Study

ASEAN Research Infrastructures (RI) Landscape Study

Towards an ASEAN Regional Research Infrastructures (RRI) Strategy

Enhanced Regional EU-ASEAN Dialogue Instrument

E-READI

Disclaimer

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● Foreword(s)

Foreword by EU Ambassador to ASEAN, H.E. Sujiro Seam

As the European Union Ambassador to ASEAN, I am happy to present the ASEAN Research Infrastructures Landscape Study. This publication represents a milestone in our Strategic Partnership with ASEAN, reflecting our commitment to fostering regional integration and enhancing EU-ASEAN scientific collaboration. The decision by the ASEAN Ministers of Science, Technology and Innovation, to prioritise the development of an ASEAN Regional Research Infrastructures Strategy, highlights the critical role of research and innovation in promoting sustainable development across the region.

Research infrastructures are enablers of scientific excellence and economic growth. The insights provided in this landscape study demonstrate that ASEAN, with its diverse and dynamic economies, is well-positioned to enhance its research capacity through regional collaboration. The Landscape Study, supported by the EU's Enhanced Regional European Union-ASEAN Dialogue Instrument (E-READI), offers a comprehensive analysis of the current state of research infrastructures in ASEAN Member States. It identifies both challenges and opportunities for collaboration, paving the way for a more integrated approach to scientific research.

The new political guidelines for the European Union 2024-2029 put research and innovation at the heart of the EU economy and global partnerships. The Global Approach to Research and Innovation adopted by the European Commission in 2021 vowed to support intra-ASEAN research and innovation cooperation. The contribution of the European Union to the ASEAN Regional Research Infrastructure Landscape Study is consistent with these priorities.

The EU-ASEAN Strategic Partnership is founded on shared values and mutual interests, aiming to tackle pressing global challenges through collaborative efforts. As we celebrate 47 years of partnership, our cooperation in science, technology and innovation is a cornerstone of this relationship, materialised by a long-standing dedicated Dialogue, in place since 2008. By leveraging our respective strengths, we can drive innovation to contribute to economic growth, inclusive social progress, and environmental sustainability.

This ASEAN Research Infrastructures Landscape Study serves as a foundational document for the forthcoming ASEAN Regional Research Infrastructure Strategy. It is not merely a report; it calls all stakeholders involved in research and innovation within ASEAN to action. The recommendations outlined emphasise the necessity of high-level political commitment, enhanced access to research infrastructures, and the establishment of effective governance frameworks.

As we move forward, let us deepen our collaboration in research and innovation, including through making the most of the opportunities offered by Horizon Europe, the EU Framework Programme for Research and Innovation. Together, we can create an environment that fosters scientific excellence, encourages knowledge sharing, supports talent mobility, and ultimately contributes to a prosperous future for both ASEAN and the EU.

I invite all stakeholders – policymakers, researchers, and industry leaders – to actively engage with this study and transform it into a living regularly updated instrument. Let us work together

to transform its insights into actionable strategies that will enhance regional integration and elevate our collective positive impact on the global stage.

I express my gratitude to all those who contributed to this important work. Your efforts are invaluable as we embark on this journey towards a more integrated and innovative ASEAN.

H.E. Sujiro Seam
EU Ambassador to ASEAN

Foreword by Secretary-General of ASEAN, Dr. Kao Kim Hourn

I am pleased to present the ASEAN Research Infrastructures (RI) Landscape Study, a significant achievement in our collective effort to strengthen and enhance the research ecosystem within ASEAN. This study marks an important step towards developing a robust ASEAN Regional Research Infrastructure (RRI) Strategy that can drive future scientific collaboration and innovation across the region.

The research infrastructure landscape in ASEAN is as diverse as the region itself, encompassing both state-of-the-art facilities and emerging institutions. This diversity offers abundant opportunities for collaboration and highlights the potential for building greater synergy in addressing common challenges. The study identifies key areas for improvement, such as financial constraints, talent retention, and the need for more accessible, cross-border research facilities. These are challenges we must address together to foster a more integrated and competitive research community. By working in partnership, we can advance sustainable development and contribute to the realization of the ASEAN Community Vision 2045.

I would like to extend my appreciation to the European Union for its continued support through the Enhanced Regional EU-ASEAN Dialogue Instrument (E-READI). As a longstanding Dialogue Partner, the EU has consistently provided invaluable support for ASEAN's development. Its experience in building a strong and dynamic research infrastructure ecosystem provides significant insights for our region. The EU's commitment to fostering science and technology partnerships aligns with the ASEAN-EU Plan of Action (2023-2027) and strengthens our shared goal of leveraging innovation to promote sustainable development and global competitiveness. Their collaboration has been crucial in advancing our vision for a cohesive and integrated research infrastructure

I also would like to express my gratitude to the dedicated people who have contributed to this report, including the Science and Technology Division of the ASEAN Secretariat who coordinated efforts across multiple stakeholders. Additionally, I thank all ASEAN Member States for their generous support in facilitating the on-site study, which has been instrumental in the formulation of this report.

This document stands as a milestone in ASEAN's journey to foster innovation, sustainability, and unity in science and technology. Together, we will continue to build a stronger, more interconnected research ecosystem that will not only benefit our region but also contribute to global progress.

DR. KAO KIM HOURN

Secretary-General of ASEAN

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In conducting our ASEAN landscape mapping exercise, we are gratefully indebted to many people, including the E-READI team, members of the ASEAN RRI Task Force, the NSTDA and Ms Sronkanok Tangjaijit for the coordination and pulling of resources needed for our exercises, and the ASEAN Secretariat Science and Technology Division.

We also offer our sincere gratitude to all the researchers, research and research infrastructure funders and stakeholders who have participated in discussions with the E-READI NKEs.

Moreover, thank you to each of those who made the round-travel possible in Southeast Asia.

… and many others.

• List of Abbreviations

AI	Artificial Intelligence
AMMSTI	ASEAN Ministerial Meeting on Science, Technology and Innovation
AMS	ASEAN Member States
AnMicro	ASEAN Network on Microbial Utilization
APASTI	ASEAN Plan of Action on Science, Technology and Innovation, 2016-2025
ASEAN	Association of Southeast Asian Nations
A*STAR	Agency for Science, Technology and Research
ASTI	Advanced Science and Technology Institute
BAC	Board of Advisers to the ASEAN Committee on Science, Technology and Innovation (COSTI)
BBMRI	European Biobanking and BioMolecular Resources Research Infrastructure
BE	Business Enterprise
BN	Brunei Darussalam
BRIN	Indonesian National Agency for Research and Innovation Agency of Indonesia (Badan Riset dan Inovasi Nasional)
CAMES	Centre for Advanced Material and Energy Sciences
CamREN	National Research and Education Network of Cambodia
CAPEX	Capital expenditure
CBHE	Capacity Building in Higher Education
COSTI	ASEAN Committee on Science, Technology and Innovation
CREATES	Council for Research & Advancement of Technology & Science, Brunei Darussalam
ECHE	Erasmus Charter for Higher Education
ERASMUS	European Community Action Scheme for the Mobility of University Students
ERASMUS+	https://erasmus-plus.ec.europa.eu/
E-READI	Enhanced Regional EU-ASEAN Dialogue Instrument
ERIC	European Research Infrastructure Consortia
ESFRI	European Strategy Forum on Research Infrastructures
EU	European Union
EURAXESS	https://euraxess.ec.europa.eu/
ERA	European Research Area
GRI	Global Research Infrastructures
GSO	Group of Senior Officials
HPC	High-Performance Computing
ID	Indonesia
IPR	Intellectual Property Rights
IRRI	International Rice Research Institute
ITC	Institute of Technology of Cambodia
JNKEs	Junior Non-Key Experts

KH	Cambodia
KPIs	Key Performance Indicators
LA	Lao People's Democratic Republic
LDC	Least Developed Countries
MGVI	Malaysia Genome and Vaccine Institute
MM	Myanmar
MISTI	Ministry of Industry, Science, Technology & Innovation - Cambodia
MoHE	Ministry of Higher Education - Malaysia
MoSTI	Ministry of Science, Technology and Innovation - Malaysia
MoST-V	Ministry of Science & Technology – Viet Nam
MoU	Memorandum of Understanding
MY	Malaysia
MYC	Multi-year Contract
NARIT	National Astronomical Research Institute of Thailand
NCP	National Contact Point
NRF	National Research Foundation, Singapore
NRI	National Research Infrastructure
NSCC	National Supercomputing Centre, Singapore
NSTDA	National Science and Technology Development Agency, Thailand
NSTP	National Science and Technology Plan, Philippines
OECD	Organisation for Economic Co-operation and Development
OPEX	Operational expenditure
PCIEERD	Philippine Council for Industry, Energy and Emerging Technology Research and Development
PCOST	ASEAN Permanent Committee on Science & Technology
PGC	Philippine Genome Center
PH	Philippines
R&D	Research and Development
RI	Research Infrastructure
RISCAPE	European Research Infrastructures in the International Landscape
RRI	Regional Research Infrastructure(s)
SG	Singapore
SingAREN	Singapore Advanced Research and Education Network
SLA	Service Level Agreement
SLRI	Synchrotron Light Research Institute, Thailand
STI	Science, Technology and Innovation
STISP	Science, Technology and Innovation Strategic Plan
SUT	Suranaree University of Technology
TF	Task Force (ASEAN Research Infrastructure)

TH	Thailand
TI	Technology Infrastructures
TINT	Thailand Institute of Nuclear Technology
TMH	Technology Management Hub
TNA	Trans-National Access
VAST	Viet Nam Academy of Science and Technology
VinaREN	Viet Nam Research and Education Network
VLRI	Very Large Research Infrastructure
VN	Viet Nam

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Executive Summary

The ASEAN Ministers of Science, Technology and Innovation decided (AMMSTI-19, June 2022) to adopt an ASEAN Regional Research Infrastructures (ASEAN RRI) Strategy as a priority. The process follows a three-phase approach with the appointment of an ASEAN RRI Task Force with representatives of the ten ASEAN Member States (AMS) (phase 1, 2022-2023), the development of an ASEAN Research Infrastructures Landscape Study (phase 2, 2023-2024), and the development of the ASEAN RRI Strategy (phase 3, 2024-2025).

The ASEAN RI Landscape Study is supported by the EU, through E-READI, in agreement with the ASEAN RRI Task Force. This report presents the findings.

From October 2023 to May 2024, three international research infrastructure experts, two from Europe and one from Malaysia, collected information about research activities, research infrastructures and respective collaborations within the ASEAN countries and between the AMS. Information was collected through on-line discussions with Task Force members and E-READI, desk research, surveys, travel within eight of the 10 ASEAN countries, and physical interviews with all the Task Force members. In addition, the experts held meetings with a range of funders, research infrastructure owners, technicians, operators and researchers.

The research-infrastructure landscape in ASEAN is heterogeneous and highly varied. There is a lack of central coordination, with procedures for prioritisation, funding, and operation differing from country to country. Often, research-infrastructure policies might also vary amongst the infrastructures within a single AMS. During their field work, the authors of this study identified a range of significant challenges that any new RRI collaboration strategy will have to take into consideration. Some of the most important challenges include the lack of financial certainty, the challenge of recruiting and retaining scientist and non-scientist expert staff, gaps in data sharing, issues related to infrastructure usage and scheduling, challenges to moving equipment and samples across borders, and decommissioning practices that are suboptimal to secure the overall efficiency of the Science, Technology and Innovation (STI) ecosystem.

However, this landscape study also concludes that the general framework conditions for closer RRI collaboration within the region are promising. The authors identified research infrastructures that are suitable for inclusion in systematic RRI cooperation in all the AMS. Many of these have unique or complimentary features that make cooperation beneficial for all parties. Through intra-regional cooperation, ASEAN countries can enhance the impact of the financial investment in scientific facilities. Cooperation may also help strengthen the region's visibility within the global scientific community.

The authors of this study suggest that now is the opportune time to develop an ASEAN RRI Strategy. Each of the STI policymakers and scientists across ASEAN that were interviewed for this study expressed a clear commitment to stronger regional cooperation. Over the past five years, several countries have significantly revamped their national STI ecosystems, laying a solid foundation for ASEAN-centred internationalisation. At the same time, several AMS have made significant investments into now-operational electronic platforms that make it easier for both internal and external users to access research facilities and services. In other words, it has never been easier for each AMS to access research infrastructures in other ASEAN countries than it is at present.

In Europe, RRIs are defined as joint facilities with frameworks of legal and economic commitments. The European approach to RRIs is characterised by a by a strong emphasis on

centralised governance, with each European Research Infrastructure Consortium (ERIC) having a single statutory seat. This often entails a significant commitment of national economic funds towards facilities located or governed from outside a potential user's own country of work or residence. The AMS may not be ready for such centralisation, and the most important first step towards closer RRI collaboration in ASEAN is to remove or limit barriers for cooperation amongst existing RIs. This may allow for the gradual increase in mutual trust and foster the natural emergence of processes that allow for higher degrees of regional integration.

Based on insights founded in this landscape study, the authors make the following recommendations for actions towards the development of a first ASEAN RRI Strategy:

- Establish high-level political commitment to the ASEAN RRI initiative.
- Make increased inter-AMS access to Research Infrastructures central to the political commitment to both enhance ASEAN RI usage (benefit for ASEAN RI owners) and strengthen ASEAN scientific excellence (benefit for ASEAN RI users).
- Appoint a liaison lead to facilitate connections horizontally and vertically across relevant organisations.
- Select a project leader by the Task Force for initial drafting and implementation of the ASEAN RRI Strategy.
- Develop an ASEAN Research Infrastructure Ontology or a glossary of relevant terms.
- Establish criteria and mechanisms to prioritise support for existing RIs.
- Implement a monitoring process for the RRI Strategy roadmap itself.
- Define a set of Key Performance Indicators (KPIs) for monitoring purposes; KPIs may be defined at various levels, such as the political or funding level, research infrastructures, or users. The KPIs must be designed so that they can function at different levels of scientific development.
- Secure a commitment for possible initiatives from at least three to four countries, along with financial resources and priorities, which may not necessarily align with their respective national priorities.
- Develop a funding mechanism clarifying responsibility for cost allocation when utilising an RRI.
- Strengthen the visibility of existing e-platforms, such as equipment browsers, and integrate them, where possible.
- Include existing collaborative networks in the initial version of the RRI roadmap.
- Strengthen existing international RI collaborations.

Over time, more attention can be given to building the relevant human capital. This includes expanding the talent pool of available scientists and non-scientists, upskilling various staff categories via joint training programmes, upskilling through increased access to different tiers of scientific infrastructures, and more effective retention of the existing RI workforce. Human capital development strategies may also seek to address barriers to freedom of movement including the movement of people, lab equipment, but also scientific samples across ASEAN.

This RRI Landscape Study is not a stand-alone document, and this report has been drafted to form a supporting foundation for the RRI Strategy that is to follow. Landscape studies are necessarily living documents, as the scientific landscape they try to capture continues to

rapidly evolve. This is even more applicable in a region as dynamic as ASEAN. It is therefore the hope of the authors that this landscape study will be seen as a pilot version of an exercise that is periodically repeated within an ever-stronger ASEAN RRI collaboration.

1 Introduction

In June 2022, the 19th ASEAN Ministerial Meeting on Science, Technology, and Innovation (AMMSTI-19) adopted the creation of a Regional Research Infrastructures (RRIs) Strategy for ASEAN as one of six annual priorities for 2023.[1] In September 2022, a kick-off meeting was organised and an ASEAN RRI Task Force was proposed, with representatives from each of the ten ASEAN countries and coordinated by the National Science and Technology Development Agency (NSTDA, Thailand). The first meeting of the ASEAN RRI Task Force was held in March 2023. At this event, terms of reference were adopted for an ASEAN RRI Landscape Study, with a mandate for it to be carried out by three external Junior Non-Key Experts (JNKEs) and with the support of the European Union, through the Enhanced Regional EU-ASEAN Dialogue Instrument (E-READI).

The JNKE research team conducted the main parts of the landscape study over a 2.5 months period between September and December 2023. This included a visit to six of the ten AMS: Cambodia, Indonesia, Malaysia, Philippines, Singapore and Thailand. Short additional visits to Viet Nam and Lao PDR were organised in May 2024, thus visits were made to eight of the ten AMS.

This report presents the findings of the ASEAN RRI Landscape Study.

For the study, the research team attempted to provide a reasonable overview of both the challenges and opportunities for RRI collaboration in ASEAN and across the AMS. This overview serves both a status report of the current RRI landscape with its frameworks and structures and as a reminder of gaps that could be addressed in the future. The Landscape Study therefore provides a foundation on which a first ASEAN RRI strategy can be built. The study did not have the scope to provide a detailed analysis of the state of (specific) scientific fields across the ASEAN region. Similarly, the authors do not claim to offer an exhaustive list of existing or potential Research Infrastructures (RIs) in ASEAN or the AMS. Rather, a landscape study should be a living, continuously renewed document. Such an analysis should provide a basis for future iterations of landscape studies to address the continuously changing Research Infrastructure landscape but also attempt a more comprehensive mapping and detailed analysis.

In their preparation of this study, the experts were met with a very heterogeneous research infrastructure (RI) landscape made up of scientific institutions of various shapes and sizes and at different levels of maturity. The lack or limited availability of regional funds for scientific collaboration is a well-established fact that might make it difficult to balance or mitigate the significant differences in RI development between the ASEAN countries. At one end of the spectrum, Singapore boasts a structured RI framework with several well-established RIs that are globally recognised and well-integrated into the international scientific community. At the other end, several countries are only at the very early stages of building an independent national landscape of scientific infrastructures with only rudimentary policy frameworks in place.

At the same time, in recent years several ASEAN countries have developed excellent electronic equipment booking platforms that have significantly increased the visibility and accessibility of scientific equipment to both internal stakeholders and external users. These

[1] ADOPTED-JMS-of-AMMSTI-19_as-of-16-June.pdf

platforms help monitor and increase facility usage and this allows for a more optimised use of resources. They also present a great starting point for increased intra-ASEAN collaboration. The transaction cost of accessing or utilising facilities in another ASEAN country is thus significantly lowered. This makes it possible, for example, to book equipment and to perform experiments that were previously not possible because the given equipment did not exist in a user's own country. It also helps facilitate the performance of experiments at a faster speed or at lower cost because the waiting list is reduced, or the pricing is lower in the recipient country. Facilitating such cross-border collaboration delivers a win-win situation for all parties involved. Each of these aspects will be elaborated upon later in this report.

The authors strongly conclude that increased RRI collaboration will benefit all of ASEAN. Moreover, during the travels, we received strong endorsements from high-level national representatives across nearly all ASEAN countries, acknowledging the significance of this collaboration and confirming their nations' willingness to engage in developing such processes.

1.1 Structure of the report

This landscape report documents the findings of the three JNKEs. This chapter explores the motivations behind pursuing enhanced research infrastructure (RI) collaboration and highlights the factors contributing to the current momentum driving this process. The second chapter describes the methodology applied in the study. Chapter 3 engages briefly with the best approach to scoping RRI collaboration, that is, how RIs may be defined in ways matching the interests of ASEAN and the AMS. Chapter 4 then provides an overview of the policies and regulatory frameworks both at the regional (ASEAN) and national (AMS) levels. Chapter 5 sets out in more detail the current RI challenges that were identified and provides suggestions as to how these might be addressed. Finally, Chapter 6 offers possible building blocks for a successful ASEAN RRI Strategy, including a list of minimum requirements, a set of suggested building blocks, and ideas for increased intra-regional and international RI collaboration.

The report is completed with a series of annexes that offer additional information on the findings, RI policies and terminology, and the methodology of the landscape study.

1.2 The benefits of a RRI collaboration

Experience in other regions suggests that RIs can play a significant role in fostering innovation, in promoting economic development, and in addressing societal challenges. There are several benefits to which RIs and RI collaboration offer the potential to contribute:

- **Economic Growth**: Research and RIs contribute to the development of cutting-edge technologies, promoting growth through innovation and attracting foreign investment. This, in turn, can enhance industrial competitiveness and create high-value jobs.
- **Human Capital Development**: Research, education and RIs are vital to the up-to-date training and development of a skilled workforce, crucial to the region's progress in science and technology.
- **Sustainable Development**: Research and RIs support the systematic investigation of sustainability, agriculture, climate change, and natural resource management, each of which is critical to ASEAN's future development.
- **International Collaboration**: By fostering cross-border collaboration and knowledge exchange, RIs help ASEAN countries engage in global research networks.

- **Attractiveness**: RIs can contribute to structuring research around topics that are important to the region and/or country. It can act as an attractor to help establish a critical mass of researchers that itself will contribute to scientific excellence. It can also contribute to retaining and attracting scientific and operating talents.
- **Capacity Building**: Training, education and retaining experts in and maximises the utilisation of RIs and fosters a skilled workforce in science and technology that will benefit the public and private sectors.
- **Optimal use of scientific resources**: Collaboration on RIs reduces the risk of duplicating equipment and facilities and helps ensure a better rate of return on scientific investments.
- **Complementary investments**: Collaboration makes it possible to prioritise complementary capital-intensive investments rather than duplicating existing facilities or equipment. For example, the synchrotrons in Singapore, Thailand, and Australia each have a different set-up. This better enables researchers in the region to pursue different lines of research.
- **Sharing advantages, overcoming national limitations**: Countries are conditioned or bound by context-specific factors. As an example, Singapore's collaboration with neighbouring countries on marine research yields broader impact and deeper regional insights, given the interconnected nature of their seas. Many such cases are likely to exist across the region.
- **Benefits of a tiered approach to science**: Not all scientific experiments require the same level of accuracy or complexity. For reasons of economic efficiency, there is little reason to pay more for access to specialised equipment if the experiment does not require it and access to low-cost infrastructures is therefore attractive. At the same time, having some access to more expensive equipment without needing to acquire it also boosts scientific excellence relative to economic outlay. Additionally, it is better for trainees to use relatively cheaper equipment that allows them to show their proficiency before accessing more expensive facilities.
- **A stronger regional profile in the international scientific community**: Clearly, many bilateral or multilateral collaborations already exist in the ASEAN scientific community. However, ASEAN neighbours are rarely amongst the AMS' top collaborators based on scientific output. RI collaboration can help increase intra-regional research collaboration and strengthen joint scientific excellence which can in turn lead to a stronger profile for ASEAN in the global scientific community.
- **Enhance strategic priorities**: ASEAN RI strategies and roadmaps should reflect the strategic needs of the region, enhancing scientific attention to the key and selected areas. The region's unique biodiversity is an example of a potential target area.
- **Build an inclusive STI ecosystem across the region**: RI collaboration can help capacity building and research quality amongst those AMS with less mature scientific installations or those with fewer resources available to researchers.
- **Create visibility, transparency and accountability**: A first step towards RI collaboration is to create greater visibility of the existing facilities and their utilisation. Such steps have already been taken in several countries with the creation of new electronic-equipment platforms. These help document and highlight gaps and the positive scientific and social impacts of RIs. Thus, they are valuable for policymakers and decision-makers.

1.3 Seizing the momentum: the time is right

The mapping of the RI landscape across ASEAN in this study revealed several favourable factors. As already stated, there is considerable political interest in closer intra-regional collaboration towards a RRI strategy. The appointment of a RRI Task Force could create the necessary momentum needed to drive the process forward. As the coordinator of this process, the NSTDA in Thailand can help solidify and accelerate the momentum towards RRI collaboration.

1.3.1 A revitalised national STI systems in the AMS

The striving for an ASEAN RRI Strategy follows a period of major transformation in the STI systems in several AMS, and many of which are still ongoing.

Examples of such fundamental change include the establishment of:

- a new Ministry for Higher Education, Science, Research and Innovation in Thailand in 2019;
- a new Ministry for Industry, Science, Technology & Innovation in Cambodia in 2020;
- a new Ministry for Science and Technology in Myanmar in 2021;
- a new Council for Research & Advancement of Technology & Sciences (CREATES) in Brunei Darussalam in 2021;
- the formulation of a single National Research and Innovation Agency (BRIN) in Indonesia in 2021; and
- the inclusion of the science sector into the Ministry of Education and Sports in Lao PDR in 2021.

These new entities are creating new national frameworks and policies covering RIs, amongst other things.

As national priorities are being developed, there is a unique opportunity for the alignment of regional and national initiatives. Regional collaboration may enhance the opportunity to maximise returns on national investments in RIs. The development of one-stop electronic platforms managing access to research equipment that was undertaken in the wake of the reorganisation of the national STI ecosystems, such as in Indonesia, has created the necessary favourable preconditions.

1.3.2 Facilitating a wave of RI renewal in ASEAN

Importantly, several of the AMS also face significant long-term investments in the restoration of large nuclear and radiation facilities that are nearing the end of their lifecycles. Thailand, Viet Nam, Indonesia, and Philippines all opened nuclear research reactors in the 1960s, while the nuclear research reactor at Malaysian Nuclear Agency became operational in 1982. Modernising and upgrading these facilities will require a series of very large scientific investments across the region over the next two decades.

Interviews with stakeholders indicated that the AMS's interest in national investment in nuclear facilities is further bolstered by the perceived advances of Small Modular Reactors as well as decarbonisation plans. On this basis, the long-term (20-50 years) need for a nuclear infrastructure is anticipated in the AMS, requiring also the availability of an adequately trained research and engineering community. To prepare for these new realities, ASEAN and the AMS may find it beneficial to commence strategic planning and appropriate advance investments sooner rather than later.

Facing this very plausible wave of large-scale expenditure on scientific facilities, the AMS would benefit from cooperation and collaboration to safeguard the optimal use of limited resources. The planned major investment in a Siam Photon Source II,[2] the first 4th generation synchrotron light source in Southeast Asia, is an example of a major scientific investment that helps motivate increased RI cooperation in ASEAN in the near future, requiring strategic action now.

1.4 Learning from the lessons of Europe (and other regions)

As ASEAN commences its collaboration on RIs, the experiences of other countries and regions in which RI collaboration has a longer history may provide for useful inspiration. There are surely examples of good practice which may be relevant for the ASEAN context. Similarly, lessons may be learned from negative experiences and approaches that proved unsuccessful elsewhere. The dialogue and collaboration with E-READI provide a good starting point for ASEAN to find inspiration from the European RI experiences.

The European Union (EU) began developing (regional) roadmaps in 2002. This has contributed significantly to the emergence of RI priority processes which have been refined over time both for the region as a whole and for most of the European countries. Through the European Strategy Forum for Research Infrastructures (ESFRI), several roadmap processes have been carried out that have matured and evolved over time. Today, it these processes consist of the following three elements:

- a description of the roadmap processes, outcomes, and impacts;
- a comprehensive landscape analysis based on well-described processes; and
- a list of current Landmarks (existing RIs) and Projects (potential future RIs).

ESFRI's processes and monitoring are well recognised and considered successful by the stakeholders involved. Up to the stage of the latest ESFRI roadmap, 41 ESFRI landmarks and 22 aspiring ESFRI projects have been facilitated. This outcome, and the maturity of the organisational process in general, have only been possible through allocating substantial human and financial resources over more than 20 years.

ASEAN would benefit from looking towards this sustained process to identify what worked well and what did not. Furthermore, ASEAN can take inspiration from other dialogue partners with extensive RI experience, such as Japan, the Republic of Korea, and Australia.

[2] Please see, for example, https://laaamp.iucr.org/__data/assets/pdf_file/0020/148421/Strategic-Plan-for-SE-Asia.pdf and https://accelconf.web.cern.ch/ipac2022/papers/mooplgd2.pdf

2 Methodology

The methodology for the landscape study was adapted from an earlier study: European Research Infrastructures in the International Landscape (RISCAPE).[3] The methodology for this study consisted of three main phases: 1. Scoping Phase; 2 Data-collection Phase; 3. Analysis Phase.

Given the limited time allocated (initially 2.5 months), some steps were carried out concurrently rather than sequentially for the scoping and data-collection phases.

2.1 The project phases

A mapping of what was assessed as the most important research instruments and laboratories was completed in collaboration with the ASEAN RI Task Force (TF) representatives. This desk study was based upon material from the documents provided to us from the TF representatives, from publications and from other written material and information available online. To enrich this information, we also developed two questionnaires. TF members were requested to complete the first, concerning national RIs; and the second was targeted to RI owners (laboratories, research equipment and instruments) to gain more in-depth knowledge of the ecosystem of the given RI. Copies of these questionnaires can be found in Annex 5.

2.1.1 Scoping phase

The initial scoping phase of the study consisted of a desk-research assessment of previous project outputs and material supplied by E-READI, the ASEAN RRI TF, and AMS contacts. In addition, we reviewed material about RI studies in Europe.

The initial desk study helped generate a preliminary list of potential ASEAN RIs. In addition, the research team developed a draft glossary based on previous material on RIs. The scoping was completed with an inception report that was discussed with and adopted by E-READI.

2.1.1.1 Develop a database of ASEAN RIs

Based on the results of the desk study, a database of potential RIs in ASEAN and AMS was set up with the use of the innovation software *Itonics*. The initial list of entities exceeded more than 120 facilities and organisations, as illustrated in Figure 1 below.

2.1.2 Data-collection phase

The data-collection phase followed three main streams, seeking to obtain information at these levels:

- ASEAN (regional);
- the AMS (national); and
- at the individual Research Infrastructure level.

This corresponds to the objective of the study to capture regional dynamics, national characteristics, and relevant differences in policies, frameworks, and approaches at the organisational RI level. To generate relevant responses, two surveys were used for the AMS country level and the RI level, respectively (for these questionnaires, please see Annex 4). The

[3] European Research Infrastructures in the International Landscape (RISCAPE). For the final report (Asmi et al., 2019), see https://zenodo.org/records/3539254.

country survey was submitted to the ASEAN RRI TF, who contributed with their written responses. These responses formed the basis of subsequent interviews with the TF members.

Figure 1 Database of organisations and RIs, based on an initial desk study

2.1.2.1 Mission: Country and RI visits

From 1 to 19 November 2023, the research team visited six of the ten AMS: Singapore, Philippines, Cambodia, Indonesia, Thailand, and Malaysia. In each country, information was gathered through interviews with the national ASEAN RRI TF representatives and other policy stakeholders, as well as through visits to a diverse set of existing or potential RIs. The itinerary of the trip was planned in collaboration with E-READI and the ASEAN RRI TF. Unfortunately, time and resource constraints only allowed for a visit to a limited subset of destinations within ASEAN and each country visited. Potential follow-up work to this study might allow for a wider geographic coverage, which would be recommended. The research team's visits to individual

RIs were primarily organised by the national TF representatives. The indication from the research team was that the visits should cover a variety of scientific fields, a variety of RI organisational types, and, to the extent time and circumstances allowed, geographical variety. Furthermore, the selection of organisations to visit should reflect national priorities which is useful for the continuance of the work with RIs within ASEAN. A secondary aim of the mission, in addition to data collection alone, was to create awareness, engagement, and ownership of the RRI process. We found that the mission was highly successful in this regard.

A second visit was carried out at the end of May 2024, as one JNKE visited Viet Nam, while the two others visited Lao PDR.

During our travels in the ASEAN region, we enjoyed dialogue with researchers, research funders, ministry representatives, ASEAN country representatives, ASEAN RRI TF members and other stakeholders. The TF members successfully motivated, mobilised and recruited relevant and influential country representatives including research funders, RI managers, influential researchers, and key stakeholders involved in relevant structures in the country. It was evident that there was strong interest at all levels in fostering increased ASEAN RRI collaboration, ranging from governmental representatives to active scientists.

During our meetings, we engaged with informed representatives who spoke candidly, expressed themselves freely and were always open to our questions. The partners that we met also inquired often about or challenged us on our tasks and responsibilities during these dialogues. It is important to stress that for most meetings ‘dialogues’, rather than ‘interviews’, is the appropriate term. While taking the landscape study and the two pre-prepared surveys as the necessary departure point, we tried to listen carefully for the situational interests, concerns and needs of each meeting partner. This added much needed nuance to our investigation, but the diversity of information and the cacophony of voices can make systematic analysis challenging. In several meetings, the research team was outnumbered by up to a factor of 10 times by RI managers, researchers, and representatives for ministries, agencies, and research-funding bodies. While such sessions might have entailed some issues with achieving in-depth information from each participant, they both reflected and fuelled the interest in advancing RIs in ASEAN.

2.1.2.2 ASEAN RRI Forum November 2023, Bangkok (Thailand)

The initial findings of this study were presented during the 1st EU-ASEAN RRI Forum in Bangkok, Thailand, 13 November 2023, and during the subsequent ASEAN RRI Forum (Bangkok, 14 to 15 November 2023). A physical workshop with nine of the ten ASEAN RRI TF representatives worked both as an important validation of the study’s work to-date and as a source of additional material for this report. At the margins of the RRI Forum, bilateral interviews were carried out with representatives of Brunei Darussalam, Lao PDR, Myanmar, and Viet Nam, i.e. the countries not visited by the research team during the first mission. These interviews contain another important source of material for the study.

2.1.2.3 Full list of interviews and visits

A comprehensive list of the key interviewees and mission visits is set out below in Table 1. As mentioned before, six out of the ten AMS were visited in November 2023, while Lao PDR and Viet Nam were visited in May 2024. For Brunei Darussalam and Myanmar, we conducted face-to-face interviews to gather information about research laboratories and research equipment.

Table 1 List of key interviews and RI facilities visited

List of key interviews and RI facilities visited	
Brunei Darussalam	Centre for Advanced Material and Energy Sciences (CAMES), Universiti Brunei Darussalam. ASEAN RRI TF representative. *Interview only.*
Cambodia	• Ministry of Industry, Science, Technology & Innovation, ASEAN RRI TF representatives, https://www.misti.gov.kh/ • Institute of Technology of Cambodia (ITC), https://itc.edu.kh/. • International University, https://www.iu.edu.kh/iuback/
Indonesia	• BRIN, ASEAN RRI TF representatives, https://www.brin.go.id/en. • Deputy for Infrastructure Research and Innovation • BRIN facilities in Cibinong • BRIN facilities in Serpong
Lao PDR	• Science Management Division, Department of Science, Ministry of Education and Sports, ASEAN RRI TF representative. • Center of Excellence in Environment, National University of Laos • Institut Pasteur du Laos
Malaysia	• Malaysia Nuclear Agency, ASEAN RRI TF representatives, https://www.nuclearmalaysia.gov.my/eng/. • Malaysia Genome & Vaccine Institute (MGVI) • Faculty of Earth Science, Universiti Malaysia Kelantan. *Interview only.*
Myanmar	• Ministry of Science and Technology. ASEAN RRI TF representatives. *Interview only*.
Philippines	• Advanced Science and Technology Institute (DOST-ASTI), ASEAN RRI TF representatives, https://asti.dost.gov.ph/ • Philippine Genome Center (PGC), https://pgc.up.edu.ph/ • Philippine Council for Industry, Energy and Emerging Technology Research and Development (DOST-PCIEERD), https://pcieerd.dost.gov.ph/ • Electronics Product Development Center (DOST-EPDC), https://epdc.dost.gov.ph/ • International Rice Research Institute, http://irri.org/
Singapore	• Agency for Science, Technology and Research (A*STAR), ASEAN RRI TF representatives, https://www.a-star.edu.sg/ • National Research Foundation Singapore, https://www.nrf.gov.sg/ • National Supercomputing Centre (NSCC) Singapore, https://www.nscc.sg/ • SingaScope / A*STAR Microscopy Platform (AMP), https://www.singascope.sg/
Thailand	• National Science and Technology Development Agency (NSTDA), ASEAN RRI TF representatives, https://www.nstda.or.th/en/. • NSTDA Supercomputer (ThaiSC), https://thaisc.io/ • Thailand Institute of Nuclear Technology (TINT, https://www.slri.or.th/en/, • Thai Synchrotron National Lab (SLRI), https://www.slri.or.th/en, • National Astronomical Research Institute of Thailand (NARIT), https://www.narit.or.th/index.php/en-home - *Group interview* • Thailand Science Research and Innovation, www.tsri.or.th. *Interview only.* • Thai research universities – *Group interview*. • Mae Fah Luang University, https://en.mfu.ac.th/home.html • Silpakorn University, https://www.su.ac.th/th/index.php • Walailak University, https://www.wu.ac.th/en

	• Suranaree University of Technology (SUT), https://www.sut.ac.th/en/ • Khon Kaen University, https://www.kku.ac.th/ • Naresuan University, https://english.nu.ac.th/
Viet Nam	• Vietnam institute of Science, Technology and Innovation

2.1.3 Analysis phase

The final phase of the study comprised the analysis of the collected material. Based on the different sources of information, we performed a preliminary analysis assessing the kinds of research equipment and existing RIs as well as the national level and ASEAN (and international) collaboration. In addition, we investigated the funding regime, competence, availability of human capital and research environments, all comprising the ecosystem of research, with a particular emphasis on the RI.

2.2 Project approach in brief

The project approach is illustrated in Figure 2 below. This presents how the study integrates three different levels of analysis: ASEAN, Country and RI level; and for which the information gathering process was slightly different.

This approach was crucially dependent upon the engagement of the TF members and the people we had the opportunity to conduct an informed dialogue with around RI matters in their country.

The study was validated in a hybrid workshop with key stakeholders on 29 February 2024, based upon a preliminary version of the RRI Landscape study, as well as via discussions at the ASEAN RRI Strategy Drafting Workshop 28-29 May 2024.

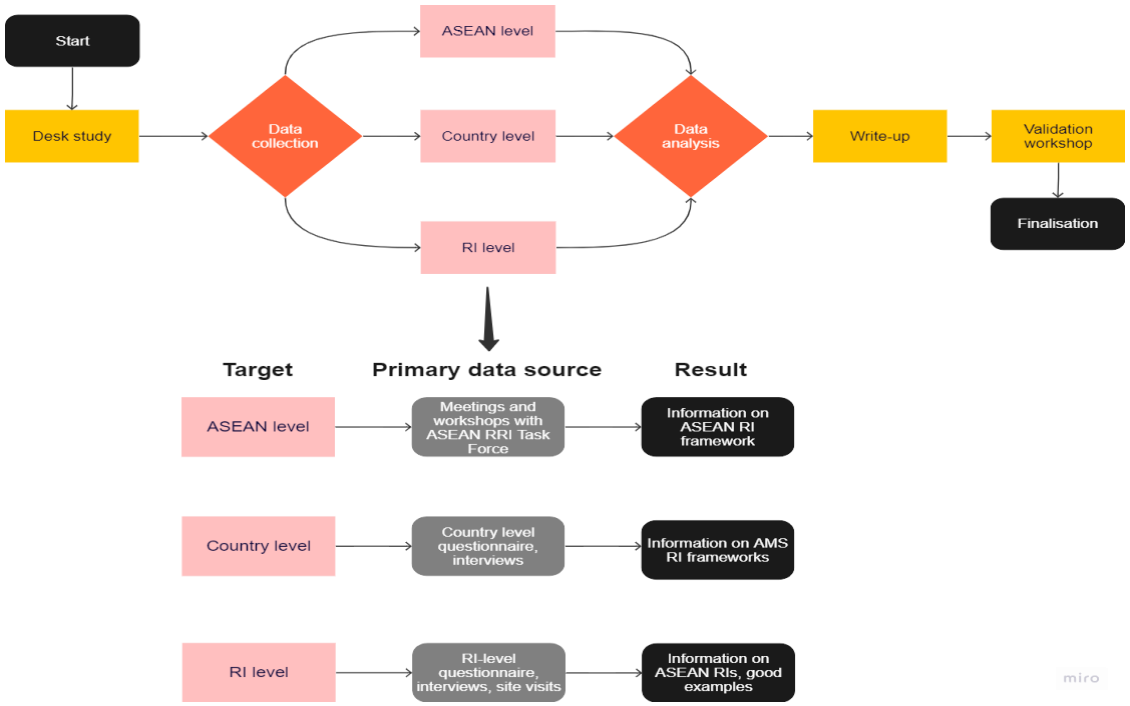

Figure 2 Project approach flow scheme

3 Towards Regional Research Infrastructures

In this chapter, we investigate important elements in establishing a Regional Research Infrastructure. Political and strategic work on RIs can and should address two mutually beneficial objectives. First, it should seek to develop effective and successful policy processes that comprise the ecosystems of the RIs. Second, it should seek to enhance the level and quality of the RIs themselves. These overlapping objectives require slightly different dynamics. For a brief elaboration on considerations for designing RI policies, please see Annex 2.

Having a shared understanding of key terms is important for fostering real dialogue and enabling initiatives. We present a draft glossary of common RI terminology in Annex 3. However, it is worth noting here that subsequent work on an ASEAN RRI Strategy may adopt a different vocabulary (Any proposed RI definition or terminology should therefore align with the needs and requirements of the given context in which it is applied. There is no 'true' definition – different elements can be included or weighted as deemed relevant)

3.1 Defining Regional Research Infrastructures

In this section, we explore how Europe is defining RI and how different kinds of RI are commonly set up. We will also examine some of the terminology used to describe the RI environment in a somewhat more precise way.

3.1.1 Defining Research Infrastructures

The European Commission defines RIs as *'facilities that provide resources and services for the research communities to conduct research and foster innovation*'.[4]

However, in their national policies even the EU Member States utilise different definitions that reflect their nation-specific priorities.[5] For example, countries strike different balances between scientific excellence and the ability to foster innovation.[6] Other elements that are considered within some national definitions include *scale,*[7] *longevity*[8] and *user access*. While outside access can take many forms, providing *some* access is a *sine qua non* for being a RI. Finally, definitions often underline that RIs are *strategic,*[9] that is, they serve the strategic interests of a nation or region. The '*strategic importance'* of a facility is also a criterion the National Research Foundation Singapore uses to assess the eligibility for consideration as a National Research Infrastructure (NRI).

A complementary approach is the OECD's definition of Very Large Research Infrastructures (VLRIs) (2023) which stresses three defining characteristics:[10]

[4] https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/european-research-infrastructures_en

[5] https://www.inroad.eu/wp-content/uploads/2018/12/InRoad_finalreport.pdf, page 92ff.

[6] Finland, for example, considers RIs on their ability to develop both research and innovation capacity, while Sweden underlines the RIs' ability to introduce new cutting-edge technology.

[7] Some countries explicitly consider specific threshold values for minimum construction or operating costs.

[8] As examples, for consideration on national RI roadmaps, the Netherlands necessitates a service life of at least an additional five years, while in Germany it requires ten years.

[9] https://www.esfri.eu/esfri-white-paper/12-research-infrastructures-strategic-investments

[10] OECD (2023), https://www.oecd-ilibrary.org/docserver/2b93187f-en.pdf?expires=1702212426&id=id&accname=ocid195730&checksum=8B35D82E114C1A54B0EE873C09D9B928, page 12.

- *Uniqueness:* the RI is unique or quasi-unique worldwide and provides world-leading capabilities.
- *Complexity:* the RI is highly complex in its organisational structure, technology and/or operation. Its scale is usually very large in terms of the required human and/or capital resources.
- *International dimension:* the RI possesses an international dimension, which is reflected in its governance, its operational footprint and user base.

There might not be any RIs in ASEAN that correspond to these strict criteria, but organisations can also be extraordinarily unique, complex, and international compared to others at a regional or national scale. For example, Southeast Asia is rich in unique cultural history and natural biodiversity that enable even localised institutions to possess certain global comparative advantages within distinct topics.

3.1.1.1 Components that can be considered when choosing a definition

Summarily, there is a list of elements that can be used as building blocks for defining what RIs *are* and what they *do:*

- facilities providing resources and support;
- serving research communities and/or fostering innovation;
- strategic importance for the geographic scope under consideration;
- scale and/or longevity beyond what is common at a given level;
- funding requirements beyond what is common at a given level;
- access for a broader user base;
- use by a user base beyond what is common at a given level;
- complexity beyond what is common at a given level;
- uniqueness within certain geographical boundaries; and
- an international dimension exceeding what is normal at a given level.

The JNKE have concluded that in the context of creating or increasing ASEAN RI collaboration, it would be counterproductive to choose a definition that is too limiting in scope. This outlook is reflected throughout this landscape study.

3.1.2 Defining an appropriate scope of RIs for the RRI landscape study and RRI strategy

Scientific facilities come in many different sizes, ranging from small laboratory equipment to major and unique global investments. RIs are, by definition, mostly connected to those larger facilities and installations, but RIs themselves, come in different shapes and sizes. This diversity is a strength. The European Council recently adopted conclusions on RIs that acknowledge the role of 'a fully functional and operational European RI ecosystem, which efficiently integrates European, national, as well as regional RIs of various sizes' as a vital cornerstone of the European Research Area.[11] A healthy Regional RI ecosystem that contains RIs of *various sizes* is likely not unique to Europe. This conclusion is also relevant as an approach for ASEAN to consider adopting.

In general, though, we expect RRIs to fall – in terms of scope and complexity – between local-to-national infrastructures (of which there are many) and global infrastructures (of which there are few). This point is illustrated in Figure 3 below.

[11] Council of the EU, 2 December 2022, https://data.consilium.europa.eu/doc/document/ST-15429-2022-INIT/en/pdf

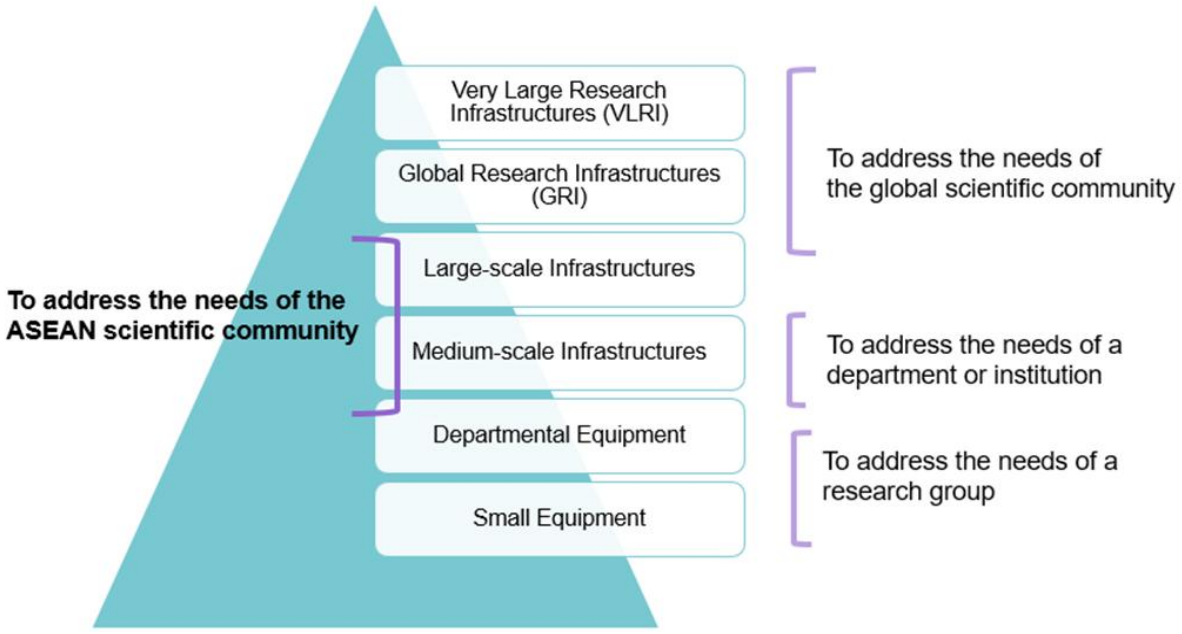

Figure 3 Finding the scope for RRIs.

3.1.3 Variants of Research Infrastructures

RIs not only come in various sizes but also in various topologies (structures). Typically, RIs are categorised as either single-sited, distributed, or virtual (see Figure 4). Single-sited RIs are, typically, large facilities based in one central location. For example, large nuclear and synchrotron facilities often fall into this category. Distributed RIs consist of distributed nodes, although there can be a central organisational node (a 'main location'). The number of nodes in a distributed RI can range from two to many. There is no set geographic parameter for the scope of a distributed RI. It can consist of multiple nodes within a single country or a territory within a single country, across an international region such as Southeast Asia or spread across the world.

There are several examples of nodes located in AMS that form part of global RIs. For example, SingaScope in Singapore is an active part of Global BioImaging,[12] whilst two facilities at the International Rice Research Institute (IRRI), Los Baños, Philippines, are listed on the Global Infrastructure Map of the International Plant Phenotyping Network.[13]

[12] https://globalbioimaging.org/

[13] https://www.plant-phenotyping.org/infrastructure_map.

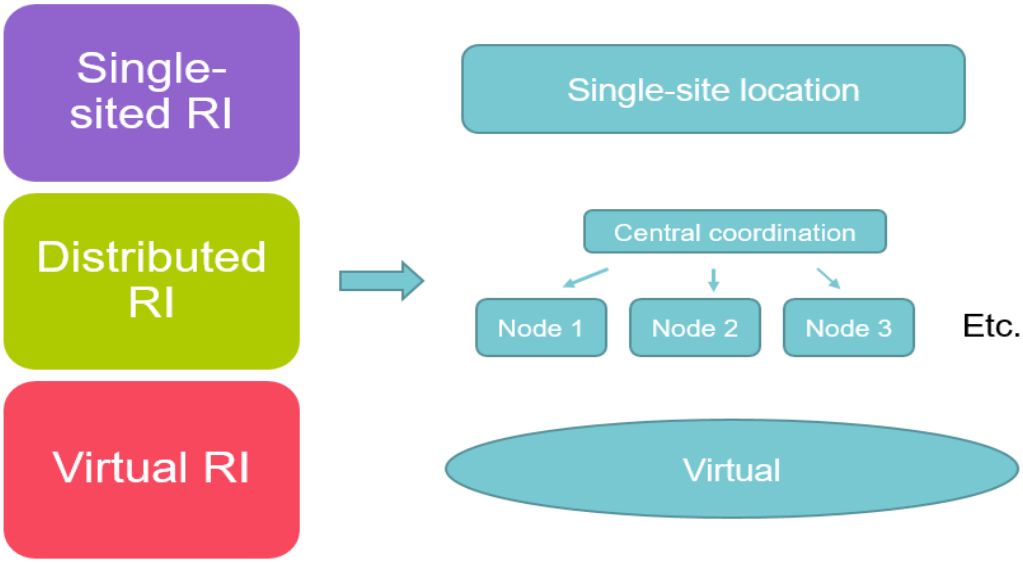

Figure 4 Single-sited, distributed and virtual research infrastructures

Virtual RIs are primarily geared towards delivering electronic and data-related services, which span across scientific disciplines and often form the backbone of modern research and technological innovation. Relevant examples include High-Performance Computing (HPC) and Supercomputing facilities and Research and Education Networks (RENs) that are also well-established in ASEAN – although perhaps not sufficiently well-coordinated across the AMS.

Pragmatically, it might be more cost-effective and attainable for ASEAN stakeholders, whether on a national or institutional level, to create a new node as part of a distributed RI compared to establishing a fully-fledged RI (single-sited or distributed) from scratch. This could be through the establishment of a new organisation or through the adaptation of an existing one. This approach may be particularly relevant for AMS with limited operational capacity or limited resources available for new scientific investments. The difference between a distributed RI and other forms of cooperation between scientific institutions, formal or informal, can be a matter of degree. Certain features might help distinguish between the two, such as the existence or absence of central coordination, a single-entry point for researchers, and coordinated allocation of resources for upgrading. This is illustrated in Figure 5 below.[14]

Figure 5 also highlights how central coordination and strategic planning can help reduce the risk of duplication and obsolescence of facilities. The potential to optimise resource usage is often the main motivation for RI at all their different levels (inside-institutions, national, international, and so on). How to enable and implement this central coordination is perhaps the key strategic concern for an RRI Strategy.

[14] Figure adapted from the South African Research Infrastructure Roadmap, https://www.gov.za/sites/default/files/gcis_document/201610/sa-research-infrastructure-road-mapa.pdf, page 11.

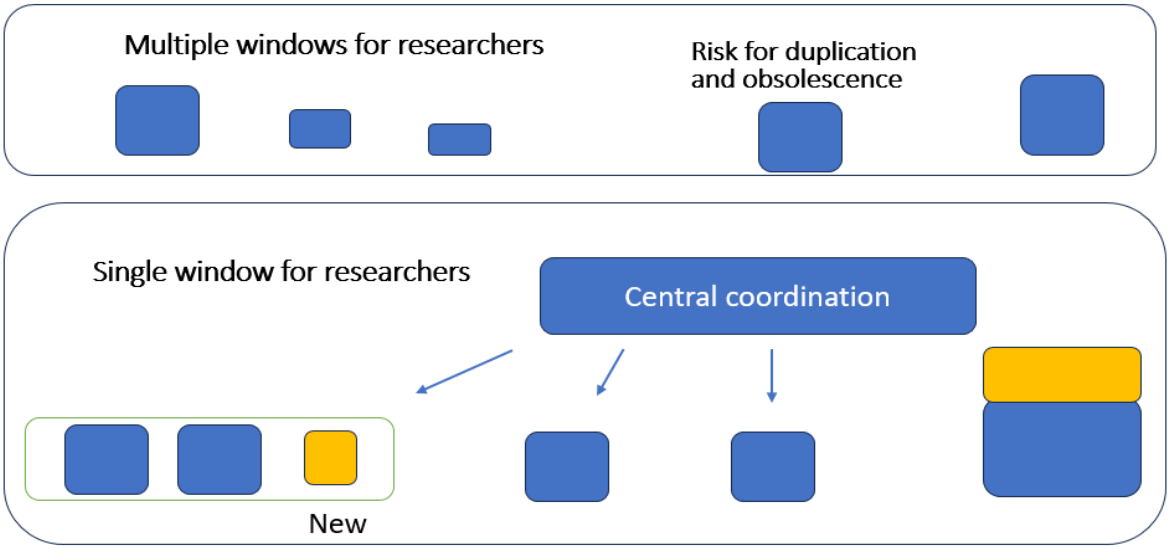

Figure 5 From loose research collaboration to a distributed research infrastructure

3.2 Regional Research Infrastructures or Regional Research Infrastructures-Collaboration?

RRI central coordination can be envisioned via strong regional institutions akin to the pan-European legal framework of the European Research Infrastructure Consortia (ERIC). This would require centralised ASEAN planning, joint prioritisation, and the availability of common funds. However, it is also possible to envision - at least as a starting point - RRIs as a *collaboration* between individual, possibly national, entities. Here, centralised ASEAN strategic planning focuses on encouraging increased collaboration between existing RIs, removing barriers to collaboration, and encouraging wider ASEAN regional participation within the operations of each RI (for example, increased access for other ASEAN researchers). This distinction between RRIs and RRIs-collaboration is illustrated in Figure 6 below.

The research team found that this distinction will be central to follow-up work on the landscape study. It is our conclusion that the *RRI-collaboration model* may prove to be the most fruitful to pursue at this time.

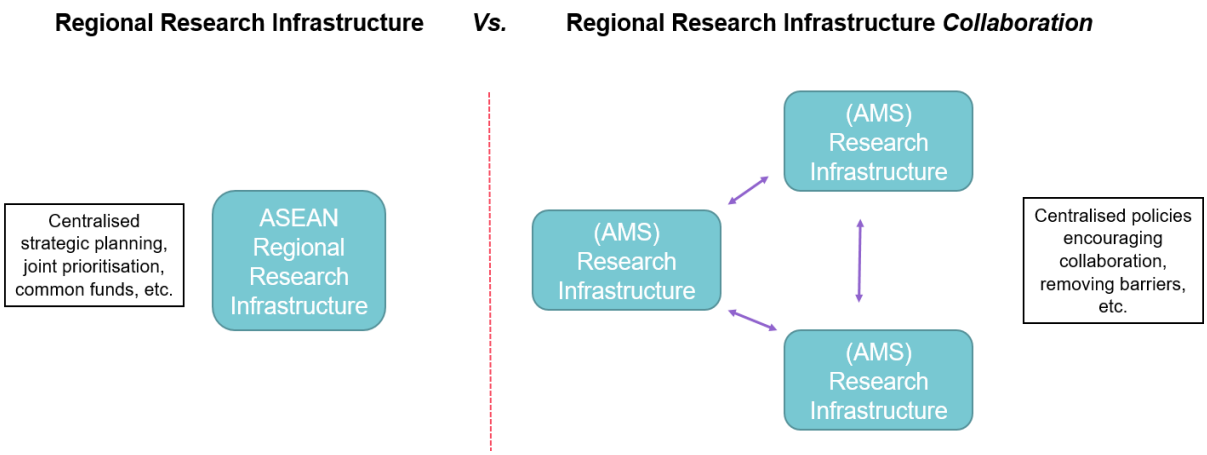

Figure 6 RRIs vs collaboration between RIs in the region

The suggestion also aligns with insights collected for this study from RI experts at the European Commission, based on the previous RI policy experience in Europe: The most significant first step is to build a transnational community base. Once the community base is in place, models for governance can be considered based on the gaps and needs of the established scientific community. Such a transnational scientific community base cannot simply be imagined, rather, it must emerge from established international cooperation.

In other words, enabling regional RI collaboration enables regional RI communities which, in turn and over time, may eventually enable RRIs with new requirements for governance models.

If or when an interest arises in creating joint RIs, the European ERIC-model might be difficult to replicate without a legal ASEAN framework matching the EU-treaties. It seems more prudent to envision a structure similar to that of international organisations.[15]

[15] Variations of such a framework is utilized for scientific institutions elsewhere, e.g. at SESAME (with its headquarters in Jordan), CERN (with headquarters in Switzerland), and The International Rice Research Institute which the research team visited in the Philippines.

4 ASEAN and AMS: Policies and Regulatory Frameworks

ASEAN asserts that STI are integral components to all AMS, regardless of the individual nation's economic status. At a regional level, the common vision is to leverage STI to share knowledge and translate the research inputs into implementable solutions that address real-life problems faced by its citizens.[16] The ASEAN Permanent Committee on Science & Technology (PCOST) was among the ten first permanent committees established in 1971. In 1978, PCOST was rebranded as the ASEAN Committee on Science & Technology (COST), with the development of the first ASEAN Plan of Action on Science and Technology (APAST). The key political level is the biannual ASEAN Ministerial Meeting on Science and Technology (AMMST). The word 'Innovation' was later added, making the relevant entities today: COSTI, APASTI, and AMMSTI.

4.1 Establishing a RRI framework in ASEAN

In contrast to the EU, for example, there is limited joint funding for scientific activities in ASEAN. Up to now, there has been no framework to highlight or prioritise ASEAN-scale RIs. It is therefore up to the regional and national stakeholders to design such a framework.

4.1.1 ASEAN Ministerial Meeting on Science, Technology and Innovation

AMMSTI-19 was held virtually 16 June 2022 and adopted six annual priorities for 2023, of which one (No. iv.) was to *'Develop an ASEAN Regional Research Strategy'*.[17] This decision was in line with the APASTI 2016-2025. Here the stated vision was to create *'A Science, Technology and Innovation-enabled ASEAN, which is innovative, competitive, vibrant, sustainable and economically integrated.'*[18] The Sub-Committee on Science & Technology Infrastructure and Resources Development, which is the relevant Sub-Committee for the work on the ASEAN RRI framework, has as one of its stated objectives to '*develop policies that set a conducive environment to strengthen the capabilities and relevant infrastructure of ASEAN in STI development, utilisation and commercialisation'*.

4.1.2 ASEAN RRI Task Force (TF)

In September 2022, an ASEAN RRI TF with representatives from each of the 10 ASEAN countries was proposed and established. The TF is mandated to drive the RRI strategy for which this landscape study is phase two. The list of members of the RRI TF can be found in Annex 3.

4.2 AMS STI areas

Research and innovation are important tools in achieving the set goals for prioritised STI areas, and the development, operating and sharing of RIs is a cornerstone of this effort. The E-READI collaboration with ASEAN is central for this development to support the ASEAN community vision 2025 with its three pillars of the ASEAN Economic Community.

To support collaboration and networks there is an active collaboration within the COSTI committees (based upon the original COST) that regularly meet, and one outcome is the

[16] https://asean.org/our-communities/economic-community/asean-science-technology-and-innovation/
[17] https://asean.org/wp-content/uploads/2022/06/ADOPTED-JMS-of-AMMSTI-19_as-of-16-June.pdf
[18] https://asean.org/wp-content/uploads/2017/10/01-APASTI-2016-2025-FINAL.pdf, page 41.

development of the action on science and technology in the APASTI. The priorities as expressed at the political level include these areas:

- Biotechnology;
- Food Science & Technology;
- Marine Science & Technology;
- Materials Science & Technology;
- Meteorology & Geophysics;
- Microelectronics & Information Technology;
- Science & Technology Infrastructure & Resources Development;
- Space Technology & Application; and
- Sustainable Energy Research.

Each of these areas has subcommittees that oversee the development and actions within ASEAN in the relevant areas. An analysis of RI activities and/or international collaboration indicates an interesting set of activities that partly underpins the prioritised areas as listed above. Some of the infrastructures are overlapping and are listed under several of the above headlines. We have set out below in Table 2 a selection of RIs that we have identified in the mapping exercise. Unfortunately, this cannot be considered as an exhaustive list of RIs in ASEAN.

Table 2 Topical overview of a selection of research facilities

Biotechnology	*Plant phenotyping;* Philippines (IRRI), Indonesia, Malaysia (MARDI), International Plant Phenotyping Network (IPPN). *Microbial resources*, AnMicro, Philippines (MRSL, ERDB, PNCM, USTCMS), Thailand (SDMC, TR, MRCEN, TBRC), Cambodia, Viet Nam (PU-BRC, MoST-V), The Asian Biological Resource Centres Network (ABRCN), Indonesia (ICEBB, BRIN, UNJCC), Myanmar. Genome analysis, Philippines (PGC), Indonesia (BRIN), Thailand (NSTDA), Singapore (SingaScope), Malaysia (MGVI). *Bioimaging*, Singapore (SingaScope), including collaboration in Global BioImaging with Europe (Euro-Bioimaging), Australia (AMMRF) and India.
Food Science & Technology	*Biobanking*, Indonesia (ICBB), Philippines (IRRI), Singapore (TR, SGH, STR, Thailand (BCC, BEDO, BIOTEC), Viet Nam, Malaysia (MARDI), Asian Network of Research Resource Centres (ANRRC), Viet Nam (IEBR, IMBT). Food Tech Innovation Center (FTIC), Singapore. *Food Innovation* Center, Department of Research and Innovation, Ministry of Science and Technology, Myanmar.
Marine Science & Technology	*Baruna Jaya Research Vessels (Deep Sea and Coastal Research),* BRIN Indonesia. *The Technology Centre for Offshore and Marine,* St John's Island National Marine Laboratory, Singapore. *Department of Marine Science, Myeik University,* Myanmar.
Materials Science & Technology	*Synchrotron Radiation sources*, Thailand (SLRI), Singapore (SSLS). *Neutron sources*, Indonesia (BRIN). *Nuclear Research Reactors*, Malaysia, Indonesia, Thailand.

Meteorology & Geophysics	*Middle and upper atmosphere*, Indonesia, Equatorial atmospheric radar. *Weather forecasting*, Malaysia, Indonesia, Thailand, Philippines, Singapore, Viet Nam. *Hazard and hazard warning*, Thailand, Malaysia, Indonesia, Singapore, Philippines. Earth Observatory of Singapore
Microelectronics & Information Technology	*Test and compliance facilities*, Philippines, Thailand, Singapore, Indonesia. National Semiconductor Translation and Innovation Centre, Singapore
Science & Technology Infrastructure & Resources Development	*Technology management hub* – led by Cambodia in ASEAN, part of COSTI.
Space Technology & Application	*Astronomy*, East Asian Observatory, Philippines, Thailand, Viet Nam (VNUHCM), Malaysia (UM, East Asian Obs.), Indonesia (BRIN). *Astrophysics* Thailand (NARIT). *Space technology and satellite development*, Thailand (GISTDA). *Space Applications*, Thailand (GISTDA). *Networks and Centres*, ASEAN Research and Training Center for Space Technology and Applications (ARTSA) in Thailand (GISTDA).
E-Infrastructures - Electronic Infrastructures (networks, HPC, disk, experts)	*Network(s),* NREN and other fibre networks in the region, all ASEAN countries, Malaysia (MYREN). Philippines (PREGINET, DOST-ASTI), Thailand (UniNet), Viet Nam (VinaREN). *Computer and storage facilities*, Singapore (NSCC), Thailand (LANTA) Philippines, HPC Mahameru of Indonesia, Malaysia, Singapore (ASPIREx), Cambodia (CamREN). *HPC school and training,* HPC-school, EU-ASEAN HPC coordination group, etc. *Grid & Cloud*, Indonesia (LIPI), LHC experiment (CERN), Tier-2 activities Malaysia (T2-MY-UMSIFIR), Thailand (T2-TH-CUNSTDA, T2-TH-SUT), Philippines (DOST-ASTI). *Artificial Intelligence resources*, all 10 ASEAN countries.
Social Science research	*World Values Surveys*, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand, Viet Nam. *Gallup World Poll*, all 10 ASEAN countries. *International Social Survey Programme*, Philippines (SWS), Thailand. *Global Barometer Surveys*, Indonesia, Malaysia, Philippines and regional Singapore, Thailand, Viet Nam. *IPUMS-International (IPUMSi),* Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Thailand, Viet Nam.

4.3 Existing structures in place

4.3.1 National policy, plan or strategy on Science, Technology and Innovation (STI)

The commitment, priority and progress in establishing national policies for STI vary among the AMS. Most of the Member States have actively formulated and implemented national policies since their independence. The duration of the policies spans between five and ten years;

Singapore, for instance, operates on a dynamic five-year policy cycle, reflecting its proactive and adaptive approach to advancing science and technology for national development. However, three countries – Brunei Darussalam, Lao PDR and Myanmar – have yet to develop and implement national STI policies, although components of STI are mentioned in the national socio-economic development plans. Brunei Darussalam and Lao PDR are currently in the process of formulating STI policies, demonstrating a proactive approach to aligning their developmental goals with advancements in science and technology. In contrast, Myanmar currently lacks explicit mention of the development of a national policy on STI. Addressing this gap would be crucial for Myanmar to actively engage in the global knowledge economy and ensure that its developmental trajectory incorporates the benefits of progress in science and technology. We have summarised our findings regarding national policies on STI in Table 3, below.

Table 3 National policy on STI and Implementing agency.

Country	National policy on STI	Year	Implementing Agency
BN	*In the process of formulating the first national STI policy*	-	CREATES
KH	National Policy on STI 2020-2030, and Cambodia's STI Roadmap 2030	2020 - 2030	Ministry of Industry, Science, Technology & Innovation
ID	*Included in the National Medium-Term Development plan*	2020 - 2024	Ministry of National Development Plan
LA	*In the process of drafting the national STI policy, existing STI elements are mentioned in the national socioeconomic development plan.*	2022 onwards	Ministry of Education and Sports and related government agencies
MY	National Science, Technology and Innovation Policy	2021 - 2030	Ministry of Science, Technology & Innovation (MoSTI)
MM	Science, Technology and Innovation Strategic Plan (2022-2027), and National STI Roadmap (2025-2030).	2022 - 2027	Ministry of Science & Technology
PH	Harmonized National Research and Development Plan	2022 - 2028	Department of Science & Technology
SG	Research, Innovation and Enterprise 2025	2021 - 2025	National Research Foundation
TH	National Science, Technology and Innovation Policy and Plan	2023 - 2027	Ministry of Higher Education, Science, Research and Innovation
VN	National Science, Technology and Innovation Strategy	2021 - 2030	Ministry of Science & Technology

The STI landscape plays a pivotal role in the socio-economic development of nations, fostering innovation, research and advancements across various sectors. Within ASEAN, the Member States recognise the strategic importance of delineating specific priority areas within the STI domain to guide and channel their efforts effectively. Table 4 provides an overview of the

distinct STI priority areas identified by each AMS, reflecting their unique national aspirations, challenges and ambitions, that is also reflected in their national policies as listed in Table 3.

Table 4 STI priority areas.

Country	STI priority areas
BN	Brunei Darussalam's STI plan is still under development, although they have developed Interim Research Funding Guidelines.[19] These stipulate that their funding priorities are for research that has the potential for human capital development, leads to the discovery of new knowledge and technology, and development of new products or improvement of existing products, processes, systems or services that may lead to increased productivity in all sectors in the economy and commercialisation. The focus is on: • Food science and technology; • Health; • Information and Communication Technology; • Energy; and • Environment and sustainable development.
KH	Based on **Cambodia's STI Roadmap 2030**: • Agricultural yield increase, produce diversification and agro-processing; • Modern production and engineering; • Health and biomedical; • Material science and engineering; and • Services and digital economy, including artificial intelligence, and space and spatial technology. Cambodia's **National Research Agenda 2025** prioritises eight areas: • Production of local food; • Generation of reliable energy supply; • Quality education; • Electronic and mechanical spare parts; • Cloud-based services; • Electricity and potable water; • Carbon neutrality; and • Digitally enhanced health.
ID	Based on the document of National Research Priority 2020-2024: • Food; • Energy; • Health; • Transportation; • Engineering; • Security and Defence; • Maritime; • Social Humanities – Education – Culture; and • Multi-disciplinary and cross-sectoral.

[19] https://www.mtic.gov.bn/cfp/CREATES%20Funding%20Guidelines.pdf

Country	STI priority areas
LA	The Lao government is the process of establishing a new National STI Strategy and Action Plan up to 2040 with a focus on: • Strengthening the STI governance and management; • Building human capital in STI; • Strengthening research capacities and infrastructure; • Research and development of STI towards driving the country's socio-economic development and environment; and • Strengthening the collaboration between the STI stakeholders. Based on the draft STI Strategy and Action Plan, the priority areas include: • Agriculture and food; • Public health; • Tourism economy; • Digital economy; • Industry, energy and mines; • Natural resources and environment; • Public works and transport; and • Education and Social sciences. The country also uses the 5-year Socio-Economic Development Plan as the basis for identifying sectors to be prioritised, including STI. Recently, the Science and Technology Law has been amended to indicate and update the principles and provision regarding research and development. In addition, a Science and Technology Development Fund is also indicated in the legislation which is facilitated by the Cabinet of Science Council under Ministry of Education and Sports.
MY	Based on the 10-10 MySTIE Framework[20] that couples the socio-economic drivers with the Science & Technology drivers (5G/6G network, sensor technology, 4/5D printing, advanced materials, advanced intelligent systems, cyber-security & encryption, augmented analytics & data discovery, blockchain, neuro technology and bioscience technology): • Energy; • Business and financial services; • Culture, art and tourism; • Medical and healthcare; • Smart technology and systems (next generation engineering and manufacturing); • Smart cities and transportation; • Water & food; • Agriculture & forestry; • Education; and • Environment & biodiversity.
MM	The Science, Technology and Innovation Strategic Plan (STISP; 2022-2027) includes 19 pillars and 93 strategies to support various national policies and missions to resolve the challenges for sustainable development in the country. The national priority areas include: • Agriculture, Biotechnology and Food Technology; • Environmental Conservation, Climate Change and Disaster Risk Management Technology; • Water resources application technology;

[20] https://www.akademisains.gov.my/10-10-mystie/ page 3.

Country	STI priority areas
	• Information, communication technology and electronic technology; • Digital transformation and AI technology; • National Health and medical science; • Nuclear Technology; • New and Renewable Energy technology; • Material and Material Science; and • Marine, Aerospace and space science technology. Importantly, the STISP also highlights the importance of cross-cutting issues such as gender equality and social inclusion in the implementation of STI initiatives and activities.
PH	The Philippines' national STI and R&D agenda prioritise these areas and sub-areas: • Space technology; • National Integrated Basic Research; • Health; • Agriculture, Aquatic and Natural Resources; • Industry, Energy and Emerging Technology; and • Disaster Risk Reduction and Climate Change.
SG	Based on the four domains outlined in the *Research, Innovation and Enterprise 2025 Handbook:*[21] • Manufacturing, Trade and Connectivity; • Human Health and Potential; • Urban Solutions and Sustainability; and • Smart Nation and Digital Economy.
TH	Based on the four strategies outlined in the National Science Research Innovation Plans (SRI Plan 2023-2027) Handbook:[22] • Development of National Economic Growth with Added-Value and Creative Economy to Raise Competitiveness, Sustainable Self-Reliance, and Readiness for the Future, with Science, Research, and Innovation. • Enhancing of Society Well-being and Environment Quality for Sustainable Development, able to Solve Challenges and Adapt to the Dynamics World, with Science, Research, and Innovation. • Development of SRI Manpower [sic] Institutions as the Foundation for Driving the National Growth and Sustainable Development of Economy and Society. • Development of Advanced Frontier Science, Research, and Innovation for New Opportunities and Future-Readiness for the Country.

[21] https://file.go.gov.sg/rie-2025-handbook.pdf

[22] https://www.tsri.or.th/files/trf/2/docs/Policy-Strategy/Thailand_SRI_Plan_5_Years_[2023-2027]_Rev1.pdf

Country	STI priority areas
VN	Based on the *Strategy for Science, Technology and Innovation Development 2021 - 2030*[23] *with a vision to 2050:* • Social sciences and humanities; • Natural sciences focusing on natural resources utilisation; • Information and communications technology; • Biotechnology for health, agriculture, processing industry and environmental protection; • New material technology; • Technology of machine manufacturing and automation; • Marine technology; • Technology in natural disaster prevention and climate change response; • Energy technology; • Environmental technology; and • Space technology. Viet Nam is currently leading the AnMicro.

4.3.2 National Research & Development (R&D) funding body and mechanism

All the AMS have national funding bodies, and these are listed in Table 5, below, although the governance of these funding bodies is diverse. This impacts the funding cycles for both research projects and RI, but also on what research political level the funding decisions are made; and this also has an impact on how close the researchers themselves are to these decisions.

Table 5 National funding body for research and research infrastructures of each AMS

Country	National funding body
BN	CREATES.
KH	Plans are underway to establish a national research funding body designed to allocate funds to public institutions to cater for research needs.
ID	Ministry of Finance, Ministry of Education, Culture, Research and Technology, BRIN, the Indonesia Endowment Fund for Education.
LA	Science and Technology Development Fund, facilitated by the Cabinet of Science Council under the Ministry of Education and Sports.
MY	MoSTI, Ministry of Higher Education (MoHE).
MM	The research budget comes from the union budget and the Ministry of Science and Technology.
PH	Department of Science & Technology.
SG	National Research Foundation.
TH	Thailand Science Research & Innovation.
VN	National Foundation for Science & Technology Development).

[23] https://en.vietnamplus.vn/strategy-for-science-technology-and-innovation-development-until-2030-approved/239685.vnp

Table 6, below, outlines the diversity of the national funding mechanisms for research and development across the AMS. It sets out details of the duration, capital and operational expenditures, key criteria for securing funding, and the potential for subsequent funding.

The common approach, adopted by Indonesia, Malaysia, the Philippines, Singapore and Thailand is that funding is primarily directed towards RIs with broad nationwide applications or pioneering new research topics. Typically, capital expenditures are covered, whilst operational expenditures are expected to be sustained by the RIs themselves. Singapore is an exception here, as the funding covers both capital and operational expenditures, but still with some requirements for a revenue from usage. The funding periods typically span two to five years, with the possibility of additional support beyond the funding period contingent upon evaluations of the performance and needs of the RIs. In Malaysia, the funding hinges on proposals submitted through the 5-year Malaysia Plan, with allocations disbursed annually. In the case of Cambodia, the recently introduced STI plan is still in the developmental phase and the funding mechanism is currently being developed. For the rest of the AMS, information regarding the funding mechanisms is presently unavailable.

Table 6 Funding mechanism

Country	National Funding for Research Infrastructure			Major criteria	Subsequent funding
	Duration	CAPEX[24]	OPEX		
BN	• 1 year for basic research • 2 years for applied research	✓	✓	• Research that has potential for human capital development. • Discovery of new knowledge and technology. • Development of new products or improvement in existing products, processes, systems or service that may lead to increases in productivity in all sectors in the economy and commercialisation. • Based on STI priority areas.	
KH	1 to 3 years	✓	✓	Based on National Research Agenda and strategic areas	Upon review request and evaluation.

[24] CAPEX: capital expenditure; OPEX: operational expenditure.

Country	National Funding for Research Infrastructure			Major criteria	Subsequent funding
	Duration	CAPEX[24]	OPEX		
ID	• Single-year contract • Multi-year contract (MYC) up to 3 years	✓	✓	• Must comply with the technocratic design of the National Medium-Term Development Plan (RPJMN). • MYC projects must comply with the institution's strategic plan, ready to be implemented and meet the government's RPJMN timeline. • Projects with high readiness, including land preparedness, design, budget capacity, and implementation.	
LA	Varies based on proposal	✓	x	Based on STI priority areas.	Submit proposal.
MY	1 – 5 years	✓	✓	Based on STI priority areas and have high societal impact.	Submit proposal.
MM	1 – 2 years	✓	✓	Based on National STI priority and National Interests / needs.	Submit proposal.
PH	2 years	✓ USD 90,000	x	• New in the field. • Nationwide utilisation. • Not duplicating others.	Difficult to obtain subsequent upgrades; must make a scientific case/ justification for the need of upgrade.
SG	5 years	✓	✓	• The National Research Infrastructure	Upon review at the end of

Country	National Funding for Research Infrastructure			Major criteria	Subsequent funding
	Duration	CAPEX[24]	OPEX		
				Framework developed by the NRF states the value should be more than SGD 25 million. • Must be applicable for multi-disciplinary domains. • Open access and serve as a collaborative platform. • Possess a business model to generate income for recovering operating costs.	the 5-year cycle.
TH	Single-year contract	✓	x	• Research facility of substantive scale (< USD 2.7481 million). • Must be applicable for multi-disciplinary domains. • Open access and serve as a collaborative platform. • Possess a business model for recovering operating costs.	Submit proposal.
VN	2021-2030	x	x	• Funded by the MoST-V. • Support start-up, Science & Technology enterprises. Four high-tech zones to attract foreign investment. • In 2022, 16 key national Science & Technology	

Country	National Funding for Research Infrastructure			Major criteria	Subsequent funding
	Duration	CAPEX[24]	OPEX		
				programmes until 2030.	

4.3.3 National integrated research resources

It is well recognised in the research realm that e-Infrastructure is an important driver for the open science regime, where it is possible and often necessary, to make data, analysis and methodology available when publishing journal articles. The e-Infrastructure is today the backbone of modern research. The improvement of accessibility to RIs is an important element for strengthening research and development initiatives within the ASEAN region. Recognising this need, Indonesia, Malaysia, the Philippines and Singapore have taken proactive steps by establishing their own nationally integrated systems for research resources, as outlined in Table 7, below. These integrated systems serve as centralised repositories, streamlining access to research resources, facilities, and expertise within each respective country.

Table 7 National e-platforms for research resources

Country	e-platform	Available facilities					Monitoring/ Performance analytics
		List of equipment	List of researchers	List of projects	Consultancy/ Services	Booking/ contact	
BN	-						
KH	A feasibility study is currently ongoing to build the platform.						
ID	e-Layanan Sains[25]	✓	-	-	✓	✓	✓
LA	Lao PDR is preparing to build the e-platform.						
MY	Knowledge Resource for Science and Technology Excellence[26]	✓	✓	✓	-	✓	-
	MyGrants[27]	-	✓	✓	-	-	✓
MM	Myanmar is preparing to build an e-platform for research laboratory infrastructure						
PH	OneLab[28]	-	-	-	✓	✓	✓
SG	A*STAR Scientific Equipment Finder,[29] Singascope[30]	✓	-	-	✓	✓	✓

[25] Badan Riset dan Inovasi Nasional (BRIN) e-Layanan Sains, https://elsa.brin.go.id/
[26] Knowledge Resource for Science and Technology Excellence, https://krste.my/
[27] MyGrants, http://portal.mygrants.gov.my/main.php
[28] Department of Science and Technology (DOST) OneLab, https://web.onelab.ph/portal/services (OneLab services are offered by local and international laboratories. However, clients will not be notified where/ which lab renders their services, they are only given the test results).
[29] A*STAR Scientific Equipment Finder, https://www.rsc.a-star.edu.sg/scientific-equipment
[30] Singascope, https://www.singascope.sg

Country	e-platform	Available facilities					Monitoring/ Performance analytics
		List of equipment	List of researchers	List of projects	Consultancy/ Services	Booking/ contact	
	NUS Equipment,[31] NTU Equipment[32]						
TH	National Research and Innovation Information System	✓	✓	✓	-	-	✓
	Science and Technology Infrastructure Databank	✓	-	-	✓	✓	✓
	National Science and Technology Information System (NSTIS) is under development	-	-	-	-	-	-
VN	Viet Nam has an e-platform (in Vietnamese) containing list of principal facilities.						

4.3.4 Existing collaboration based on scientific co-authorship

All AMS are actively engaging in collaborative efforts with other countries through diverse channels, including research grants or existing networks of researchers. In Table 8, we have evaluated the top collaborators based on scientific co-authorship, a significant portion of collaborative partnerships involves non-ASEAN countries. The top collaborators, listed alphabetically, include Australia, China, France, Japan, South Korea, the United Kingdom and the United States. Only Brunei Darussalam, Cambodia, Indonesia, Malaysia and Myanmar have fellow AMS listed amongst their top collaborators. Thailand emerges as a prominent collaborator for Cambodia, Lao PDR and Myanmar, whilst Viet Nam is also among the top collaborators for Lao PDR.

Table 8 Top 5 partners for scientific co-authorship

Top 5 partners for scientific co-authorship, 2017-2019 (number of papers)[33]					
Country	1st collaborator(s)	2nd collaborator(s)	3rd collaborator(s)	4th collaborator(s)	5th collaborator(s)
BN	***Malaysia*** (220)	*China* (160)	*UK* (152)	*Australia* (142)	***Indonesia*** (111)

[31] NUS Equipment, https://research.nus.edu.sg/research-facilities/project_tag/equipment/
[32] NTU Equipment, https://www.ntu.edu.sg/research/research-capabilities/facilities
[33]Source: https://unesdoc.unesco.org/in/documentViewer.xhtml?v=2.1.196&id=p::usmarcdef_0000377481&file=/in/rest/annotationSVC/DownloadWatermarkedAttachment/attach_import_695a116d-182b-4cfd-bcdf-49244b96ad87%3F_%3D377481eng.pdf&updateUrl=updateUrl7020&ark=/ark:/48223/pf0000377481/PDF/377481eng.pdf.multi&fullScreen=true&locale=en#USR-20%20SE%20Asia_v3.indd%3A74477, page 686.

KH	*USA* (345)	*France* / ***Thailand*** (248)		*UK* (246)	*Australia* (222)
ID	***Malaysia*** (3,633)	*Japan* (3,548)	*Australia* (1,805)	*USA* (1,743)	*UK* (1395)
LA	***Thailand*** (240)	*UK* (163)	*USA* (160)	*Australia* (145)	***Viet Nam*** (124)
MY	*UK* (4,807)	*India* (3,851)	*Australia* (3,741)	*USA* (3,716)	***Indonesia*** (3,633)
MM	*Japan* (321)	*China* (291)	***Thailand*** / *USA* (236)		*UK* (169)
PH	*USA* (1,503)	*Japan* (961)	*China* (723)	*UK* (693)	*Australia* (658)
SG	*China* (15,327)	*USA* (10,129)	*UK* (5,486)	*Australia* (4,257)	*Germany* (2,578)
TH	*USA* (5,742)	*Japan* (3,704)	*UK* (3,149)	*China* (2,577)	*Australia* (1,980)
VN	*USA* (2,462)	*Japan* (2,327)	*Korea, Rep.* (2,302)	*Australia* (1,881)	*China* (1,841)

4.3.5 Research & Development Performance

R&D investment, when represented as a percentage of a country's Gross Domestic Product serves as an indicator of the support received by the research ecosystem. The performance of the R&D sector can be measured through various indices such as the Global Innovation Index, Nature Index for research output and Clarivate's list of Highly Cited Researchers.

According to the latest available comprehensive list of R&D expenditure for the ASEAN region up to 2021, Singapore and Thailand stand out with the highest R&D expenditures at 2.16% and 1.33%, respectively. The other eight AMS reported R&D expenditures below the 1% threshold, a target set by many developing nations. It is noted that some countries' data in the table may not reflect the latest expenditure; further desktop research shows that, as of 2022, seven out of these eight AMS maintain R&D expenditures below 1%, with Malaysia being the exception at 1.08%.

R&D activities are primarily driven by the business enterprise (BE), the higher education, government, and private non-governmental organisation sectors. The COVID-19 pandemic is deemed to have impacted the R&D contribution from the BE sector. To revitalise and strengthen the R&D ecosystem, some countries have implemented initiatives to encourage increased BE investment, including mechanisms such as providing tax incentives through private-public funding matching.

In assessing the R&D performance of the AMS, as set out in Table 9, Singapore, Malaysia, Thailand and Viet Nam emerge as the top innovators (Global Innovation Index 2023), and contributors to research output (Nature Index 2023). Examining impact through Clarivate's list of Highly Cited Researchers in 2023, Singapore leads in citations, followed by Malaysia and Thailand, whilst the other AMS are not listed.

Table 9 R&D performance of the AMS

COUNTRY	R&D expenditure as a percentage of GDP[34]		Global Innovation Index 2023 rankings[35]				Research Output based on Nature Index 2023[36]		
	% GDP	Latest year	Score	Global rank	Income group rank	Region rank	Count	Share	Rank
BN	0.28	2018	23.5	87	49	14	3	0.10	168
KH	0.12	2015	20.8	101	21	15	11	2.17	100
ID	0.28	2020	30.3	61	5	12	105	16.22	53
LA	0.04[37]	2002	18.3	110	26	16	8	0.5	135
MY	0.95	2020	40.9	36	2	8	124	14.19	58
MM	0.15	2021	16.4 (2022)	116 (2022)	31 (2022)	17 (2022)	12	1.39	116
PH	0.32	2018	32.2	56	4	11	91	6.06	72
SG	2.16	2020	61.5	5	5	1	1365	535.94	18
TH	1.33	2020	37.1	43	5	9	300	60.05	40
VN	0.43	2021	36.0	46	2	10	104	29.48	45

Using the Nature Index 2023 by country, we further evaluated the performance of research output for the period between 1 August 2022 – 31 July 2023 (using the latest available data) and identified the leading research institutions in each AMS, and this is presented in Table 10.

Table 10 Top research institutions listed in the AD Scientific Index 2024 (accessed 22 February 2024)

Country	Top institutions in the country	Region Rank	World Rank
BN	University of Brunei Darussalam	355	1612
	Universiti Teknologi Brunei	715	2658
	University Islam Sultan Sharif Ali	3217	8740
	Seri Begawan Religious Teachers University College	8484	18512
	Politeknik Brunei	10153	21199
KH	Institut Pasteur du Cambodge	1225	3988
	University of Puthisastra	1796	5443
	Institute of Technology of Cambodia	1981	5865
	IIC University of Technology	3439	9172
	Royal University of Agriculture Cambodia	6190	14667
ID	Universitas Gadjah Mada	497	2061
	Universitas Teknokrat Indonesia	499	2070
	Universitas Indonesia	734	2716
	Institut Teknologi Bandung	737	2724

[34] http://data.uis.unesco.org/index.aspx?queryid=3684

[35] https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000-2023-section1-en-gii-2023-at-a-glance-global-innovation-index-2023.pdf

[36] https://www.nature.com/nature-index/country-outputs/generate/all/global

[37] https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS

	Universitas Negeri Malang	739	2729
LA	Institut Pasteur du Laos	4236	10977
	National University of Laos	4403	11327
	Souphanouvong University	6022	14328
MY	Universiti Putra Malaysia	32	282
	University of Malaya	49	391
	Universiti Teknologi Malaysia	65	486
	Universiti Sains Malaysia	66	487
	Universiti Teknologi MARA	235	1185
MM	Yangon Technological University	5098	12650
	University of Medicine Mandalay	5295	13022
	University of Mandalay	6057	14417
	University of Veterinary Science Yezin	6154	14581
	University of Computer Studies Yangon	6628	15382
PH	International Rice Research Institute	369	1656
	University of the Philippines	628	2457
	De La Salle University Manila	762	2786
	University of the Philippines Diliman	983	3311
	Ateneo de Manila University	1435	4562
SG	National University of Singapore	1	32
	Nanyang Technological University	4	76
	Singapore Management University	188	1032
	Duke-NUS Graduate Medical School Singapore	192	1043
	Singapore University of Technology and Design	207	1083
	A*STAR	641	2390
TH	Chulalongkorn University	105	676
	Mahidol University	156	893
	Chiang Mai University	279	1343
	Khon Kaen University	334	1533
	King Mongkut’s University of Technology Thonburi	426	1858
VN	Duy Tan University	427	1860
	Can Tho University of Medicine and Pharmacy	456	1947
	Viet Nam National University Hanoi	669	2544
	Nguyen Tat Thanh University	1028	3429
	University of Economics Ho Chi Minh City	1041	3463

5 AMS RI Challenges and How to Address Them

This chapter reviews insights gathered from interviews with members of the ASEAN RI TF and relevant stakeholders. These interviews revealed a set of shared challenges faced by most AMS, alongside unique challenges faced by individual countries. Figure 7 illustrates the general internal factors (national/ regional/ RI) and external factors that affect the operations and performance of the RIs in ASEAN in general. These are further elaborated in Sections 5.1–5.7. The gaps identified and corresponding suggestions for improvement are set out in Section 5.8.

5.1 Financial challenges

A predominant issue across the region is the persistent challenge of securing sustained funding. This challenge stems from dynamic factors such as changing national priorities due to political restructuring, periods of unrest, and the natural evolution of socio-economic priorities over time. Additionally, technical intricacies related to financing governance also further complicate the challenge. A typical funding duration for RIs in most countries spans up to five years, with disbursements occurring annually based on the RI's proposal and the ongoing monitoring of its performance. The funding coverage encompasses capital expenditures (CAPEX), operational expenditures (OPEX), or a combination of both. In the general landscape, most countries tend to cover only CAPEX, with OPEX covered by the organisation's annual budget. Singapore is the only country that offers 100% funding coverage for both CAPEX and OPEX, with the condition of charging for the use of the facilities to encourage more responsible usage. This generated income is then allocated for research purposes, such as purchasing of consumables or upskilling of staff.

RIs in most countries have in recent years turned to offering paid services as a means of generating income to cope with the dwindling amount of annual OPEX budgeting and CAPEX funds. The Philippines, however, suffer from an intricate technical financial governance. Funding in the Philippines is limited to just one year and there are restrictions on retaining their generated income, as the income must be directed to the government. These short-term financial commitments combined with restrictive financial policies fall short in facilitating effective planning, development, and sustained operations of RIs. This limitation impedes their ability to gather momentum and deliver meaningful contributions to scientific advancement. To unlock the full potential of RIs, the need for a more flexible financial framework becomes evident – one that supports a more extended funding horizon and greater autonomy to manage generated income.

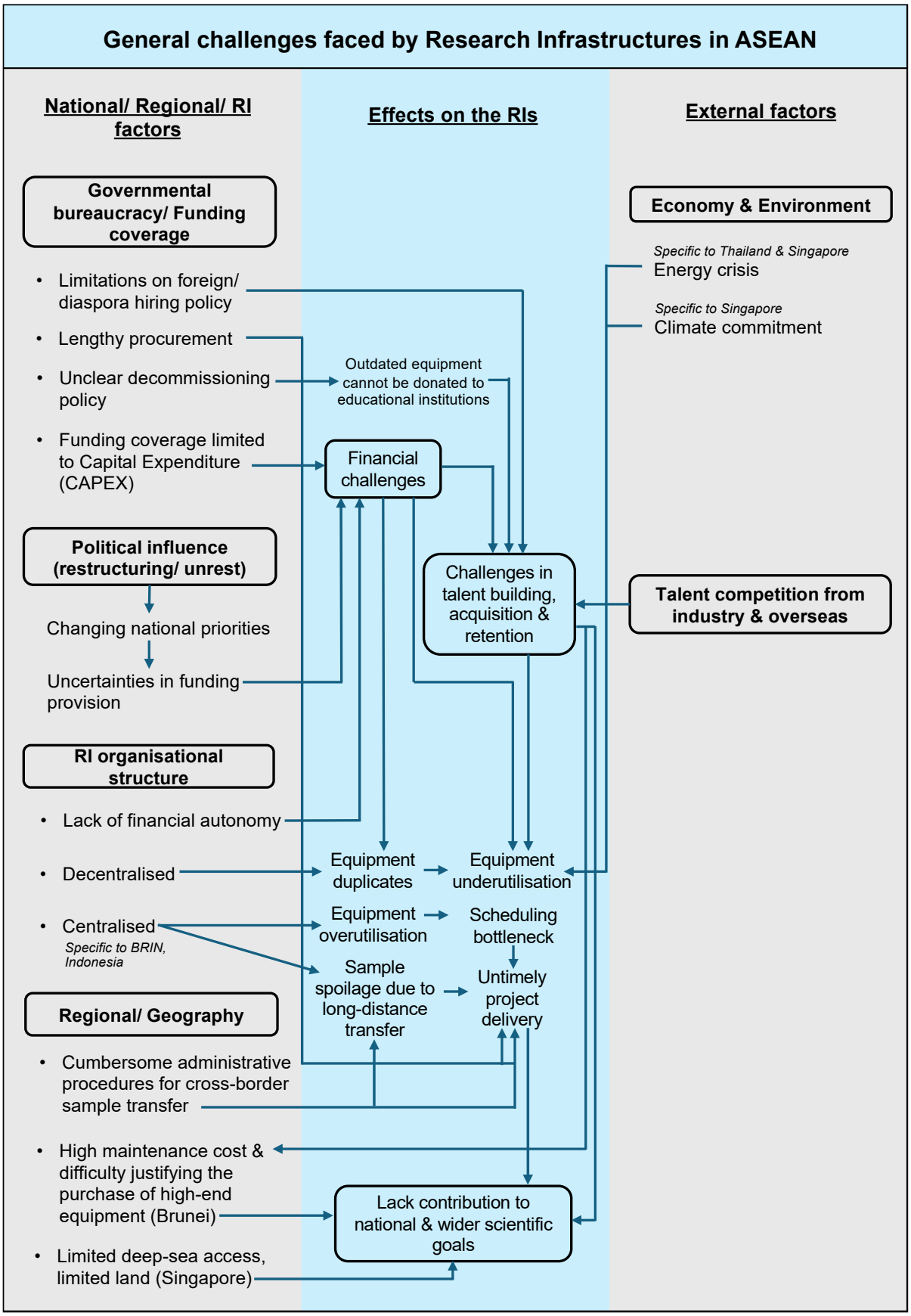

Figure 7 Flowchart of general ASEAN RI challenges

5.2 Talent acquisition and retention

All the countries in the ASEAN region suffer from a lack of human resources, both in research and in support of the research environment, including RI. This is, of course, not unique to the region, and across the world there are mitigating actions taken to try to attract and retain human capital, but there are aspects that are particular to the ASEAN region. ASEAN encompasses diverse countries, each with its own unique characteristics and approaches to human resource development and these differences must be considered in the retention of human capital. There is a need for most of these countries to increase the level of education amongst the population, and this is one particularly consequential reason for the lack of research talent in the region. Related to this is the language barrier that exists for a relatively large part of the population. This hinders collaboration. All the AMS grapple with these problems. Two critical aspects are observed here, though, one concerning the acquisition and retention of research talent pools and another concerning the lack of specialised non-scientific (technical) talents.

5.2.1 Acquisition and retention of research talent

Despite a different pace of development, each AMS has implemented advanced education initiatives, particularly in graduate studies, over the past few decades. Scholars are granted scholarships to pursue studies up to the PhD level with an obligation to return and serve their country for a specified period (typically two or three times the years of study). However, our interviews gathered a unanimous insight across all the Member States that many scholars opt to leave after fulfilling their service bond in pursuit of better pay offers by industries or research institutions abroad. This talent drain is seen to be delicately linked to the funding structure for RIs or the hiring policies specific to each country.

Major RIs in ASEAN generally cater to national priorities and are therefore subject to hiring local talent. Some member states, on the other hand, support the hiring of foreign nationals. For example, in Indonesia, the centralised research body, BRIN, is the sole public entity with the privilege to hire foreign nationals for technical assistance, while public universities lack this privilege. Malaysia allows public higher education institutions to hire foreigners, but governmental research agencies do not. Singapore adopts a more flexible approach, allowing foreign hires in both the public and private sector for research and other supporting roles, excluding core governmental positions reserved exclusively for Singapore nationals. In contrast, the remaining member states generally restrict the hiring of foreign nationals.

In response to the restrictions in hiring foreign nationals, Indonesia and the Philippines have turned to its diaspora, encouraging skilled scientists to return by offering them senior positions to aid in the establishment or management of RIs within the country. In Indonesia, BRIN has been implementing the Diaspora Scientist Recruitment since 2022. Diaspora scientists can be affiliated as government scientists without having to go through the placement test if they are recommended by a particular research centre and align with the national research priorities. Similarly, the Philippines initiated the ‘Balik Scientist Program’ in 1967 and this was officially implemented in 2018. This incentivises senior Filipino scientists abroad to return for a period of up to two years. However, despite these efforts, the programme continues to face challenges in retaining these scientists for more than two years, primarily due to the limited availability of senior positions within the country.

5.2.2 The lack of specialised non-scientific (technical) talent

Shifting the focus to the broader research environment, it is necessary to foster a future-ready ecosystem conducive to advanced research. RIs require not only scientific talents (researchers) but also technical, non-scientific talents such as operators, engineers and technicians. However, all the AMS struggle with a shortage of such talents. In most RIs in ASEAN, particularly those that are linked with higher education institutions, highly specialised equipment is often under the care of researchers rather than technicians. Graduate and doctorate students are trained to utilise this equipment, and they subsequently become the 'technicians' for the equipment. The common scenario across ASEAN is that when these student-technicians graduate, if there are no positions available at the institute, they often opt to pursue opportunities in the industry or institutes abroad, leaving the RI crippled. This challenge is particularly pronounced in the management and maintenance of digital infrastructures encompassing networks, storage, computing capacity, software and time-critical appliances. The expertise in this specific domain is currently in high demand not only in ASEAN but also globally due to the ongoing Artificial Intelligence (AI) deluge, particularly enhanced by the emergence of generative AI (such as ChatGPT). AI has already transformed knowledge-based technologies and businesses and will most likely continue to be a game changer and possibly even more disruptive in the near future. The lack of specialised talents in computing prompts both the public and private sectors around the world to meet the challenges associated with AI by hiring experts in computing, statistics and data managers. This makes an already challenging situation with retaining computer specialists even more demanding. There is currently not any easy solution to this challenge.

5.2.3 International and non-academic competition for talent

Adding a further complication to this challenging environment is the inability of ASEAN research institutes to compete with advanced research institutes abroad. ASEAN research institutes have made and continue to make efforts to attract talent by offering scholarships to study at the institutes. However, they face stiff competition from international scholarships, and individuals often prefer pursuing studies in more advanced institutes abroad than in their home region. To attract local talent, the International Rice Research Institute in the Philippines, through its collaboration with the Korea International Cooperation Agency, offers funded talent mobility and capacity-building initiatives, including:

- funded internships for Filipino students;
- funded masters' scholarships at the University of the Philippines Los Baños;
- funded PhD scholarships with three years in participating South Korean universities and one year at the University of Los Baños (with a service bond in the Philippines up to twice the study period);
- training on HPC; and
- hosting a joint annual scientific convention and quarterly international webinars.

5.2.4 Possible ways to mitigate the lack of talent

It is important to acknowledge that for the specific challenges in RI collaboration, human capital must be considered in a broader sense than for research. The research environment should be stimulated, and it is well known that operators, engineers and technicians are an integral part of the RI. Indeed, it is recognised that human capital is the most important asset in an RI, as it is comparably easy to build the technology compared to training experts that assist with and run the technology. An integral part of modern RIs is the digital e-infrastructure to which

most RIs are connected. This includes network, storage, computing capacity, software, and time critical appliances, and requires a different set of skills which, by themselves, are not necessarily a dedicated part of the RI. This can be a part of a national centre, as is often referred to as a national HPC installation. Some of the RIs have, and must have, dedicated resources for storage and computing. This might be related to demanding storage and/or computing needs or might be related to the degree of sensitivity for the data that is analysed. This kind of expertise is currently in heavy demand in the ASEAN, but also globally because of the AI-deluge.

One approach towards mitigation is to make the workplace more attractive by centralising some of the activities to create a critical mass of experts. We know from experience that this will have an effect over time as the attractiveness of an expert community tends to attract talent but also retain talent. The challenge with retaining experts that supports the RI environment is accentuated by the lack of computer experts caused by the surge in AI competence needs, but it is also highly relevant for the experts working with RIs, thus the operators, technicians and engineers. The value of the investment of a RI is critically dependent upon the expertise of the personnel that operate it, and the target must be to have an optimal use of that infrastructure by researchers in both the public and private sector, in addition to the industry in the ASEAN region.

5.3 Procurement and decommissioning challenges

Another crucial challenge faced by RIs centres on the bureaucratic processes entailed in procuring essential research equipment. This is more critical in the Philippines than in other AMS, (excluding Brunei Darussalam, Lao PDR, Viet Nam and Myanmar where information is presently unavailable).

In the Philippines, the public sector often contends with a lengthy sequence of approvals, involving multiple layers of bureaucratic scrutiny in the procurement of research equipment. This not only extends the procurement timeline but also introduces uncertainties that may impact the planning and execution of research projects. Delays in acquiring essential equipment and consumables can impede the progress of ongoing research initiatives and potentially lead to setbacks in the execution of greater initiatives of national importance. In addition to this, several research institutions also mentioned challenges acquiring research equipment suitable for the region's hot and humid climate, as most equipment is designed for cooler and drier conditions. Examples include the hardware materials in supercomputing equipment (Singapore), mobile biosafety Level 3 lab procured from France that are used in Malaysia, and various equipment in Lao PDR.

Conversely, decommissioning of outdated or malfunctioning equipment also presents its own set of challenges. In most countries, we observed obsolete and broken equipment lying within the institutes due to decommissioning policies that restrict donation or lack clear regulations on the efficient disposal or repurposing. Exceptions to this are Singapore's ASPIRE-1 supercomputer, which was decommissioned in August 2023 and donated to the Institute of Technical Education, and Indonesia's BRIN who donated the Baruna Jaya 7 Research Vessel to Pattimura University. This practice ensures continued knowledge transfer, thus ensuring sustainability of human capital development.

5.4 Scheduling bottlenecks when facilities are centralised

One of the distinct challenges highlighted during our interviews and site visits is specific to Indonesia's centralised research body, BRIN. Researchers within BRIN have expressed concerns about scheduling bottlenecks that lead to significant delays in their work. Compounding this challenge is the spatial diversity of the research institutes within the BRIN umbrella, where sending samples to a central location is time-consuming. Researchers expressed their hope to have core equipment available at their own facilities, justifying that this not only reduces travel time (and cost) but also reduces the queue for heavily used equipment at the central facility.

BRIN is also taking a rather unique approach to scheduling and pricing. According to the information given, equipment can be booked by all on a first-come-first-served basis and with the same pricing structures for internal and external users. If BRIN researchers wish to use certain facilities, they may therefore find themselves at the back of the waiting list without any preferential treatment compared to other users. With up-to-date data from the informative and impressive electronic platform utilised, ELSA, we learned that there is currently a higher usage of facilities by external users than internal. This is in many ways impressive and commendable, and it shows a high level of societal impact of the research facilities. However, there can be a risk that the high external usage comes with a price for the institution's own researchers.

5.5 Low utilisation

Contrary to the challenges of scheduling bottlenecks or the over-utilisation of research equipment, stakeholders we interviewed also highlighted the issue of underutilisation. This can be attributed to various factors, including those mentioned earlier, as well as external influences. The insufficient funding for RIs and research projects restricts researchers from fully utilising available equipment, and challenges in low human resources also contribute to underutilisation. External factors, highlighted by two countries are Singapore's climate commitment and Thailand's economic challenges related to the energy crisis.

In Thailand, the escalating cost of electricity in recent years is impacting the full utilisation of research equipment due to financial constraints.

5.6 Moving equipment and/or samples between the AMS

Another significant issue raised pertains to the transportation of samples and/or research equipment, particularly between the AMS or within a country's geographical expanse. This is particularly critical in the biomedical, natural and material science fields involving the transport of biological specimens by air or surface. Both currently and historically, biological specimens have been dispatched to developed countries such as South Korea, Japan, Australia, the United Kingdom and United States. This not only incurs substantial cost but also leads to significant delay in implementing immediate measures. To address this challenge, the Philippine Genome Center (PGC) has proactively sought government investment in high-throughput genome sequencing equipment. This strategic effort proved beneficial and timely during the pandemic period, where the PGC played a crucial role in sequencing COVID-19 samples in collaboration with health workers from the Manila National Institutes of Health of the University of the Philippines. This collaborative effort provided scientists with vital scientific information to effectively mitigate the spread of the disease. Additionally, stakeholders have highlighted the issue of cumbersome administrative procedures within the standard operating protocols, which may vary between countries. These administrative hurdles add an additional

layer of complexity for researchers, further complicating the efficient movement of samples and equipment. As a potential solution, streamlining and harmonising administrative processes at the regional level could significantly enhance the fluidity of scientific collaboration and research endeavours within the ASEAN community.

Concerning domestic logistical challenges, especially for geographically extensive countries like Indonesia, Malaysia and the Philippines, stakeholders have raised a concern about time-consuming transportation, increasing the risk of sample spoilage and causing delays in sample analysis. This challenge is compounded when samples need to be transported to centralised RIs housing major research equipment, as exemplified in the Indonesian case discussed in section 5.1.4. A potential solution could involve formulating a strategy for the distribution of research equipment across various research institutions based on priority needs or tiers, such as basic/core, medium-throughput, high-throughput. This approach can better cater to the specific needs of individual research institutes, fostering a more efficient and accessible research environment.

5.7 Country-specific challenges

Based on interviews and site visits with the ASEAN RI TF members and stakeholders, we identified some country-specific challenges for Brunei Darussalam, Lao PDR, Myanmar, and Viet Nam as well as to some extent Cambodia. Whilst these countries share the challenges described above, certain conditions within each country have led to comparatively lower investment and slower development of RIs, contributing to a lag in scientific advancement. Addressing these country-specific challenges is a top priority for the successful development and implementation of the ASEAN RRI strategy.

A common challenge in countries with growing economies is the prioritisation of economic development with low-hanging fruit in sectors relying on natural resources and which require a low-skilled workforce to sustain their economies, such as manufacturing and tourism. In Brunei Darussalam, there is a heavy reliance on natural resources where human resources are pooled from abroad. Both Cambodia and Lao PDR have in the past relied on official development assistance funds to acquire basic RIs for education. However, our observations in Cambodia indicate that most of this research equipment is outdated compared to those in most other AMS, impeding the development of advanced skills necessary for producing high-skilled talent. Despite governmental higher-education schemes being in place in all countries, except Myanmar where able individuals fund their own studies, the challenge persists as many skilled individuals opt for better opportunities in industry or abroad. Brunei Darussalam faces an additional challenge with regards to its small population size and geographical location, described as ‘remote’ by the stakeholder. Nestled between Kalimantan, Indonesia and two Bornean states of Malaysia, the cost of maintaining specialised high-end research equipment is deemed high, as technicians often need to be flown in from neighbouring countries, which is often costly and prolongs downtime. This logistical challenge, coupled with a small population size that makes it difficult to build a critical mass for use of specialised, high-end equipment makes it challenging to justify obtaining government funding for the purchase of such equipment.

To overcome this challenge, Brunei Darussalam builds their research capability by collaborating with other countries such as Singapore and the UK, to use their equipment over there. Whilst this approach may seem pragmatic in the short term, it raises concerns about long-term efficiency. The funds allocated for research or travel grants could potentially be

better strategically used for direct investment in RI or talent mobility within Brunei Darussalam or the broader ASEAN region. This shift in focus would not only enhance the country's research capabilities but also contribute to collective growth and collaboration within the ASEAN framework.

5.8 Gaps identified and suggestions for improvement

The challenges outlined within sections 5.1.1 to 5.1.7 underscore the need for an enhanced collaborative and strategic approach. The AMS have taken steps to overcome the challenges set out above and some of these we have already discussed. Here, we would like to set out a summary of the gaps identified along with corresponding suggestions for improvements that could be adopted in the ASEAN RRI Strategy. The improvements suggested in the table below are in large part inspired by the best practices adopted by some member states and are also supplemented by experiences drawn from Europe.

Table 9 Best practices and suggestions for improvement.

1.	**Existing network of collaboration is fragmented**
	Suggestions for improvement: Every AMS has an existing network of local, regional and international collaboration. However, our interviews revealed that many are still struggling to find appropriate potential collaborators. We suggest that each country increase the visibility of their RIs and researchers via an e-platform. Indonesia, Malaysia, Singapore, Philippines and Viet Nam have such platforms, although the Philippines' e-platform is specific to laboratory analysis whilst Viet Nam's e-platform is in Vietnamese. We note that Lao PDR is in the process of building the e-platform. With such e-platforms in place in each individual ASEAN country, they could be integrated into a unified network, such as the upcoming Technology Management Hub proposed by the ASEAN TF on Technology Management Hub (TMH) that is being led by Cambodia and Indonesia. The TMH would serve as an integrated online system that matches research with innovation-driven actors to accelerate and catalyse innovation. This interconnected system would facilitate seamless collaboration, enabling researchers from different member states to access a broader range of resources and expertise, thus enhancing the collective strength of the ASEAN community in the field of STI. Over time, and with the development and implementation of an ASEAN RRI Strategy, a similar unified network of ASEAN RIs could become a one-stop shop for researchers seeking equipment, facilities and research infrastructures across the entire ASEAN region.
2.	**Lack of talent pool inhibited by policies of hiring foreign nationals**
	Suggestions for improvement: Building upon the existing yet fragmented collaboration network, we encourage prioritising the recruitment of ASEAN nationals. We suggest the formal establishment of a cohesive regional collaborative network for the ASEAN region, aligning with the proposal put forth by the ASEAN Talent Mobility Task Force. Presently, ASEAN nationals and some non-ASEAN countries benefit from visa-free access within the ASEAN region for tourism purposes. However, challenges arise when some researchers exploit tourist visas for research, leading to the potential for legal complications. To address this, we propose exploring the idea of introducing trans-ASEAN visa-free access specifically for ASEAN nationals engaged in research-related activities or those proposed in

Chapter 6. Regarding building a joint pipeline for talent, we recognise that addressing visa frameworks for non-ASEAN nationals may require a more extended timeline and legal procedures, we therefore encourage ASEAN RIs to leverage on international programmes, as detailed in chapters 5 and 6, to facilitate seamless and effective cross-border collaborations.

Following the models of Indonesia and the Philippines, implementing a returning scientists programme to incentivise diasporic nationals to return to their country and help in establishing and managing RIs is highly commendable. However, in the experience of the Philippines, potential returning scientists have expressed discouragement due to the bureaucratic hurdles in applying for the programme. Additionally, retaining existing returning scientists is hindered by the limited availability of senior positions within the country when their contracts end. Thus, it is imperative to address these challenges to optimise the effectiveness of any such programme. Streamlining the application process and creating more senior positions within the country can significantly enhance the attractiveness and sustainability of the returning scientists initiative.

RIs can also engage in initiatives boosting the domestic talent pool. For example, in the Philippines, PGC has involved itself in a systematic train-the-trainers programme; by providing targeted education to those education the next-generation scientists (such as bioinformaticians) they hope to generate a larger and better-equipped critical mass to draw from over time.

3.	**Lack of monitoring on equipment usage performance**

Suggestions for improvement:

Mechanisms for monitoring and evaluation of usage of research equipment can be improved by:

- establishing key performance metrics for evaluating equipment usage, such as uptime, utilisation rates, and user satisfaction to improve the effectiveness of usage and identify areas for enhancement;
- conducting periodic user surveys (this can provide insight into any challenges or bottlenecks faced by users) to help to identify areas for improvement; and
- enhancing (open) communication channels between users and administrators/ RI managers to encourage researchers to report maintenance needs or operational challenges.
- Proposed monitoring mechanisms must be versatile and able to incorporate the diverse set of RI systems across various AMS. However, tracking and ensuring, e.g., increasing uptime and higher utilization rates is relevant in all AMS despite differences in starting points.

4.	**Income generation: unsustainable pricing structures**

Suggestions for improvement:

Generating income is a vital strategy for ensuring the sustainability of the RIs. However, from our observations, due to their predominantly national or government-level operations, these infrastructures often adopt a pricing structure that leans towards the minimum, justifying it as a societal benefit to minimise access barriers. Countries like Indonesia and the Philippines deliberately maintain low pricing, emphasising the advantage of attracting a higher volume of users rather than having them opt for other countries in the region such as Singapore and the broader Asia Pacific. Here, there is the potential to explore a tier-based pricing structure or business model, differentiating costs for research use, business applications or other relevant purposes.

Specific to the Philippines, income generated must be directed to the government rather than being directly reinvested to the RIs. Changing this in the short term is challenging as it is tied to governmental governance structures.

5.	**Lack of financial autonomy and procurement challenges**

Suggestions for improvement:

National RIs are often bound by governmental procedures which can be cumbersome and hinder their financial and operational efficiency. To address this, we suggest, wherever feasible, that RI leverage the status of a statutory body or a non-profit organisation for long-term assurance of funds and sustainability. Attaining such status provides a cost-effective avenue for delivering research services/ output, offering advantages that may not be as readily available to the government or government-linked RI. This status generally grants autonomy over finances, operational flexibility, policy and operational continuity and other privileges, which foster enhanced managerial operations and talent management capabilities. For example, existing RIs such as Indonesia's BRIN, Malaysia Genome and Vaccine Institute (a not-for-profit organisation), Sabah Parks (conservation-based state government statutory body) and Singapore's A*STAR have autonomy over their finances, which enables them to operate more effectively and sustainably.

6.	**Lack of sustained funding**

Suggestions for improvement:

Leverage international organisations specific to the domain to obtain funding. For example, the *nuclear technology sectors are actively tapping into the funds provided by the* International Atomic Energy Agency (IAEA)[38] under the IAEA Technical Cooperation Programme which focuses on nuclear technology and applications. We suggest other domains to tap into such funds specific to their domains wherever possible. For other funding that is not provided by such organisations, the AMS could consider allocating such funds.

Another suggestion is to consider implementing a strategy for divesting research equipment/ infrastructure by incentivising business entities. This approach could involve putting in place mechanisms to ensure that the operation and services provided contribute to national R&D objectives at an economically viable scale. In so doing, surplus or outdated equipment can be repurposed efficiently, but also encourages the private sector's involvement in supporting R&D initiatives aligned with national goals.

7.	**Procurement challenges**

Suggestions for improvement:

Many RIs report difficulties with procurement. In certain countries, this is tied to national regulatory frameworks that might be difficult to change. Granting RIs special statutes might offer some more degree of freedom from red tape compared to the public sector in general.

For other RIs, procurement is a complicated issue, as it requires significant scientific understanding (making sure that the right equipment is procured) in addition to other sets of skills, such as economic and regulatory expertise. Building and retaining strong teams with both sets of skills is difficult. Joint specialised staff training across different RIs (perhaps even across countries) might help embedding the right expertise in the RI ecosystem.

8.	**Lack of/ Unclear policies on decommissioning**

Suggestions for improvement:

[38] https://www.iaea.org/about/governance/list-of-member-states

Donating ‘old’ equipment associated with competence building for the specific equipment will create a closer collaboration and possibility over time to increase the utilisation of more modern infrastructure. For example, donating to educational institutions as NSCC of Singapore achieved this, where they donated the decommissioned ASPIRE-1 supercomputer to the Institute of Technical Education for continued knowledge transfer thus contributing to human capital development.

- Rather than sustaining RIs with limited funding or permanently closing down an infrastructure when the allocated funding or contract expires, a strategic approach involves the divestment of the infrastructure to a third party, typically a business entity.
- Note that equipment donations are only recommended when the benefits of competence building outweigh the associated costs and logistical challenges (i.e. with transportation across AMS). If not, donations can worsen existing relationships. However, it is believed that even keeping this in mind, there is a great potential to increase added value from ‘old’ equipment through repurposing it. As the logistical barriers for trans-ASEAN collaboration are lowered, this potential will become even greater.

9.	**Non-working equipment**

Suggestions for improvement:

For broken/ non-working equipment, we have encountered that some of the AMS have challenges with a proper Service Level Agreement (SLA) for bought equipment. In cases of breakdown or malfunction, the purchase in some case does not include an SLA that caters for this for the expected lifetime of the equipment. One reason for this, we have learned, is regulatory where it is only possible to buy the equipment at just a ‘standard’ guarantee time.

When purchasing equipment, an expected lifetime must be considered and an SLA to cater for error of faulty conditions should be included in the purchase and should be included in the tender for the equipment.

10.	**Gaps in data sharing**

Suggestions for improvement:

All RIs must strive to make their data FAIR: Findable, Accessible, Interoperable, Reusable. This requires, for example, adhering to data standards and working toward continuous improvement of data quality.

It was observed, for example, as an issue in AnMicro that member organisations are not using the same and interoperable software systems, it might be that more advanced solutions is too costly. Ensuring common software and data frameworks, helped by centralised funds if needed, is important to enable greater RI collaboration.

11.	**Barriers for transfer of materials and equipment**

Suggestions for improvement:

The international guaranteed scheme ATA Carnet (‘Passport for goods’) reduces some barriers related to transnational transfer of samples and equipment. In ASEAN, the scheme is in force in Indonesia, Malaysia, Singapore, Thailand, and Viet Nam. The remaining countries could consider accession.

6 Next steps: Towards an ASEAN RRI Strategy / Roadmap

6.1 Building trust to raise the comfort level to enable RRI collaboration

Establishing research and RI collaboration amongst multiple countries is a complex endeavour, particularly concerning the allocation of financial resources and setting the intended duration of the collaboration. This landscape study revealed that each of the AMS have already established robust regional and international collaborations through partnerships in various research activities and initiatives including nuclear research, astronomy, astrophysics, microbial utilisation (AnMicro), and engagement with international organisations for additional research and capacity building support. Additionally, ASEAN, through support from E-READI has taken steps to coordinate efforts such as the ASEAN High Performance Computing School and the Southeast Asia network focused on social sciences and the humanities.

In this chapter, we aim to provide recommendations on how to strengthen the existing collaborations amongst the AMS and outline general features that should be in place for successful development in RI collaborations. Establishing a set of requirements for establishing and operating RIs serves as a foundational step that we believe will facilitate effective processes and informed decision-making, fostering trust and practical solutions for promoting collaborations.

For an effective ASEAN RRI, there is a need to build upon existing ASEAN relationships and to formalise research networks and collaborations around research and RIs within the ASEAN region. Eventually, this will most likely involve the commitment of financial resources, personnel, and equipment that will necessitate formal contractual agreements. Whilst it may be prudent to first initiate more informal cooperation modes at this early stage, the development of transparent processes is still important. With transparent and trust-building processes, collaboration may evolve into strong commitments over time. In Europe, agreements on research and RI collaborations developed over a period of 20 years through ESFRI and were both complex and extensive. Such complexities may hinder rather than promote collaboration at the current stage of ASEAN cooperation.

The primary and critical focus area is to remove barriers for cooperation between existing RI entities. Aiming high with strong ambitions for RRI collaboration, it is, subsequently, crucial to have a critical mass of ASEAN countries committed to developing, signing, and implementing collaborative agreements. Whilst involving most AMS is advantageous, having more than two countries as the founding members of future RI collaborations offer benefits in integrating national aspects into the collaboration. Practical experience among founding members will create trust and strengthen the collaboration over time. It is crucial to acknowledge that collaboration occurs at different levels, and an ASEAN RRI would ideally receive support from all AMS. However, the level of commitment may vary, leading to what can be described as a ‘variable geometry’ approach, wherein parties have flexibility in determining the scope of collaboration beyond a minimum set of agreed terms. For example, resources such as finances, personnel, consumables, and suchlike can vary, but there needs to be a common minimum basis of collaborative principles.

In the short term, we recommend that the actions set out here should be considered.

- A high-level political commitment to the ASEAN RRI initiative.

- Appointment of a liaison lead to facilitate connections horizontally and vertically across relevant organisations.
- Designation of a project leader by the TF for initial drafting and implementation of the ASEAN RRI Strategy.
- Development of an ASEAN RI Ontology, serving as a glossary for RI terms.
- Establishment of criteria and mechanisms to prioritise support for existing RIs.
- Implementation of a monitoring process for the roadmap itself.
- Defining a set of monitoring KPIs for political, funder and user levels versatile enough to function across AMS.
- Securing commitment from at least three to four countries, along with financial resources and priorities, which may not necessarily align with national priorities.
- Development of a funding mechanism clarifying responsibility for cost allocation when utilising an RRI.
- Integration of existing e-platforms, such as equipment browsers, that over time can develop into a single unified network or platform (one-stop for researchers seeking equipment, facilities, or research infrastructures).
- Inclusion of existing collaborative networks in the initial version of the RRI roadmap.
- Strengthening of existing international RI collaborations.

In the medium term, it is advisable to consider these actions:

- Systemisation of all costs related to an RRI.
- Development of service catalogues outlining available RI services.
- Establishment of training networks for all professions related to RRIs, including considering a new career pathway for RRI personnel.
- Exploration of Trans-National Access (TNA) opportunities with other regions of the world.
- Implementation of a mechanism to prioritise the development of RRIs.
- Individual countries articulate which RI to build and prioritise.
- Pursuit of bilateral agreements with other regions for RI collaboration.

It is important to note that the variable geometry approach, whilst beneficial for operational collaboration, can complicate administrative processes. Consulting with external parties experienced in operating this collaborative approach is recommended, such as the ERA-NET-plus mode in the EU. This is particularly important if the establishment of a common funding pool is set as one of the elements in a future collaboration between (some) AMS.

Despite the short timeframe of this landscape study, we have mapped the dimensions of current research and RI to inform the initiation of ASEAN RRI strategy. We have addressed themes such as varieties of RIs in Chapter 3, governance, and policy frameworks in Chapter 4, identifying challenges to RI collaboration and sustainability with some suggestions on how to address these in Chapter 5. In Section 6.2, a set of suggested initiatives is provided to guide the progression toward an ASEAN RRI strategy. Ultimately, we would like to emphasise the pivotal role of the ASEAN RRI TF in articulating the strategy and advocating for its significance to policymakers and funders.

6.2 Suggested strategic initiatives

There is a dire need for ASEAN leadership and leadership development for the competences needed for an optimal utilisation of the investments made in RIs. Here, we present a series of

suggested initiatives aimed at developing the ASEAN RRI Roadmap. These strategies are crafted to address the key challenges identified in our study and capitalise on existing collaborative frameworks and initiatives.

6.2.1 Establishing a common definition of RIs and RRIs

In Chapter 3, we emphasised the need for establishing a common language and framework for RI and RRI. Transitioning from the current state of (some) RRI to a more committed and forward-looking RRI collaboration requires a shared understanding facilitated by clear definitions and transparent dialogue on collaboration conditions. This foundational step is crucial for fostering effective cooperation and maximising the impact of collaborative efforts. Moreover, the leadership and proactive engagement of the ASEAN RRI TF are instrumental in driving this initiative forward and ensuring its success.

6.2.2 Performing a periodic landscape analysis of RI and RRIs

Even though a landscape mapping, if somewhat limited, was conducted from October 2023 to mid-December 2023, it is recommended to undertake a more structured and comprehensive analysis of the RI landscape in ASEAN. We recommend approaching future landscape mapping from the perspectives of societal and scientific needs of the individual countries. The current approach is guided by political objectives, whilst the future approach should be substantiated by scientific case studies encompassing every ASEAN country. This approach aims to identify commonalities and shared scientific priorities across the region. The challenge and advantage in these two, top-down and bottom-up approaches are that both, in principle, are needed, as each contributes distinct insights to the overall analysis.

6.2.3 Streamlining structural and financial governance of RI and RRIs

The costing for RI is complicated, particularly if all aspects are to be calculated. Costing related to purchasing, operating, and maintenance of equipment are relatively straightforward and can be accurately calculated based upon the tender process when the acquisition was completed. Operating costs can be estimated based upon the human interaction and consumables needed to run the equipment. Costs that are more involved and not directly accessible are related to those for using space, for visiting researchers, data-streams, computing, storage and network capacity and the people operating these facilities. In addition, costs related to readiness might also have to be included in a complete costing picture.

Another aspect in acquiring and operating research infrastructure is how the equipment is financed, and how the sustainability of the equipment is handled. There is a wide range of funding models for research infrastructure, from a national yearly fee to per-use-fee, to free use and also where the RI owners must generate income equal to the cost of operating the equipment. Economic sustainability is one of the main challenges in efficiently utilising the investment for RI, and currently there is no single optimal solution. Individual, local models are used to fit both the research community and the willingness to pay for the services to more institutionalised models where there is a combination of a fixed fee, and variable costs related to the use of the RI. This is often reflected in how access to the RI is managed. Here, there can be a combination of access based upon excellence, and one based upon wider access in addition to market-driven access, as most often this is related to public-private partnership and collaboration. We see that in ASEAN marked driven needs is often one reason that (expensive) RI has been acquired.

There is no single model for how costs should be handled for external usage of RIs. In certain ASEAN countries, costs are set almost deliberately low – this helps attract users and spurs innovation. However, as a guiding principle, the cost structure should facilitate an environment of economic sustainability that will maintain operation (service), maintenance and decommissioning. Cost structures should also consider the needs for equipment service and downtime, and both planned and interrupted should be included. A guiding principle we see from other regions is that the RI is operated so long as there is a demand for the services given. Over time, the equipment might be too old to produce useful, high-quality data for researchers, and then usage diminishes. So, depending upon the cost structure, a best practice will include a pre-agreed reflection on how to cover the purchasing and planned maintenance, the operation of the equipment and later decommissioning, in an economical sustainable way.

Cost structures for *regional* RIs should also consider the travel costs for scientists to use the equipment. In Europe, this is referred to as TNA (trans-national access). Centralised funds may help cover this, but, in general, agreements must be clear as to how to share the cost between the RI owner and users. As mentioned above, this can often be handled with use of a variable geometry approach for the cost structure. The costs here include both travel and staying close to the equipment, as well as the use of operators, engineers, and technicians along with the handling of data-streams and proper treatment of the generated data, and its ownership.

Not all RI requires physical access. In several cases, research conducted with the use of RI can be done so remotely via regional and/or a national network. This can still induce cost for the RI owner, and this too must be clarified.

6.2.4 Establishing RI e-catalogues in each AMS and connect them into a wider ASEAN e-catalogue

Several of the AMS already have or plan to develop a platform for equipment browsing for researchers, public users and others (such as industry and other private stakeholders). This overview of research equipment is a first step towards establishing an integrated planning organisation around RI and research. An equipment browser will enable an overview of the current platform ownership, as is found in Singapore (A*STAR), Indonesia (BRIN), and Malaysia (MoSTI & MoHE).

In Europe, an analogue is the Service Catalogue, but a Service Catalogue has a much wider application and definition.

We conclude that the most effective ASEAN RRI collaboration will build upon the already-existing electronic platforms. An RRI Strategy should help make the existing catalogues visible to all ASEAN parties, and it should, at a minimum, encourage the development of similar solutions in the remaining countries.

6.2.5 Strengthening patent management and technology transfer via a Talent Management Hub

Concurrent to the development of the ASEAN RRI Strategy, Cambodia and Indonesia are leading the development of an ASEAN TMH (Technology Management Hub), with support from E-READI and COSTI. The TMH seeks to accelerate a cross-border technology transfer model. One target is to develop an online platform that matches research with innovation-driven, private-sector actors to accelerate and catalyse innovation. It is highly recommended

to utilise this new opportunity, once it is available, also as a catalyst for generating the societal and economic impact of RI investment. The following actions should be considered:

- leverage digital platforms for talent acquisition, training, and communication;
- reach out beyond the ASEAN region to attract talent;
- stay informed about industry standards and local market conditions to adjust compensation strategies accordingly; and
- consider flexible work arrangements and remote-work options to accommodate diverse employee needs. Regularly seek feedback from employees and use it to make improvements in work processes and organisational policies.

Embrace diversity and inclusion initiatives to create a more inclusive workplace. Adapting and customising based on the characteristics of each ASEAN country will contribute to the overall success of human capital development, recruitment and retention efforts in the region.

In several AMS, innovation and testing facilities are presented as among the countries' most important RIs. It is recommended to consider how strategic cooperation on these facilities might enhance integrated economic development across ASEAN. For example, attracting and developing electronic, automotive, aeronautic or marine industries to the region would be helped by access to world-class research, development, and testing facilities. However, in an integrated region it might not be necessary for the facilities to be available in the same member state as where the industry investment is made. If industrial users of one AMS increase their usage of facilities in another AMS, this will benefit both the country hosting or owning the RI and the host country of the industrial user.

6.2.6 Joint training in the management of Intellectual Property Rights

A specific example of skills that are required in RIs to supplement scientific skills, which was raised during our interviews, is the management of Intellectual Property Rights (IPR). Patent management is an important aspect of the innovation process of translating research achievements into market-ready technologies, products, and services. As such, effective IPR management is an important aspect of tech transfer. It also corresponds to the ASEAN vision of STI-enabled economic development. However, it might be difficult to develop a peer community on IPR management-related issues at the level of each institution. A joint network across RIs, such as facilitating joint trainings, was therefore suggested in interviews as a potentially productive development for ASEAN RRIs.

6.2.7 Strengthening the talent pool

In the RI realm, there are several layers of competence that must be gained and held to create stability and, over time, sustainability. In the end, it is the experience and knowledge of the people supporting the use of RI that will be critical to the performance of the use of the equipment. To achieve an internationally acknowledged operation of research equipment, it is the quality standards, maintenance, calibration for accuracy and precision, life-cycle documentation and upgrading that is the difference between standard research equipment and being a part of an international RI. It is also acknowledged that the most critical part of a RI environment is its skilled workers.

A common agreed training for all the people that constitute an RI environment is necessary. This is part of securing a given level of competence that creates an environment of experts (non-scientists) which can over time become a critical mass.

Structured training with both a commonly agreed curriculum and outcomes will form a solid basis for ASEAN scientists. There are several reasons that this is important for the region. First, it creates a common base of knowledge where the AMS can build a foundation with similar competencies and joint capacities for the themes to teach. Perhaps even more importantly, are the networks established for such arrangements, where even short (one week) arrangements can still create connections that can already positively affect dialogues and career development.

Moreover, there is the potential for these benefits:

- Helps identify talents.
- Gives knowledge that diffuses vertically, which is important over time especially at the funding-political level.
- Can contribute to an understanding of the need for building an alternative career, parallel to the research career, an RI career pathway (please see chapter 6).
- Demonstrates the necessity for mobility – not only for researchers but also for 'RI-talent'.

Initiated by E-READI, the first HPC school was arranged in July 2021 by Thailand. Because of the COVID-19 pandemic the training and classes were conducted virtually. The HPC School is a one-week programme for ASEAN researchers mainly (but not necessarily) at the postgraduate level. Invited speakers and teachers are from Europe, Japan, and ASEAN. The second school was also arranged in Thailand, this time physically in December 2022. In December 2023, the third HPC school was held physically in BRIN, Indonesia.

The ASEAN Talent Mobility (ATM) Community is supported by E-READI. Objectives of the initiative include the wish to establish STI mobility policies and develop on online platform system that is expected to provide one-stop information for STI talent. The vision is that talent circulation enhances mutual competitiveness. The first phase of the ATM Platform Plan is completed, and a database of the ASEAN Talent Pool is now online.[39] During the upcoming years, more features are likely to be added. The ASEAN Talent Community might form an especially important part of developing a joint pipeline for talent for RIs. Linking the ASEAN RRI Strategy and the ASEAN Talent Community is therefore a clear recommendation.

6.2.7.1 Talent mobility

The responsibility for training around selected RIs, including computing, network and storage (in our visits, referred to as HPC) must be distributed among the ASEAN countries. This can be based upon existing collaborative networks or upon national priorities. The frequency, the size of the training group, the lecturers and involvement of industry must be decided on an individual basis, but it is recommended to arrange this at least once per year. The funding of these activities should be agreed upon and should reflect the economic capability of each country. Successful examples can be found in the collaboration between the Baltic states and the Nordic countries. Here, the location of training has been placed in a low-cost country and this has provided location, food and other local expenses, whilst travel, accommodation and costs for external lectures are covered by the higher-income countries. ASEAN enjoys good collaboration with several countries outside the region and has traditionally been able to attract funding from these (Japan, the EU, Korea, the US, and so forth) and could utilise these collaborations to fund some of the activities for a period.

[39] https://asean-talent.nxpo.or.th/

6.2.7.2 Building a new career path for research infrastructure personnel

We have concluded that several actions must take place to address the challenges at hand regarding recruiting, retaining and attracting talent to work in RI environments. In Europe, this is discussed as an important part of the sustainability of RIs. The suggestions are structural in the sense that they can and should be considered as regular and repeated actions for the ASEAN region and within each country. Similar action could also be considered for scientists, but there are other drivers and motivations at play such as scientific accreditation and influence in addition to a well-known career path.

Another mechanism we see in some of the other regions is a career development path with an alternative career than that of a scientific path. This can create a recognised and commendable choice for experts that do not pursue a career as a scientist. This can contribute to a clearly divided career choice and also a balanced reputation between the scientists and experts. As an example, in Europe an e-MBA training and title has been developed as one module towards an alternative career path for those that do not pursue a science career. There are also other benefits to the diversification of careers around RIs, as it also underlines and documents the need for highly skilled experts required to support the optimal utilisation of RIs. Moreover, it is part of the real cost in addition to purchasing, installing, operating and over time decommissioning RIs. Finally, it is important to conduct exit interviews with departing employees, to ascertain the reasons for employee turnover and address any underlying issues that might exist.

Recently, the international RI Global BioImaging published a report promoting *career paths* of Imaging Scientists.[40] Graham Wright, Director of the Research Support Services at A*STAR and head of A*STAR's Microscopy Platform is the lead author of the career paths report. He was also interviewed for this landscape study. The paper specifically addresses a narrow scientific discipline; however, many of its conclusions will be applicable for RI personnel across all domains.

On recruiting and retaining staff the report states:[41]

'In contrast to the well-established and defined career pathways and hierarchies in traditional academic positions at universities and research institutes, including Imaging Scientists, are relatively recent additions to the research landscape. As a result, job descriptions for managerial and instrument scientist positions vary significantly between institutions and lack universal standardization. Recognizing the importance of diverse career paths, encompassing both academic and core facility roles, is vital for a thriving research ecosystem. These paths complement each other in advancing scientific knowledge and require distinct skill sets and expertise.

[...] Core facility staff tend to occupy a role which blends technical, administrative, managerial and research skills, but their job descriptions and scope of role and responsibilities often do not match the actual work carried out. Consequently, they often go unacknowledged and unrecognised for their contributions.'

[40] Global Bioimaging: Charting a Course for Success: International Recommendations for Imaging Scientist Careers in Core Facilities.

[41] Global Bioimaging: Charting a Course for Success: International Recommendations for Imaging Scientist Careers in Core Facilities. Page 12.

Core facility staff in RIs are integral to their successful operation. This is true for a range of staff categories, from instrumentation technicians to data professionals, and research infrastructure procurement specialists to RI managers. These are all functions that require balancing scientific and research skills with other types of skills. Whilst their work for the scientific community is often unacknowledged, job opportunities outside academia often abound. Data scientists and those with expertise in HPC are good examples, and where many of our interviews revealed RIs struggling to recruit and retain sufficiently qualified staff. The recognition of the vital role of the *non-scientists* in RIs may, in itself, help with the recruitment and retaining of essential talent. Another step towards building career paths is to encourage joint training programmes for core facility staff, across ASEAN for example. This kind of investment in training can target staff within a singular scientific discipline, as with Imaging Scientists, but it can also bring together RI core-staff in similar roles across disciplines. Expert knowledge on RI management, procurement, data processes and suchlike are not altogether dissimilar, even though the RI targets different scientific fields.

6.2.7.3 Explore the possibility of hiring foreign nationals

Major RIs in ASEAN generally cater to national priorities and are therefore subject to hiring only local talent, as discussed in Chapter 5. This is a severely limiting factor for the attracting and retaining of (foreign) RI talent on a temporary or permanent basis. We recommend addressing the possibility of making it easier to hire foreign talent. For example, it could be made possible to recruit other ASEAN nationalities on new special ASEAN researcher work visa schemes, and/or hire foreign nationals on time-limited contracts.

6.2.8 Strengthening ASEAN collaboration

As illustrated in Figure 7 and discussed in chapters 1 and 4, the RRI initiative entails long-term commitments and collaboration on research and RIs. Strengthening this collaboration necessitates the establishment of common interests and mutually beneficial opportunities, both bilaterally and multilaterally. Table 9 presents several suggestions aimed at increasing and strengthening the collaboration.

6.2.8.1 International collaboration

There are good opportunities for increasing international collaboration, however, it might require strategic actions to make use of them.

We have summarised some of the possible levels of cooperation and provided examples of strategic steps and actions which could help see them implemented in Table 11, below. These are written primarily from the perspective of increased cooperation with European partners, but similar initiatives could be explored with other ASEAN dialogue partners. Several AMS already enjoy strong dialogue on RIs with Japan and the Republic of Korea.

Table 11 Opportunities for international collaboration

Opportunities for increasing international collaboration	**ASEAN level**	**International level**	**Examples of possible strategies and actions**
High-level cooperation	ASEAN level	Partner country/region	Establish an entity similar to the EU-Community of Latin American and Caribbean States Working Group on Research Infrastructures.
Targeting VLRIs	ASEAN level	Very Large Research Infrastructures	Establish a strategy for greater ASEAN and AMS collaboration with existing VLRIs (Very Large Research Infrastructures). Whilst VLRIs are often welcome to increased international collaboration, it can be difficult to attain for single research groups or institutions.
RI to RI cooperation	ASEAN RIs	International RIs	The signing of a Memorandum of Understanding (MoU) between an ASEAN RRI and an International RI. A possible MoU between AnMicro and the European Biobanking and BioMolecular Resources Research Infrastructure (BBMR ERIC) was discussed during the ASEAN RRI Workshop in Bangkok 13-15 November 2023.
Trans-National Access	ASEAN researchers and research groups	International RI	Increase access to international RIs to perform research, gather data, build international networks etc. Some European RIs[42] offer TNA supported by EU funding.[43] TNA usually means free of charge, transnational access to RIs or installations for selected user groups, and includes logistical, technological and scientific support and the specific training necessary for external researchers seeking to use the infrastructure.[44] The Horizon Europe Coordination and Support Action RICH Europe provide access to information Transactional Access and Virtual Access opportunities and calls during the NCP Portal: https://horizoneuropencpportal.eu/ri

[42] The European Commission has published an informative list of RIs offering free Transnational Access, although the list has not been updated since October 2018: https://research-and-innovation.ec.europa.eu/document/download/ee2d822f-3781-4b44-8845-f5e8af557877_en?filename=ris_offering_tna_october2018.docx

[43] https://research-and-innovation.ec.europa.eu/partners-networking/access-research-infrastructure/access-european-research-infrastructures_en

[44] Cf. https://eu-interact.org/accessing-the-arctic/.

Visiting researchers and staff	ASEAN RI	International researchers and research groups	Attract international researchers and expert staff to build up local capacity, increase international visibility etc. The EU's Erasmus+ Programme supports higher-education mobility. The AMS can take part in certain actions of the programme, subject to specific criteria or conditions. For example, ASEAN-RI staff affiliated with a higher education institute may receive funding for training at European institutions for 5-60 days of physical mobility (not counting travel time). It is also possible, using EU internal policy funds, to fund European specialists providing teaching at AMS facilities.

Annex 1: Country Analyses

Brunei Darussalam

Brunei Darussalam is a relatively young country (gained independence in 1984) and is still building its human capital. National STI policy is currently in process. In 2021, the Council for Research and Advancement of Technology and Science (CREATES) was established to develop a national STI framework, policies and plans for STI-related research every five years.

Research & Innovation Framework

- Teaching universities are slowly transforming into research universities.
- Priority goes to providing local students the access to research equipment in the country itself.
- The selection of advanced research equipment is guided by the need for robustness or durability. This is to minimize the risk of breakdowns and downtimes.

Challenges

- Difficulty justifying multi-million equipment due to low utilisation and expensive maintenance costs.
- Cumbersome process for cross-border sampling transfer.

Identified possible RIs

- Universiti Brunei Darussalam (UBD)
- UBD Centre for Advanced Material and Energy Sciences (CAMES), described in the JST APRC report 2022.
- UBD Institute of Applied Data Analytics, described in the EU-HPC Study (2022).

Uniqueness and complementarities relevant to ASEAN RRI

Access to unique and vast Borneo flora and fauna specie through the Kuala Belalong Field Studies Centre, UBD for biodiversity research.

Science, Technology & Innovation (STI)	
National STI Policy	In the process of formulation.
Implementing Agency	Council for Research Advancement of Technology & Science (CREATES)
National Funding Body	
R&D Investment (2018)	0.28
Global Innovation Index	87 (Global); 14 (Asia)
Research Output Rank (Nature Index 2023)	168
Top 5 partners for scientific co-authorship (2017-2019)	1. Malaysia 2. China 3. UK 4. Australia 5. Indonesia
Top 3 Institutions (AD Scientific Index 2024)	1. Universiti Brunei Darussalam 2. Universiti Teknologi Brunei 3. University Islam Sultan Sharif Ali
Landscape study visit	
Interview only. Dr Abdul Hanif Mahadi, Director of UBD Centre for Advanced Material & Energy Sciences	
Hopes & interests for the ASEAN RRI Strategy	
Policy for ease in collaboration within ASEAN countries. Promote researchers' mobility (e.g. special visa etc.)	

Cambodia

Since 2021, the Cambodia government has been proactively advancing its STI sector with the goal of propelling the nation towards high-income status by 2050. Significant efforts have been made to recruit local scientists and engineers into key positions within the MISTI. Currently, plans are underway to create a conducive R&D environment equipped with robust facilities and support systems to attract and retain national talents, as well as to refine its R&D funding and technology transfer mechanisms.

STI/ Research priority areas

- Production of local food
- Generation of reliable energy supply
- Quality education
- Electronic and mechanical spare parts
- Cloud-based services
- Electricity and potable water
- Carbon neutrality
- Digitally enhanced health

Challenges

- Talent acquisition and retention.
- Research output lack competence to produce industry-grade output.
- Limited R&D investment from the business sector.

Identified possible RIs

- Institute of Technology of Cambodia
- Royal University of Phnom Penh (fundamental natural sciences)
- Royal University of Agriculture
- Institut Pasteur du Cambodge (Health sciences)

Uniqueness and complementarities relevant to ASEAN RRI

- Not identified.

Science, Technology & Innovation (STI)	
National STI Policy	National Policy on STI 2020-2030, and Cambodia's STI Roadmap 2030
Implementing Agency	Ministry of Industry, Science, Technology & Innovation (MISTI)
National Funding Body	In progress of establishment.
R&D Investment (2015)	0.12 % of GDP
Global Innovation Index	101 (Global); 15 (Asia)
Research Output Rank (Nature Index 2023)	100
Top 5 partners for scientific co-authorship (2017-2019)	1. USA 2. France, Thailand 3. UK 4. Australia
Top 3 Institutions (AD Scientific Index 2024)	1. Institut Pasteur du Cambodge 2. University of Puthisastra 3. Institute of Technology of Cambodia
Landscape study visit & interview	
• Dr Sokly Siev, Deputy Director General, General Department of Science, Technology & Innovation, Ministry of Industry, Science & Technology (MISTI) • Dr Or Chanmoly, Institute of Technology of Cambodia (ITC) • Dr Kongkhea Phan, Dean, Faculty of Science & Technology, International University	
Hopes & interests for the ASEAN RRI Strategy. Interest for Information System platform to be developed. Free-access ASEAN patent system like Korea's COMPASS	

Indonesia

In 2021, five former research agencies were consolidated in one research entity–the National Research & Innovation Agency (BRIN). BRIN operates solely as a research hub and has the privilege of hiring foreign researchers that public universities do not. BRIN obtains funding through the government or national and international bank loans. The RI development concept adopted is Design, Build, Operate and Transfer. For example, after the financing scheme for an RI comes to an end, the RI is transferred to a private partner locally or internationally via an open tender or via the Public Private Partnership Scheme.

STI/ Research priority areas

- Food
- Energy
- Health
- Transportation
- Engineering
- Security and Defence
- Maritime
- Social Humanities – Education – Culture
- Multi-disciplinary and cross-sectoral

Challenges

- Overutilisation and underutilisation of certain research equipment.
- Scheduling bottlenecks due to centralised facilities.
- Sample spoilage due to extensive geographical distance.

Identified possible RIs

- BRIN
- Indonesian Agency for Meteorological, Climatological & Geophysics (BMKG)

Uniqueness and complementarities relevant to ASEAN RRI

- BRIN's biodiversity & conservation have the most publication.

Science, Technology & Innovation (STI)	
National STI Policy	Included in the National Medium-Term Development plan (2020-2024)
Implementing Agency	Ministry of National Development Plan
National Funding Body	• Ministry of Finance, Ministry of Education, Culture, Research and Technology (MOECRT) • National Research & Innovation Agency (BRIN) • Indonesia Endowment Fund for Education (LPDP)
R&D Investment (2015)	0.28% of GDP
Global Innovation Index	61 (Global); 12 (Region)
Research Output Rank (Nature Index 2023)	53
Top 5 partners for scientific co-authorship (2017-2019)	1. Malaysia 2. Japan 3. Australia 4. USA 5. UK
Top 3 Institutions (AD Scientific Index 2024)	1. Universitas Gadjah Mada 2. Universitas Teknokrat Indonesia 3. Universitas Indonesia
Landscape study visit & interview	
• National Research & Innovation Agency (BRIN) in Cibinong and Serpong	
Hopes & interests for the ASEAN RRI Strategy To be filled by the T.F. member	

Lao People's Democratic Republic

Lao PDR is currently in the process of drafting the National Science, Technology and Innovation Strategy and Action Plan 2025-2040, which will set the vision, goals, strategic plan and priorities for Lao PDR. This is a new STI Strategy and Action plan due to the government reform with the science sector being transferred to the Ministry of Education and Sports.

STI/ Research priority areas

- Agriculture and food
- Public health
- Tourism economy
- Digital economy
- Industry, energy and mines
- Natural resources and environment
- Public works and transport
- Education and Social sciences

Challenges

- Underutilisation of equipment due to talent shortage.
- The innovation infrastructure system is not yet strong, the laboratories and facilities for research and development of science, technology and innovation of universities and research institutes are not yet meeting the needs.
- Limited R&D investment and participation from the business or private sector.

Identified possible RIs

- Institut Pasteur du Laos
- Science & Innovation Institute, Ministry of Education & Sports
- Center of Excellence in Environment, National University of Laos

Uniqueness and complementarities relevant to ASEAN RRI

- Virology
- Bioinformatics

Science, Technology & Innovation (STI)	
National STI Policy	In the process of formulation (National STI Strategy & Action Plan 2026-2040).
Implementing Agency	Ministry of Education and Sports (MOES) and related government agencies
National Funding Body	Science and Technology Development Fund
R&D Investment (2015)	0.04% of GDP
Global Innovation Index	110 (Global); 16 (Region)
Research Output Rank (Nature Index 2023)	135
Top 5 partners for scientific co-authorship (2017-2019)	1. Thailand 2. UK 3. USA 4. Australia 5. Viet Nam
Top 3 Institutions (AD Scientific Index 2024)	1. Institut Pasteur du Laos 2. National University of Laos 3. Souphanouvong University
Landscape study visit & interview	
• Science Management Division, Department of Science, Ministry of Education & Sports • Center of Excellence in Environment, National University of Laos • Institut Pasteur du Laos	
Hopes & interests for the ASEAN RRI Strategy Training/ talent mobility to enhance the capacity of local researchers to utilise research equipment and perform advanced research. Standardisation of laboratories	

Malaysia

Research, development & innovation are predominantly carried out by higher learning institutes (HLI) under the purview of the Ministry of Higher education, as well as Government research institutes (GRI) operating under various ministries. A national R&D databank portal, krste.my (Knowledge Resource for Science and Technology Excellence, Malaysia) and grant application portal, MyGrants.gov.my, were established to facilitate seamless exchange of research-related information among researchers, scientists, students, policymakers, and decision makers.

STI/ National Research priority areas

- Energy Security Biodiversity
- Medical & healthcare
- Cyber Security Transportation and Urbanisation Food Security Plantation Crops and Commodities Water Security Environment and Climate Change
- Others

Challenges

- Uncertainties with long-term funding.

Identified possible RIs

- Malaysia Nuclear Agency
- Malaysian Genome & Vaccine Institute
- UMK-Tropical Rainforest Research Centre
- Danau Girang Field Centre
- Higher education institutions

Uniqueness and complementarities relevant to ASEAN RRI

Each HLI and GRI in Malaysia strategically specialises in specific niches that serves to establish a unique competitive advantage within their respective domains of expertise. This targeted strategy aims not only to cultivate in-depth knowledge but also ensures that investments in research infrastructure are precisely directed toward areas of specialised significance.

Science, Technology & Innovation (STI)	
National STI Policy	National Policy of Science, Technology and Innovation (NPSTI) 2021-2030
Implementing MInistry	Ministry of Science & Technology (MOSTI)
National Funding Body	Ministry of Science & Technology (MOSTI), Ministry of Higher Education
R&D Investment (2020)	0.95% GERD per GDP (%)
Global Innovation Index (2023)	36 (Global); 8 (Asia)
Research Output Rank (Nature Index 2024)	52
Top 5 partners for scientific co-authorship (2017-2019)	1. UK 2. India 3. Australia 4. USA 5. Indonesia
Top 3 Institutions (AD Scientific Index 2024)	1. Universiti Putra Malaysia 2. University of Malaya 3. Universiti Teknologi Malaysia
Landscape study visit & interview	
• Malaysia Nuclear Agency • Malaysian Genome & Vaccine Institute • Faculty of Earth Science, Universiti Malaysia Kelantan *(Interview only)* • Sabah Foundation *(Interview only)* • Sabah Parks *(Interview only)*	
Hopes & interests for the ASEAN RRI Strategy To ensure the collaboration between ASEAN Member Countries and dialogue partners in research activities and research infrastructures are fully optimised for the targeted strategies and outcomes for sustainability of ASEAN RRIs	

Myanmar

The Ministry of Science & Technology (MOST) was established in 1996 and was dissolved in 2015 and incorporated into the Ministry of Education. In 2021, MOST was set up again. There are no independent RIs and each ministry contains a research unit. Most universities in Myanmar are teaching universities and only 10 are research universities. Currently, the government does not have special dedicated R&D fund. Research budget is utilised from each ministry/ university's current budget.

STI/ Research priority areas

Areas centred around use of technology in

- Food, agriculture, biotechnology
- Environmental conservation, climate change & disaster risk management
- Water resources application
- ICT & electronics
- AI & digital transformation
- National health & medical science
- Nuclear technology
- New & renewable energy
- Materials & material science
- Marine, aerospace and space science

Challenges

- Human capital development with critical lack of technical talents
- Insufficient research equipment

Identified possible RIs

- Department of Agriculture Research
- Department of Medical Research
- Advanced Center for Agricultural Research and Education (Yezin Agriculture University)
- Department of Research and Innovation
- National Analytical Laboratory
- National Institute of Metrology Myanmar
- National Health Laboratory
- Department of Biotechnology Research

Uniqueness and complementarities relevant to ASEAN RRI

Not identified.

Science, Technology & Innovation (STI)	
National STI Policy	Science, Technology and Innovation Strategic Plan (2022-2027), and National STI Roadmap (2025-2030) and Strategic Plans
Implementing Agency	Ministry of Science & Technology (MOST)
National Funding Body	The research budget comes from the union budget and Ministry of Science and Technology (MOST).
R&D Investment (2015)	0.15% of GDP
Global Innovation Index (2022)	116 (Global); 17 (Region)
Research Output Rank (Nature Index 2023)	116
Top 5 partners for scientific co-authorship (2017-2019)	1. Japan 2. China 3. Thailand, USA 4. Indonesia
Top 3 Institutions (AD Scientific Index 2024)	1. Yangon Technological University 2. University of Medicine Mandalay 3. University of Mandalay
Landscape study visit & interview	
Interview only. Dr Thazin Han & Dr Zaw Min Naing, Department of Research & Innovation, Ministry of Science & Technology	
Hopes & interests for the ASEAN RRI Strategy To be filled by the T.F. member	

Philippines

The Department of Science & Technology (DOST) coordinates the national STI activities and supports business incubators for start-ups and commercialisation; while the Advanced Science, Technology & Innovation (ASTI) of DOST leads the R&D on ICT and Microelectronics, including the operation of science infrastructures. Recently, ASTI has encountered difficulties in keeping pace with the escalating demand for high performance computing (HPC) resources and capacity as more RIs and universities are looking to leverage HPC for advancing their R&D initiatives.

STI/ Research priority areas

- Space technology
- National Integrated Basic Research
- Health
- Agriculture, Aquatic & Natural Resources
- Industry, Energy & Emerging Technology
- Disaster Risk Reduction & Climate Change

Challenges

- Difficulty getting funding due to changing national priorities.
- Difficulty justifying funding for equipment upgrades.
- Cumbersome bureaucratic process & policy for procurement and foreign hiring.
- Unclear decommissioning policies.

Identified possible RIs

- Philippine Genome Center
- University of the Philippines
- International Rice Research Institute

Uniqueness and complementarities relevant to ASEAN RRI

- Rice gene banks

Science, Technology & Innovation (STI)	
National STI Policy	Harmonized National Research and Development Agenda (2022-2028)
Implementing Agency	Department of Science & Technology (DOST)
National Funding Body	Department of Science & Technology (DOST)
R&D Investment (2015)	0.32% of GDP
Global Innovation Index	56 (Global); 11 (Region)
Research Output Rank (Nature Index 2023)	72
Top 5 partners for scientific co-authorship (2017-2019)	1. USA 2. Japan 3. China 4. UK 5. Australia
Top 3 Institutions (AD Scientific Index 2024)	1. International Rice Research Institute 2. University of the Philippines 3. De La Salle University Manila

Landscape study visit & interview

- Philippine Genome Center (PGC)
- Advanced Science & Technology Institute (ASTI), Philippine Council for Industry, Energy & Emerging Technology (PCIEERD) and Electronics Product Development Center (EPDC) of the Department of Science & Technology
- International Rice Research Institute (IRRI)

Hopes & interests for the ASEAN RRI Strategy That a National Implementation Strategy be developed consistent with the Regional (ASEAN) RRI Strategy

Singapore

The National Research Foundation (NRF), which is directly under the Prime Minister's Office, oversees all STI and R&D activities, with a well-defined criteria for a national research infrastructure: "a research facility that, because of its strategic importance, funding, scale, and/or potential domain user base, is operated as a national resource and open to all researchers across all domains and areas of research in Singapore". A noteworthy feature of its funding for RIs is that it covers both capital and operating expenditures. The A*STAR Equipment Finder supports the R&D activities through a web portal.

STI/ Research priority areas

- Manufacturing, Trade and Connectivity (MTC)
- Human Health and Potential (HHP)
- Urban Solutions and Sustainability (USS)
- Smart Nation and Digital Economy (SNDE)

Challenges

- Shortage of technical talents.
- Lack of collaboration opportunities in biodiversity conservation.
- Limited deep sea access and land.

Identified possible RIs

- St John's Island National Marine Lab
- National Synchrotron Programme
- National Supercomputing Centre
- SingAREN Lightwave Internet Exchange (SLIX)

Uniqueness and complementarities relevant to ASEAN RRI

- Low-energy synchrotron
- Supercomputing facilities

Science, Technology & Innovation (STI)	
National STI Policy	Research, Innovation and Enterprise 2025 (2021-2025)
Implementing Agency	National Research Foundation (NRF)
National Funding Body	National Research Foundation (NRF)
R&D Investment (2015)	2.16% of GDP
Global Innovation Index	5 (Global); 1 (Region)
Research Output Rank (Nature Index 2023)	18
Top 5 partners for scientific co-authorship (2017-2019)	1. China 2. USA 3. UK 4. Australia 5. Germany
Top 3 Institutions (AD Scientific Index 2024)	1. National University of Singapore 2. Nanyang Technological University 3. Singapore Management University
Landscape study visit & interview	
• Agency for Science, Technology & Research (A*STAR) • National Supercomputing Centre (NSCC) • National Research Foundation Singapore (NRF; *interview only*)	
Hopes & interests for the ASEAN RRI Strategy Practical and sustainable, based on a RRI collaboration model. Considers how the private sector can play a role (e.g. via a PPP model). Focuses on both intra-regional and extra-regional (e.g. with Dialogue Partners) collaboration. Takes into account the need for talent mobility. Leverages international standards such as for data sharing	

Thailand

The Thailand Science Research Innovation (TSRI), which is directly under the Ministry of Higher Education, Science, Research and Innovation (MHESI), oversees all STI and R&D activities. The National Science and Technology Development Agency (NSTDA) supports R&D in universities and other institutions using in-house national technology centres.

STI/ Research priority areas

- Development of National Economic Growth with added-value and creative economy
- Enhance society well-being and environment quality for sustainable development
- Develop Science, Research and Innovation manpower
- Advanced, future-ready frontier research and innovation
- Space technology and applications

Challenges

- Energy crisis (rising electricity bills)
- Funding difficulty
- Talent shortage/ retention
- Equipment underutilisation & upgrade

Identified possible RIs

- Synchrotron Light Research Institute
- National Astronomical Research Institute of Thailand (NARIT)
- Geo-Informatics and Space Technology Development Agency (GISTDA)

Uniqueness and complementarities relevant to ASEAN RRI

- Supercomputing resources (LANTA)
- High-energy synchrotron facilities

Science, Technology & Innovation (STI)	
National STI Policy	National Science, Technology and Innovation Policy and Plan (2012-2021)
Implementing Agency	Ministry of Science & Technology
National Funding Body	Thailand Science Research & Innovation (TSRI)
R&D Investment (2015)	1.33% of GDP
Global Innovation Index	43 (Global); 9 (Region)
Research Output Rank (Nature Index 2023)	40
Top 5 partners for scientific co-authorship (2017-2019)	1. USA 2. Japan 3. UK 4. China 5. Australia
Top 3 Institutions (AD Scientific Index 2024)	1. Chulalongkorn University 2. Mahidol University 3. Chiang Mai University

Landscape study visit & interview

- National Research & Innovation Agency (NSTDA)
- Thailand Research universities (refer Table 1).

Hopes & interests for the ASEAN RRI Strategy To be filled by the T.F. member

Viet Nam

R&D activities are managed by the Ministry of Science & Technology (caters to overall science and technology including natural and social science and the Academy of Science (directly under Prime Minister's office and caters to natural sciences). The principal research facilities in Viet Nam are funded by the government and through Official Development Assistance (ODA). These facilities are published on a web-portal, but available only in Vietnamese, sti.vista.gov.vn, Accessible to all. Usage of facilities is on payment or grant collaboration basis, and fast track priority is given to internal staff only.

STI/ Research priority areas

- Social sciences and humanities
- Natural resources utilisation
- Information & communications technology
- Biotechnology for health, agriculture, processing industry & environmental protection
- New material technology
- Machine manufacturing & automation technology
- Marine technology
- Technology in natural disaster prevention and climate change response
- Energy technology
- Environmental technology
- Space technology

Challenges

- Low technology ownership due to limited funds to develop own tech or perform R&D. Existing technologies are all imported.
- Limited research equipment (currently only has 18 RIs).

Identified possible RIs

- Japan-France micro satellites
- AnMicro leadership

Uniqueness and complementarities relevant to ASEAN RRI

- Shrimp export
- Genome-microbe big data for health care & agriculture
- Four high-tech zones

Science, Technology & Innovation (STI)	
National STI Policy	National Science, Technology and Innovation Strategy (2021-2030)
Implementing Agency	Ministry of Science & Technology (MOST)
National Funding Body	National Foundation for Science & Technology Development (NAFOSTED)
R&D Investment (2021)	0.82% of GDP
Global Innovation Index	43 (Global); 9 (Region)
Research Output Rank (Nature Index 2023)	45
Top 5 partners for scientific co-authorship (2017-2019)	1. USA 2. Japan 3. Republic of Korea 4. Australia 5. China
Top 3 Institutions (AD Scientific Index 2024)	1. Duy Tan University 2. Can Tho University of Medicine and Pharmacy 3. Viet Nam National University

Landscape study visit & interview

- Dr Quyet-Tien Phi, Institute of Biotechnology (interview only)
- Assoc. Prof. Dr. Vu Van Tich, President of VISTI, Vietnam Institute of Science, Technology and Innovation (VISTI).
- Deputy Director, Ms. Vu Thi Tu Quyen, International Cooperation Department (MOST)

Hopes & interests for the ASEAN RRI Strategy To be filled by the T.F. member

Annex 2: Designing Research Infrastructure Policies

Political and strategic work on RIs can and should address two symbiotic objectives. Firstly, it should seek to devolve effective and successful policy processes surrounding the RIs. Secondly, it should seek to enhance the level and quality of the RIs themselves. These overlapping objectives require slightly different dynamics.

The OECD and Science Europe STI Policy Paper (2020) 'Optimising the operation and use of national research infrastructures'[45] highlights some of the challenges for the two separate target groups of RI funders and decision makers and RI managers.

	For portfolio management	**For user-base optimisation**
Challenges	1. Addressing RI requirements in the context of the whole research base.	1. Understanding and monitoring the current user base of RIs.
	2. Long term planning for Ris.	2. Access mechanisms to facilities, resources, and services.
	3. Budget availability vs. demand (including operating costs and balancing new and existing RIs).	3. Data access mechanisms.
	4. National vs. international investment.	4. Cost sharing and pricing.
	5. Transparency of decision processes (including research, strategic and socioeconomic factors).	5. Administrative and support services.

A.2.1 Towards effective research infrastructure policies

The 2020 ESFRI White Paper 'Making Science Happen: A new ambition for RIs in the European Research Area'[46] reflects elements of collaborative learning after almost two decades of joint RI policy since the establishment of the ESFRI in 2002. The research team considers that the points are relatively generalisable to other regional contexts, and that they also offer relevant insights for ASEAN RRI policy.

ESFRI highlights several features which make the overall RI policy more effective:

- Regular updates and inventories of existing RIs and identification of needs and gaps.
- Transparent prioritisation of national needs that take regional perspectives into account.
- Coordination of regional RI 'road-mapping' processes into national research and innovation ecosystems, including outreach to other relevant national policy areas.
- Prioritisation of new and existing RIs in view of available funding for RIs.

[45] https://www.oecd-ilibrary.org/science-and-technology/optimising-the-operation-and-use-of-national-research-infrastructures_7cc876f7-en.

[46] https://www.esfri.eu/sites/default/files/White_paper_ESFRI-final.pdf

- Setup of coordination structures for RIs at ministry levels.
- Supporting coherence between national and regional RI processes.

In addition, several points are expanded into individual recommendations. These are highlighted here in Figure 8 and described in more detail below. Several of the elements relate as much to effective RIs as to effective RI policies.

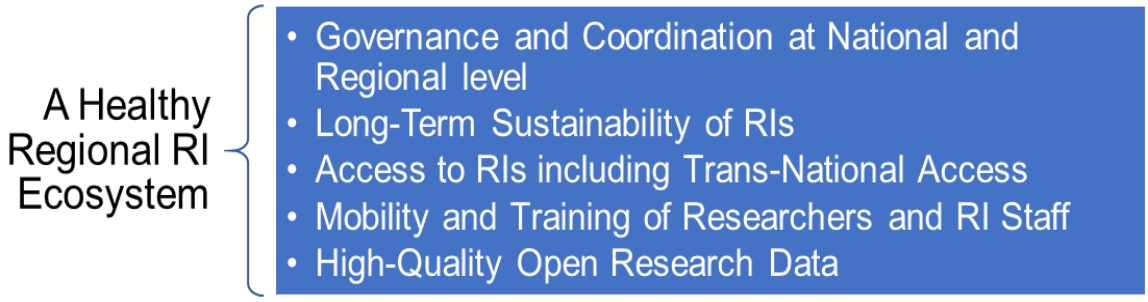

Figure 8 Elements of a healthy RI ecosystem

Governance and coordination at national and regional level

A functioning RI ecosystem requires sustained political ownership and commitment at all levels. Early communication between decision makers in AMS on emerging RIs is crucial to reach common regional objectives in ways consistent with national interests.

This is particularly important for distributed infrastructures that are often strongly dependent on national road-mapping and national financial commitments. A crucial challenge is to ensure common procedures and priorities, whilst respecting the diversity of national research systems.

In an ASEAN context, implications of this recommendation could relate both to the regional policy-setup and to the setup within the AMS. A condition for international communication and coordination on national RI policy priorities is that there is intra-national communication and coordination.

The guiding model for RI policy decision makers and funders developed by the OECD and Science Europe adds a few more elements to this governance process.[47]

Strategic planning requires a strong review process that collects both bottom up and top-down inputs that help create a forward-oriented plan for RI needs that reflects national and regional research and innovation strategies.

The policy process should be set up to reflect *community inputs*, i.e., input from the scientific community, existing RI organisations and operators, and other stakeholders with direct knowledge of research, data, and operational needs.

[47] OECD/Science Europe STI Policy Paper (2020): Optimising the operation and use of national research infrastructures, https://www.oecd-ilibrary.org/science-and-technology/optimising-the-operation-and-use-of-national-research-infrastructures_7cc876f7-en.

A portfolio of RIs should be evaluated in such a way as to allow for existing and potential new RIs to be examined together. This might require streamlining methods of calculating and including both capital investments and operational costs (including personnel costs).

The process should facilitate both *competition and complementarity*. New RI proposals should take existing capacity into account and justify new requirements. Competition can be encouraged at the strategic planning stage to ensure that the highest priority and quality of facilities are selected. It is encouraged to create processes to ensure that local policies do not lead to unnecessary duplication of RIs and sub-optimal investment and usage.

International engagement of national and regional RIs should be engaged. It should also be considered if international RI options might serve the regional/national needs, as this could provide a viable alternative to new investment. This can help select and develop the best and most impactful fit for the regional and national research needs, while an international outlook can also help to increase external international recognition of ASEAN RIs.

A.2.2 Towards effective research infrastructures

Many dynamics are also happening at the level of the research infrastructure. Policies and frameworks at the institutional level can be addressed and supported at the general strategic level, although the flexibility for institutions to design context-specific measures may be recommendable.

Long-term sustainability of research infrastructures

It is an essential precondition for a successful RI that it can sustain itself over a long-term period (i.e. longer than traditional research projects, collaborations, and facilities). However, long-term sustainability is a complex challenge.

According to the ESFRI, long-term sustainability requires an adequate legal and financial framework that is embedded in a supportive, policy-driven environment. The principle of sustainability of funding is important. This relates not only to construction; when establishing new infrastructures, its funders should – if possible – plan from the start for the financing of the different phases of the RI lifecycle - conceptual development, design, construction, operation, and decommissioning or divestment - taking also into account human resource needs.

For RIs to remain relevant over their full life cycle, the *sine qua non* is continued scientific excellence. Whether and how facilities retain scientific excellence over their lifetime is therefore an important topic for RI decision makers facing the need for prioritisation.

A specific part of optimal RI portfolio management relates to adequate considerations of which facilities can be closed or divested to other means.[48] Timely identification helps optimise spend profiles and allows for an orderly transition.

Access to research infrastructures including trans-national access

Ensuring TNA is a long-time objective of European RI policy. The provision of RI access for researchers in other ASEAN countries is also a likely cornerstone of future ASEAN RRI policy.

[48] OECD/Science Europe (2020).

However, as the ESFRI notes, policy objectives have been difficult to achieve in practice. Major bottlenecks have been lacking availability (such as when competing with internal or national users), lack of useful funding mechanisms, and issues related to personal data, security, and intellectual property may be more sensitive in a trans-national context.

The biggest difference in experience with access to RIs relates not to centralised versus distributed RIs, but to the difference between physical, remote, and virtual access.

It is important that access policies are open, transparent, and equal. However, several types of access policies can be adopted that fit these goals, and the choice of access policy should match the needs and priorities of the specific RI.

The European Charter for Access to Research Infrastructures, which ESFRI refer to here, provide three main examples of access policies for outsiders:

1) Excellence-driven access;
2) Market-driven access; and
3) Wide access.

RIs should have a clear understanding of their overall user base, and how access units, resources, and costs are distributed within that user base (including in-house users).

When feasible, RI managers should consider the automation of user-monitoring processes as well as ‘dashboard thinking’ that allows for key results to be communicable to internal and external decision makers.

Optimising the use-potential of an RI may require different measures depending on whether the research infrastructure is capacity-limited or if it has some additional or unlimited capacity to expand.

For a capacity-limited RI, optimisation measures may necessitate:

1) the adaptation of current user selection processes and quality assessment criteria;
2) improved management of the time and space occupied by users; and/or
3) the promotion of remote, virtual, and/or secondary access that might help alleviate capacity bottlenecks.

For RIs with capacity to expand, attracting new user-groups can help optimise use. This could entail:

1) opening access to a new group of researchers;
2) encouraging researchers from different disciplines;
3) allowing use from other sectors, such as industry or the public sector; and/or
4) opening access to international researchers, such as those from other ASEAN countries.

A clear rationale should be defined prior to the implementation of measures to optimise the use of a RI and should be accompanied by a thorough analysis of benefits and costs.

Pricing policies vary between and within RIs, reflecting different priorities. As such, the need for flexibility is recognised. However, RIs should ensure that the pricing policies for all access modes are clear and costs transparent. The OECD and Science Europe also suggests that merit-based academic usage should, when possible, be provided openly and ‘free-from-cost’.

Mobility and training of researchers and RI staff

Fostering the training of RI managers, operators and users plays an important part in RI success. Therefore, appropriate training and skills development for RI staff at various levels is crucial, from top management to scientists to technicians and supportive personnel.

Without adequate human resources, even the best scientific equipment will not be used optimally.

However, while mobility is highly ingrained in academia and research work, there are still many obstacles, which can still be addressed. This is likely as true in ASEAN as it is in Europe.

High-quality open research data

The effective provisioning of high-quality scientific data, with effective metadata descriptors, ease of access, interoperability and reusability, improves the value of the output of RIs for the international and regional scientific community. At the same time, it assures a robust quality control of the produced data sets.

An important implication here is that the interoperability of data streams should be a key concern for RI policies and strategies. Another important recommendation of the ESFRI here is that they highlight the vital role of data professionals for the activities of RIs. ‘Supportive measures at an appropriate scale’ for data professionals should be considered.

At the institutional level, RIs should also encourage their uses to employ data-management practices that encourage secondary use of the data produced. Data generated from RIs is often unique and valuable, but without the proper processes in place secondary use may not be as high as it potentially could be.

Annex 3: Glossary of Common Terminology for Research Infrastructures

Term	Definition
Annual Full Cost	The full cost is a method for calculating the cost price of a product on an annual basis. In the case of the RIs, the annual full-cost calculation includes investment costs (construction investments, purchase of equipment, depreciation, de-commissioning), functioning costs (operating of the equipment and of the facilities) and personnel costs.
Access	Access refers to the legitimate and authorised physical, remote and virtual admission to, interactions with and use of RIs and to services offered by RIs to users. Such access can be granted, amongst others, to machine time, computing resources, software, data, data-communication services, trust and authentication services, sample preparation, archives, collections, the set-up, execution and dismantling of experiments, education and training, expert support and analytical services (European Commission 2016).
Access policy	An access policy defines how a RI regulates, grants and supports access to (potential) users from academia, business, industry and public services. The access policy of a RI should define the access in terms of access units, state the specific access mode, clarify the conditions for access, describe the processes and interactions involved in the access and elaborate on the support measures facilitating the access, if existing (European Commission 2016).
Access unit	The access unit is a measure specifying the access offered to the users. RIs are responsible for the definition of access units, which may vary from, for example, precise values like hours or sessions of beam time processing time, to gigabytes transmitted for the conduction of complex experiments and projects up to quotations based on an inventory of Users' needs (European Commission 2016).
Benchmarking	Standards by which the performance of an intervention can be assessed in a non-arbitrary fashion. Such a standard will often be the best in the same domain of intervention or in a related domain (European Commission 2013).
Budget	Annual financial plan drawn up according to budgetary principles, which provides forecasts and authorises an estimate of future costs and revenue and expenditures, with detailed descriptions and justifications (the latter in 'budgetary remarks') (European Commission 2017f).
Business plan	A documented rationale justifying the feasibility of a specific RI. It includes a description of the physical infrastructure, the plans for services and access, the legal and governance structure and the expectation of return on investment, for example, as a socio-economic impact.

Case study	A technique involving the examination of a limited number of specific cases which the evaluator anticipates will be revealing about the programme as a whole (European Commission 2019).
Cost-benefit analysis	A tool for judging the advantages of an intervention (such as RI construction and implementation) from the point of view of all the groups concerned, and on the basis of a monetary value attributed to all the positive and negative consequences of the intervention (European Commission).
Data management strategy	The process of planning or creating strategies/plans for handling the data created, stored, managed and processed by an organisation. It is an IT governance process that aims to create and implement a well-planned approach in managing an organisation's data assets.
Decommissioning	Activities that result in the termination of all RI operations (ESFRI 2016b).
Distributed research Infrastructure	A distributed facility is an RI with a common legal form and a single management board responsible for the whole RI, and with a governance structure including amongst others a strategy and development plan and one access point for users although its research facilities have multiple sites.
Econometrics	A field of economics that applies mathematical statistics and the tools of statistical inference to the empirical measurement of relationships postulated by economic theory.
Eligibility conditions	Prerequisites (minimum conditions) required of any RI prior to their assessment for being included in the national RI roadmap (European Commission 2017e).
Ex-ante evaluation	Evaluation procedure based on forecasts rather than actual results. Ex-ante evaluation is considered necessary for a robust decision-making process leading to the setting up of a new infrastructure, and for major upgrades or reorientation of existing RI (ESFRI 2011).
Ex-post evaluation	Evaluation procedure based on actual results/facts rather than forecasts. Ex-post evaluation is used to demonstrate the quality of the research output and achievements, to account for the resources invested and to monitor value for money and cost effectiveness, including appropriate management of the RI (ESFRI 2011).
Financial plan	A financial plan includes information about the economic viability of the RI. It would normally address three main elements: i) the proposed overall budget for the infrastructure; ii) a description of the sources from which RI activities will be funded together with regional/ national public co-funding); and iii) the financial tables for the RI profiling the expected expenditure from all sources over the full period of the programme (European Commission 2017c).

Full time cost	This is the overall cost of the whole life cycle of a RI. It covers those costs derived from design, planning, implementation, running and even decommissioning of the facility.
Funding body	A body or authority in charge of budget implementation tasks (European Commission 2013, 2017e).
Governance	The 'governance' of RIs corresponds to the sets of institutional structures, principles, rules and procedures through which the interests of the various stakeholders as well as the lines of authority, responsibility, and accountability between them find their expression (ESFRI 2012).
In-kind resources or in-kind resource valorisation contributions	Conversely to cash contributions, in-kind contributions represent the provision of goods or services to an organisation by one of its members. An in-kind contribution can consist either of the direct provision of a tangible asset to the infrastructure or of expenditure incurred directly by the contributor, which benefits the infrastructure and satisfies its objectives. They include goods, use of services and facilities, professional services or expertise in the form of staff time, provision of or access to equipment, or special materials.
In-kind resources	These are valued in monetary terms according to rules agreed upon beforehand by the members of the organisation in the statutes or bylaws and accounted for as part of the member's contribution to the budget.
Indicator	An objectively verifiable measurement which reflects the activity, assumption, or effect being measured (European Commission 2013).
Intervention	Any action or operation carried out by public or private authorities regardless of its nature (policy, programme, measure or project) (European Commission 2013).
Key Performance Indicator (KPI)	A metric that is used to track the performance, effectiveness or efficiency of a service or process. KPIs are generally important metrics that will be aligned to critical success players and important goals. KPIs are therefore a subset of all possible indicators, intended to allow for monitoring [see also indicator] (European Commission 2017d).
Landscape analysis	Comparative analysis aimed at assessing a RI within its competitive ecosystem. This typically includes an analysis of strategies through strengths and weaknesses, outputs and services, and growth models. It can include many different pieces of information, such as the main services to be provided or the economic return.
Legal framework	This consists of a broad system of rules that governs and regulates decision making, agreements, internal laws, etc., which has been selected by the facility's partners for enabling the management and ensuring the legal representation of the facility in all its relationships with external stakeholders.

Lifecycle	The life cycle of a RI consists of distinct phases which are each characterised by specific funding and decision processes. According to the definition proposed by the G7 Group of Senior Officials on RIs, five RI life-cycle stages are identified: ● Development Stage; ● Design Stage; ● Implementation Stage; ● Operations Stage; and ● Termination Stage. (OECD 2017).
Management structure	The management structure refers to the organisation of the hierarchy of authority, which defines accountability and communication channels within an organisation and with its external environment. Each organisation has its unique management structure based on its operations, but the common denominator present in every organisation's management structure is that it defines the flow of responsibility within an organisation. It also defines who is responsible for each role in an organisation (IAC Publishing 2017).
Management system	The entirety of policies, processes, procedures and related resources and capabilities aimed at effectively performing management tasks in a given context and for a given subject (EGI 2016).
Monitoring	The continuous process of examining the performance of RIs including the delivery of outputs and the supply of services to intended beneficiaries. It is carried out during the lifecycle of a RI with the intention of correcting any deviation from operational objectives [ESFRI sometimes uses the term 'interim evaluation' instead of monitoring] (ESFRI 2011).
Observational and Exploratory Platforms are part of National Facilities	The Platforms: ● are committed to long-term operations; ● are operated by personnel with identified expertise in running the platforms; ● use measurement methodologies and procedures compliant with the standards of calibration, operation and quality assurance; ● make data available to users; ● can provide physical access for users, if respective capacity and expertise is proven; ● follow specific technical requirements; and ● consist of more than one Unit (as defined below).
Open access	The practice of providing online access to scientific information that is free of charge to the user and that is reusable. In the context of R&D, open access to 'scientific information' refers to two main categories: ● peer-reviewed scientific publications (primarily research articles published in academic journals); ● scientific research data: data underlying publications and/or other data (such as curated but unpublished datasets or raw data). (European Commission 2017b).

Operational costs	Operational costs are also known as running costs and refer to day-to-day costs of operations derived from running RI services. They include personnel costs, equipment maintenance cost, consumables, etc.
Organisational level funding	Organisational level funding is defined as 'the total of national budgets in a given country, attributed to an research performing organisation, with no direct selection of a R&D project or programmes and for which money the organisation has more or less freedom to define the research activities to be performed' (Van Steen 2012).
Peer review	The process whereby peers (stakeholders of equivalent position / practice area) review projects, policies or practices (European Commission 2013).
Policy	A policy is typically described as a plan of action to guide decisions and achieve rational outcome(s). The term can be used in different settings: government, private-sector organisations and groups, and individuals. (European Commission 2013).
Research infrastructure	Facilities, resources and services that are used by the research communities to conduct research and foster innovation in their fields. They include major scientific equipment (or sets of instruments), knowledge-based resources such as collections, archives or scientific data and e-infrastructures such as data and computing systems and communication networks. Such infrastructures may be 'single-sited', 'virtual' or 'distributed' (European Commission 2010b, ESFRI 2011).
RI lifecycle	The lifecycle of a RI includes concept development, design, preparation, implementation, operation and decommissioning (termination) (ESFRI 2016a, 2016b).
Roadmap	A specialised type of strategic plan that outlines activities an organisation can under- take over specified timeframes to achieve stated goals and outcomes (International Energy Agency 2014).
Road-mapping	The evolving process by which a roadmap is created, implemented, monitored and updated as necessary (International Energy Agency 2014).
Single-sited research Infrastructure	A RI located in a unique place (European Commission 2017a).
Social impact	The social impact of a specified human activity is the intrinsic set of its direct and indirect consequences on humankind in terms of economy and human-resource capacity including all factors susceptible to influence our day-to-day life in the short term as well as in the longer term (Technopolis Group 2015).

Stakeholder	A person, group or organisation directly or indirectly associated with or affected by the implementation of a policy intervention (European Commission 2013)
Sustainability	The definition of RI sustainability is understood as the capacity for a RI to remain operative, effective and competitive over its expected lifetime (OECD 2017).
Total cost of ownership	The total cost of ownership is an analysis intended to uncover all the lifetime costs that follow on from owning certain kinds of assets. As a result, this is sometimes called a lifecycle cost analysis (Schmidt 2017).
Unit	A Unit can be an instrument/ a Database / a Registry / an e-Infra unit.
User	Users of RIs can be individuals, teams and institutions from academia, business, industry and public services. They are engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of projects. Teams can include researchers, doctoral candidates, technical staff and students participating in research in the framework of their studies (European Commission 2016).

Annex 4: ASEAN Regional Research Infrastructures Strategy Taskforce Country Representatives

Country	Name/Position	Position/Organization
Brunei Darussalam	Dr Haji Abdul Hanif bin Dato Paduka Haji Mahadi, Director	Centre for Advanced Material and Energy Sciences (CAMES), Universiti Brunei Darussalam
Cambodia	Dr Sokly Siev, Deputy Director General	General Department of Science, Technology & Innovation, Ministry of Industry, Science, Technology & Innovation
	Mr Raksmey Thinh, Chief Office of Technology Transfer Research	
Indonesia	Ms Indriyani, Coordinator of Program and Budgeting for Deputy of Research and Innovation Infrastructure	National Research and Innovation Agency (BRIN)
	Ms Ana Harlina, Coordinator of Research and Innovation Infrastructure's Partnership *(alternate)*	
Lao PDR	Ms Viengpasith Vanisaveth, Director of Division	Science Management Division, Department of Science, Ministry of Education and Sports, ASEAN RRI TF representative. *Interview only.*
	Ms Anny Phommachanh, Technical Staff *(alternate)*	
Malaysia	Dr Faridah binti Mohamad Idris, Director, Malaysian Nuclear Agency	Ministry of Science, Technology and Innovation
	Dr Fairuz Suzana binti Mohd Chachuli, Senior Research Officer, Malaysian Nuclear Agency *(alternate)*	
Myanmar	Dr Zaw Min Naing Deputy Director General, Department of Research and Innovation	Ministry of Science and Technology
	Dr Tin Mar Lynn, Director, Department of Biotechnology Research *(alternate)*	
	Dr Hla Myo Aung, *Director, Department of Research and Innovation (alternate)*	
Philippines	Ms Jelina Tanya H. Tetangco, Senior Science Research Specialist, Research and Development Division	DOST-Advanced Science and Technology Institute

	Mr Bayani Benjamin R. Lara, Supervising Science Research Specialist, Solutions and Services Engineering Division *(alternate)*	
Singapore	Dr Hazel Khoo, Executive Director, Research Office	Agency for Science, Technology and Research (A*STAR)
Viet Nam	Mr Nguyen Nam Hai, Director General	Department of Planning and Finance (MoST)
	Mr Bui Tuan Thanh, Official *(alternate)*	
Thailand	Dr Uracha Ruktanonchai, Executive Vice President	National Science and Technology Development Agency (NSTDA)
	Ms Sronkanok Tangjaijit, Acting Director of International Collaboration Division *(alternate)*	

Annex 5: Surveys and Questionnaires

1. Survey for the ASEAN RRI Task Force and national officials

This survey is designed to collect information relevant to the ASEAN Research Infrastructure Landscape Study. The study is commissioned by ASEAN and E-READI and will support the development of an ASEAN Regional Research Infrastructure (RRI) Strategy, as adopted as one of seven ASEAN Annual Priorities 2023 at the 19th ASEAN Ministerial Meeting on Science, Technology, and Innovation (AMMSTI-19).

The Landscape Analysis is expected to showcase a diversity of Research Infrastructures and Research Infrastructure elements in the ASEAN Region from very large-scale single-site Research Infrastructures, to distributed and virtual RIs to Platforms and individual Units (as defined in the Glossary). The study is built from the qualified assumption that each country in the region already has research facilities or organisations in place that can be considered as RIs or parts of RIs (such as Platforms and Units).

The granularity and quality of the final Landscape Analysis is to a high degree dependent on the country-level information we get from the survey respondents. This will be important for how countries and RIs are presented in the final ASEAN Research Infrastructure Landscape report, as well as for the usefulness of the study after its conclusion, e.g., in developing an ASEAN RI Roadmap. We, therefore, hope that you will prioritise completing the survey and that you and/or others in your organisation will be available for potential follow-up questions and discussions.

1. **Name of the respondent**

Please write your answer here:

Purpose: We would like to record the name of the respondent for follow-up, and further questions, and to understand the position of the person. Note that personal information will not be shared outside the research team and that no personal data of respondents will appear in project reports or publications unless explicitly agreed later on with the consent of informants.

Example question/comment: 'Can you state your name for the record?'

2. **Title and organisation**

Please write your answer here:

Purpose: Same reason as the name of the respondent. Need to confirm their position in the organisation.

3. **What is your mandate and responsibility related to the work on the ASEAN RRI Task Force on Research Infrastructures (RIs)/Platform/Unit (reference to the Glossary)?**

Please write your answer here:

Purpose: Establishing the mandate and responsibility of respondents help contextualise responses. Information provided is not shared outside the research team and will not feature in any project reporting.

4. **Who can we contact for further information, comments, and queries? Please provide name & email.**

Please write your answer here:

Purpose: Other people in or outside the organisation of the respondent who may be available for follow-up details, investigations, and questions. The contact information is crucial for future follow up.

Example question/comment: 'Do you have names or an address you wish to provide us for the future questions, comments and similar? This information will also be recorded for further reference.'.

Terminology: Please provide the contact details in English.

5. **Do distributed, single-sited or virtual Research Infrastructures/Platform/Unit exist in your country? (yes/no)**

Please write your answer (yes/no) here:

Purpose: Brief question establishing the respondents' view on the maturity of RIs in his/her country.

6. **Can you provide 2-3 examples of the most important RIs/Platforms/Units in your country?**

Please write your answer here:

Purpose: Gathering information relevant to the ASEAN Landscape Analysis. Respondents' prioritisations will help us select RIs for additional analysis and give an idea about what is considered good RI examples in various countries.

7. **What are the most important RIs in the ASEAN region you would like to have access to?**

Please write your answer here:

Purpose: Gathering information relevant to the ASEAN Landscape Analysis. Respondents' priorities understand the need for access to ASEAN RIs.

8. **What are the most important international RIs you would like to have access to?**

Please write your answer here:

Purpose: Gathering information relevant to the ASEAN Landscape Analysis. Respondents' priorities understand the need for access to international (non-ASEAN) RIs.

9. **Does your country have e.g., policies, frameworks, roadmaps, or policy documents related to RIs and RI policies? If so, would it be possible to provide copies or links? If not, do you have similar documents for Platforms or Units?**

Please write your answer here:

Purpose: Some countries and regions have developed RI roadmaps and RI policies. If these exist in your country, it would be very valuable information for our analysis. Vision documents, national research and innovation strategies could also be useful and relevant in this context.

Terminology: Please provide the contact details in English.

10. **Can you provide a brief description of key stakeholders (public and private) in your country's research infrastructures ecosystem? If there is not an established RI ecosystem, information on the general research ecosystem can be provided.**

Please write your answer here:

Purpose: To gather information on national research- and RI ecosystems. This will help contextualise the landscape analysis and inform possible recommendations.

Example question/comment: 'What are some of the major players – governmental organisations, innovation councils, etc. – that shape the RI landscape of your country?'

11. What is the primary or main source of funding for Research Infrastructures/Platform/Unit in your country?

Please write your answer here:

Purpose: To gather documentation on how Research Infrastructures obtain their main funding in various countries. Information on funding for distributed RIs, national registries, national libraries, statistical offices, cultural heritage centres, etc. is also highly appreciated.

12. Does your country have a policy concerning how long current RIs should remain in operation?

Please write your answer here:

Purpose: To understand how the future of existing RIs is considered from the national level.

Example question/comment: 'How long are current RIs expected to be operational without major needs for major reinvestments? Are there any plans for decommissioning existing RIs? Does the lifecycle of operations of current RIs extend significantly beyond traditional lifecycles of research projects?'

13. Does your country have a policy for the long-term funding of RIs/Platforms/Units?

Please write your answer here:

Purpose: To understand how the future of existing RIs is considered from the national level.

Example questions/comment: How long are current RIs expected to be operational without major needs for major reinvestments? Are there any plans for decommissioning existing RIs? Does the lifecycle of operations of current RIs extend significantly beyond traditional life cycles of research projects.

14. What kind of societal or grand challenges and policy areas do the RIs/Platforms/Units in your country help address?

Please write your answer here:

Purpose: To understand how various Research Infrastructures relate to societal and scientific topics.

Example question/comment: 'Are any of the RIs in your country related to current national and regional research infrastructure initiatives in ASEAN in areas such as the bio-circular green economy (BCG), High Performance Computing (HPC), synchrotron development, satellite use, microbial utilisation, and marine research?'

15. Are there national initiatives, policies or frameworks related to RI/Platform/Unit access policies?

Please write your answer here:

Purpose: To gather information on national level perspectives on access to RIs and access policies of RIs.

Example question/comment: 'Access policy is an important part of Research Infrastructures in many regions. In the EU, for example, access to outside researchers is a precondition for being considered for RI roadmaps. Are there similar national policies or considerations related to RI access in your country?'

16. **Are there national initiatives, policies or frameworks related to RI/Platform/Unit data policies?**

Please write your answer here:

Purpose: To gather information on national level perspectives on RI data policies.

Example question/comment: 'Data policies is an important part of Research Infrastructures in many regions. In the EU, for example, adherence to FAIR-principles and Open Data policies are preconditions for RI-funding. Policies related to data privacy and data security are also often considered highly important. Are there national policies or considerations related to RI data policies in your country?'

17. **Are there national initiatives, policies or frameworks related to RI/Platform/Unit and general researcher mobility policies?**

Please write your answer here:

Purpose: To gather information on national level perspectives on RI researcher mobility policies.

Example question/comment: 'Assessing opportunities for researcher mobility and human resource development is an important part of the ASEAN RI Landscape Study. Are there national policies or considerations related to researcher mobility related to Research Infrastructures or related to researcher mobility in general in your country?'

18. **Are there national initiatives, policies or frameworks related to measuring impacts of RIs?**

Please write your answer here:

Purpose: To gather information on national level perspectives on collection of data on RI impacts. Impacts can be considered in many different ways: Usage statistics, industry collaboration, socio-economic impact (e.g., via econometrics), scientific impact (e.g., via bibliometrics). Tracking global and regional rankings, for example of supercomputers (Top500), can also be considered as a way of tracking impact.

Example question/comment: 'Does your country actively collect or encourage the collection of information regarding how RIs are being used, how they collaborate with stakeholders, or on their scientific impact or ranking?'

19. **Does your country on a national level engage in bilateral, regional, or international collaboration related to development of RIs/Platforms or RI policies?**

Please write your answer here:

Purpose: To gather information about existing international collaborations and devise ideas about possible recommendations for increased collaboration. The information can be related to existing ASEAN initiatives, but we are especially hoping to gather information beyond the ASEAN-level.

Example question/comment: 'On a national level, is your country engaged in research policy collaborations with other countries or regions? On a national level, is your country engaged in RI policy collaborations with other countries or regions? This can be bilateral, with or through a region of countries such as ASEAN, or internationally.'

20. Can you briefly describe your, or your country's, hopes, aims, and visions for RI-development (or Platform development) in your country in 5-10 years?

Please write your answer here:

Purpose: To gather information on AMS' vision for RIs in the future.

Example question/comment: 'How would you hope to see RI policies develop in your country over the next 5-10 years? How would you hope to see ASEAN RI policies develop over the next 5-10 years? What kind of new RI (or RIs) would you like to see running in your country 10 years from now?'

21. Are there other themes or considerations you find important to state?

Please write your answer here:

Purpose: Important aspects or themes we have not considered, but that you feel is important to point out for the RI Landscape report.

2. Survey for Research Infrastructures (RIs)

1. **Name of the respondent**

Please write your answer here:

Purpose: We need to record the name of the respondent. Provenance requires us to know who is answering the questions: For follow-up, and further questions, and to understand the position of the person.

Example question/comment: 'Can you state your name for the record?'

2. **Job title and organisation**

Please write your answer here:

Purpose: Same reason as the name of the respondent. Need to confirm their position in the organisation

3. **Who can we contact for further comments/queries?**

Please provide name & email.

Please write your answer here:

Purpose: The contact information is crucial for provenance, and makes it possible to return to the person answering (or the organisation)

Example question/comment: '*Do you have an address you wish to provide us for the future questions, comments and similar? This information will also be recorded for further reference. You will have the opportunity to check the data stored from your answers*'.

Terminology: use English translation if official is found – also record official name in local language is reasonable within Latin alphabet

4. **Organisation full name**

Please write your answer here:

Purpose: For presentation of results.

Example question/comment: '*What is the full name of your organisation*?'

Terminology: (note: use English translation if official is found – also record official name in local language if reasonable within Latin alphabet)

5. **Organisation short name**

Please write your answer here:

Purpose: For presentation of results.

Example question/comment: '*Is there a short name for your organisation, or an acronym typically used*?'

Terminology: (note: use English translation if official is found – also record official name in local language if reasonable within Latin alphabet)

6. **Website address of the organisation**

Please write your answer here:

Purpose: For presentation of results.

Example question/comment: '*What is the main website for your organisation*?'

7. **Head office address**

Please write your answer here:

Purpose: For records, and for geographical coverage

Terminology: Head office: The administrative headquarters of an organisation. This is usually where the director is located.

Example question/comment: '*What is the location and address of your head or coordination office (if any*)?'

8. **Official contact email**

Please write your answer here:

Purpose: For records, gives the location of information collection. We would need a way for the future users of the RISCAPE reports to contact the organisation if needed. Thus, an email address (not personal if possible) is advantageous.

Example question/comment: '*What is the official contact email for your organisation*?'

9. **ESFRI in Europe divides research infrastructures in three categories: 1. single-sited, 2. virtual, 3. distributed. Which do you think best describes your organisation, if any? Please also**

describe if your organisation represents a node or a platform in a distributed research infrastructure.

(You can give additional information in the next question.)

Please provide your answer here:

Purpose: Categorise the RIs according to the different types based on previous (ESFRI, OECD) classifications.

Terminology:

- *Single-sited*: Research infrastructure, where majority (or all) of the services are provided in one geographical location
- *Distributed*: Distributed infrastructure has their main research activities (facilities) distributed geographically wide area.
- *Virtual*: Virtual refers to infrastructure, where the direct user access to services is done completely on-line (usually data or computing). Typically, these are data-oriented e-infrastructures (cyber infrastructures).

Example question/comment: 'ESFRI in Europe divides research infrastructures in three categories: single-sited, virtual, distributed [explain if needed], which do you think best describes your organisation, if any?'

10. **If needed, you can give some additional information related to previous question on the type of your organisation**

Please write your answer here:

Examples: Some RIs have multiple types of infrastructure in the same organisation, combination of a single site & multiple satellite sites, etc.

11. **What is the primary or main source of funding (e.g. international/national/regional funding agency, governmental agency, user fees)**

Please write your answer here:

Purpose: To gather information about the contextual ASEAN RI Landscape analysis and develop ideas about future development. Knowing the agencies and ministries mainly responsible for the funding makes it easier for involved funding organisations to develop collaboration projects.

Example question/comment: 'Which organisation(s) or ministries provide mainly your funding?'

12. **To estimate the scale of your organisation: If you were building your organisation today, what would be the approximate construction costs (order of magnitude estimate, 2023 terms)?**

Please write your answer here:

Purpose: This information is only important to evaluate the overall scale of the operations, not an accurate estimate of actual value.

Example question/comment: E.g. 1 million euro, 10 million euros, 100 million euros, etc. Use any currency suitable and 2023 values if possible.

13. **To estimate the scale of operations, what are the approximate total running costs of your organisation (order of magnitude, including secondments, in-kind contributions, etc.)?**

Please write your answer here:

Purpose: To determine the approximate scale of operations, not to evaluate actual value.

Example question/comment: Eg. 100 000 euro/year, 1m euro/year, etc. Use any currency but indicate which. Use 2023 values if possible. The information is used only to estimate the scale of operations and should be approximate.

14. **Are these operational costs 'standalone' or are they calculated on the basis of a larger organisation within which the research infrastructure is located?**

Please add details here:

Purpose: In some cases, the 'research infrastructure' is a part of a larger science performing organisation. This question is intended to help to determine the scale of operations estimated from the infrastructure or the whole organisation.

15. **Does your organisation have an operational time horizon well beyond a typical science project in your field?**

Please add your response here:

Purpose: Time Horizon is necessary to identify organisations that are intended for long time operations (typical for research infrastructures). This is important to identify potential collaboration opportunities.

16. **Can you provide additional information related to the timescale of your organisation? For example, does your organisation have an existing long-term funding decision from your main funding source?**

Please write your answer here:

Purpose: To gather additional information about the timescale of the RI, determine the funding duration and current sustainability situation - this is important to determine potential collaboration opportunities. 'Long term' here is the same as in the previous questions: i.e. far longer than usual science projects.

Example question/comment: What is the maximum duration of funding agreement in place, i.e. how many years? What other information could you provide to us to determine the timescale of the organisation? On what basis have you identified this time horizon? Do organisational documents include references for long time operations? Do you have a termination/winding up date? Is this published?

17. **Are there specific technical, scientific or societal problems your organisation aims to address?**

Please write your answer here:

Purpose: To capture the focus of the organisation and to find out potential pairings in the regional and European RI landscape.

18. **Are there societal, scientific or other grand challenges do you specifically aim to respond to?**

Please write your answer here:

Purpose: To capture focus of the organisation and to find organisations with similar overarching aims. This supplements the previous question with a broader societal view. Examples of challenges are e.g. the missions in EU's Horizon Europe-programme (adaptation to climate change, cancer, oceans, climate-neutral and smart cities, soil) and current national and regional research infrastructure initiatives in ASEAN (e.g. bio-circular green economy (BCG), High Performance Computing (HPC), synchrotron development, satellite use, microbial utilisation, and marine research).

Example question/comment: To which grand challenges does your organisation respond? Is your organisation involved in current ASEAN initiative topics?

19. **What kind of research services and resources do you provide for research or researchers?**

Please write your answer here and give examples, if possible:

Purpose: To capture the organisation services.

Examples can be, for example,

- Local research facilities (i.e. laboratory)
- Mobile research instruments (i.e. mobile laboratory)
- Remote sensing instruments (i.e. sensors mounted on aircraft, satellite, other) Datasets (data archive/repository, databases other)
- Specialised research tools or services (i.e. scientific software, data management system)
- Computing (local supercomputer, distributed computing based on Grid/Cloud services)
- Other

20. **What kinds of access for these services (physical, virtual, remote, or other) does your organisation provide?**

Please write your answer here:

Purpose: We need to find out what types of access are there in general for this facility. Typical cases are physical, virtual/data, and remote access

Terminology:

- Access: Access refers to the legitimate and authorised physical, remote and virtual admission to, interactions with and use of Research Infrastructures and to services offered by Research Infrastructures to Users. Such Access can be granted, amongst others, to machine time, computing resources, software, data, data-communication services, trust and authentication services, sample preparation, archives, collections, the set-up, execution and dismantling of experiments, education and training, expert support and analytical services.
- Physical: Physical access means direct hands-on access on the facility or service on-site
- Virtual: Virtual access refers to direct user access to services (usually data or computing) done completely on-line.
- Remote: Remote access refers to access where the actual use of the physical of virtual service is done by the request of the User, i.e. by user directly

21. **Are there any policies or procedures for determining access (for example an independent peer review process)?**

    Please provide details here:

Purpose: To gather information on the main access methodology. Example question/comment: How is access possible? How is access determined? What is the basis for granting access?

22. **Can you estimate the proportion of your research infrastructure's services available to external parties (i.e. those not funded by your organisation)?**

    Please give an indicative answer here:

Purpose: To determine the possibility of accessing the services. Replies are not meant to capture the order of magnitude of external access, not precise values (e.g. less than 10 percent, 25-50 percent, more than 75 percent, etc.). If there are specific quotas or limitations, this should also be mentioned.

23. **How much of the services are actually used by external parties? Does this differ by service type?**

Please write your answer here:

Purpose: To elaborate on the previous question and evaluate actual usage of the services.

24. **How can researchers from other ASEAN countries or from European organisations currently access your organisation/services?**

Please write your answer here:

Purpose: To determine potential collaboration possibilities for inter-regional mobility or collaboration with European partners.

Example question/comment: How can researchers from other ASEAN countries or from the EU access your organisation?

25. **Do you have existing collaboration agreements with research organisations outside your own country? Which ones?**

Please write your answer here:

Purpose: To assess current international collaboration among ASEAN RIs. In addition to formal collaboration agreements and MoU's, non-formalised existing cooperation can be added.

26. **Do you have an existing data policy publicly available? Can you a provide a link?**

Please write your answer here:

Purpose: To evaluate data policies and data access policies and possibilities. If possible, please provide the link to an English-language version.

Example question/comment: 'Do you have a data policy, and can you provide details and a link to this document?'

27. **Do you use open licences for data produced in your organisation?**

Please write your answer here:

Purpose: Data access evaluation

Example question/comment 'Do you use open licences (e.g. Creative Commons) for your data products?'

28. **Do you track facility usage, scientific and societal impacts in systematic ways (either by yourself or via other parties)?**

Please write your answer here:

Purpose: Scientific and societal impact is a major part of determining the role and position of a research infrastructure. Methods for this are developing and thus we need to collect information on how this is approached. Impact can also be considered as infrastructure usage, industry collaboration, positions on global rankings (e.g. Top500 supercomputers, university rankings), etc.

Example question/comment: 'Do you, or someone else, e.g. your funder, follow the scientific or social impact of research done in your facility in a systematic way? Is it tracked by you? By third parties?'

29. **Do you have reports on your (scientific or societal) impact publicly available?**

If yes, please provide a link to the information here:

Purpose: To gather relevant documents, for further analysis if needed

Example question/comment: 'Do you have a readymade impact assessment available (in any form)? If so, where?'

30. **Can you provide information (or a link) on user statistics, number of users (per service if possible), access times, altmetrics?**

Please write your answer here:

Purpose: Collect user statistics numbers to determine the scale of operations (for future collaboration purposes)

31. **Does your organisation exist on a current international or national roadmap (or similar prioritisation document) - and what is your position in there?**

Please write your answer here:

Purpose: Evaluate the position of the organisation based on the national prioritisation, roadmap or similar status. If applicable, please give the title or location of the roadmap/document.

Terminology: Roadmap: In research infrastructure terminology, a roadmap is a specific, high-level document, describing the long-term plans for developing and operating key shared infrastructure services for researchers.

Example question/comment: Does your organisation exist on these roadmaps (or similar plans) - and what is your position in there?

32. **Are there current plans to add new facilities, geographically extend facilities or do major upgrades in your organisation? Can you give a timescale?**

Please write your answer here:

Purpose: To assess ongoing developments in the ASEAN RI Landscape, estimate potential for long-term collaboration and common development goals, avoid duplication of effort across countries.

Example question/comment: What, if any, are the plans to upgrade or extend your facilities?

33. **Geographic scope of RI**

These questions are asked to capture the range of the facility's geographical scope. It can be used to identify gaps in global coverage and gaps in specific regions. Where are your facilities located? For distributed infrastructures, what geographical area do you cover?

Please write your answer here:

34. **Are there central facilities, and where are they located?**

Please write your answer here:

Purpose: Central facilities can be important for defining a geographical centre of operations. These are also good to determine where the main activities are located. For single-sited RIs this is non-issue, as the facility usually is the main central facility

35. **Are there significant secondary locations outside of the main locations? If so, where?**

Please write your answer here:

Purpose: Sometimes a single-sited or area does not make good impression of what is actually done in an infrastructure - this gives a possibility to elaborate e.g. if there is a single site, but outlying additional sites

36. **Technical scope**

Technical capabilities: What are the specific capabilities of your organisation? What are the significant capabilities of your organisation?

Please write your answer here:

37. **Please give details of how your organisation differs from similar facilities outside ASEAN?**

Please write your answer here:

Purpose: To assess complementary and uniqueness of ASEAN RIs.

Example question/comment: In Europe, there is a research infrastructure called X which specialises in these capabilities. Are you familiar with it and if so, what do you consider as the main difference in the approaches?

38. **Are your operations significantly dependent on external service providers? (E.g. data transfer, data analysis, data storage)**

Please write your answer here:

39. **Do you provide key services to other facilities, research infrastructures or similar?**

Please write your answer here:

40. **What kind of further collaboration with ASEAN or European RIs could be possible in your opinion?**

Please write your answer here:

41. **Does your organisation belong to global initiatives or collaborations to solve particular challenges?**

Please write your answer here:

Purpose: Determining the RI challenges from different perspective

42. **Other questions/comments (open ended)**

Please write your answer here:

Purpose: To gather additional information based on whatever the interviewed person wishes to bring up.

Example question/comment: In the end, do you have something else you wish to bring up on your organisation? You are free to comment and make suggestions on what are the main points you think should be brought up.