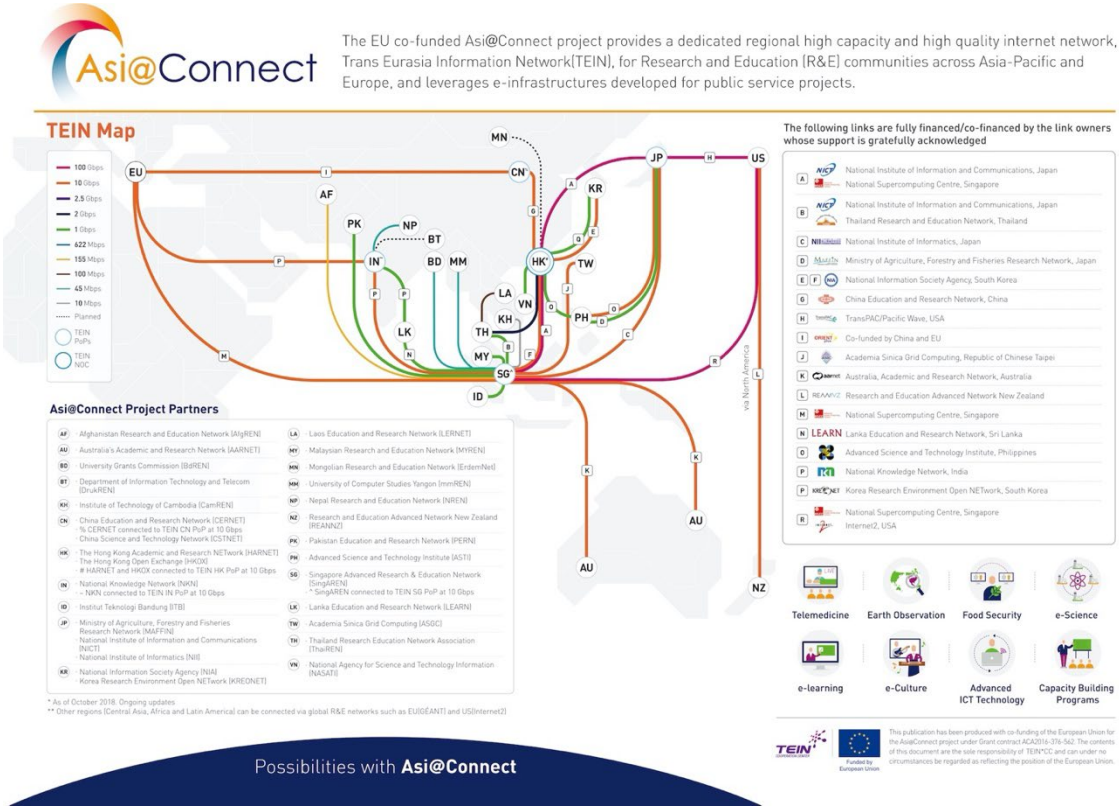


Figure 27: Overview of the Asi@Connect/TEIN Network map

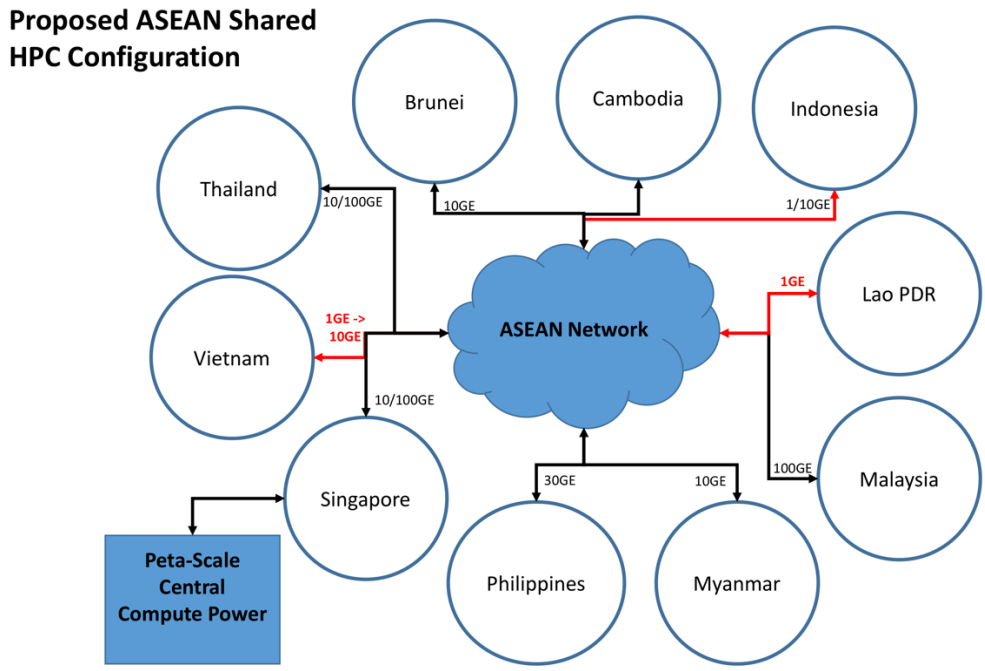


Figure 28: Proposed ASEAN shared HPC facility [Source: ASEAN HPC TF report to COSTI-76 meeting, June 2019]

D. Gender dimension in HPC core R&D, management and support staff as well as HPC user/researcher development program

The survey covered a question tied to the gender breakdown of HPC staff (Full Time Equivalent) employed between men and women within the core HPC Management R&D, and support staff categories. Gender balance can play a role in the societal impact of HPC development as HPCs are key economic drivers providing the ability for scientific breakthroughs that are impossible without leading edge computer resources. Enabling equality of opportunity and participation is also important to increase this competitiveness.

In the case of the AMS, the information on precise statistics was hardly provided (only in four (4) answers), and reflect a majority (if not exclusive) male environment.

In EU, PRACE has established the "PRACE Women in HPC Workshop" in 2009 and held a "PRACE year of Women in HPC" in 2015 with the aim to promote diversity within the HPC community, raising the profile of female professionals in HPC and engages the community, challenging the stereotypes of an HPC scientist. At international events, such as ISC and SC, the Women in HPC initiative draws great interest from the HPC and scientific community. For example, in the recent ISC19, there was an early/mid career posters on HPC topics for the 10th International Women in HPC Workshop.[206]

[206] http://www.prace-ri.eu/women-in-hpc-workshop-isc19/

During the interview and exchanges performed when conducting this study, 5 women working with HPC-related activities were identified who expressed interest in learning more about the "PRACE Women in HPC" and here we marked them in the list as "women scientists with a strong interest in improving the opportunities for women".

Based on a field interviews, they stated that they have been active in supporting HPC related research – some not only in their own country but also in Europe and/or other international locations. Perhaps their profile as female professionals in HPC might provide examples for other women who contemplate a career in HPC enabled science and infrastructure development. Below is the non-exhaustive list of their names and institutions and domain interests:

- Dr. Regina Yulia Yasmin, Meteorological, Climatological & Geophysical Agency (BMKG-Indonesia), HPC Administration & Disaster Response
- Dr. Armida L. Latifah, Research Centre for Informatics, Institute of Science (RCI/P2I-LIPI – Indonesia), Climate Modelling Research.
- Ms. Jelina Tanya H. Tetangco, Senior Science Research Specialist, Advance Science and Technology Institute (ASTI-DTO – Philippines), HPC Management and Administration
- Ms. Phan Ngoc Phuong Linh, International Cooperation Group Leader, General Management Department (Satellite Technology Application Center (STAC), Ho Chi Minh City – part of Vietnam Academy of Science & Technology (VAST), Inter-agency Cooperation on HPC
- Dr. Pham Thi Mai Thy, Senior Researcher, Climate Modelling and Remote Sensing

Chapter 9 : Cross Analysis with EU pools for Staff and Support services

Of particular interest for the EU-ASEAN collaboration, a tied integration with the PRACE/EuroHPC HLST (High Level Support Team) is pertinent for the highest level of support. As a reminder, those levels are traditionally defined as follows:

1. ***Level 1*** support corresponds to questions that can be typically solved within a day, e.g. for instance issues related to HPC facility access and data transfer, simple account management task, Job scheduling questions or Software environment questions.
2. ***Level 2*** support corresponds to questions that require up to 5 working days, e.g. complex account management tasks including usage reporting, complex software environment issues, requests for new applications integration on the platform (installation, configuration, licensing) etc.
3. ***Level 3*** support corresponds to expert support questions that can require over 5 working days, i.e. when vendor involvement is required, very complex software environment questions, complex applications integration on the platform and/or application performance profiling and tuning for the HPC facility
4. ***Level 4*** support includes complex application performance profiling and tuning for the HPC facility, long term project missions with domain experts and/or application codesign.

The below Figure 29 reports the type of support level provided by the interviewed organization featuring HPC resources

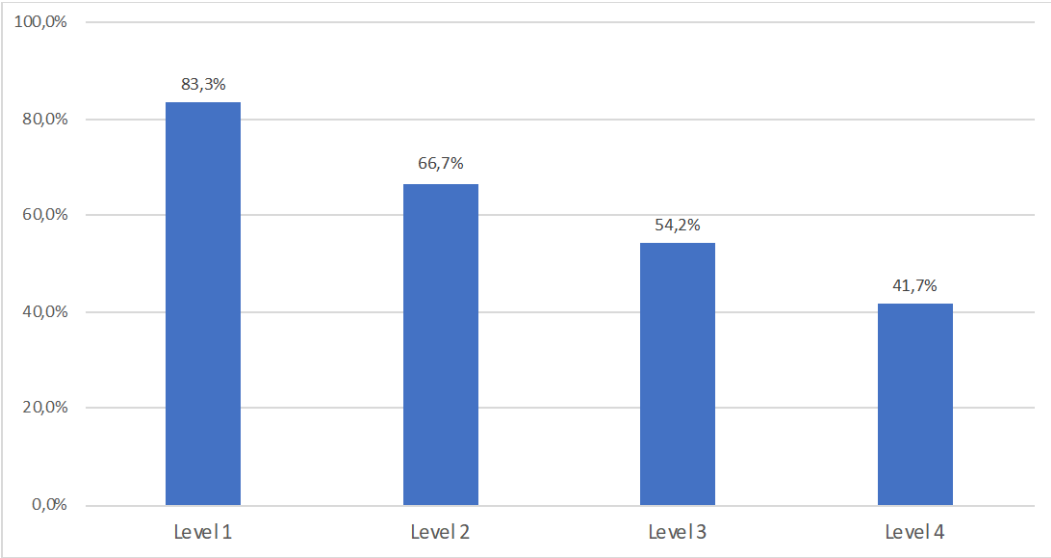


Figure 29: Type of support level offered in the interviewed institutes featuring HPC resources

To compensate the missing expert personnel dedicated to the support levels (starting with Level 2, but more importantly as regards the level 3 and 4), **access to PRACE/EuroHPC High Level Support Teams (HLST) and expert teams is wished**, especially for user applications support. It is also suggested for the **existing HPC centres offering the highest support to act as coordinator for National**

HPC Support Teams (a role that can be for instance rotated on an annual basis). A **MoU between the EU-ASEAN Coordination Group and this coordinator is expected to leverage HPC and e-Research capabilities to support and accelerate modern research within each AMSs and enhance inter-ASEAN collaboration[207].**

In complement to the access to EU support levels 3 and 4, several AMS proposed to share this type of support between several centres, each focusing on specific application domains depending on local interest and expertise. For example, one centre may focus on Molecular Dynamics when another one might focus on bioinformatics and Artificial Intelligence. This would reduce number of expert personnel per centre, while allowing to serve a wide spectrum of applications.

The situation of the majority of the HPC user community (as reported in the Figure 8) permits also to reflect an **expected need and support for code parallelization, HPC and Big Data workflow management but also for data management (transfer, quotas, archiving, privacy etc.)**.

The way the support service for IT/HPC issues are handled among the interviewed AMS HPC centers is depicted in the Figure 30. The collaboration with EU HPC HLST will have to expand the existing approach based on ticketing system, while allowing for email exchange tied to the open tickets to ensure a compliance with the existing context where email is the reported as the primary interaction medium (91.7% of the cases) when implementing support service related to IT/HPC issues.

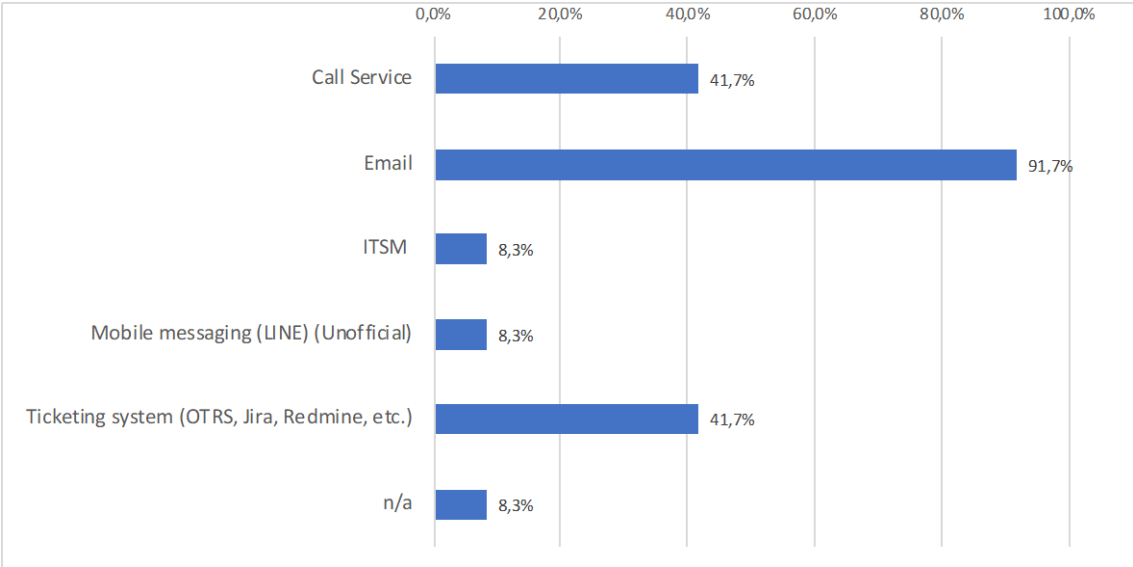


Figure 30: Implemented approaches for support service related to IT/HPC issues

On a separate topic, a large majority of the interviewed AMS reported the need to need for support from external sources when preparing tender document tied to HPC procurement – see Figure **31**. The experience and **support of EU/PRACE/EuroHPC for preparing tender document tied to HPC procurement and system**

[207] e-Research is the term applied to the use of advanced information and communication technologies (ICT's) to the practice of research. Key areas include collaboration, computation (including high performance computing), visualisation, research data management and tools.

prototyping is thus suggested as an excellent way to fill the identified gap at this level.

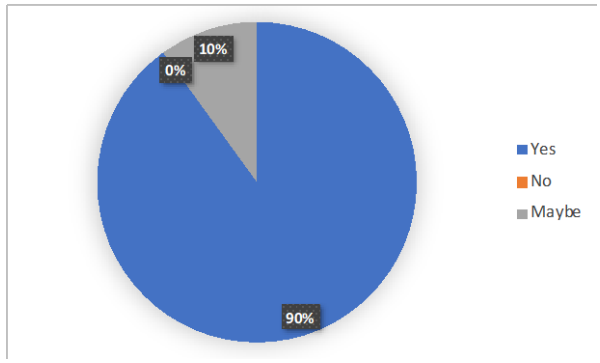


Figure 31: Reported need for support from external sources when preparing tender document tied to HPC procurement.

Chapter 10 : Conclusion, Summary of challenges and Recommended Actions

ASEAN HPC developments are ongoing and can benefit for the synergies and strategic developments performed on Europe for several years.

As per the ToR (Terms of References) piloting this study, the following challenges (one per section) were raised. Our recommendations (when applicable) to address each of these challenges are then summarized, eventually by pointing to the relevant chapter of the present report.

Challenge 1: Synthetic review of EU HPC projects and strategy

- See Chapter 3

Challenge 2: In-depth study of ASEAN HPC ecosystem

- Existing HPC-related Research Infrastructures in each AMS: see Chapter 4.
  - Names and point of contacts for each centre are proposed on APPENDIX A: Identified ASEAN research infrastructures contacted and relevant for the synergy analysis with EU Centre of Excellence.
  - AMS benefitting from a national Tier-1 HPC facility:
    - Philippines (ASTI)
    - Singapore (NSCC), current computing capacity: 1010 TFlops
    - Thailand (ThaiSC), current computing capacity: 531 TFlops
  - AMS featuring one or several local Tier-2 HPC facilities:
    - Brunei Darussalama (IADA)
    - Indonesia (BMKG, P2I/LIPI, LAPAN Bandung)
    - Malaysia (UPM/UTM/PU)
    - Singapore (A*CRC)
    - Thailand (HAII/NHC, TMP)
    - Vietnam
  - AMS not reporting any HPC facility:
    - Cambodia
    - Lao PDR
    - Myanmar
- Available knowledge and skills: widespread, see Chapter 4.

Challenge 3: Consolidating the ASEAN HPC facility developments

- See Chapter 8
- **Contribution and support for the setup of the shared HPC facility governance** (governing board, scientific committee for access project call as per PRACE model, etc.). In particular:
  - Contribution to the definition of the fully **transparent peer-review process for resource allocation** on the ASEAN shared HPC facility**,** PRACE inspired i.e. based on scientific excellence**.**
  - **Contribution to the definition of specific HPC support programs for SMEs** (similar to SHAPE or the EuroHPC Centre of Competences)

- **Enhanced synergies for the foreseen future HPC services**, for instance **HPC/AI services** bringing toward the development of **new elastic Cloud/Access mode of HPC/data/AI Accelerated resources**

- **Access to PRACE/EuroHPC High Level Support Teams (HLST**), especially for L2 to L4 support levels **and nomination of National HPC Support Teams** each with a National Coordinator at a leading institution (which can be rotated on an annual basis)**.** MoU's between EU-ASEAN Coordination Group with that institution to leverage HPC/e-Research capabilities to support and accelerate modern research within each AMSs and enhance inter-ASEAN collaboration.[208]

- **On-demand support for preparing AMS tender document** tied to HPC procurement and system prototyping.
  - This would be typically done by EU Tier-0 HPC Research Centres or collaborative entities responsible for the procurement processes

- **Consolidation of the GEANT network and interconnection with the TEIN network**

- **Dedicated PRACE/EuroHPC Access program opened to AMS for joint research project allowing access to the EU supercomputing Tier-0 centres**, while supporting the initial developments in collaboration with EU Center of Excellence (CoEs) over the ASEAN Tier-1 HPC centres.

- **Contribution to the definition of an integrated data services and resources to support research, where ASEAN researchers and practitioners from any research discipline can preserve, find, access, and process data in a trusted environment,** inspired by the EUDAT Collaborative Data e-infrastructure

Challenge 3: Identify key HPC application areas of joint interest among AMS

This study permitted to confirm the sectoral entry points and joint priority areas having a significant societal impact among all AMS, thus matching not only the ASEAN priority and interest, but also the expertise of the EU Center of Excellence (CoEs) and associated programs (such as ECMWF).

- Disaster Prevention
- Precision Agriculture
- Weather Forecasting and Climate Change
- AI & Big Data Analytics
- Material Science, Molecular Modelling and Computational Chemistry
- Bioinformatics
- Hydroinformatics

For each priority area, an EU-ASEAN working group should be formed to plan the way forward of the sectoral cooperation. ASEAN and the EU could propose members of the working group.

[208] e-Research is the term applied to the use of advanced information and communication technologies (ICT's) to the practice of research. Key areas include collaboration, computation (including high performance computing), visualisation, research data management and tools.

Challenge 4: Reinforce Region-to-Region i.e. EU-ASEAN HPC cooperation and exchanges on selected priority application areas of joint/mutual interest

- **Definition of a FET-HPC** (or whatever name provided to this program under the new calls to be releases under the EuroHPC JU) **[joint] call with ASEAN** on collaborative research projects bringing together European and ASEAN researchers in application domains tied to HPC around shared thematics[209].
    - This would also permit to extend identified EU funding frameworks for short term-visits (such as EuroLab-4-HPC or HPC-Europa-3)

- **Contribution to improved training strategies to reach, support and upskill the HPC professionals and HPC researchers-users (particularly how to generate and engage new users across ASEAN) with HPC tools and management skills.** This could take the form of an increase in the number of face-to-face and or flexible learning (combined FTF and online) training offered in ASEAN and/or in EU as well as the development of online training modules and portal. **To concretise this development, it is foreseen the following actions:**
    - **Access to incoming PRACE Training Centers (PTCs) and CoEs events** (see Chapter 7), especially for trainings tied to applications dealing with seismic, climatology, meteorology, geophysics and remote sensing (or satellite earth observations)
    - **Access to European Centre for Medium-Range Weather Forecasts (ECMWF) trainings,** especially on use and Intepretation of ECMWF products**.**
    - **Organisation of a joint conference and dissemination events** (for instance a Bi-annual HPC workshop to be held alternatively in EU and ASEAN, Summer School etc.) organized at the research level for each identified joint priority application areas, and for the HPC operational teams to share best-practices and return of experience.
    - Careful selection of type of people attending (selection committee EU/ASEAN) selection rules

- **Human capacity development program specifically through EU-ASEAN consortium exchange around HPC** (similar to the EU Erasmus Program)

- **Support for the joint definition of recognized/approved HPC training and certificates.** For instance, definition of Shared/joint Master with HPC specialization HPC (operational management, DC). In addition, participation/support for ASEAN Member States (AMS)

    - HPC centers operational and support staff certifications, for instance CISCO, Red Hat certification, ICTP, certification for TIER data center and IT security, Big Data, RHCSA, RHCE, HPC administrator
    - Training to lower operational costs and improve quality assurance in Data Centre Energy Efficiency/Sustainability, Information Security and all other aspects of DC operations[210]

[209] A similar approach was done for instance with Argentina with the FETHPC-03-2019 call entitled "International Cooperation on HPC with Argentina". It comprises a call for Research and Innovation Action (RIA) with an indicative budget of €500,000.

[210] HPC Operational aspects include:

- **Easy access to a centralised communication medium** to facilitate AMS awareness of HPC-related events organized In Europe (PRACE/EuroHPC/CoEs etc.).
    - **Development of a portal/website for ASEAN and EU HPC specialists** to engage, connect and share information-centric research capabilities, provide link to ASEAN and EU experts that can provide online help for researchers to collaborate, manage, share and understand information as well as facilitate access to a large and growing number of advanced visualisation facilities hosted at various universities and other research agencies in EU, ASEAN and the Asia-Pacific region.

- **Keeping up with leading-edge HPC technologies:**
    - Learning from 'best practice' in engagement with the Private Sector (ICT Companies and Company HPC Users). For example: PRACE Industrial Advisory Committee (Dr. Lee Margetts, Chair); Indonesia-NVIDIA-BNU AI R&D Centre; Vietnam-HoChiMinhCity Univ. of Tech-Collaborations with Intel, NVIDIA, Hewlett-Packard Enterprise, Oracle, Leibniz Supercomputer Center (Germany) & Local Partners.

- **Develop high impact use case using HPC in ASEAN** (ex: multi hazard early warning system)**,** in collaboration with EU CoEs and expert centers and EU scientific**.**

In all cases, we suggest to perform an **impact analysis and review of the EU-ASEAN collaboration** within one year (ideally on a regular basis)

- DC Operations Audit & Certification, DC Facility Audit & Certification (e.g. ANSI/TIA-942 or Uptime Tier),
- Environmental Management/EE (ISO 14001/50001 Environmental Management System or SS 564 Green Data Centres)
- Information Security/Cloud Security (ISO 27001 Information Security or SS 584 Multi Tier Cloud Security (MTCS);
- Quality Management / IT Service Management (ISO 9001 Quality Management System or ISO 20000 IT Service Management)
- Air Quality/Cleanliness (ISO 14644 Air Quality)
- Safety and Health Management (SS 506 Occupational Safety and Health Management)
- Business Continuity Management / BCDC (ISO 22301 Business Continuity Management or SS 507 BC/DR for Service Providers

APPENDIX A: Identified ASEAN research infrastructures contacted and relevant for the synergy analysis with EU Centre of Excellence

Country	Contacted Research Institute	Primary Contact Detail
Brunei Darussalam	Universiti Brunei Darussalam, Ministry of Education	Dr. Abdul Ghani Haji Naim, Head-HPC Lab ghani.naim@ubd.edu.bn
Cambodia	Department of E- government, Ministry of Posts & Telecommunication	Mr. Huot Dasakhem, Senior Staff Dasakhem.huot@mpt.gov.kh
Indonesia	(1) Meteorological, Climatetological and Geophysical Agency (BMKG) (2) Research Centre for Informatics, Institute of Sciences (P2I-LIPI) (3) National Institute for Aeronautics and Space Research (LAPAN) (4) Research Centre for Oceanography, Institute of Science (P2O-LIPI) (5) Inixindo IT Institute	Dr. Dwikorita Karnawati, Head of Agency dwiko@bmkg.go.id Dr. Yan Rianto M.Eng, Head of RC yan.rianto@lipi.go.id Mr. Chusnul Tri Judianto, Head of ICT Division/Centre. chusnul.tri@lapan.go.id Dr. Dirhamsyah M.A., Head of Research Centre dirhamsyah@lipi.go.id Mr. Didik Rudiarto, Chief Operating Officer didikpr@inixindo.co.id
Lao PDR	Institute of Technology Computer and Electronic, Ministry of Science and Technology	Mr. Saysongkham Phanouvong, Senior Staff sphanouvong@gmail.com
Malaysia	(1) Dept of Cell and Molecular Biology Faculty of Biotechnology and Biomolecular Sciences, Universiti Putra Malaysia (UPM) (2) Centre for AI & Robotics, Universiti Teknologi Malaysia (UTM) (3) Universiti Teknikal Malaysia (UTeM), Melaka (4) Centre for Computing, Centre for Bioinformatics, School of Data Sciences, University Perdana, Putrajaya	Dr. Suhaimi Napis, Faculty Member/HPC Sr.Research Scholar suhaimi@upm.my Dr. Kumeresan A. Danapalasingam, Senior Research Staff and KOL-MY kumeresan@utm.my Dr. Anusuriya Devaraju, Data Scientist & Machine Learning Expert, University of Bremen (MARUM) adevaraju@marum.de Dr Farhan Sjaugi, Senior Lecturer and HPC Lab Administrator farhan@perdanauniversity.edu.my Associate Professor Chan Huah Yong,

	(5) School of Computer Sciences, Universiti Sains (US)	HPC Researcher hychan@usm.my
Myanmar	Faculty of Computer Science University of Computer Studies, Yangon, Ministry of Education	Dr. Sabai Phyu sabaiphyu@ucsy.edu.mm
Philippines	(1) Advance Science & Technology Institute, Department of Science & Technology (ASTI-DOST) (2) Philippines Green Building Council (3) ideacorp-advocacy NGO on ICT4development, information security & data privacy	Prof. Joel Joseph S. Marciano, Acting Director j.marciano@asti.dost.gov.ph Christopher de la Cruz, CEO chrisdelacruz@philgbc.org Dr Emmanuel C (Boying) Lallana eclallana@ideacorpphil.org
Singapore	(1) National Super Computer Centre (NSCC) (2) A*Star Computational Resource Centre (2) Green Buildings Innovation Cluster (GBIC), Research Group, Building and Construction Authority of Singapore (BCA) (3) Energy Research Institute @Nanyang Technical University (ERI@N)	Prof. Tan Teen Wee, Head of NCSSC tinwee@nscc.sg Tay Kheng Tiong, Chief Executive Officer kttay@acrc.a-star.edu.sg Dr Gau Chun Ping, Acting Director Gao_Chun_Ping@bca.gov.sg Prof. M Yew Wah Wong, Senior Research Fellow, Nanyang Tech University, Energy Research Institute mywwong@ntu.edu.sg
Thailand	National Electronics and Computer Technology Center (NECTEC), National Science and Technology Development Agency (NSTDA), Ministry of Higher Education, Science, Research and Innovation	Dr. Piyawut Srichaikul, NECTEC, Manager NSTDA Supercomputer Centre (ThaiSC) piyawut.srichaikul@nectec.or.th
Vietnam	(1) Hanoi University of Science and Technology (HUST) (2A) Vietnam National Space Centre (VNSC), Hanoi and (2B) Satellite Technology Application Center (STAC), Ho Chi Minh City – both part of Vietnam Academy of Science & Technology (VAST)	Dr. Nguyen Huu Duc, Head of HPC Lab and Deputy VC on ICT duc.nguyenhuu@hust.edu.vn Assoc. Prof. Dr. Pham Anh Tuan, Director General patuan@vnsc.org.vn Dr. Lam Dao Nguyen, Director ldnguyen@vnsc.org.vn Prof. Nam Thoai, Fac. of Info. Technology, HMUT-Ho Chi Minh City

	(3) Ho Chi Mihn City University of Technology (HCMUT)	University of Technology namthoai@hcmut.edu.vn

APPENDIX B: E-READI Survey

Online version: https://goo.gl/forms/6nvUN8K99ZG3lEzA2 .

A PDF version can be requested to the authors of this report:

Sebastien Varrette, PhD. (EU) & Idris F Sulaiman, PhD (ASEAN)

Contact: sebastien.varrette@gmail.com

APPENDIX C: Upcoming ASEAN International Events tied to HPC

Organisation	Event	General Chair / Contact
BMKG, Indonesia	18th World Meteorological Congress (CG18), 3-14 June 2019 https://public.wmo.int/en/events	Dr. Dwikorita Karnawati Head of Agency
RCI/P2I-LIPI, Indonesia	The 2019 International Conference on Computer, Control, Informatics and its Applications (IC3INA 2019), Tangerang, South of Jakarta, Indonesia on 23-24 October 2019 http://situs.opi.lipi.go.id/p2i/	Dr. Yan Rianto M. Eng. Head of Centre
LAPAN, Indonesia	GEO Week 2019 and the GEO Ministerial Summit, 4-9 November 2019, Canberra, Australia. http://www.earthobservations.org/geoweek19.php	Prof. Thomas Djamaluddin Head of Agency
RCO-LIPI, Indonesia	Oceanography Science Week, February 2020 http://oseanografi.lipi.go.id/shownews/124	Dr. Dirhamsyah M.A
Inixindo IT Institute EPI-AP.com (NL) **Intel Indonesia Corp../ Intel A-Pac, Singapore**	Data Centre Infrastructure Training https://inixindo.co.id/index.php/trainings/data-center HPCAsia, which is an international conference series on HPC technologies in Asia Pacific region, Fukuoka-Japan (15 Jan 2020) https://www.myhuiban.com/conference/2243	Mr. Didik P. Rudiarto Chief Operations Officer Fransiskus Leonardus Country Lead Indonesia
UPM, Malaysia	Asia-Pacific Advance Network (APAN 48), 22-26 July 2019 https://apan48.my/	Prof. Dr. Suhaimi Napis Senior Lecturer
NSCC and A*STAR, Singapore	SuperComputing Asia 2020 , 24-27 February 2020, Singapore https://www.sc-asia.org/ The International Built Environment Week (IBEW), 4-6 Sept2019, Singapore https://www.bca.gov.sg/ibew-international-built-environment-week.html Regional Building Performance Simulation Association Conferences (held every even year), August 2020, Asia http://www.ibpsa.org/regional-conferences/ http://www.ibpsa.org/ibpsa-projects/	Prof. Tan Tin Wee Chief Executive NSCC Tay Kheng Tiong Chief Executive Officer A*STAR
VNSC, Vietnam	International Committee for Earth Observations, 33rd CEOS Plenary : Ha Noi, Viet Nam, October 14th – 16th, 2019 http://ceos.org/meetings/33rd-ceos-plenary	Assoc. Prof. Dr. Pham Anh Tuan, Director General
HCMUT, Vietnam	International Conference on Advanced Computing and Applications (ACOMP 2019 – IEEE) and 5th International Conference on Future Data and Security Engineering (FDSE 2019), NhaTrang, Vietnam, November 27-29, 2019 http://cse.hcmut.edu.vn/fdse2019/	Prof. Dr. Nam THOAI, Head of HPC Laboratory and Professor at Faculty of Information Technology

APPENDIX D: List of Figures

APPENDIX E: List of Tables

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The present report surveys key ASEAN existing facilities and HPC capabilities, and recommends plans to define a shared capacity at regional level. Building an ASEAN regional HPC capacity and a surrounding ecosystem would require grasping a vast set of aspects from infrastructures, human capacity to regional common interests.

The standing ASEAN HPC Task Force that gathers officials of the ten countries has expressed interest to cooperate with the EU and exchange best practice on how the EU model for shared regional resources could be useful. Therefore, a cross analysis was performed to seek shared interests for collaboration between the EU and ASEAN Member States.

High Performance Computing (HPC) is a strategic tool for competitive science. However, on many areas such as for health or environment being for covid-related or climate applications it is possible to cooperate and move forward together based on mutual benefits. A possible ambition could be to setting an EU-ASEAN joint-roadmap with joint activities and mechanisms between the two regions.

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