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Asia and Pacific Research Center

# Trends in the Development of Advanced Research Equipment and Shared Research Facilities in ASEAN Countries

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Japan Science and Technology Agency

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# Executive Summary

Through surveys on advanced research equipment, comparisons were drawn between the equipment used in public research institutions and public universities in 10 ASEAN countries, with Japan as the benchmark. For microscopy equipment, equipment from Japanese manufacturers such as JEOL, Olympus and Nikon were prevalent in ASEAN countries. For material analysis equipment, the presence of Japanese-branded equipment from JASCO, Shimadzu, Horiba and other manufacturers were also confirmed. However, unlike Japan, the share of Japanese manufacturers in both microscopy and material analysis equipment in ASEAN countries is low, with US and European manufacturers having a stronger presence. For biotechnology analysis equipment, there is a strong presence of Western-manufactured biotechnology analysis equipment in Japan, with many of the same equipment models used in Japan being utilized in ASEAN countries. While research equipment from Chinese manufacturers were also confirmed, there appears to be a limited presence in terms of advanced research equipment.

Basic information on the science and technology policies of each country were organized, followed by policy information on advanced research equipment and shared research facilities. Twenty main shared research facilities were then interviewed to ascertain their operational status. ASEAN countries have wide economic disparities and significant differences in the amount of research investment and efforts to promote science and technology. Therefore, differences were also observed in the development of advanced research equipment and shared research facilities. It should be noted that the concept of shared use is not new in ASEAN countries. Public research institutions and universities lease out equipment and provide testing services as part of their social responsibility, as access to advanced research equipment is limited in developing countries. In addition to this background, there is an emerging trend to actively utilize shared research facilities. Considering new and unique developments, the features of shared research facilities in ASEAN countries were organized in this survey into five categories. Some advanced countries, such as Singapore, manage their operations efficiently through strict policy-based management and use of systems, while others, such as Malaysia and Indonesia, have taken initiatives to turn large sections of their public institutions into shared-use facilities. There are also countries where the economic level is low, and the development of advanced research equipment appears to be immature.

Generally, there is a common consensus that the concept of a shared research facility is highly beneficial in many ways. However, there are many difficulties in ensuring that facilities can operate efficiently and effectively. One possible way to support establishment of science and technology cooperative infrastructure in ASEAN countries is to provide a separate or a full-service package for shared research facilities in accordance with their needs. Considering the structure of issues in each country, providing appropriate support from various angles, such as policy formulation, provision of equipment from Japanese manufacturers, human resource development of engineers, and so forth, is expected to help build a foundation for science and technology cooperation in ASEAN countries, enhance the presence of Japan in ASEAN countries, and promote science and technology exchanges between Japan and ASEAN countries.

# Foreword

Background and Objectives

The enhancement and strengthening of research infrastructure is essential for maintaining and improving scientific and technological innovation. However, advanced research equipment is expensive, and it is difficult for facilities to maintain a comprehensive range of equipment. In Japan, in addition to individual procurement at each research institution and laboratory, joint use of research equipment is being promoted from the perspective of visualizing resources and making efficient use of research equipment at universities. When researchers are considering joint research, one of the key points that determines whether joint research is possible is whether the partner country has an environment in which advanced research equipment can be used. Therefore, it is important to understand whether the researchers in the partner country have access to equipment, including at shared research facilities. On the other hand, in emerging countries, there are cases where research funds are scarce and there are economic constraints on the procurement and maintenance of research equipment. Understanding the state of development of advanced research equipment and shared research facilities in each country will clarify the gap between the ideal environment for research equipment and the actual environment for its use. Cooperation in the development of an environment to eliminate this gap may lead to an increase in Japan's presence in that research field and may also lead to increased recognition and exports of Japanese research equipment.

This survey seeks to confirm the status of the development of advanced research equipment and shared research facilities at universities and public institutions in the 10 ASEAN countries in the Asia-Pacific region. These countries are experiencing remarkable growth, and are expected to promote further scientific and technological exchange with Japanese researchers. In addition, policies related to the development of advanced research equipment and shared research facilities and the status of the development of major research facilities in each country will be investigated, and their respective characteristics and issues will be clarified. The survey will provide points of reference when developing advanced research equipment and shared research facilities in Japan, and this project will also identify areas in which Japan can collaborate to build a foundation for science and technology cooperation infrastructure in each country.

Survey methodology

The basic information on advanced research equipment and on the science and technology policies surveyed in each country, policy and funding surveys, and the state of the development of advanced research equipment based on policies were mainly accomplished through desktop research, supplemented by information obtained from interviews. For the survey of major shared research facilities, information was compiled mainly from interviews with the shared research facilities that served as survey subjects. A total of 20 major shared research facilities in ASEAN countries were interviewed. The selection method was based on the following factors: the comparative size of facilities in countries in which shared research facilities could be confirmed, the diversity of universities and public research institutions, and the elimination of bias in the region. Note that the development of shared research facilities in three countries – the Kingdom of Cambodia, Lao People's Democratic Republic (Lao PDR), and the Republic of the Union of Myanmar – is either extremely immature or unconfirmed, and it was not possible to select facilities in these countries to be surveyed.

Thus, the results of the surveys of each country are presented in alphabetical order, with the seven countries whose facilities were selected listed first, followed by the three countries without facilities to be surveyed.

Reference information (exchange rate)

The following are the exchange rates for each country based on the Bank of Japan's reported ministerial ordinance rate (March 2022):

- 1 American dollar (USD) ≒ 115 yen
- 1 Singapore dollar (SGD) ≒ 85.10 yen; this is the same for 1 Brunei dollar (BND)
- 1 Malaysian ringgit (MYR) ≒ 27.49 yen
- 100 Indonesian rupiah (IDR) ≒ 0.80 yen
- 1 Philippine peso (PHP) ≒ 2.24 yen
- 100 Thai baht (THB) ≒ 346.15 yen
- 100 Cambodian riel (KHR) ≒ 2.83 yen
- 100 Lao kip (LAK) ≒ 1.02 yen
- 1 Myanmar kyat (MMK) ≒ 0.06 yen
- 100 Vietnamese dong (VND) ≒ 0.51 yen

# Contents

# 1 Organization of basic information on advanced research equipment

## 1.1 Advanced research equipment covered in this survey

Before surveying advanced research equipment and shared research facilities in each country, the team carrying out the survey selected the advanced research equipment to be surveyed. In terms of the type of equipment, the decision was made to focus on highly versatile research equipment that is used across different fields, such as microscopy equipment and material analysis equipment; biotechnology analysis equipment, which is used in medical and agricultural fields; and processing equipment, which is used for semiconductors and in some precision machinery sectors.

The price of advanced research equipment varies according to the manufacturer, specifications, and available options; estimated costs have been presented in the table below with reference to contract prices awarded by universities and public institutions in Japan for equipment.

**Table 1-1: Equipment surveyed and approximate prices**

| Versatility | Approximate price | | | |
|---|---|---|---|---|
| | <10 million yen | 10 million to 100 million yen | 100 million to 1 billion yen | 1 billion to 5 billion yen |
| High versatility | Infrared spectrograph (FT-IR) | TEM | Cryo-electron microscope | |
| | Specific surface area/pore size distribution measuring device | SEM | XPS | |
| | | Laser microscope (confocal microscope, multiphoton microscope, Raman microscope, etc.) | | |
| | | X-ray diffraction equipment | | |
| | | GC/MS | | |
| | | LC/MS | | |
| | | NMR | | |
| | | ESR | | |
| | | Particle distribution analyzer | | |
| | | Thermal analysis equipment (TG-DTA/DSC) | | |
| | | Universal testing machine | | |
| Medium versatility | Peptide synthesizer | DNA sequencer (NGS) | | |
| | Real-time PCR | Flow cytometry system | | |
| Low versatility | Dicing equipment | Sputtering equipment | Electron-beam lithography equipment | |
| | | Dry etching RIE equipment | | |
| | | Ion implanter | | |

(Created by the authors)

The equipment selected, a summary of research fields, and their relationship to the equipment in question are shown in the table below. Microscopy equipment and material analysis equipment are used in a wide range of fields, while research equipment associated with processing is used in a limited number of fields.

**Table 1-2: Equipment surveyed and relationship with academic fields**

| Research area | | | Equipment comparison table | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Subject type | Field | Discipline | Microscopy | Material analysis | Powder analysis | Thermal analysis | Material testing | Biotechnology | Processing | Other |
| Integrated and new areas | Integrated areas | Informatics | | | | | | | | Super computer |
| | | Neuroscience | ✓ | ✓ | | | | ✓ | | |
| | | Experimental zoology | ✓ | ✓ | | | | ✓ | | |
| | | Human medical engineering | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | |
| | Combined new areas | Environmental studies | ✓ | ✓ | | | | ✓ | | |
| | | Nano/micro science | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | |
| | | Genomics | ✓ | ✓ | | | | ✓ | | |
| | | Biomolecular science | ✓ | ✓ | | | | ✓ | | |
| Science and technology | Mathematical and physical sciences | Astronomy | | | | | | | | Telescope, observation equipment, etc. |
| | | Physics | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| | | Earth and planetary sciences | ✓ | ✓ | | | | | | |
| | | Plasma science | ✓ | ✓ | | | | | ✓ | |
| | Chemistry | Basic chemistry | ✓ | ✓ | | | | | | |
| | | Complex chemistry | ✓ | ✓ | | | | ✓ | | |
| | | Material chemistry | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| | Engineering | Applied physics/engineering science | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| | | Mechanical engineering | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| | | Electrical and electronic engineering | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | |
| | | Civil engineering | | ✓ | ✓ | | ✓ | | | |
| | | Architecture | | ✓ | ✓ | | ✓ | | | |
| | | Material engineering | ✓ | ✓ | | | ✓ | | | |
| | | Process engineering | ✓ | ✓ | | | ✓ | | ✓ | |
| | | General engineering | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| Biology-related subjects | Biology | Basic biology | ✓ | ✓ | | | | ✓ | | |
| | | Biology | ✓ | ✓ | | | | ✓ | | |
| | Agriculture | Agriculture | ✓ | ✓ | | | | ✓ | | |
| | | Agricultural chemistry | ✓ | ✓ | | | | ✓ | | |
| | | Fisheries | ✓ | ✓ | | | | ✓ | | Ships, etc. |
| | | Animal husbandry/veterinary science | ✓ | ✓ | | | | ✓ | | |
| | | Boundary agriculture | ✓ | ✓ | | | | ✓ | | |
| | Medicine, dentistry, and pharmacology | Pharmaceutical sciences | ✓ | ✓ | | | | ✓ | | |
| | | Basic medicine | ✓ | ✓ | | | | ✓ | | |
| | | Boundary medicine | ✓ | ✓ | | | | ✓ | | |
| | | Internal clinical medicine | ✓ | ✓ | | | | ✓ | | |
| | | Surgical clinical medicine | ✓ | ✓ | | | | ✓ | | |
| | | Dentistry | ✓ | ✓ | | | | | | |

(Created by the authors)

## 1.2 Overview of equipment surveyed and major manufacturers

The team organized the equipment surveyed in the form of an equipment overview and the main equipment manufacturers. Nyusatsu no Mori (FiveDrive Inc.), a database for information concerning tender and award, was used when specifying the main manufacturers. The team used this database to confirm the manufacturers of the equipment surveyed, which had been awarded a contract by national and other public universities and public research institutions, etc. in Japan; in the main, equipment that was procured through a contract award multiple times is summarized in the table below.

Note that there are differences between equipment used in universities and public research institutions and by private companies, meaning it is important to be aware of the possibility that companies listed as main manufacturers may not be the same as those with a top market share.

### Table 1-3: Overview of equipment surveyed and main manufacturers (in no particular order, excluding legal status and titles)

| Versatility | Broad equipment category | Medium-level category (main equipment) | Overview | Approximate price | Major manufacturers used by Japanese universities, etc. | | |
|---|---|---|---|---|---|---|---|
| High versatility | Microscopy equipment | TEM | Transmission electron microscopy. An electron beam is irradiated at a sample and microscopic substances are observed via the strength of the electron beam that passes through. | 10 million to 100 million yen | JEOL | Thermo Fisher Scientific (US) | Hitachi High-Tech Corporation |
| | | SEM | Scanning electron microscopy. Observing the surface of a sample by irradiating an electron beam at it. | 10 million to 100 million yen | JEOL | Thermo Fisher Scientific (US) | Hitachi High-Tech Corporation |
| | | Cryo-electron microscope | A high-performance TEM equipped with the function to observe at low temperatures. Structures from inside living things can be frozen alive and observed without dye. | 100 million to 1 billion yen | JEOL | Thermo Fisher Scientific (US) | |
| | | Laser microscope (confocal microscope, multiphoton microscope, Raman microscope, etc.) | A laser microscope is a microscope system that obtains images by irradiating a beam of a specific wavelength onto an object and measuring the reflected light. | 10 million to 100 million yen | Olympus | ZEISS (Germany) | Nikon |
| | | XPS | In addition to qualitative and quantitative analysis, chemical bonding state analysis that determines the characteristics of materials is performed for elements (Li to U) existing on the surface of several nanometers. | 100 million to 1 billion yen | ULVAC-PHI | Shimadzu | JEOL |
| | Material analysis equipment | Infrared spectrograph (FT-IR) | Analyzes organic components included in substances using infrared spectroscopy. | <10 million yen | JASCO | Shimadzu | |
| | | X-ray diffraction equipment (XRD) | Identifies and quantifies substances through analysis of diffraction lines obtained by irradiating x-rays on substances with crystalline structures. | 10 million to 100 million yen | Rigaku | Shimadzu | Bruker (US) |
| | | GC/MS | Combined equipment that uses both GC and MS; qualifies and quantifies organic compounds. | 10 million to 100 million yen | Shimadzu | JEOL | |
| | | LC/MS | Combined equipment that uses both LC and MS; unlike GC/MS, which is used for volatile substances, LC/MS can be applied to a wide range of areas, from volatile to hardly-volatile substances. | 10 million to 100 million yen | Shimadzu | JEOL | AB Sciex (US) |
| | | NMR | Analyzes the molecular structure of a substance at an atomic level by inserting a nucleus into a magnetic field and observing the resonance of the nuclear spin. | 10 million to 100 million yen | Bruker (US) | JEOL | |
| | | ESR | Observes the behavior of unpaired electrons in target substances using a magnetostatic field and microwaves, and explores the state of the substances around them. | 10 million to 100 million yen | Bruker (US) | JEOL | |
| | Powder analysis equipment | Particle size/distribution analyzer | Investigates the sample particle groups being measured to see the size of the particles present (particle diameter) and the percentages thereof. | 10 million to 100 million yen | Beckman Coulter (US) | MicrotracBel | Horiba |
| | | Specific surface area/pore size distribution measuring device | Measures the comparative surface area and pore distribution of a sample. | <10 million yen | Shimadzu | MicrotracBel | |
| | Thermal analysis equipment | TG-DTA/DSC | TG stands for thermogravimetry. TG-DTA makes simultaneous use of TG and DTA (differential thermal analysis), and TG-DSC uses TG and DSC (differential scanning calorimetry). | 10 million to 100 million yen | NETZSCH (Germany) | Rigaku | Hitachi High-Tech Corporation |
| | Material testing | Universal testing machine | Measures the tensile strength, ductility, malleability, etc. of a material. | 10 million to 100 million yen | Shimadzu | | |
| Medium versatility | Biotechnology analysis equipment | Peptide synthesizer | Synthesizes peptides with amino acid sequences as designed by humans. | <10 million yen | CEM (US) | Biotage (Sweden) | Gyros Protein Technologies (Sweden) |
| | | Real-time PCR | Real-time PCR measures the DNA replication process via PCR in real-time. | <10 million yen | Thermo Fisher Scientific (US) | Bio-Rad Laboratories (US) | |
| | | Various sequencers (next-generation DNA sequencer) | Determines DNA base sequences made up of adenine (A), thymine (T), guanine (G), and cytosine (C). NGS carry out millions of sequencing reactions in parallel. | 10 million to 100 million yen | Thermo Fisher Scientific (US) | Illumina (US) | Pacific Biosciences (US) |
| | | Flow cytometry system | Analysis equipment used in flow cytometry, mainly for individual observations of cells. | 10 million to 100 million yen | Becton, Dickinson and Company (US) | Beckman Coulter (US) | Sony |
| Low versatility | Processing equipment | Electron-beam lithography equipment | Draws using electron beans when forming fine devices and planned circuit patterns on chips during the production of semiconductor devices, etc. | 100 million to 1 billion yen | Elionix | JEOL | Advantest |
| | | Sputtering equipment | Sputtering equipment produces a thin membrane on the surface of a target substance in a vacuum when forming thin layers such as semiconductors, insulators, and metals on a chip in order to realize the functionality of a semiconductor device, etc. | 10 million to 100 million yen | Shibaura Mechatronics | ULVAC | |
| | | Dry etching RIE equipment | Creates a thin layer of pattern via etching on the surface of a sample during the manufacturing process of a functional device. RIE (reactive ion etching) is a detailed process used in dry conditions without any chemical solvents, etc. | 10 million to 100 million yen | Samco | Sumitomo Precision Products | ULVAC |
| | | Ion implanter | Alters the properties of a material by the synthesis of crystalline materials, transformation via heat treatment, and ion doping etc., in accordance with an aim. Ion implantation involves the implantation of ionized substances in solids, which alters their solid-state properties. | 10 million to 100 million yen | ULVAC | Nissin Electric | |
| | | Dicing equipment | Separates circuits into individual units from a wafer and encapsulates them into chips. Dicing equipment separates circuits into individual units. | <10 million yen | DISCO | | |

(Created by the authors based on public information from manufacturers, etc.)

## 1.3 Use of equipment surveyed in universities and research institutions

The equipment surveyed was organized into equipment that has been installed and equipment with equivalent specifications, based on contract award information of national and other public universities and public institutions in Japan. In many cases, contract awards that have been publicized have not included the manufacturer or model information, and in these cases the team searched for relevant equipment hypothesized based on publicly available information from awarding institutions, and, if applicable, presented the assumed details in the table below.

**Table 1-4: Main equipment used in Japanese universities and research institutions, etc. (in no particular order, and excluding legal status and titles)**

| NO | Broad category | NO2 | Medium-level category (equipment) | Manufacturer | Model/equivalent product used in universities, etc. |
|---|---|---|---|---|---|
| 1 | Microscopy | 1 | TEM | JEOL | JEM-2200FS<br>JEM-2100Plus |
| | | | | Thermo Fisher Scientific (US) | Talos F200C G2<br>Talos F200X S |
| | | | | Hitachi High-Tech Corporation | HF5000<br>HT7800 |
| | | 2 | SEM | JEOL | JSM-7900F<br>JSM-IT200 InTouchScope<br>JCM-7000 NeoScope |
| | | | | Thermo Fisher Scientific (US) | Quanta 200 3D<br>Quanta 250 |
| | | | | Hitachi High-Tech Corporation | SU9000<br>SU3800 / SU3900<br>FlexSEM 1000 / FlexSEM 1000 II |
| | | 3 | Cryo-electron | JEOL | CRYO ARM™ 300 (JEM-Z300FSC)<br>CRYO ARM™ 200 (JEM-Z200FSC) |
| | | | | Thermo Fisher Scientific (US) | Tundra Cryo-TEM<br>Krios G4 Cryo-TEM<br>Glacios Cryo-TEM for Life Sciences |
| | | 4 | Laser microscope (confocal microscope, multiphoton microscope, Raman microscope, etc.) | Olympus | FV3000<br>FV1200 |
| | | | | ZEISS (Germany) | LSM800<br>LSM780 |
| | | | | Nikon | A1 MP＋/A1R MP＋ |
| | | | | Nanophoton | RAMANtouch |
| | | 5 | XPS | ULVAC-PHI | PHI VersaProbe 4 |
| | | | | Shimadzu | KRATOS ULTRA2 |
| | | | | JEOL | JPS-9030 |
| 2 | Material analysis equipment | 1 | Infrared spectrograph (FT-IR) | JASCO | FT/IR-4000/6000 series |
| | | | | Shimadzu | FT-IR |
| | | 2 | X-ray diffraction equipment (XRD) | Rigaku | SmartLab<br>Ultima IV |
| | | | | Shimadzu | MAXima_X XRD-7000<br>XRD-6100 |
| | | | | Bruker (US) | D8 DISCOVER<br>D2 PHASER |
| | | 3 | GC/MS | Shimadzu | GCMS-TQ8040 NX<br>GCMS-QP2020 NX |
| | | | | JEOL | JMS-TQ4000GC<br>JMS-Q1600GC |
| | | 4 | LC/MS | Shimadzu | LCMS-9030<br>LCMS-8060NX |
| | | | | JEOL | JMS-T100LP AccuTOF LC-plus 4G |
| | | | | AB Sciex (US) | Triple Quad 5500+ |
| | | 5 | NMR | JEOL | JNM-ECZL series FT NMR<br>JNM-ECZR series FT NMR<br>JNM-ECZS series FT NMR |
| | | | | Bruker (US) | AVANCE NEO<br>Ascend NMR magnets<br>AvanceCore |
| | | 6 | ESR | JEOL | JES-X3 Series ESR |
| | | | | Bruker (US) | Magnettech ESR5000<br>microESR |

| NO | Broad category | NO2 | Medium-level category (equipment) | Manufacturer | Model/equivalent product used in universities, etc. |
|---|---|---|---|---|---|
| 3 | Powder analysis | 1 | Particle size/distribution analyzer | Beckman Coulter (US) | Multisizer 4e |
| | | | | MicrotracBel | SYNC |
| | | | | Horiba | nano Partica SZ-100V2 |
| | | 2 | Specific surface area/pore size distribution measuring device | MicrotracBel | BELSORP MAX II<br>BELSORP MINI X |
| | | | | Shimadzu | TriStar® II Plus<br>ASAP 2460 |
| 4 | Thermal analysis | 1 | TG-DTA/DSC | NETZSCH (Germany) | STA449 F1/F3/F5 Jupiter<br>DSC 214 Polyma |
| | | | | Rigaku | Thermo plus EVO2 TG-DTA8122 |
| | | | | Hitachi High-Tech | TG-DSC NEXTA STA |
| 5 | Material testing | 1 | Universal testing | Shimadzu | Autograph AGX-V<br>Autograph AGS-X |
| 6 | Biotechnology analysis equipment | 1 | Peptide synthesizer | CEM (US) | Liberty Blue |
| | | | | Biotage (Sweden) | Initiator+ Alstra |
| | | | | Gyros Protein Technologies (Sweden) | Purepep Chorus |
| | | 2 | Real-time PCR | Thermo Fisher Scientific (US) | QuantStudio 1/3/5/6 |
| | | | | Bio-Rad Laboratories (US) | CFX Connect |
| | | 3 | Various sequencers (next-generation DNA sequencer) | Illumina (US) | NextSeq 2000 |
| | | | | Thermo Fisher Scientific (US) | Ion GeneStudio S5 System |
| | | | | PACIFIC BIOSCIENCES (US) | Sequel II/ IIe system |
| | | 4 | Flow cytometry system | Becton, Dickinson and Company (US) | BD FACSLyric |
| | | | | Beckman Coulter (US) | Navios EX |
| | | | | Sony | SH800S |
| 7 | Processing equipment | 1 | Electron-beam lithography equipment | Elionix | ELS-BODEN |
| | | | | JEOL | JBX-9500FS |
| | | | | Advantest | F7000 |
| | | 2 | Sputtering equipment | Shibaura Mechatronics | CFS-4EP-LL |
| | | | | ULVAC | ACS-4000 |
| | | 3 | Dry etching RIE equipment | Samco | RIE-10NR |
| | | | | Sumitomo Precision Products | Si Deep RIE System for R&D |
| | | | | ULVAC | NE-550EX |
| | | 4 | Ion implanter | Nissin Electric | NH-20SR |
| | | | | ULVAC | IMX-3500 |
| | | 5 | Dicing equipment | DISCO | DAD3220/3221 |

(Created by the authors based on the database for information concerning tender and award won and public information from relevant institutions)

In addition, information about the equipment in the 20 shared research facilities surveyed in ASEAN countries has been organized into the table below. Many institutions do not publish manufacturer and model names, so the information was compiled based on details confirmed from public information and interviews. Thus, it is important to note the possibility that this does not cover all equipment. Moreover, the team was not able to confirm whether any ASEAN shared research facilities possessed certain pieces of equipment, including processing equipment. However, the subjects upon which these outcomes are based were limited to 20 facilities, so this does not preclude the presence of the equipment in question in ASEAN countries.

**Table 1-5: Equipment used in ASEAN shared research facilities (in no particular order and excluding legal status and titles)**

| NO | Broad category | NO2 | Medium-level category (equipment) | Manufacturer | Models used in shared research facilities (country of use is indicated in the brackets*) |
|---|---|---|---|---|---|
| 1 | Microscopy equipment | 1 | TEM | JEOL | JEM2200FS, JEM2100, etc. (all SG) |
| | | | | Thermo Fisher Scientific (US) | Tecnai G2 20 (TH), Tecnai T12 (SG), Talos 120c (SG), etc. |
| | | 2 | SEM | Hitachi High-Tech Corporation | FlexSEM 1000 II (SG), etc. |
| | | | | JEOL | JSM-7600F, JSM-6701F, JSM-6510, etc. (all SG) |
| | | | | Thermo Fisher Scientific (US) | Helios600 DualBeam, Nanolab G3 CX, Prisma E (all SG) |
| | | | | TESCAN (Czech Republic) | MIRA (TH) |
| | | 3 | Cryo-electron microscope | Thermo Fisher Scientific (US) | Titan Krios (ID, MY, SG), etc. |
| | | 4 | Laser microscope (confocal microscope, multiphoton microscope, Raman microscope, etc.) | ZEISS (Germany) | LSM980, LSM900, LSM800, LSM780, LSM710, ELYRA PS.1 (all SG) |
| | | | | Olympus | FV3000, FV1200, FV1000 (all SG) |
| | | | | Leica (Germany) | Leica Stellaris, TCS SP8 Confocal and STED 3x (all SG) |
| | | | | Horiba | LabRAM HR (VN) |
| | | | | LaVision (Germany) | Trim II Multiphoton (SG) |
| | | | | PerkinElmer (US) | UltraVIEW VoX (SG) |
| | | | | Nikon | NSTORM, A1R (all SG) |
| | | 5 | XPS | Malvern PANalytical (Netherlands) | Axios Max (BN) |
| 2 | Material analysis equipment | 1 | Infrared spectrograph (FT-IR) | Shimadzu | IRTracer-100 (BN) |
| | | | | Thermo Fisher Scientific (US) | Nicolet iS50 FTIR (ID) |
| | | | | Bruker (US) | Vertex 70 (TH) |
| | | | | Agilent Technologies (US) | Cary630 (BN) |
| | | 2 | X-ray diffraction equipment (XRD) | Shimadzu | XRD-7000 (BN) |
| | | | | Bruker (US) | D8 Advance (TH, VN) |
| | | 3 | GC/MS | YL Instrument (S. Korea) | GCMS YL6900 (ID) |
| | | | | Agilent Technologies (US) | HP 6890GC-HP5973 MSD (VN) |
| | | 4 | LC/MS | Agilent Technologies (US) | 6530 Accurate-Mass Q-TPF LC/MS (BN) |
| | | | | Bruker (US) | Easy-nLC-microOTOF (TH) |
| | | | | Shimadzu | LCMS-QP8000, LCMS-2010 (all VN) |
| | | 5 | NMR | Bruker (US) | Ascend-400 (TH) |
| | | 6 | ESR | Not applicable in the institutions surveyed | - |
| 3 | Powder analysis equipment | 1 | Particle size/distribution analyzer | Beckman Coulter (US) | LS100Q (MY) |
| | | | | Malvern PANalytical (Netherlands) | Nano S90 (TH), Zetasizer Nano ZS (BN, TH) |
| | | 2 | Specific surface area/pore size distribution measuring device | Manufacturer name unknown | - |
| 4 | Thermal analysis equipment | 1 | TG-DTA/DSC | Mettler Toledo (Switzerland) | DSC1 STARe System (BN, MY) |
| 5 | Material testing | 1 | Universal testing machine | INSTRON (US) | 5596-B1-E2-F3-G2, 5985, 1123 (all TH) |
| 6 | Biotechnology analysis equipment | 1 | Peptide synthesizer | Manufacturer name unknown | - |
| | | 2 | Real-time PCR | Bio-Rad Laboratories (US) | CFX96 (ID, MY, PH) |
| | | | | Thermo Fisher Scientific (US) | QuantStudio (PH) |
| | | | | Biometra (Germany) | Analytik Jena TAdvanced 96 SG (VN) |
| | | | | PCRmax (UK) | Eco48 Real Time PCR (ID, PH) |
| | | 3 | Various sequencers (next-generation DNA sequencer) | Illumina (US) | NextSeq2000 (ID), NextSeq1000, Miseq (ID), Novaseq (ID), iSeq100 (PH) |
| | | | | Thermo Fisher Scientific (US) | SeqStudio (SG) |
| | | 4 | Flow cytometry system | Beckman Coulter (US) | Cytoflex LX, Moflo Astrios Sorter (all SG) |
| | | | | Becton, Dickinson and Company (US) | LSR Fortessa (SG), FACSymphony (SG), FACSCanto II (TH) |
| | | | | Thermo Fisher Scientific (US) | Attune NxT (PH) |
| | | | | Yokogawa Electric | Flowcam 8400 (SG) |
| | | | | Cytek Biosciences (US) | Cytek Aurora (SG) |
| 7 | Processing equipment | 1 | Electron-beam lithography equipment | There is electron-beam lithography equipment in CAMES in Brunei, but the details of the manufacturer, etc. are unknown. Although there is a shared research facility for semiconductor research equipment in Malaysia, there is no consistency in equipment names. | |
| | | 2 | Sputtering equipment | | |
| | | 3 | Dry etching RIE equipment | | |
| | | 4 | Ion implanter | | |
| | | 5 | Dicing equipment | | |

*BN: Brunei, ID: Indonesia, MY: Malaysia, PH: Philippines , SG: Singapore, TH: Thailand, VN: Vietnam

(Created by the authors based on public information from relevant institutions and interview details)

When the state of development of equipment in Japan and in ASEAN was compared, the team was able to confirm the presence of microscopy equipment made by JEOL, Hitachi High-Tech Corporation (Hitachi), Olympus, Nikon, and others in ASEAN countries. However, while Japanese manufacturers held an overwhelming share of this market in Japan, the team confirmed some pieces of equipment made by the German firms ZEISS and Leica in ASEAN, as well as those from Japanese companies. The share of American company Thermo Fisher Scientific was also higher than in the Japanese market. The situation was similar for material analysis equipment: although the team confirmed the presence of equipment made by Shimadzu and other Japanese companies in ASEAN, they also found many examples of equipment from the American companies Bruker and Agilent Technologies. In addition, they also found examples of equipment from a Korean manufacturer in Indonesia, although the numbers were limited. When it came to powder analysis equipment, thermal analysis equipment, and material testing equipment, Japanese manufacturers had a high share in Japan, but procurement of their equipment in ASEAN was limited; instead, numerous examples of equipment from American and European companies were confirmed. In terms of biotechnology analysis equipment, the share of American and European companies was overwhelmingly high in both Japan and ASEAN, including equipment from the American companies Thermo Fisher Scientific; Beckman Coulter; Becton, Dickinson and Company; and Illumina. Note that it was not possible to confirm specific equipment names or manufacturer information for processing equipment in the facilities surveyed on this occasion.

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# 2 Country survey: Brunei Darussalam

## 2.1 Basic information on science and technology policies

Brunei Darussalam (Brunei) is a country with a small territory and a small population, but has the second-highest GDP per person among ASEAN countries after Singapore thanks to its status as an oil-producing country. It has wealth, high standards of living, and high levels of welfare, but when it comes to research, its human resources are leaving for other countries, hindering the improvement of its research and development capabilities. The government is aware of this human resources issue, and has established the development of human resources as a key area in its long-term development plan WAWASAN 2035, which is to be accomplished by 2035.

The country's long-term development plan vision is made up of the following three areas:

・Political stability to maintain social, cultural, and historical values;
・Diverse challenges to modernize the lifestyle of its citizens;
・Creating value for the citizens and communities of the future.

The country has also set down three goals, as noted below:

・To realize education in accordance with international standards and foster skilled human resources;
・To improve the quality of life of its citizens;
・To ensure a national income that falls within the top 10 countries in the world and build a dynamic and sustainable economy.

To fulfill the above goals, Brunei has established 13 strategic fields: education, economy, security, institutional development, local business development, infrastructure development, social security, environment, health, religion, land use, infrastructure and info-communication technology, and manpower planning. Since the government announced WAWASAN 2035 in 2007, it has also set five-year national development plans.

Several of Brunei's government departments are involved in its policies concerning science and technology, which are being implemented in a cross-departmental fashion. To ensure this is carried out effectively, the government has set up the Majlis Tertinggi Wawasan Brunei 2035 council, which monitors national development operations and projects. Until 2019, the implementation of areas related to science and technology and areas related to research development were split into two departments, with the Ministry of Energy, Manpower and Industry (MEMI) managing science and technology and the Brunei Research Council (BRC) of the Prime Minister's Office (PMO) controlling research and development. In 2019, MEMI became the Ministry of Energy, and the functions for managing science and technology were transferred to the Ministry of Transport and Infocommunications (MTIC), together with the research and development functions that had belonged to the BRC. After this, MTIC managed both science and technology and research and development in a centralized manner, and decided to establish the Council for Research and Advancement of Technology and Science (CREATES) under the MTIC umbrella on April 10, 2021. CREATES has inherited the science and technology functions held by the council and the research and development functions held by the BRC; it determines the national science and technology innovation policy, drafts strategies, approves the budgets for science and technology and research and development, and provides support for the promotion of research and development and the commercialization of science and technology to enable national development.

Brunei' s GERD (Gross Expenditure on R&D) as a percentage of GDP is approximately 0.3%, and funding is concentrated in higher education institutions. By field, the main funding is in the agricultural sciences, the natural sciences, and the medical sciences, as shown below.

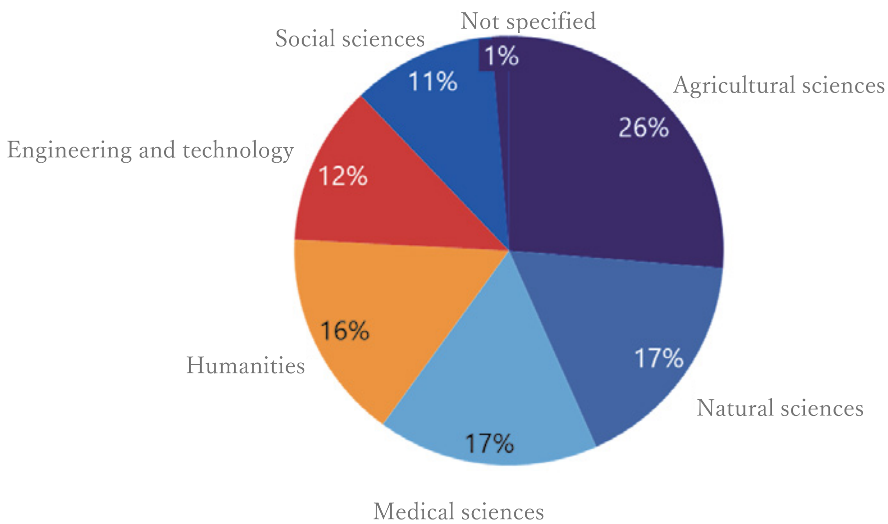


**Figure 2-1: Breakdown of national research and development funding (2018)**
(Created by the authors based on UNESCO data)

## 2.2 Policy/funding survey

The BRC serves as a funding organization, and offers the Applied Research Fund, Industrial Research Fund, and the Commercialisation Support Programme in accordance with the phase of the research. The Applied Research Fund and the Industrial Research Fund can be used for research equipment; overviews of these two funds are given below.

・The Applied Research Fund

The Applied Research Fund is defined as being for the use of scientific knowledge for the development of new products and services with a high return on investment and high potential for commercialization. The maximum grant for a single project is 300,000 BND, with a research period of two years. Eligible recipients are higher education institutions in Brunei, research institutions based in Brunei, government research institutions, and researchers who are members of NPOs associated with these institutions.

・The Industrial Research Fund

The Industrial Research Fund is defined as being for research and development activities to improve or produce existing products, technology or services with the aim of commercialization in the world of industry. Applicants for this fund are responsible for half their research expenses, and the other half is paid for by the Brunei government. The grant period is two years, and the upper limit is 2 million BND per project. Eligible organizations include private companies registered in Brunei and foreign companies, higher education institutions and research institutions which established joint ventures or partnered with Bruneian higher education institutions, government institutions, NPOs and private companies within the country.

The team could not find any policies or programs with the goal of shared use.

## 2.3 State of development based on policies, etc.

As stated above, the team could not find any policies connected with shared use. However, Brunei's representative national university, Universiti Brunei Darussalam (UBD), contains the Centre for Advanced Material and Energy Sciences (CAMES), which focuses on nano-engineering and renewable energy research, and shared use does occur here. CAMES is an institution established in accordance with an initiative to convert UBD from a university for education to a university for research, funded by the BRC.

## 2.4 Survey of major shared research facilities

The team carried out an interview at UBD's CAMES, Brunei's shared research facility, gaining an overview of the facility and surveying its practices.

### 2.4.1 Centre for Advanced Material and Energy Sciences (CAMES), Universiti Brunei Darussalam

Purpose of establishing facility

CAMES is a facility engaged in research on the fields of energy and advanced materials, with a focus on the theme of sustainability. CAMES' priority areas include nanophotonics, catalysis, sensors, and solar energy. It gathers researchers from across disciplines and provides a platform for the conceptualization of ideas and the development of solutions.

CAMES was established 12 years ago, as part of an initiative to convert UBD from a university for education to a university for research. Both the promotion of research activities and the importance of joint research were raised during the process of considering this initiative, and so the Innovation & Enterprise Office, which promotes industry-academia collaboration, and CAMES were established. The Innovation & Enterprise Office is responsible for administrative procedures, such as selecting collaborators for joint research and the management thereof, whereas CAMES is in charge of technical work such as managing, purchasing, and repairing research equipment, as well as research functions.

When CAMES was first established, no thought was given to the shared use of research equipment; the plan was to monetize it through patent income and joint research. Nonetheless, once it started operating, those involved became aware that there was a need for external researchers and private companies to use the equipment, so it came to be involved in shared use.

Assignment of personnel for facility operations

There are 15 people assigned to manage and maintain CAMES' equipment. Of these, 12 are people on short-term assignment from vendors, etc., and the other three are staff responsible for managing and purchasing equipment. The number of people does, however, change as time passes.

Fostering human resources associated with facility operations and the use of equipment

There is no system or program to foster human resources associated with equipment. This is already outsourced.

Current state of equipment

The main research equipment installed is listed in the table below.

**Table 2-1: Typical research equipment (in no particular order)**

| Research equipment | Manufacturer | Model |
|---|---|---|
| Ball Miller | Retsch (Germany) | PM400 |
| DSC | Mettler Toledo (Switzerland) | DSC1 STARe System |
| FT-IR | Shimadzu | IRTracer-100 |
| FT-IR | Agilent Technologies (US) | Cary 630 |
| Furnace | Brother Furnace (China) | XD-1400 ST |
| Furnace | Thermoconcept (Germany) | High Performance Chamber Furnace HTK 16/18 |
| Glovebox | GS Glovebox Systemtechnik (Germany) | GS019811 |
| Laser Flash | Linseis (Germany) | LFA1000 |
| LC/MS | Agilent Technologies (US) | 6530 Accurate-Mass Q-TPF LC/MS |
| Microhardness tester | LECO (US) | LM248AT |
| Nano and Zetasizer | Malvern Panalytical (UK) | Zetasizer Nanoseries Nano-ZS |
| Nanoindentation tester | CSM Instruments (US) | Ultra Nanoindentation Tester |
| Photovoltaic Characterization | Bentham (UK) | PVE300 |
| Spin coater | Suss Microtec (Germany) | LabSpin 6/8 |
| UV-Vis-Near IR Spectrometer | Agilent Technologies (US) | Cary Series UV-Vis-NIR Spectrophotometer |
| Viscotester | Thermo Fisher Scientific (US) | HAAKE Viscotester 7 Plus |
| XRD | Shimadzu | XRD-7000 |
| XRF | Malvern PANalytical (Netherlands) | Axios Max |
| SEM | Unknown | - |
| Electron-beam lithography equipment | Unknown | - |

(Created by the authors based on materials received and CAMES' public information)

Form and scope of sharing

External partners may use the equipment in the facility. However, the facility is not completely open; instead, it is open to researchers and partners carrying out joint research in Brunei and in other countries, and equipment is shared with them. A "partner" is a researcher from a Bruneian research institution or university, or a researcher from a foreign university. If they are engaged in joint research with CAMES, Japanese researchers are also able to make use of the equipment, and there are past examples of this.

Developing rules for shared use

There are two forms of shared use: joint research and consulting services. When it comes to joint research, it is necessary to sign an agreement with CAMES, and obtain the approval of the Innovation &

Enterprise Office concerning the details of the agreement. In the case of joint research, participants can use CAMES' equipment. Those who wish to do so receive training for the Safety Rules and Regulation, and later undergo training in that research facility, learning how to use the equipment and the rules of the facility. For the latter training, the people responsible for the technology in the research facility act as lecturers. If a researcher is involved in the shared use of facilities and/or equipment and publishes a paper, the paper must note the fact that the researcher used CAMES.

On the other hand, when it comes to consulting services, there is no need for an agreement with CAMES; only an application is required. CAMES provides testing services and advice for testing that is appropriate for verifying hypotheses, in accordance with the content of external users' applications.

Amount of money given and income/expenditure

Budget amounts are not published, but around half of the money, excluding fixed costs such as personnel expenses, is used for equipment purchases, and the other half is used for equipment management and maintenance. The center does not have a huge income, so it is difficult to keep the facility's income and expenditure in the black.

Facility operation KPI

The Innovation & Enterprise Office has established KPI concerning the number of joint studies, their income, and university ranking. In CAMES, the production of high-impact research outcomes is a KPI. In addition, it is desirable for there to be at least 25 publications in international academic journals each year; the center achieves this and more.

Implementation of personnel exchanges

To encourage joint research on an international level, CAMES has implemented diverse exchange activities through the UBD Research Mobility Scheme, sending young researchers to foreign research institutions. Moreover, when it comes to initiatives concerning equipment, the center also provides training for research activities (including research equipment), when researchers and students arrive from other countries.

Research outcomes and representative projects, as seen from patents and papers

・International patents: 11

・Total published papers: 28; 5 of these listed in SCI.

The number of published papers from CAMES is at least 50% of the number of research papers published by the university as a whole. Moreover, two large research projects are currently underway. CAMES is also expecting joint research cooperation with Mitsubishi Chemical Corporation.

Examples of major papers are shown below. The reason there are few published papers when compared to the KPI of 25+ papers in international academic journals is assumed to be because many submissions to academic journals are not covered by the database for papers used here, the Research Information Sharing Service (RISS).

**Table 2-2: Representative examples of papers**

| Name of paper | Authors | Year published | Number of citations | Publication |
|---|---|---|---|---|
| Near infrared surface-enhanced Raman scattering based on star-shaped gold/silver nanoparticles and hyperbolic metamaterial. | Chih-Hsien Lai, Guo-An Wang, Tsung-Kai Ling & Hai-Pang Chiang, Tzyy-Jiann Wang, Po-kai Chiu, Yuan-Fong Chou Chau (CAMES), Chih-Ching Huang, Hai-Pang Chiang | 2017 | 69 | Scientific Reports |
| Simultaneous realization of high sensing sensitivity and tunability in plasmonic nanostructures arrays. | Yuan-Fong Chou Chau (CAMES), Chee Ming Lim (CAMES), N. T. R. N. Kumara (CAMES), Nyuk Yoong Voo (CAMES), Chan-Kuang Wang, Linfang Shen, Hai-Pang Chiang, Hai-Pang Chiang, Chung-Ting Chou Chao, Hung Ji Huang, Chun-Ting Lin | 2017 | 60 | Scientific Reports |
| Enhanced Carbon monoxide-sensing properties of Chromium-doped ZnO nanostructures | I. Y. Habib (CAMES), Hafiz Armi Noor (CAMES), Chee Ming Lim (CAMES), Abdul Hanif Mahadi (CAMES), N. T. R. N. Kumara (CAMES), Aimi Asilah Tajuddin (UBD) | 2019 | 37 | Scientific Reports |

(Created by the authors based on RISS. Information accurate as of March 20, 2022)

Issues associated with facility maintenance and operations

New pieces of research equipment are being introduced one after another, and equipment is aging. Moreover, there is an awareness of the need to polish CAMES' own expertise and strengths; to accomplish this, it is essential that advanced research equipment is always maintained.

Due to COVID-19, the number of joint studies with external research institutions and private companies has dropped, and it is no longer possible to hold detailed exchanges face-to-face, so it takes more time and costs more than normal to conclude joint research contracts.

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# 3 Country survey: Republic of Indonesia

## 3.1 Basic information on science and technology policies

The Republic of Indonesia (Indonesia) established its national long-term development plan (Rencana Pembangunan Jangka Panjang Nasional (RPJPN)), a foundational plan for economic development, in 2004. This plan was written as a long-term development plan for the 20-year period from 2005 to 2025, and raised the establishment of a knowledge economy and science and technical capabilities as issues in the science and technology field. In addition, to realize this long-term plan, the government has set medium-term development plans (Rencana Pembangunan Jangka Menengah Nasional (RPJMN)) every five years. The development of primary industries (such as resources) and the private sector was a key theme in the RPJMN that finished in 2019. Moreover, the current RPJMN (from 2020 to 2024), which covers the final phase of the long-term plan, includes the goal of further strengthening the domestic economy by raising the quality of Indonesia's human capital, and increasing its competitive power in the global market. The changing RPJMN are shown in the table below.

**Table 3-1: Overview of national medium-term development plans (RPJMN)**

| | First plan | Second plan | Third plan | Fourth plan (final) |
|---|---|---|---|---|
| Period | 2005-2009 | 2010-2014 | 2015-2019 | 2020-2024 |
| Policies | Enforcing laws and establishing fundamental human rights through domestic legislation and administrative reform. Eliminating discrimination. | Improving the quality of human resources by promoting science and technology capabilities and strengthening economic competitiveness, and driving innovation in all fields. | Strengthening economic competitiveness by improving the competitive power of natural resources, the quality of human resources, and science and technology capabilities, driving development in each field, and enhancing comprehensive strength. | Driving development based on the principles of justice and fairness, developing human resources and improving science and technology capabilities, and aiming for sustainable economic development. |
| Key fields | ・Food security<br>・New/renewable energy<br>・Transportation<br>・Information and communication<br>・Defense and security<br>・Health and medicine<br>・Materials | ・Society and culture<br>・Economics<br>・Science and technology<br>・Infrastructure<br>・Politics<br>・Defense/security<br>・Law/national institutions<br>・Localities/space<br>・Natural resources/environment | ・Education<br>・Health<br>・Infrastructure<br>・Food<br>・Energy<br>・Maritime affairs and the oceans<br>・Tourism | ・Fostering human resources<br>・Infrastructure<br>・Tourism<br>・Regulatory reform<br>・Economic development |

(Created by the authors based on RPJMN)

The Indonesian government set the goal of ensuring that R&D expenditure is 1% of its GDP; it is currently around 0.2%, and around 80% of this is expenditure by the government and public institutions, etc. Research and development funding from the private sector is still limited. Changes in R&D expenditure and a breakdown thereof are shown in the figure below.

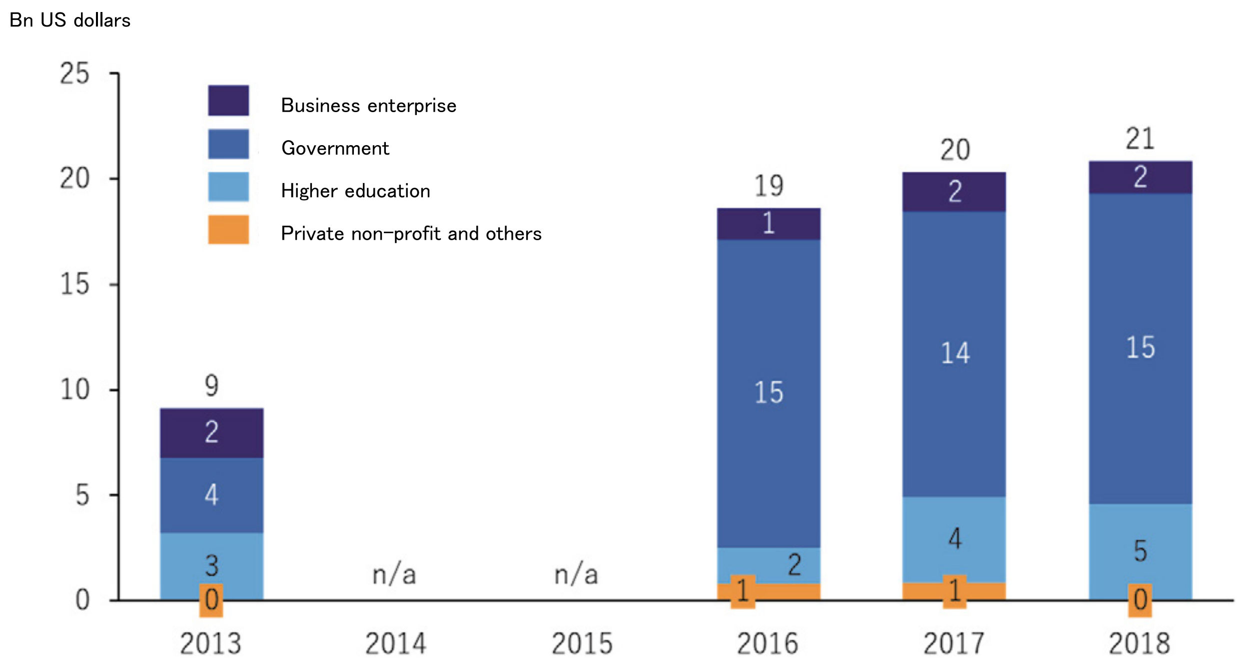


**Figure 3-1: Changes in national research and development expenditure and a breakdown of this**
(Created by the authors based on UNESCO data)

Multiple initiatives have been put into place in the research and development area, based on the 2020 to 2024 RPJMN, and, together with the implementation of law No.11/2019 (the Sisnas Iptek law), the government is considering an effective form of research investment to consolidate science and technology policy organizations and public research institutions, as well as to promote research and development.

On the organizational side of things, the Ministry of Research, Technology and Higher Education (RISTEKDIKTI), which was responsible for measures concerning science and technology and higher education, has been reorganized, and the management of everything from the establishment of science and technology policy to funding and the management of public research institutions has been integrated into the newly established National Research and Innovation Agency (Badan Riset dan Inovasi Nasional (BRIN)). Consequently, public research institutions, including the Indonesian Institute of Sciences (Lembaga Ilmu Pengetahuan Indonesia (LIPI)) and the Agency for the Assessment and Application of Technology (Badan Pengkajian dan Penerapan Teknologi (BPPT)), have been integrated under the umbrella of BRIN.

## 3.2 Policy/funding survey

As stated above, research and development funding from the government is overwhelmingly larger than funding from the private sector. Moreover, Indonesian universities play major roles as educational institutions, while public research institutions, including national research labs, are responsible for a lot of advanced research. As a result, the development and maintenance of advanced research equipment progressed mainly in public research institutions. On the other hand, due to differences in supervisory authorities, public research institutions operated based on their own individual budgets and rules, and so their facilities and equipment maintenance were ineffective. The government was aware of this issue; bringing these under the BRIN umbrella means that budgets are now allocated by BRIN, and there is an expectation that resources will be integrated and optimized, key research themes will be specified, joint research will be promoted, rules for management and application will be unified, research facilities will become more open, and a research ecosystem will be built. Be that as it may, BRIN is currently in the middle of a transitional period for the integration of facilities, and it is likely that a certain period of time will be needed for such a large reorganization.

The table below contains an overview of law No.11/2019 (the Sisnas Iptek law), which sparked the reorganization.

**Table 3-2: Main points of law No.11/2019, concerning the national system for science and technology (the Sisnas Iptek law)**

| Main initiative | Overview |
|---|---|
| Establishment of National Research and Innovation Agency (BRIN) | The National Research and Innovation Agency (BRIN) was founded as an independent organization to oversee research in public research institutions and universities. BRIN is responsible for research and innovation policy functions. Four independent research institutions established as independent non-departmental governmental institutions (LPNK) (LIPI, BATAN, LAPAN, BPPT) and 44 research institutions connected to government departments are being integrated into BRIN based on Presidential Regulations 33 and 78 of 2021. On the other hand, jurisdiction over universities lies with the Directorate General of Higher Education, Ministry of Education, Culture, Research and Technology. |
| Formation of research and development funds | In 2019, the government provided 990 billion IDR to form research funds for the promotion of research and development. In 2020 it allocated an additional 5 trillion IDR. |

(Created by the authors based on the Sisnas Iptek law)

When it comes to advanced research equipment in universities, there are some cases of faculties with expertise procuring advanced research equipment. There are also cases in which equipment is provided through donations and other monies from the private sector. However, there is an awareness that the chief role of universities lies in education, and so many universities, including major Indonesian universities, have only basic research equipment. Moreover, this research equipment is not associated with specific laboratories; universities spearhead its acquisition for different faculties and departments, and so there are many cases of shared use within universities. There are also cases of facilities being developed based on capital from the private sector, although these are few in number. In 2021, the German firm Merck set up a joint laboratory (the FMIPA UI Collaboration Laboratory) with Universitas Indonesia, contributing funds of 3 billion IDR for research equipment and fittings to advance innovation in environmental monitoring, chemical analysis, microbiology, molecular biology, and the areas of food, agriculture, and waste treatment. As the budget for research and the development and maintenance of research equipment in universities is limited, universities that devote effort to research are interested in obtaining research funds and money to develop and maintain equipment through collaborations with private companies, etc.

In terms of public funding organizations in Indonesia, the Indonesian Science Fund (Dana Ilmu Pengetahuan Indonesia (DIPI)) was set up in 2016. The DIPI provides funding to researchers via grant programs, but does not include the purchase of research equipment as a use for its funds. Thus, it is assumed that researchers will either use research equipment belonging to their affiliated institution, or make use of equipment in shared research facilities.

In Indonesia, many public research institutions and university facilities are open not just to their own researchers but also to external researchers and private companies. Categories of shared research facility in Indonesia and examples of major institutions in each category are shown in the table below.

**Table 3-3: Shared research facility categories and examples of institutions (in no particular order)**

| Shared research facility category | Policy support for shared use | Examples of institutions |
|---|---|---|
| 1. Maintains facilities/mechanisms based on policy programs and enables shared use | Yes | Public research institutions under the BRIN umbrella<br>・Lembaga Ilmu Pengetahuan Indonesia (LIPI)<br>・Badan Pengkajian dan Penerapan Teknologi (BPPT)<br>・Lembaga Penerbangan dan Antariksa Nasional (LAPAN)<br>・Badan Tenaga Nuklir Nasional (BATAN). |
| 2. University or public research institution maintains facilities of its own volition and enables shared use | No | ・Universitas Indonesia<br>・Institut Teknologi Bandung<br>・Brawijaya University<br>・Science Techno Parks |

(Created by authors based on interview content)

Many of the public research institutions integrated into BRIN have offered the shared use of facilities and analysis services to other researchers and private companies for some time as part of their role as public research institutions. However, any rules associated with shared use were established independently, and there were also cases in which there were no rules, and shared use went ahead based on past customs. After integration under the BRIN umbrella, the rules for shared use will be standardized, and the equipment of each facility will be registered on BRIN's shared use system, ELSA. Those who wish to make use of equipment can make an application or request testing services via ELSA. As this is currently in a transition period for integration, however, ELSA's information coverage only extends to some institutions—mainly those of LIPI.

On the other hand, universities are not compelled by policy, and in many cases their facilities are open to other researchers and people from private companies based on their own volition. One of their purposes in doing this is for the use of research equipment to lead to joint research and the acquisition of external funds. Research equipment obtained by universities is used as a weapon to obtain external funds. Despite this, much of the equipment belonging to universities is basic; expensive advanced research equipment is limited.

The FY2022 budget for BRIN, with public research institutions under its umbrella, is around 6.1 trillion IDR; of this, 2.2 trillion IDR is assigned to research infrastructure. This includes the maintenance of infrastructure such as facilities, the purchase of new equipment, and costs such as equipment maintenance. It must be noted that as there are also at times other sources of funds for the development and maintenance costs, etc. of research equipment, the 2.2 trillion IDR is not the total amount of money available for research infrastructure investment.

## 3.3 State of development based on policies, etc.

BRIN is in the process of integrating four independent research institutions established as non-departmental governmental institutions (Lembaga Pemerintahan Non Kementerian (LPNK))—LIPI, the National Nuclear Energy Agency of Indonesia (Badan Tenaga Nuklir Nasional (BATAN)), the National Institute of Aeronautics and Space of Indonesia (Lembaga Penerbangan dan Antariksa Nasional (LAPAN)), and BPPT—and 44 other research institutions connected to government departments. The research institutions under its umbrella have research facilities across Indonesia. Many of the facilities previously offered shared use functions, and will provide shared equipment use and testing services based on BRIN rules after their integration with BRIN. It is assumed that the BRIN rules will be based on the LIPI rules, but this is still a transition period, and the operating rules are not standardized.

The table below contains an overview of the major research institutions: the four former LPNK institutions.

**Table 3-4: Overview of four former LPNK institutions**

| | LIPI | BPPT | LAPAN | BATAN |
|---|---|---|---|---|
| Facility overview | Established to carry out the government's mission in scientific research fields. Also responsible for determining national policy in scientific research fields. | A research institution that promotes research concerning the appraisal of technology and its practical application. | An institution responsible for long-term aerospace research for private and military use. | A research institution that specializes in the research, development, and use of nuclear science and technology. |
| Research fields | Its main research fields include biodiversity, the environment and oceans, food security, agriculture and animal husbandry, and health and pharmaceuticals. | The development and application of biocompatible materials, energy-related materials, composite materials, and nanomaterials. | Aerospace research related to the private sector and the military. | The research, development, and use of nuclear science and technology. |
| Facilities | Approx. 47 | Approx. 9 | Unknown | 3 |
| Staff | 3,934 | 3,124 | 1,246 | Unknown |
| Approach to sharing (before integration) | Open | Open | Open | Open |
| Scope of sharing (before integration) | All researchers, including those from the private sector. Provided equipment sharing and testing services. | All researchers, including those from the private sector. Mainly testing services. | Same as left | Same as left |

(Created by authors based on public information on each institution)

## 3.4 Survey of major shared research facilities

The team carried out interviews at the former LPNK LIPI, the Indonesian Center for Agricultural Biotechnology and Genetic Resources Research and Development (Balai Besar Penelitian dan Pengembangan Bioteknologi dan Sumber Daya Genetik Pertanian (BB Biogen)) which fell under the Ministry of Agriculture, and the Faculty of Medicine, Universitas Indonesia (UI), gaining an overview of each facility and surveying the current state of affairs. As noted above, many of BRIN's rules and systems use LIPI as a base. Thus, the team confirmed how LIPI operated in the past, and what changes are being made with its integration into BRIN. There are numerous research facilities under the LIPI umbrella, but within LIPI the Biotechnology Centre (its name was changed to the Integrated Genomic Facility with the BRIN integration) is noted to be a typical LIPI facility, and this was the facility interviewed. On the other hand, BB Biogen is a research institution that received its budget from the Ministry of Agriculture and operated based on its own policies. It is in the middle of its integration into BRIN, and the team confirmed how it offered shared use functions in the past, and how this is changing with the BRIN integration. In the case of UI, there is no policy support for shared research facilities, but the university as a whole is shifting to become more open. The team confirmed the background to this and current initiatives.

While the representatives of LIPI had felt changes from integration with BRIN, they recognized that no major changes had taken place regarding research equipment and policy for shared use. On the other hand, the representatives of BB Biogen took a positive stance, as they had been operating based on ambiguous rules, including their budget, and now budgets are being set in an optimal manner and they are operating based on clear rules. The integration of public research institutions is a massive project, and those involved are aware that feasibility and the time needed until it is realized are issues.

### 3.4.1 Integrated Genomic Facility (former LIPI Biotechnology Centre)

Purpose of establishing facility

The Biotechnology Centre was a research facility set up under LIPI in 1986. LIPI has five departments (earth sciences, life sciences, engineering, social sciences and humanities, and scientific services); the Biotechnology Centre's research area of biotechnology fell under the life sciences. The following are its five biotechnology research themes:

- Molecular biological foods (pharmaceuticals, plant biotechnology supporting energy security)
- Bioprocess engineering
- The development of health biology products
- The development of pharmaceuticals based on biological resources from the seas and the land
- Animal biotechnology (breeding, nutritional genome information science, animal health science, etc.)

With LIPI's integration into BRIN, the Biotechnology Centre has become the Integrated Genomic Facility (in the process of transitioning).

Assignment of personnel for facility operations

The Integrated Genomic Facility has around 170 researchers, who are all full-time staff. On the other hand, technicians and assistants, etc. are employed as circumstances require based on the allocated budget. Staff are recruited from the general public, and the main hires are new graduates from universities, etc.

Before the integration into BRIN, LIPI researchers were also responsible for its facilities. However, there are now dedicated personnel in the Research and Innovation Infrastructure Department, which oversees facilities within BRIN, and these personnel manage the facilities and equipment.

Fostering human resources associated with facility operations and the use of equipment

When it comes to learning how to use equipment, the equipment vendors provide training opportunities when the equipment is supplied, etc. (especially in the case of high-value equipment). Moreover, a prerequisite for equipment use is that only researchers and technicians who fully understand how to use that piece of equipment may do so.

Current state of equipment (major research equipment)

As this institution integrates into BRIN and becomes the Integrated Genomic Facility, it is in the process of purchasing some new equipment. Its main research equipment is listed below (in no particular order):

・Cryo-electron microscope (Thermo Fisher Scientific (US); in progress)
・Next generation sequencers (NGS) (Illumina (US); Miseq and Novaseq)
・HRMS (Luminex (US))
・IRMS
・EAM
・ICPMS
・TOC
・FT-IR
・Cell Imaging Multimode Reader (Agilent (US); BioTek Cytation 5)
・HPLC
・Droplet Digital PCR
・Fluorometer
・LC/MS
・GC/MS

There is an obligation for information concerning facilities and research equipment to be published on ELSA, BRIN's platform, and anyone can check this. However, the standard operating procedures and establishment of fees are still under consideration, so the facility information on the platform is limited.

When procuring new equipment, the people responsible for research and innovation infrastructure in BRIN ask researchers for ideas for equipment to procure. The researchers who want to obtain equipment write the reason that the equipment is needed and propose the merits of obtaining it, and if these are acknowledged the equipment is purchased for shared use. When it is procured, researchers cannot specify the manufacturer or model; they only write the necessary specifications. Based on this content, BRIN's representatives make an open appeal to vendors, and first-phase and second-phase reviews are carried out. They do refer to researchers' opinions when selecting a vendor. Moreover, in addition to superficial pricing, they also consider factors such as maintenance costs and whether it is possible to use non-original consumables, and finally BRIN's Research and Innovation Infrastructure Department makes a decision. Equipment maintenance is generally carried out by the vendor that supplies the equipment.

Form and scope of sharing

LIPI had a fully open policy before its integration with BRIN. As facilities that fall under the BRIN umbrella all follow a policy of openness, the research equipment of the Integrated Genomic Facility is also open access.

The scope of sharing is such that all researchers from research institutions, universities, and private companies, both within and outside of Indonesia, can use its equipment. However, some expensive equipment and equipment that is difficult to use is offered in the form of testing services.

The ratio of facility users is split fairly evenly between internal researchers and external users. The main external users are university researchers, graduate students, private companies, and researchers from foreign research institutions that are engaged in joint research.

Developing rules for shared use

In the past, rules were determined by each institution (LIPI, BPPT, etc.) and facility, but from now on BRIN will unify the set rules. This is an ambiguous area due to the current period of transition.

Under the policy of fair equipment use for all users, it is necessary for every user to book equipment usage through ELSA, regardless of their affiliation (or lack thereof) with the facility. Users from organizations outside of BRIN must pay a usage fee set by BRIN for each piece of equipment when they use it. The usage fees have been set to cover equipment maintenance costs and operator personnel costs. Meanwhile, BRIN researchers are assigned ELSA points each year, and pay to use equipment with those ELSA points. Researchers can also gain extra ELSA points by publishing papers and undertaking joint research.

Amount of money given and income/expenditure

The facility budget for the Integrated Genomic Facility is around 200 billion IDR over two years. The team were not able to find a breakdown of facility costs, but they did find that in another facility, the Biosafety Laboratory, around 60% of the budget was used in connection with equipment.

Facility operation Key Performance Indicators (KPI)

From the perspective of shared research facilities, the usage rate of equipment is expected to exceed the set ratio in the facility's third year; in the fourth year, the expectation is that income from shared use will cover equipment maintenance fees, with no funding assistance from the Ministry of Finance.

However, research outcomes are a major KPI for LIPI, and high target values have been set for each facility and researchers, including the number of papers mentioned below. LIPI research outcomes are unconnected to the shared use of equipment, and research outcomes achieved via shared use are not counted as KPI.

Implementation of personnel exchanges

・Webinars introducing new research equipment

Webinars that invite experts to introduce new facility equipment are held periodically as one of BRIN's initiatives. These seminars are open to external researchers as well as BRIN members.

・Annual report (webinar)

Activity reports are given each year, and include reports on research outcomes and equipment maintenance, etc. In the past, people associated with the facility and close researchers were invited; the event has moved online as a result of COVID-19 so more people can participate, offering an opportunity to learn about the facility.

・Assistance for joint research

One of the assistance programs provided by BRIN is conditional upon being engaged in joint research with a BRIN researcher. Applicants can be researchers from universities or research institutions as well as from the private sector, and assistance is provided for up to seven years. Exchanges also occur through this program and others like it.

Research outcomes as seen from patents and papers

The following are the facility's research targets for 2021. The team were unable to confirm accurate outcomes, but these targets were mostly met. In addition, as stated above, these targets have no connection to shared use. Examples of papers are shown below.

・Papers in Indonesia: 150; international papers: 50
・Patents: 15; licensed patents: 2
・Technology for practical application: 15
・Number of paper citations: 1,000

**Table 3-5: Representative examples of papers from the Integrated Genomic Facility (former LIPI Biotechnology Centre)**

| Title | Authors | Year published | Publisher | Number of citations |
|---|---|---|---|---|
| Efficacy, toxicity study and antioxidant properties of plantaricin E and F recombinants against enteropathogenic Escherichia coli K1.1 (EPEC K1.1) | Ellen Lindi Lathifah Hanny, Apon Zaenal Mustopa, Sri Budiarti, Huda Salahudin Darusman, Ratih Asmana Ningrum & Fatimah | 2019 | Molecular Biology Report | 9 |
| Development of Higher Molecular Weight of Recombinant Human Interferon Alpha-2a by Albumin Fusion Technology in Methilotropic Yeast Pichia Pastoris | Ratih Asmana Ningrum, Neng Herawati, Andri Wardiana | 2017 | International Journal on Advanced Science, Engineering and Information Technology | 4 |

(Created by the authors based on Google Scholar. Information accurate as of March 31, 2022)

Issues associated with facility maintenance and operations

In Indonesia, all public research institutions are being integrated into BRIN, but as there is a huge number of these, there are concerns about the appropriate management of facilities and equipment, and whether full optimization is possible.

Moreover, integration into BRIN is currently underway, and there are many unclear areas with regard to the process of integration; the assumption is that the integration of facilities and installations will take time, as will the standardization and development of rules.

From the perspective of the shared use of equipment, there will be operational variation according to the equipment; there will be equipment that is well used and equipment that is not used as much. A situation might arise in which it is hard to book the well-used equipment. Consequently, adjustment is needed for urgent projects to ensure that there is one piece of equipment for use in special cases. This kind of adjustment will require those involved to discuss the situation and obtain agreement before using the equipment, rather than simply making a booking on the system.

### 3.4.2 Indonesian Center for Agricultural Biotechnology and Genetic Resources Research and Development (BB Biogen)

Purpose of establishing facility

BB Biogen was established in 2004 as a research organization belonging to the Agency for Agricultural Research and Development, under the umbrella of the Ministry of Agriculture. It has six research labs, which are expected to produce technological innovation for agriculture using biotechnology.

- Seed Quality Testing Lab
- In-Vitro Conservation Lab
- Chemistry and Biochemistry Lab
- Microbiology Lab
- Cell and Tissue Biology Lab
- Molecular Biology Lab

BB Biogen is in the process of integrating with BRIN. Although there is no clear decision yet, the idea that the research facility will be integrated into BRIN but departments with practical functions will be absorbed by the Ministry of Agriculture is being considered.

There were no clear rules concerning shared use in BB Biogen, but if a request was received from a university or other organization, the facility would allow the shared use of equipment, and carry out testing services on request. However, as BB Biogen is currently undergoing an integration process with BRIN, discussions are underway concerning all equipment being open access in accordance with BRIN policy, similar to other facilities under the BRIN umbrella.

Assignment of personnel for facility operations

As of 2020, there were a total of 149 people in the organization; they can be broken down into:

- Researchers: 67
- Technicians: 23
- Operators: 56
- Other: 3

Fostering human resources associated with facility operations and the use of equipment

When it comes to learning how to use equipment, the equipment vendors provide training opportunities when the equipment is supplied, etc. However, there is no particular training other than this. If a researcher, etc. is using an expensive piece of equipment such as an NGS, the facility will confirm they have sufficient experience.

Current state of equipment (major research equipment)

The facility's main equipment is listed below (in no particular order). All of the facility's equipment is to be made available on the ELSA platform in accordance with BRIN's policy, but as this is a transitional period the information available is limited.

- Next-generation sequencer (NGS) (Illumina (US); NextSeq 2000)

・Real-time PCR
・Centrifuge (Eppendorf (Germany); Centrifuge 5810)
・UV irradiation system (Biorad (US); Chemidoc EQ)
・Spectrophotometer (Biorad (US); Smartspec Plus Biorad)

The budget for purchasing new research equipment has come from the Ministry of Finance. Proposals arrive suddenly, rather than on an annual basis. When a proposal arrives, the facility creates an internal list of desired equipment and submits this in order of precedence. What is purchased depends on the budget. Equipment is generally used until it breaks, but if there are no spare parts and/or it cannot be repaired, or it needs to be switched with another piece of technology based on research objectives, then it will be replaced. For example, the PCR the facility possessed was not capable of high resolution, so it was replaced with the real-time PCR recently.

Form and scope of sharing

Before integration with BRIN, the facility offered shared use of equipment on request from universities and research institutions based on the idea of open access. However, as it didn't make any large-scale declarations of shared use, external users made up around 5% of users, with the majority being internal users. Foreign researchers also made use of equipment, but were few in number, with researchers from Korean research institutions engaged in joint research making use of facilities and equipment.

On the other hand, after integration into BRIN, all equipment information will be available on the ELSA platform to comply with BRIN policy, and anyone will be able to use the system and book equipment.

Developing rules for shared use

There were no clear rules in the past. External users who hoped to use equipment would apply to BB Biogen, indicating their wish to use its equipment. They would get internal approval based on this, and be able to use it. When external users made use of equipment, there would always be someone present to supervise. There was no price list, and in many cases equipment use was free. The facility would also provide testing services on request. For example, a seed germination test would be carried out for 35,000 IDR per sample.

After integration with BRIN, the facility will follow BRIN' s policy and so applications will be processed through the ELSA platform, with set prices for the use of equipment.

Amount of money given and income/expenditure

The budget is a grant from the Ministry of Finance. Amounts relating to facility operation are not disclosed.

Facility operation KPI

There were no clear rules in the past, and shared use of equipment occurred in accordance with requests, so there were no KPI. Once the facility has transitioned to operations under BRIN, it will be possible to set some KPI, but at present no particular decisions have been made.

Implementation of personnel exchanges

There are no initiatives to encourage shared use, but the facility does carry out initiatives for the creation of opportunities for joint research and to improve capabilities. The following are examples of this:

・BB Biogen Seminars

Every month, researchers present the details of their research, exchanging knowledge with researchers from other research institutions and creating a foundation for joint research. This has moved online due to the effects of COVID-19, more researchers can now participate from a wider area.

・Sending researchers to other countries

The facility sends researchers overseas to improve their capabilities and/or achieve post-doctoral qualifications.

Research outcomes as seen from patents and papers

As a research institution, the facility' s KPI (2021) are as follows. As stated above, these have no relation to shared use. KPI are generally met.

・Papers in Indonesia: 60

・International papers: 25

・Patents: 5

Representative research projects and the details thereof

Typical project themes are as follows. Examples of major papers are given in the table below.

・Crop breeding

・Fundamental science projects, such as genome analysis

・Genetic engineering

**Table 3-6: Examples of representative papers from BB Biogen**

| Title | Authors | Year published | Publisher | Number of citations |
|---|---|---|---|---|
| Nucleotide Variations of Gamma Ray-Irradiated ChiliPepperMutant Genotypes Based on Gene-Specific PrimersRelated to Fruit Size Character | Kristianto Nugroho, Trikoesoemaningtyas Trikoesoemaningtyas, Muhamad Syukur, Puji Lestari | 2021 | Jurnal Agro Biogen | n/a |
| Genetic Analysis of Chili PepperM2 Population from Gamma Irradiation Treatment Based on Morphological Characters | Kristianto Nugroho, Trikoesoemaningtyas, Muhamad Syukur, dan Puji Lestari | 2021 | Jurnal Agronomi Indonesia | n/a |

(Created by the authors based on Google Scholar. Information accurate as of March 31, 2022)

Issues associated with facility maintenance and operations

The budget is inadequate, and it is hard to say that enough research equipment is maintained. Moreover, there is also research equipment for which the facility is not providing the normal required maintenance. The reason is unclear, but the value of equipment purchased by BB Biogen and reagents are expensive when compared to research institutions overseas. Due to the price of reagent costs, there are cases in which it is cheaper for researchers to outsource testing rather than do it themselves. In addition, as noted above, the rules and processes for equipment development and maintenance were not clear, and it was not straightforward to procure new equipment.

There is an expectation that the above issues will be solved once the facility is integrated into BRIN and its policies are standardized. Equipment with value will be procured and maintained at this facility, and shared use of this will engender advantages not only for the facility itself but also for related institutions.

### 3.4.3 Faculty of Medicine, Universitas Indonesia (UI)

Purpose of establishing facility

UI is a completely self-governed national university representative of Indonesia, which also puts effort into research with the aim of becoming an interdisciplinary research hub within Asia. As stated above, in Indonesia the role of universities lies largely in education rather than research, but UI has around 65 research facilities. The Faculty of Medicine is focusing its efforts on research in particular, which has three major research institutions:

- Indonesia Medical Education and Research Institute: This consists of a nine-story two-tower building; one tower serves as the research building, the other as the education building;
- Cardiovascular Research Center: A facility that specializes in cardiovascular diseases;
- In the Depok City Science Techno Park: In addition to the Faculty of Medicine, other research facilities, including those of UI' s Faculty of Pharmacy, are located here.

The institutions listed above permit the use of facilities and equipment by external users, but this is not supported by policy; as a national university with advanced research equipment, there is a strong sense that UI provides research environments for researchers from other institutions to make effective use of its equipment.

This report summarizes the content of interviews with a focus on initiatives for shared use in the Cardiovascular Research Center, which falls under the jurisdiction of the head of the research and education section of UI' s Faculty of Medicine, who acted as an interviewee.

Assignment of personnel for facility operations

The staff of the Cardiovascular Research Center under the jurisdiction of the interviewee consist of the following:

- Cardiovascular physicians: 30
- Researchers studying for their doctorate: 15
- Foundational researchers in molecular biology: 5
- Statisticians: 2

As the researchers act as technicians and handle research equipment themselves, there are no technicians who are solely responsible for equipment management and operation.

Fostering human resources associated with facility operations and the use of equipment

Training associated with the use of research equipment is generally provided by the equipment manufacturer, and there are no training programs or education programs run by the facility. However, researchers are required to obtain and renew GCP (Good Clinical Practice).

Current state of equipment (major research equipment)

The main research equipment of the Cardiovascular Research Center is listed below (in no particular order). Information concerning the equipment currently possessed by the Center is not publicly available on its website, etc.

- Next generation sequencer (Illumina (US); NextSeq 550)
- Real-time PCR (Bio-Rad (US); CFX96)
- Real-time PCR (PCRmax (UK); Eco48 Real Time PCR)
- Cell imaging (Agilent Technologies (US); BioTek Cytation1)
- Multimode spectrophotometer (Agilent Technologies (US); BioTek Instrument- Synergy H1MF)
- FT-IR (Thermo Fisher Scientific (US); Nicolet iS50 FTIR + NIR spectrometer)
- Ultraviolet visible-near infrared spectrophotometer (Thermo Fisher Scientific (US). NanoDrop On)
- GC/MS (YL Instrument (Korea); GCMS YL6900)

Form and scope of sharing

The Cardiovascular Research Center's shared use policy is based on open access. However, it is not open to everyone who want to make use of its facilities/equipment. People who wish to make use of these apply to the Cardiovascular Research Center via email, stating the content of their research and the equipment they wish to use. The Center checks the content of the application, and decides whether to permit the use of its facilities. Many applications have been granted in cases in which the research field is one upon which the Center is focused. There are no restrictions on researchers, so even researchers affiliated with foreign institutions and researchers from the private sector are given permission (or not) based on the same application process. UI's Faculty of Medicine is close to Kobe University's School of Medicine, and extends invitations to professors of Kobe University. There are cases of Japanese researchers using equipment in this facility. All new applications are subject to appropriate review.

The research facilities in the science park are striving to systematically promote open shared use. More specifically, they have set up a portal site, similar to BRIN's ELSA platform, and are building a system that will introduce shared equipment online as well as allow users to book equipment via the system.

Developing rules for shared use

There are basic rules for use, and external researchers, etc. who want to use the Center's facilities and equipment must pay a set fee. The fees differ depending on the user. Researchers and students who are affiliated with UI can generally use facilities and equipment free of charge, and students from other universities can use them at prices that are less than the standard cost.

If an external user is using equipment, they must do so under the guidance of a researcher who is a member of the Cardiovascular Research Center.

Amount of money given and income/expenditure

Income from the shared use of facilities and installations in the Cardiovascular Research Center is not clear, nor is it high. In addition, if equipment is needed in research facilities such as the Center, the university must produce a proposal for the Ministry of Finance detailing the usage aims of the equipment and the outputs it will produce. The research achievements of UI's Faculty of Medicine have been acknowledged, so the majority of equipment requested in the past has been provided.

<u>Facility operation KPI</u>

No KPI are set with regard to the shared use of facilities or equipment at the Cardiovascular Research Center.

<u>Implementation of personnel exchanges</u>

To ensure that the university's facilities and equipment, including those of the Faculty of Medicine, are used more effectively, UI is promoting initiatives to ensure they are open to outside users, etc. Typical examples include announcing information concerning the equipment in the Science Techno Park on a portal site, and constructing a mechanism that allows external users to make bookings easily.

In terms of exchange from the perspective of research, the university is proactively driving joint research in and outside of Indonesia. When it comes to foreign countries, it is engaged in joint research with many Japanese universities in particular. Moreover, it actively runs exchange programs for researchers and students, including programs with Japan.

<u>Research outcomes as seen from patents and papers</u>

As noted above, when it comes to the shared use of facilities and equipment there is a strong sense that UI is providing research environments for researchers from other institutions to make effective use of its installations; there is no proof of research outcomes from shared use.

<u>Representative research projects and the details thereof</u>

The Center is considering producing catheters locally, as a unique initiative. Promoting national production of medical equipment and medical consumables is important for the development of the medical industry. Currently, most of the catheters used in UI are made by Terumo, in factories in Vietnam, and are then imported to Indonesia. The Center is focusing on this issue via industry-academia collaboration through companies and institutions in Indonesia and other countries.

<u>Issues associated with facility maintenance and operations</u>

Whether a researcher is able to engage in shared use in the Cardiovascular Research Center is judged based on their application; the facility does not have the issue of equipment being over-used so that internal researchers cannot use it. Moreover, it has a secure budget for the purchase and maintenance of research equipment, so there is no awareness of any major issues.

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# 4 Country Survey: Malaysia

## 4.1 Basic information on science and technology policies

Malaysia is a relatively developed country in ASEAN, with a GDP per capita of around 10,400 USD (2020). Policies and systems connected with science and technology in Malaysia fall under the jurisdiction of the Ministry of Science, Technology and Innovation (MOSTI). In 2021, MOSTI's overall budget was 4.2% higher than the previous year, coming to 935 million MYR, with around 17% of this being used for research and development, experiments, and similar activities. Its GERD (Gross Expenditure on R&D) as a percentage of GDP is approximately 1% (2018); in 2010, the breakdown of research and development spending saw the most allocated to the natural sciences (58%), but in 2018 the largest area was engineering and technology (36%), revealing a shift in fields of investment.

Malaysia's long-term policy concerning science and technology is based on the National Science, Technology and Innovation Policy (Dasar Sains, Teknologi dan Inovasi Negara (DSTIN)) 2021–2030. DSTIN 2021–2030's vision is "a sustainable, inclusive and scientific society towards a high-tech nation," with the mission of "driving inclusive & sustainable development through the development and application of progressive STIE [Science, Technology, Innovation and Economy]." To achieve its vision and mission, the government has set the following six "thrusts":

・Responsive STI governance;
・Technology development through R&D and C&I;
・Local technology-based industry;
・Adaptive STI talent;
・Enculturation and application of STIE;
・Global prominence.

To achieve the DSTIN 2021–2030 vision, the government has also established the 10-10 Malaysian Science, Technology, Innovation and Economy Framework (10-10 MySTIE). This framework raises the idea of applying 10 science and technology drivers to 10 economic sectors, as shown below. The government has also announced that they would determine a research roadmap based on this framework, but this has not been made public as of this report.

**Table 4-1: 10-10 MySTIE Framework's science and technology drivers and economic sectors**

| Science and technology drivers | Economic sectors |
|---|---|
| 1. 5G/6G | 1. Energy |
| 2. Sensor technology | 2. Business & financial services |
| 3. 4/5D-printing | 3. Culture, arts & tourism |
| 4. Advanced materials | 4. Medical & healthcare |
| 5. Advanced intelligent systems | 5. Smart technology & systems (next-generation engineering and manufacturing) |
| 6. Cyber-security & encryption | 6. Smart cities & transportation |
| 7. Augmented analytics & data discovery | 7. Water & food |
| 8. Blockchain | 8. Agriculture & forestry |
| 9. Neuro technology | 9. Education |
| 10. Bioscience technology | 10. Environment & biodiversity |

(Created by the authors based on 10-10 MySTIE)

## 4.2 Policy/funding survey

From the perspective of the maintenance and development, etc. of advanced research equipment, the Malaysian Science and Technology Information Centre (MASTIC), which falls under MOSTI, offers diverse funding programs. This report introduces the CREST R&D Grant and Research Acculturation Collaboration Effort (RACE).

CREST R&D Grant

・Overview: A grant program to encourage research cooperation between universities and industry, to enable technological development in the electrical and electronics industry. Research carried out in universities through this cooperation is utilized for the development of industry. The government covers up to half of the necessary costs.
・Funding organization: A board of directors made up of representatives from relevant academic societies and government bodies.
・Eligibility: This grant was started for research in Penang, but is now expanding across the whole area.

RACE

・Overview: A grant program to improve the research capabilities of non-research universities that partner research universities. Raises the level of research at non-research universities and in so doing encourages technological innovation.
・Funding organization: Ministry of Higher Education (MOHE).
・Eligibility: University research facilities, excluding those of research universities, and researchers.

The Malaysian Science and Technology Information Centre (MASTIC), which falls under the MOSTI umbrella, is spearheading the country's science and technology policy concerning shared use. MASTIC manages research exchanges, equipment and facility management, and funding on a platform known as KRSTE. My, which is made up of five modules. This platform forms a foundation for solutions to science and technology issues, and ensures the comprehensive management of (1) research organizations and research facilities in the country, (2) research personnel, (3) equipment owned by registered institutions, (4) research themes, and (5) information concerning commercialization. Checking this platform enables users to confirm the equipment owned by each research institution and whether it is available for shared use. The key information of each module is shown below.

(1) STI Organization

Collects information about research organizations and research facilities in the country that are registered as facilities that allow shared use, and users can confirm information such as institution names, facility names, addresses, contact details, and research fields.

(2) MyHRSTI

Accumulates information about researchers engaged in research and development in government institutions, public and private research institutions, higher education institutions, and non-governmental institutions in Malaysia, allowing users to check their names, affiliated organizations, positions, contact details, research fields, achievements, papers, etc.

(3) National Scientific Facilities and Equipment (NSFE)

NSFE is a system to encourage the sharing of facilities and equipment among the research community. NSFE gathers information on the equipment of registered research institutions, allowing researchers to use this system to check which shared research facility possesses the equipment they need and apply to use it. Moreover, the government and research institutions can avoid procuring duplicates of equipment by checking the state of equipment at nearby facilities. The information registered on NSFE is:

- Facilities: Facilities that carry out R&D activities, including research laboratories, monitoring centers, and testing institutions
- Equipment: Equipment and installations worth at least 100,000 MYR used for research, analysis, education, experiments, investigations, etc.
- Details: Costs associated with shared use of equipment, services provided, technological advisory services, etc.

Public research institutions and public higher education institutions are required to register their information on NSFE. However, MASTIC is encouraging private research institutions and similar organizations to participate in KRSTE. My to ensure more effective and efficient use of facilities and equipment.

(4) R&D Project Bank

This has been accumulating information on science and technology innovation projects since the Eighth Malaysia Plan. Moreover, information regarding ongoing research and development is updated regularly by the organizations and researchers involved, and users can check research outcomes and progress.

(5) Technology Market (TECHMart)

A system that encourages the transfer of technology to the private sector, enabling private business operators to search for installations and technology in which they are interested by accessing the database.

The KRSTE. My platform was developed in 1994 as a database to manage science and technology facilities and research equipment. Since its development, its functions have gradually increased, and it is now a system that encompasses information on public institutions, researchers, facilities and equipment, projects, and patents.

## 4.3 State of development based on policies, etc.

As noted above, Malaysia's public research institutions and public higher education institutions are managed by a platform called KRSTE. My, and are registered as shared research facilities on NSFE.

In accordance with MASTIC's policy, there are 85 facilities registered as shared research facilities on NSFE, including public research institutions, public universities, technical colleges, and hospitals. A list of registered facilities is shown below.

Table 4-2: List of shared research facilities in Malaysia registered on NSFE (in no particular order)

| NO | Name of facility | Category |
|---|---|---|
| 1 | AGENSI ANGKASA MALAYSIA (MYSA) | Research institution |
| 2 | AGENSI NUKLEAR MALAYSIA (ANM) | Research institution |
| 3 | INNO BIOLOGICS SDN BHD | Research institution |
| 4 | INSTITUT PENYELIDIKAN DAN KEMAJUAN PERTANIAN MALAYSIA (MARDI) | Research institution |
| 5 | INSTITUT PENYELIDIKAN HIDRAULIK KEBANGSAAN MALAYSIA (NAHRIM) | Research institution |
| 6 | INSTITUT PENYELIDIKAN PERHUTANAN MALAYSIA (FRIM) | Research institution |
| 7 | INSTITUT PENYELIDIKAN PERIKANAN (FRI) | Research institution |
| 8 | INSTITUT PENYELIDIKAN PERIKANAN (FRI-BINTAWA SARAWAK) | Research institution |
| 9 | JABATAN KIMIA MALAYSIA (KIMIA) | Research institution |
| 10 | MALAYSIAN BIOECONOMY DEVELOPMENT CORPORATION SDN BHD (BIOECONOMY) | Research institution |
| 11 | MIMOS BERHAD | Research institution |
| 12 | NATIONAL INSTITUTES OF BIOTECHNOLOGY MALAYSIA (NIBM) | Research institution |
| 13 | TENAGA NASIONAL BHD (TNB-RESEARCH) | Research institution |
| 14 | INFRASTRUCTURE UNIVERSITY KUALA LUMPUR (IUKL) | Higher education institution |
| 15 | INTERNATIONAL MEDICAL UNIVERSITY (IMU) | Higher education institution |
| 16 | MALAYSIA UNIVERSITY OF SCIENCE AND TECHNOLOGY | Higher education institution |
| 17 | POLITEKNIK KUCHING SARAWAK (POLIKU) | Higher education institution |
| 18 | POLITEKNIK MERLIMAU MELAKA (PMM) | Higher education institution |
| 19 | POLITEKNIK MUKAH SARAWAK (PMU) | Higher education institution |
| 20 | POLITEKNIK PORT DICKSON (POLIPD) | Higher education institution |
| 21 | POLITEKNIK SULTAN HAJI AHMAD SHAH (POLISAS) | Higher education institution |
| 22 | POLITEKNIK TUANKU SULTANAH BAHIYAH (PTSB) | Higher education institution |
| 23 | POLITEKNIK UNGKU OMAR (PUO) | Higher education institution |
| 24 | UNIVERSITI ISLAM ANTARABANGSA MALAYSIA (IIUM) | Higher education institution |
| 25 | UNIVERSITI KEBANGSAAN MALAYSIA (UKM) | Higher education institution |
| 26 | UNIVERSITI KUALA LUMPUR (UNIKL) | Higher education institution |
| 27 | UNIVERSITI MALAYSIA PAHANG (UMP) | Higher education institution |
| 28 | UNIVERSITI MALAYSIA PERLIS (UNIMAP) | Higher education institution |
| 29 | UNIVERSITI MALAYSIA SARAWAK (UNIMAS) | Higher education institution |
| 30 | UNIVERSITI MALAYSIA TERENGGANU (UMT) | Higher education institution |
| 31 | UNIVERSITI MONASH MALAYSIA (MONASH) | Higher education institution |
| 32 | UNIVERSITI PENDIDIKAN SULTAN IDRIS (UPSI) | Higher education institution |
| 33 | UNIVERSITI PERTAHANAN NASIONAL MALAYSIA (UPNM) | Higher education institution |
| 34 | UNIVERSITI PUTRA MALAYSIA (UPM-IBS) | Higher education institution |
| 35 | UNIVERSITI SAINS ISLAM MALAYSIA (USIM) | Higher education institution |
| 36 | UNIVERSITI SAINS MALAYSIA (USM-PULAU PINANG) | Higher education institution |
| 37 | UNIVERSITI TUN HUSSEIN ONN MALAYSIA (UTHM) | Higher education institution |
| 38 | UNIVERSITI UTARA MALAYSIA (UUM) | Higher education institution |
| 39 | TECHNOLOGY PARK MALAYSIA (TPM) | Technology park |
| 40 | JABATAN MINERAL DAN GEOSAINS MALAYSIA (JMG) | Other |
| 41 | JABATAN PERTANIAN SARAWAK (DOA) | Other |
| 42 | LEMBAGA KOKO MALAYSIA (LKM) | Other |
| 43 | LEMBAGA PERLESENAN TENAGA ATOM (LPTA) | Other |
| 44 | PLANETARIUM NEGARA (PLANETARIUM) | Other |
| 45 | PUSAT DARAH NEGARA (PDN) | Other |

| NO | Name of facility | Category |
|---|---|---|
| 46 | HOSPITAL ALOR GAJAH | Hospital |
| 47 | HOSPITAL BENTONG | Hospital |
| 48 | HOSPITAL BETONG | Hospital |
| 49 | HOSPITAL DALAT | Hospital |
| 50 | HOSPITAL DUNGUN | Hospital |
| 51 | HOSPITAL JASIN | Hospital |
| 52 | HOSPITAL JELEBU | Hospital |
| 53 | HOSPITAL JEMPOL | Hospital |
| 54 | HOSPITAL JENGKA | Hospital |
| 55 | HOSPITAL KANOWIT | Hospital |
| 56 | HOSPITAL KINABATANGAN | Hospital |
| 57 | HOSPITAL KOTA TINGGI | Hospital |
| 58 | HOSPITAL KUALA PENYU | Hospital |
| 59 | HOSPITAL KUDAT | Hospital |
| 60 | HOSPITAL LIMBANG | Hospital |
| 61 | HOSPITAL MERSING | Hospital |
| 62 | HOSPITAL PAKAR SULTANAH FATIMAH MUAR | Hospital |
| 63 | HOSPITAL PEKAN | Hospital |
| 64 | HOSPITAL PITAS | Hospital |
| 65 | HOSPITAL PORT DICKSON | Hospital |
| 66 | HOSPITAL QUEEN ELIZABETH | Hospital |
| 67 | HOSPITAL RAUB | Hospital |
| 68 | HOSPITAL SARIKEI | Hospital |
| 69 | HOSPITAL SIBU | Hospital |
| 70 | HOSPITAL SIPITANG | Hospital |
| 71 | HOSPITAL SULTANAH AMINAH | Hospital |
| 72 | HOSPITAL SULTANAH HAJJAH KALSOM CAMERON HIGHLANDS | Hospital |
| 73 | HOSPITAL SUNGAI BULOH | Hospital |
| 74 | HOSPITAL TAIPING | Hospital |
| 75 | HOSPITAL TAMPIN | Hospital |
| 76 | HOSPITAL TANAH MERAH | Hospital |
| 77 | HOSPITAL TANJONG KARANG | Hospital |
| 78 | HOSPITAL TENGKU AMPUAN AFZAN | Hospital |
| 79 | HOSPITAL TUANKU AMPUAN NAJIHAH KUALA PILAH | Hospital |
| 80 | HOSPITAL TUARAN | Hospital |
| 81 | HOSPITAL UMUM SARAWAK | Hospital |
| 82 | KPJ DAMANSARA SPECIALIST HOSPITAL | Hospital |
| 83 | MOUNT MIRIAM CANCER HOSPITAL | Hospital |
| 84 | PANTAI HOSPITAL IPOH | Hospital |
| 85 | SUNWAY MEDICAL CENTRE | Hospital |

(Created by the authors based on public information on KRSTE. My)

## 4.4 Survey of major shared research facilities

The team interviewed a total of four institutions: three public research facilities registered on NSFE, and one national university, gaining an overview of each facility and surveying the current state of affairs.

### 4.4.1 National Applied R&D Centre (MIMOS)

Purpose of establishing facility

MIMOS is an institution that operates on a government budget; it has multiple facilities under its umbrella, each with advanced research equipment, and these are also open to university researchers and researchers from private companies. One of the aims of the Centre is to provide a good quality research environment to researchers who are unable to access advanced research equipment or advanced precision equipment.

Assignment of personnel for facility operations

According to KRSTE. My, the number of personnel associated with this facility and its equipment operations in February 2022 was:

・Engineers: 50

・Research officers: 12

Fostering human resources associated with facility operations and the use of equipment

There are no training programs or systems for equipment operation or equipment use.

Current state of equipment

The Centre's major research equipment is shown in the table below. It is MIMOS' responsibility to maintain the equipment it owns. However, some equipment was purchased jointly with companies or other research institutions. This equipment is under shared management.

**Table 4-3: Representative facilities and equipment for shared use (in no particular order)**

| Facility name | List of equipment |
|---|---|
| FAILURE ANALYSIS & MATERIAL ANALYSIS | ・3D X-RAY<br>・ATOMIC FORCE MICROSCOPY (AFM)<br>・ATOMIC FORCE MICROSCOPY AND RAMAN<br>・AUGER ELECTRON SPECTROSCOPY (AES)<br>・CHEMICAL DECAPSULATOR (DECAP)<br>・CONFOCAL MICROSCOPE<br>・CRYO ULTRA MICROTOME<br>・DIGITAL MICROSCOPE<br>・DUAL BEAM (DB)<br>・ELECTRON ENERGY LOSS SPECTROSCOPY (EELS)<br>・ENERGY DISPERSIVE SPECTROSCOPY (EDS)<br>・FIELD EMMISSION SCANNING ELECTRON MICROSCOPE (FESEM - Hitachi High-Tech Corporation)<br>・FIELD EMMISSION SCANNING ELECTRON MICROSCOPE (FESEM - JEOL )<br>・FOURIER TRANSFORM INFRARED SPECTROSCOPY (FTIR)<br>・GAS CHROMATOGRAPHY - MASS SPECTROMETRY/MASS (GCMS-MS)<br>・HALL EFFECT<br>・HIGH POWER CURVE TRACER (CT)<br>・IC BACKSIDE POLISHER<br>・INDUCTIVELY COUPLED PLASMA MASS SPECTROMETRY (ICPMS)<br>・ION POLISHER<br>・LASER DECAPSULATOR (DECAP)<br>・MECHANICAL POLISHER<br>・NANOINDENTER AND MICROINDENTER WITH SURFACE PROBE MICROSCOPY (SPM)<br>・OPTICAL BEAM INDUCED RESISTANCE CHANGE (OBIRCH)<br>・PHOTON EMMISSION MICROSCOPE (PEM)<br>・PRECISION ETCHING COATING SYSTEM (PECS)<br>・REAL TIME X-RAY<br>・SURFACE PROFILER<br>・THERMAL EMMISSION MICROSCOPE (THERMAL IMAGING)<br>・TOF SECONDARY ION MASS SPECTROMETRY (TOF-SIMS)<br>・TRANSMISSION ELECTRON MICROSCOPE (TEM)<br>・UV-VIS-NIR<br>・X-RAY PHOTOELECTRON SPECTROSCOPY (XPS) |
| APPEARANCE DESIGN & MECHANICAL MODELLING | ・3D PRINTER (FDM)<br>・3D SURFACE SCANNER<br>・SLS RAPID PROTOTYPING MACHINE |
| WAFER LEVEL TESTING | ・AUTO PROBER<br>・AUTO WAFER PROBER<br>・DC PARAMETRIC TESTER<br>・DIAMOND 10 FUNCTIONAL TESTER<br>・POWER DEVICE TESTER |
| RELIABILITY SERVICE | ・FREE FALL DROP TESTER<br>・HAST/AUTOCLAVE TEST CHAMBER (PRESSURE COOKER) |

| Facility name | List of equipment |
|---|---|
| IC DESIGN - SYSTEM BACKEND REALIZATION | ・BOUNDRY SCAN INSERTION<br>・CIRCUIT SIMULATOR<br>・IC DESIGN ANALOG DESIGN ENVIROMENT<br>・IC DESIGN ANALOG DESIGN ENVIROMENT XL TIER<br>・IC DESIGN CALIBRE ADVANCED DEVICE PROPERTIES<br>・IC DESIGN EXTRACTION TOOL<br>・IC DESIGN FLOOR PLANNER<br>・IC DESIGN HDL COMPILER TOOL<br>・IC DESIGN INCISIVE ENTERPRISE SIMULATOR XL TIER<br>・IC DESIGN LAYOUT DESIGN ENVIROMENT GXL TIER<br>・IC DESIGN LAYOUT DESIGN ENVIROMENT L TIER<br>・IC DESIGN LAYOUT EDITOR<br>・IC DESIGN LAYOUT EXTRACTION<br>・IC DESIGN LAYOUT VERIFICATION<br>・IC DESIGN LAYOUT VERSUS SCHEMATIC CHECKER XL TIER<br>・IC DESIGN LOGIC SYNTHESIS TOOL<br>・IC DESIGN MULTI-MODE SIMULATOR<br>・IC DESIGN PHYSICAL VERIFICATION<br>・IC DESIGN PLACE AND ROUTE<br>・IC DESIGN PLATFORM FOR VERIFICATION AND EXTRACTION<br>・IC DESIGN POWER SYNTHESIS<br>・IC DESIGN RTL FUNCTIONAL VERIFICATION<br>・IC DESIGN RTL SYNTHESIS<br>・IC DESIGN RULE CHECKER XL TIER<br>・IC DESIGN SCHEMATIC EDITOR<br>・IC DESIGN SCHEMATIC EDITOR L TIER<br>・IC DESIGN SCHEMATIC VERILOG INTERFACE<br>・IC DESIGN STATIC TIMING AND POWER ANALYSIS TOOL<br>・IC DESIGN TIMING ANALYSIS TOOL<br>・IC DESIGN VERILOG SIMULATOR<br>・IC DESIGN VHDL COMPILER TOOL<br>・MEMORY BUILD IN SELF-TEST<br>・SCAN TEST INSERTION<br>・SILICON-PROVEN IP |
| IC DESIGN - CHARACTERIZATION & PRODUCTION | ・3D LASER SCANNING<br>・AUDIO PRECISION<br>・HTC VIVE VIRTUAL REALITY SYSTEM<br>・LECROY MOTOR ANALYZER<br>・SEMICONDUCTOR DEVICE ANALYZER<br>・SPECTRUM ANALYZER - |
| WIRELESS TECHNOLOGY & SYSTEM DESIGN LAB | ・AGILENT E5071C, ENA SERIES NETWORK ANALYZER, 9kHz - 8.5GHz<br>・CMW500, WIDEBAND RADIO COMMUNICATION TESTER<br>・N5242A, PNA-X NETWORK ANALYZER, 10MHz - 26.5GHz<br>・N9030A, PXA SIGNAL ANALYZER, 3Hz - 26.5GHz<br>・R&S CMW100, WIRELESS COMMUNICATION TEST SET |
| MIMOS LABORATORY | ・PS-Provision of Hellosoft GPRS Protocol (402000820) |

| Facility name | List of equipment |
|---|---|
| NOT ATTACHED TO ANY FACILITY | ・CLIMATIC TEST CHAMBER (TEMPERATURE/HUMIDITY)<br>・CLIMATIC TEST CHAMBER (TEMPERATURE/HUMIDITY) + VIBRATION TEST SYSTEM<br>・HIGH TEMPERATURE OVEN<br>・PS_Layout Parasitics Extraction Software PS-Synopsys Formality Functional Equivalence Check<br>・RAIN SIMULATION CHAMBER (LIGHT/HEAVY/BLOWING)<br>・Real Time X-Ray<br>・SALT SPRAY TEST CHAMBER<br>・SMART SCOPE (3D MEASURING EQUIPMENT)<br>・SOLAR RADIATION SIMULATION CHAMBER (XENON WEATHER OMETER)<br>・TENSILE TEST SYSTEM<br>・THERMAL SHOCK TEST CHAMBER<br>・VIBRATION TEST SYSTEM (3-AXIS SHAKER) |

(Created by the authors based on public information on KRSTE. My)

Form and scope of sharing

The Centre has ensured the shared use of its facilities and equipment from its foundation. More specifically, it provides equipment sharing and testing services, including for external parties. There are no limits to the scope of its sharing; researchers in Malaysia can use its facilities, as can researchers who are members of Japanese universities.

Developing rules for shared use

There are no particular rules and anyone can apply to use equipment, etc. via NSFE. However, users must adhere to the rules of common sense. These assume that users understand how to use the equipment in question. If a license is required to handle equipment, the user must hold that license.

Usage fees are only disclosed to those who wish to use equipment, etc., but use is offered at inexpensive rates for public benefit purposes.

Amount of money given and income/expenditure

Funding for equipment maintenance and development and facility operation is mainly from the government, but the details have not been made public. Moreover, as this is a public institution, there is no real concept of income and expenditure.

Facility operation KPI

No specific KPI have been set for the Centre, including for shared use, but contribution to the five-yearly science policy program determined by the government is important. There is also an awareness that the Centre plays a key role in supporting the government as an R&D center, for example by developing new technologies and strengthening collaboration with stakeholders.

Implementation of personnel exchanges

The Centre does not hold events or carry out initiatives to encourage shared use, but those concerned with fostering research personnel are as follows:

・MIMOS Strategic Training. Advancement and Recognition (M*STAR)

This was introduced in 2007, and makes it possible to convert work history into credits at MIMOS, and to obtain graduate or specialist qualifications and receive compensation through the patent indemnity system. Moreover, based on their work history, participants can apply for financial support to engage in higher education or for programs to prove their capabilities.

・CATS (Centre of Advance Technical Skills)

This facility provides web application program development courses for graduates of public polytechnics (technical colleges). Graduates can attend diverse software engineering courses provided by MIMOS, which enable them to build up experience before they launch their careers.

・Internships

These programs aim for undergraduate, master's, and doctoral students to gain practical experience in the ICT field at MIMOS. Students participate in MIMOS' internal projects via their internship, and can gain practical and learning experiences.

Research outcomes as seen from patents and papers

The Centre does not monitor research outcomes from shared use.

In terms of outcomes as a research institution, the Centre has 2313 international patents, and 236 total published papers (including 2 in the Science Citation Index (SCI)).

Representative research projects and the details thereof

As the Centre is a research institution that covers many fields and themes, it is difficult to select projects that represent it as an organization. It is engaged in diverse projects in a wide range of fields, including renewable energy, EV, palm oil, data analysis, and online solutions.

Issues associated with facility maintenance and operations

Much of MIMOS' research equipment is hardware, and so human hands are needed for many processes—from procurement to installation, maintenance and management. Moreover, while it takes a long time to plan the procurement of research equipment and for it to be installed and introduced, technology is developing at a rapid pace, so the Centre must understand changing technologies and the changing needs of users, and handle this appropriately.

Other

The KRSTE. My platform was constructed by MIMOS. The use rate of KRSTE. My is high in MIMOS, and it gets many applications to use equipment via NSFE. Moreover, 5-10% of MIMOS' income is based on applications for shared use via NSFE.

### 4.4.2 Standard and Industrial Research Institute of Malaysia (SIRIM)

Purpose of establishing facility

The Standard and Industrial Research Institute of Malaysia (SIRIM) is a national research and development institution established in 1975. It has research facilities for each research field, and owns multiple research labs in Malaysia. It aims to contribute to the realization of the policies set down by the national government by supporting advanced research and small- and medium-sized companies.

Its R&D department is divided into nine themes: industrial biotechnology, environmental technology, mechanical technology, bio/natural gas, energy management, nano technology, sensors, biomedical research, and smart manufacturing.

Assignment of personnel for facility operations

According to KRSTE. My, SIRIM had the following personnel involved in research in February 2022.

・Technicians: 106
・Technical executives: 91
・Engineers: 24
・Engineering coordinators: 3
・Measurers: 5

・Researchers: 84
・Research analysts: 19
・Analysis consultants: 11
・Lecturers: 2

Fostering human resources associated with facility operations and the use of equipment

The management and operation of facilities and research equipment is chiefly carried out by researchers.

Current state of equipment (major research equipment)

Research facilities and major research equipment are as follows (in no particular order):

■ Industrial Biotechnology Research Centre
・HPLC
・Laser particle size/distribution analyzer (Beckman Coulter (US); LS100Q)

■ Environmental Technology Research Centre
・GC/MS
・ICP spectrometer
・Ion chromatography
・Mercury analysis equipment
・Element analysis equipment (Elementar (Germany); Vario EL III)

■ Advanced Materials Testing Laboratory
・XRD

Form and scope of sharing

SIRIM normally provides standardized support for companies and testing services. It also ensures its facilities are open and available for shared use to make effective use of its assets, including research equipment.

There are no limits to the scope of its sharing. On top of researchers from universities and public research institutions, people associated with private companies can also make use of its equipment, etc. Researchers who are members of Japanese universities and similar organizations may also use its equipment, etc., and there are past examples of them doing just that.

Developing rules for shared use

When using facilities and equipment, researchers must submit an agreement concerning facility use. The agreement consists of general information, such as the assignment of responsibility in the case of an accident.

Amount of money given and income/expenditure

When obtaining and maintaining research equipment, SIRIM uses its own income, such as that from patents, receiving no grants from the government. Its income and expenditure information has not been disclosed.

Facility operation KPI

There are over 30 KPI associated with facility operation, but none concerning the shared use of equipment such as the operating ratio or user numbers. There is an awareness that staying in the black and the commercialization of research are particularly important KPI.

Implementation of personnel exchanges

As increasing its income and staying in the black are key goals for SIRIM, it carries out a variety of personnel exchanges at both regional and national levels. This includes those with universities and companies. In addition to events held by SIRIM, it also often co-sponsors events held by other institutions. More specifically, it proactively introduces research outcomes to promote commercialization. In recent years, these activities have been centered on webinars.

Research outcomes as seen from patents and papers

Facilities and equipment within this organization have been available for shared use for a long time, so it is difficult to specify information about relevant patents and papers with a focus on shared use. SIRIM's outcomes as an organization are shown below. The top three papers by number of citations are also shown in Table 3-4.

・International patents: 130

・Total published papers: 312; number listed in SCI: 0

Representative research projects and the details thereof

In recent years, biotechnology for industrial use has been a priority area. SIRIM is involved in numerous projects for the development of new cosmetics products—for example, developing products using rambutan skin.

Issues associated with facility maintenance and operations

As an organization, it is important for SIRIM to commercialize its research projects and improve its profitability through successful commercialization; it is not aware of any major issues in terms of shared research facilities and their operation. To achieve commercialization, there is a need to understand market trends, and so SIRIM must obtain the research equipment needed according to trends in a timely manner.

**Table 4-4: Representative examples of papers**

| Title | Authors | Year published | Number of citations | Publication |
|---|---|---|---|---|
| Effects of water absorption on Napier grass fibre/polyester composites | M.Haameem J.A., M.S.Abdul Majida, M.Afendia, H.F.A.Marzuki (SIRIM), E. Ahmad Hilmi (SIRIM), I.Fahmi, A.G.Gibson | 2016 | 77 | Composite Structures |
| Powder injection molding of biocompatible stainless steel biodevices. | Muhammad Aslam, Faiz Ahmad, Puteri Sri Melor Binti Megat Yusoff, Khurram Altaf, Mohd Afian Omar (SIRIM), Randall M.German | 2016 | 42 | Powder Technology |
| Catalytic steam reforming of complex gasified biomass tar model toward hydrogen over dolomite promoted nickel catalysts | Ru ShienTan, Tuan Amran Tuan Abdullah, Saiful Azam Mahmud (SIRIM), Rohaya Md Zin (SIRIM), Khairuddin Md Isa | 2019 | 38 | International Journal of Hydrogen Energy |

(Created by the authors based on RISS. Information accurate as of March 9, 2022)

### 4.4.3 Universiti Malaysia Terengganu (UMT)

Purpose of establishing facility

Universiti Malaysia Terengganu (UMT) is Malaysia's marine research institution, and was established as a research lab under the government. It has been converted to a university, and is engaged in research and education that focuses on fields related to the ocean. Most of the equipment in the university's facilities is available for shared use.

Assignment of personnel for facility operations

UMT has multiple facilities, and equipment in each facility is available for shared use. As staff are present in each facility, the team were not able to accurately grasp the total number of people involved. People connected to facilities are managed in three categories—researchers, users, and managers—but there are some cases in which researchers are categorized as users.

The Central Service Center is responsible for the overall management of shared research facilities. This Center maintains and manages equipment in an appropriate manner, and encourages sharing, with the aim of providing access to advanced research equipment for researchers inside and outside of UMT while keeping costs down. It also hopes to improve the quality of research both in UMT and outside it as a result.

Fostering human resources associated with facility operations and the use of equipment

In the past, UMT had sufficient budget, and so it hired external specialists as staff to manage and operate equipment. However, UMT no longer has that financial leeway, and so it outsources to specialist organizations such as vendors, and internal staff operate equipment with vendor support.

As yet, there are no clear programs or systems to foster human resources associated with facility operations and the use of equipment.

Current state of equipment (major research equipment)

The following is a list of the university's research facilities and the major research equipment installed there (in no particular order).

■ Faculty of Ocean Engineering Technology and Informatics (Fakulti Teknologi Kejuruteraan Kelautan dan Informatik)

・FT-IR
・Benchtop X-Ray Diffractometer（XRD）
・Gas chromatography (GC)

■ Faculty of Fisheries and Food Science (Fakulti Perikanan dan Sains Makanan)

・FT-IR Spectrometer
・ICP-OES (ICP spectrometer)
・HPLC
・Texture Analyzer
・DSC

■ Centre of Research Field Service (Pusat Perkhidmatan Penyelidikan dan Lapangan)

・GC/MS
・HPLC
・Ion chromatography
・Total organic carbon/total nitrogen automatic measuring equipment
・Specific surface area/pore size distribution measuring device
・TGA/DSC

■ Institute of Marine Biotechnology

・FT-IR
・HPLC
・Real-time PCR
・Bioanalysis equipment (PROKARYOTE)
・Bioanalysis equipment (EUKARYOTE)

■ Institute of Tropical Aquaculture and Fisheries

・Automatic particle sampling system

<u>Form and scope of sharing</u>

In terms of the form of sharing, the use of facilities and equipment has been open ever since UMT's establishment. Moreover, with regard to the scope of sharing, its facilities and equipment are open to all, regardless of whether the user is a corporation or individual, and regardless of their nationality. Researchers who are members of Japanese institutions may also make use of UMT's facilities and equipment. There are three sharing methods:

・Shared use of equipment (The cases of use have increased in the last five years. Labs have also been established with the goal of joint research.)
・Provision of testing services
・Borrowing and leasing equipment

Developing rules for shared use

UMT manages its facilities based on ISO17025 (an international standard for joint research and development) and its internal rules and standards.

UMT's internal users are split into the following categories:

- Teaching & Learning (no usage fee): Use of equipment, etc. by UMT students as part of their education.
- R&D (usage fee): Use of equipment, etc. by university researchers for the purpose of research.
- Technology Educator Consultants (usage fee): Staff known as TECs provide support for using equipment and testing support in response to requests from students, researchers, etc.

The university confirms the content of the applications of external users, and evaluates whether they are suitable to be users of its facilities and equipment. Permission to use facilities and equipment is issued if the applicant passes the evaluation (the evaluation standards have not been published). Anyone engaged in joint research with a UMT researcher is considered to be a UMT internal researcher. Usage fees vary according to the research theme, equipment used, and affiliation; there are no clear standards.

Amount of money given and income/expenditure

Around one third of the facility budget is used for facility maintenance and to procure, maintain, and manage research equipment.

Facility operation KPI

UMT's key goals include expanding the services it provides to users while adhering to ISO17025, and making effective use of UMT assets to generate income.

Implementation of personnel exchanges

UMT does not hold seminars or events to promote the shared use of equipment. From the perspective of research, joint research by individual researchers is being carried out, as is joint research with Malaysian universities and international joint research with foreign universities. Notably, there has been an increase in joint research outside of universities since around 2020; in the last five years, the establishment of laboratories and the number of cases of people engaging in shared use of research equipment with the aim of joint research have also increased. On the other hand, exchanges with private institutions are limited.

In the past, UMT received support from JICA to purchase a ship. Exchanges also take place through study abroad programs with universities in Hokkaido and Kyushu, which are strong in marine research.

Research outcomes as seen from patents and papers

The university's facilities and equipment have been available for shared use for a long time, so it is difficult to specify information about relevant patents and papers with a focus on shared use. UMT's outcomes as a university are shown below. The top three papers by number of citations are also shown in the table below.

- International patents: 55
- Total published papers: 5036; 31 of these listed in SCI

**Table 4-5: Representative examples of papers from UMT**

| Title | Authors | Year published | Number of citations | Publication |
|---|---|---|---|---|
| Novel Proton Conducting Solid Bio-polymer Electrolytes Based on Carboxymethyl Cellulose Doped with Oleic Acid and Plasticized with Glycerol. | M. N. Chai & M. I. N. Isa | 2016 | 98 | Scientific Reports |
| Enhanced Capacitance of Hybrid Layered Graphene/Nickel Nanocomposite for Supercapacitors | Norsaadatul Akmal Mohd Zaid & Nurul Hayati Idris | 2016 | 41 | Scientific Reports |
| Opportunistic spawning of tropical anguillid eels Anguilla bicolor bicolor and A. bengalensis bengalensis | Takaomi Arai (UBD), Siti Raudah Abdul Kadir (UMT) | 2017 | 32 | Scientific Reports |

(Created by the authors based on RISS. Information accurate as of March 9, 2022)

Issues associated with facility maintenance and operations

The aging of facilities and equipment is an issue. Due to budget constraints, it is difficult for UMT to maintain existing research equipment, let alone obtain new equipment. As they are facilities that are available for the shared use of research equipment, including for external researchers, these should be maintained so the equipment can be used at any time.

### 4.4.4 Department of Chemistry Malaysia (KIMIA)

Purpose of establishing facility

The Department of Chemistry Malaysia (Jabatan KIMIA Malaysia (KIMIA)) is a technical agency that falls under MOSTI. It was established to provide testing and analysis, quality control and research, and chemical training for public institutions and private companies. It now has offices in 14 states and federal territories, including Kedah, Pulau Pinang, Melaka, and Johor, and mainly provides services in each area. One of this organization's aims is to provide research infrastructure to researchers who are unable to access advanced research equipment, etc., and it offers support for research in different regional facilities.

Assignment of personnel for facility operations

There is a total of around 1,200 staff members in the organization as a whole.

Fostering human resources associated with facility operations and the use of equipment

The training department provides on-demand education to foster human resources. This includes content that covers equipment management and how to use it. The content of the training provided varies depending on the degrees and experience of the participants.

Securing human resources who can handle equipment is an issue, and KIMIA is proactively developing its training programs from the perspective of fostering human resources.

Current state of equipment (major research equipment)

The major research equipment in each facility is listed below.

**Table 4-6: Representative shared research equipment (in no particular order)**

| Facility name | Equipment list |
|---|---|
| BAHAGIAN BIOTEKNOLOGI | DNA SEQUENCER |
| | REAL-TIME PCR |
| BAHAGIAN KRIMINALISTIK | GAS CHROMATOGRAPHY MASS SPECTROMETER |
| | FOURIER TRANSFORM INFRA RED SPECTROPHOTOMETER MICROSCOPE |
| BAHAGIAN NARKOTIK | GAS CHROMATOGRAPHY MASS SPECTROMETER |
| | FOURIER TRANSFORM INFRA RED SPECTROPHOTOMETER (PORTABLE) |
| | FOURIER TRANSFORM RAMAN SPECTROPHOTOMETER (PORTABLE) |
| | GAS CHROMATOGRAPH WITH FOURIER TRANSFORM INFRA RED SPECTROPHOTOMETER |
| | LIQUID CHROMATOGRAPHY-TANDEM MASS SPECTROMETER |
| BAHAGIAN KUALITI AIR | GAS CHROMATOGRAPHY MASS SPECTROMETER |
| BAHAGIAN PENYELIDIKAN DAN KALIBRASI | LIQUID CHROMATOGRAPHY SYSTEM WITH TANDEM MASS SPECTROMETER |
| | GAS CHROMATOGRAPHY MASS SPECTROMETER - LARGE VOLUME |
| | INJECTION SCANNING ELECTRON MICROSCOPY WITH ELECTRON DISPERSIVE X-RAY |
| BAHAGIAN INDUSTRI | FLUORESCENT SPECTROMETER |
| | FOURIER TRANSFORM INFRA RED SPECTROPHOTOMETER (FASTNESS TESTER) |
| | GAS CHROMATOGRAPHY MASS SPECTROMETER |
| BAHAGIAN PEMERIKSAAN DOKUMEN | FOSTER FREEMAN RAMAN SPECTRAL COMPARATOR |
| BAHAGIAN TOKSIKOLOGI | GAS CHROMATOGRAPHY MASS SPECTROMETER |
| | LIQUID CHROMATOGRAPHY TANDEM MASS SPECTROMETER |
| PUSAT LATIHAN KIMIA MALAYSIA | FOURIER TRANSFORM INFRA RED SPECTROPHOTOMETER |
| BAHAGIAN KIMIA MAKANAN | GAS CHROMATOGRAPHY MASS SPECTROMETER |
| | GAS CHROMATOGRAPHY TANDEM MASS SPECTROMETER |
| BAHAGIAN KIMIA ALAM SEKITAR | X-RAY FLUORESCENCE MACHINE |
| | GAS CHROMATOGRAPHY MASS SPECTROMETER |
| | GAS CHROMATOGRAPHY HIGH RESOLUTION MASS SPECTROMETER |
| | FOURIER TRANSFORM INFRA RED SPECTROPHOTOMETER |
| | X RAY DIFFRACTION ANALYZER |
| | X RAY FLUORESCENCE SPECTROMETER |
| | X RAY FLUORESCENCE ANALYZER |
| JKMN JOHOR | GAS CHROMATOGRAPHY MASS SPECTROMETER |
| | DNA SEQUENCER |
| | FOURIER TRANSFORM INFRA RED SPECTROPHOTOMETER |
| | X-RAY FLUORESCENCE SPECTROMETER |

(Created by the authors based on public information on KRSTE. My)

Form and scope of sharing

KIMIA's sharing takes the form of openness. As a nation, Malaysia is promoting the sharing of research equipment. Users must pay a set fee when using equipment.

There are no limits to the scope of sharing; any researcher, including those from public institutions, private companies, domestic institutions and foreign institutions, can access equipment. There are no particular qualifications or conditions for use.

Service requests are the main form of use by researchers, etc. from outside the organization. KIMIA has relatively new and advanced research equipment, but rather than researchers wanting to use it themselves for investigations, there is a greater need for the use of services that produce fast results.

Developing rules for shared use

Government institutions and research institutions that sign an MOU (Memorandum of Understanding) can make use of shared research facilities without any limitations. Moreover, government institutions and public institutions can use equipment free of charge. Meanwhile, other institutions can use equipment after sending an application letter and receiving permission from the institution in question. They must also pay a usage fee based on the price set by the institution in question.

Amount of money given and income/expenditure

This is not public information and cannot be disclosed.

Facility operation KPI

There are no KPI associated with sharing, using, or maintaining research equipment, or any similar activities.

Implementation of personnel exchanges

There are no particular personnel exchanges associated with shared use.

Research outcomes as seen from patents and papers

This is not an institution that is focused on research; its main objective is providing support according to the needs of researchers and companies, so outcomes such as research papers are limited.

Issues associated with facility maintenance and operations

When it comes to research equipment, there is a need to replace aging equipment and procure new equipment, but there is a lack of funding and a lack of personnel, as well as a lack of operational and management know-how, all of which are issues.

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# 5 Country survey: Republic of the Philippines

## 5.1 Basic information on science and technology policies

According to UNESCO statistics data from 2015, GERD (Gross Expenditure on R&D) as a percentage of GDP in the Philippines is small: around 0.2%. On the other hand, there is an awareness of the importance of science and technological development, and at the start of the 2000s, the government established a long-term plan: the National Science and Technology Plan for 2001-2020 (NSTP 2020). NSTP 2020 noted that there was a call for "S&T [science and technology] to be the foundation of future economic development"; the plan also stated the importance of macroeconomic stability with equitable growth based on free enterprise, agriculture, and fisheries modernization with social equity, comprehensive human development, and good governance, as well as noting the research and development (R&D), technology transfer, human resources development, S&T promotion, information dissemination and advocacy, and linkaging or networking needed to achieve this. The goals of NSTP 2020 were:

<u>Developing human resources</u>

- Increasing the number of scientists to 380 per million people;
- Providing various benefits to science and research personnel who return to the country from overseas.

<u>Strengthening relevant infrastructure (R&D contributions, etc.)</u>

- Providing support to enhance R&D capabilities in regional universities (Niche Centers in the Regions (NICER)) based on the Science for Change program;
- Providing research funding in cooperation with the Commission on Higher Education (CHED).

<u>Support for technological innovation</u>

- Ensuring financial support to increase technological capabilities through a support program that enhances the technical capabilities of small- and medium-sized companies (the Small Enterprises Technology Upgrading Program (SETUP));
- Focusing efforts on increasing the number of weather observatories and Doppler radars to innovate technology to prevent natural disasters, and providing programs, etc. to prevent landslides.

NSTP 2020 has finished, and many of its set goals were reached, including a substantial increase in the number of scientists. However, it cannot yet be said that science and technology and research investment levels are adequate, and so the government has established its next long-term plan, AmBisyon Natin 2040, for further science and technology development. When it comes to the state's integrated foundational research agenda, this long-term plan has set healthcare; farming, fisheries, and natural resources; industry, energy, and new technologies; reduced risk of disaster; and adaptation to climate change, etc. as themes in key sectors. Moreover, the following key agendas have been established to realize the AmBisyon Natin 2040 roadmap:

1. R&D for solutions to urgent issues.
2. R&D to improve productivity.
3. R&D to use and manage potential resources.
4. R&D to develop new technology for the national interest.
5. The reduction of climate change and disaster risks.
6. Technology transfer and commercialization using R&D outcomes.
7. Support for the production sector (the manufacturing industry).
8. More advanced facilities and the improvement of science and technology services (strengthening regional infrastructure/facilities/R&D, etc. through funding support).
9. Developing human resources for science and technology.
10. Collaboration with regional areas (collaboration with regional science and technology universities, improving the capabilities of regional science and technology universities).
11. Cooperation between industry, universities, and international institutions (co-laboratories).

In the Philippines, basic plans are established by the Department of Science and Technology (DOST), which is responsible for implementing and overseeing science and technology policy. DOST executes 20–30% of the government's total budget for R&D. Departments other than DOST have their own, separate research budgets, including the Department of Trade and Industry (DTI), Department of Agriculture (DA), Department of Health, Department of Environment and Natural Resources (DENR), and Department of Transportation and Communications (DOTC); they promote science and technology through the institutions under their respective umbrellas. Moreover, CHED has functions to draft policies and plans for higher education, and ensures coordination with research and development projects carried out by universities. Specialist schools and universities that carry out research in the Philippines collaborate with committees under the Science and Technology Coordinating Council (STCC) to undertake initiatives based on key research fields in the Philippines. STCC also possesses functions to coordinate between government departments and sectors associated with science and technology activities; its role is to develop programs to solve special science and technology concerns by establishing state coordination councils for different sectors as needed.

## 5.2 Policy/funding survey

DOST's policies regarding advanced research equipment within the Philippines are shown in the table below. There are several funding programs, but when it comes to funding for obtaining and maintaining equipment, it should be noted that there are also programs associated with other government departments in addition to the programs funded by DOST.

**Table 5-1: Policies and programs associated with advanced research equipment**

| Program | Overview | Subsidy amount |
|---|---|---|
| NICER (Niche Centers in the Regions for R&D) | Establishes R&D centers in regions for regional development | USD 1.7 million |
| CRADLE (Collaborative R&D to Leverage PH Economy for RDIs and Industry) | Stimulates R&D through industry-academia-government collaboration (needs private partners) | USD 100,000 per project |
| DOST PCIEERD (Philippine Council for Industry, Energy, and Emerging Technology Research and Development) | DOST PCIEERD's Infrastructure Development Program (IDP) provides support to advance facilities in regional laboratories and research institutions that lack research facilities in particular fields | Unknown |

(Created by the authors based on the content of each program)

Shared research facilities are broadly divided into those associated with DOST and those associated with DTI. The facilities associated with DOST consist of public research institutions and national universities. One designated condition for receiving a subsidy when establishing a new research center or facility with equipment in a university or similar institution is that said center or facility serves as a shared research facility. Regardless of policy support, in many cases equipment owned by public research institutions and national universities is open to other universities and external researchers in accordance with their wishes, and a lot of institutions have become open in a practical sense.

Meanwhile, shared research facilities associated with DTI aim to develop small- and medium-sized companies and strengthen the country's industrial foundation, and consist of facilities that are assumed to create prototypes and carry out experiments to enable small- and medium-sized companies to develop their products and services. These facilities are known as Fablabs/co-working spaces or Shared Service Facility for MSMEs [micro, small and medium enterprises], and maintain the fundamental equipment needed by small- and medium-sized companies. Consequently, there were differences in the specifications and user affiliations of the equipment and facilities surveyed for this report. Since 2013, DTI has spent over 3 billion PHP to operate over 3,000 of these facilities.

## 5.3 State of development based on policies, etc.

The following six facilities are associated with DOST and have publicly declared themselves open to shared use.

**Table 5-2: List of shared research facilities in the Philippines (in no particular order)**

| | Name of facility | Research field |
|---|---|---|
| 1 | University of the Philippines - Visayas | Biology, biotechnology |
| 2 | University of the Philippines - Mindanao | Biotechnology |
| 3 | Industrial Technology Development Institute - Biotechnology Facilities | Biology |
| 4 | Industrial Technology Development Institute - Material Science Facilities | Materials engineering |
| 5 | Industrial Technology Development Institute - Nanotechnology Facilities | Nanoengineering |
| 6 | Advanced Science and Technology Institute | Electrical engineering |

(Created by the authors)

These shared research facilities consist of open facilities and research facilities. Below is an example of a facility overview. The details of the facilities will be given in the next section.

Industrial Technology Development Institute – Material Science Facilities

These are shared research facilities maintained by a public research institution on the assumption they will be subject to shared use; their goals include research and development in the surface engineering and special materials fields, technology transfer, technological support for the world of industry, and the provision of specialist knowledge. In addition to researchers who are members of the research institution, other researchers can also use the equipment and analysis services by paying a set fee.

## 5.4 Survey of major shared research facilities

The team carried out interviews at the Advanced Science and Technology Institute (ASTI) and the University of the Philippines' Philippine Genome Center Visayas and Philippine Genome Center Mindanao, which are public research facilities under DOST, gaining an overview of each facility and surveying their practices.

### 5.4.1 Advanced Science and Technology Institute (ASTI)

Purpose of establishing facility

ASTI is a research institution under DOST, established in 1987. DOST covers seven research fields, and ASTI's research is mainly focused on the fields of electronic materials and digital content.

Assignment of personnel for facility operations

ASTI's staff consists of a total of around 200 personnel; approximately 15 staff members are responsible for its shared facilities.

Fostering human resources associated with facility operations and the use of equipment

The government recognizes the importance of developing human resources who can operate research equipment in an appropriate way, and there are around 20 staff members who specialize in usage support for research equipment and human resources development.

Current state of equipment (major research equipment)

ASTI's major research equipment is listed below, in no particular order:

■ EPDC Lab (PCB testing/manufacturing equipment)

・3D printer

・3D scanner (LMI Technologies (Canada); HDI100 Series)

・3D scanning software (LMI Technologies (Canada))

■ EPDC Lab (electromagnetic compatibility testing equipment)

・EMC testing equipment

■ EPDC Lab (parametric testing equipment)
・Handheld XRF
・Signal analyzer
・Vector signal generator

Form and scope of sharing

Since its foundation, one of ASTI's goals has been to provide good-quality research opportunities and environments for universities and companies that face difficulties obtaining/maintaining advanced research equipment.

With regard to the scope of sharing, ASTI's facilities and equipment may be used for the research objectives of private companies, as well as those of researchers in universities or research institutions. Researchers who are members of foreign research institutions can also make use of them. In the past, joint research with European research institutions was carried out using the equipment in these facilities. More recently, there has been increased use by researchers who are members of private universities. There have also been many cases of use by private operators with regard to electronics testing.

Developing rules for shared use

There are no clear rules, and no set usage fees. Users must contact a representative to apply to use ASTI's facilities. In many cases, a researcher affiliated with a university or similar organization who is using the facilities for academic or research purposes does so without charge. However, if special conditions are required, or the user is a private operator, they pay an appropriate cost. Although there is a fee, the cost is low when compared to the price of outsourcing to a private operator.

Research on high performance computing is also a field of focus, and if there is a need for a researcher to use facilities or equipment for this, a research environment is provided free of charge.

Amount of money given and income/expenditure

The funding to operate ASTI's facilities is entirely obtained via grants from the government. The budget is organized through discussion with the Department of Finance. ASTI's budget in FY2022 is around 8.7 million USD; of this, around half—4.5 million USD—is being spent in connection with facilities (for example facility maintenance and equipment maintenance and development).

Facility operation KPI

ASTI has no KPI as a shared research facility. It is operated based on government budget grants, and so no incentives are provided through achievement. As a research institution, however, ASTI's KPI include proactive international cooperation and the formation of research partnerships, and the number of research papers.

Implementation of personnel exchanges

There are no particular events or programs concerning shared use, but ASTI does exert itself with regard to international joint research, focusing on exchanges between researchers. Among these are many researchers who have obtained their bachelor' s, master' s, or graduate degrees in East Asia, Europe, or elsewhere. With regard to Japan, there are a lot of scholars who visit Hokkaido University.

Research outcomes as seen from patents and papers

ASTI' s research outcomes as an institution are as follows. Although this is unrelated to shared use, a list of representative examples of papers from this institution with high numbers of citations is also included below.

・International patents: 4

・Total papers published: 110

**Table 5-3: Representative examples of papers from ASTI**

| Title | Authors | Year published | Number of citations | Publication |
|---|---|---|---|---|
| Predicting decisions of the philippine supreme court using natural language processing and machine learning | Michael Benedict L. Virtucio, Jeffrey A. Aborot, John Kevin C. Abonita, Roxanne S. Aviñante, Rother Jay B. Copino, Michelle P. Neverida, Vanesa O. Osiana, Elmer C. Peramo, Joanna G. Syjuco, Glenn Brian A. Tan | 2018 | 23 | IEEE(2018 IEEE 42nd Annual Computer Software and Applications Conference (COMPSAC)) |
| Rice Galaxy: an open resource for plant science | Venice Juanillas, Alexis Dereeper, Nicolas Beaume, Gaetan Droc, Joshua Dizon, John Robert Mendoza(DOST-ASTI), Jon Peter Perdon(DOST-ASTI), Locedie Mansueto, Lindsay Triplett, Jillian Lang, Gabriel Zhou, Kunalan Ratharanjan, Beth Plale, Jason Haga, Jan E Leach, Manuel Ruiz, Michael Thomson, Nickolai Alexandrov, Pierre Larmande, Tobias Kretzschmar, Ramil P Mauleon | 2019 | 11 | GigaScience |
| Near-Realtime Flood Detection from Multi-Temporal Sentinel Radar Images Using Artificial Intelligence | R. M. de la Cruz, N. T. Olfindo, Jr., M.M. Felicen, N. J. B. Borlongan, J. K. L. Difuntorum, J. J. S. Marciano, Jr. | 2020 | 3 | ISPRS(Volume XLIII-B3-2020, 2020 \| XXIV ISPRS Congress, Commission III (Volume XLIII-B3-2020)) |

(Created by the authors based on Google Scholar. Information accurate as of March 31, 2022)

Issues associated with facility maintenance and operations

ASTI does not have sufficient budget, and so there are concerns about ensuring the budget for procuring new equipment and maintaining existing equipment. Thus, it cannot be said that the models, specifications, and maintenance of the current research equipment in its facilities are adequate.

Another issue is researchers leaving (changing occupation). There is an awareness of the importance of setting up enriched research environments, etc. not only to gain new researchers but to ensure that current researchers continue their research for a long period of time.

### 5.4.2 University of the Philippines – Philippine Genome Center Visayas (PGC Visayas)

Purpose of establishing facility

The University of the Philippines is a national research university with multiple campuses around the country; of these, four campuses have research centers. These research centers consist of genomics research centers, molecular biology centers, and regional research centers, among others. There are labs that fall under the umbrella of each research center, including labs for materials science, nanotechnology, biology, chemistry, and microbiology. The Philippine Genome Center Visayas (PGC Visayas) was established as a facility in 2019, and offers equipment sharing and testing services not only to researchers who are members of the University of the Philippines, but also to external researchers. The majority of users are researchers in the Visayas area, and the equipment, etc. is used by researchers from around 30 universities.

Assignment of personnel for facility operations

PGC Visayas consists of a total of 27 people. Around three quarters of these are researchers, and besides their research, they are engaged in the general work of operating the Center, including managing facilities and research equipment, training, and providing different types of service. The remaining quarter are administrative staff.

Fostering human resources associated with facility operations and the use of equipment

There is a training department within the Center, which provides training on the use of research equipment. This training is split into introductory training and practical training, and provided in accordance with the proficiency levels of the people who are going to use the research equipment.

Current state of equipment (examples of equipment for shared use)

PGC Visayas' major research equipment is listed below, in no particular order:

・Automatic sampling equipment for cells, etc. (Thermo Fisher Scientific (US); Kingfisher Duo Prime)
・Bioanalyzer (Agilent Technologies (US))
・Flow cytometer (Thermo Fisher Scientific (US); Attune NxT)
・Real-time PCR (Bio-Rad (US); CFX96 Touch)

Form and scope of sharing

PGC Visayas accepts funding for the benefit of the public from governmental funding institutions on the condition that its facilities have shared usage functions. The concept of sharing equipment owned by a university is a general one, and so ensuring PGC Visayas has shared usage functions was not a hurdle.

There are no limits to the scope of sharing. The facilities and equipment are mainly used by national public universities and governmental institutions within the country, but are available for all researchers, including those from private universities, private research institutions, and foreign universities.

Developing rules for shared use

As stated above, all researchers can make use of the Center's facilities. However, there are usage fee categories—generally an MOU that sets out specific conditions of use is signed and documented in advance to ensure that inexpensive usage fees (special fees) are applied to a university or research institution. After this agreement is signed, the user submits their application, including the details of their research and the equipment they expect to use. Based on this application, researchers are given training in advance on how to use the equipment. Users of the facility are obligated to undergo this training.

The fees for shared use and testing services are inexpensive compared to other institutions. If an MOU is signed, further discounts are applied.

Amount of money given and income/expenditure

PGC Visayas is given around 100 million PHP, and around 7.5% of this is used to purchase, maintain, manage, and operate facility research equipment.

PGC Visayas' income/expenditure is in the red. However, this Center was established in 2019 and so is comparatively new, meaning that this is not currently considered to be a major issue. PGC Visayas has most recently prioritized the construction of relationships with research partners. Nonetheless, it is important that its accounts move into the black in the medium and long term.

Facility operation KPI

KPI related to the shared use of equipment include the number of MOUs signed with universities and other organizations making use of shared research facilities, and the number of clients the Center secures, such as private companies using testing services.

However, very little time has passed since the Center was established, and currently there are more debates about the satisfaction of the researchers using the Center than about achieving KPI. PGC Visayas is surveying the satisfaction levels of researchers using its facilities, working to understand users' opinions and carrying out initiatives to make improvements.

Implementation of personnel exchanges

PGC Visayas has no direct initiatives, but DOST has a foreign exchange system; it invites foreign researchers and provides affiliated researchers with experiences in institutions overseas.

Outside of the above program, joint research is being carried out with foreign universities at the level of individual researchers—an example of the creation of a network between PGC Visayas and foreign institutions.

Research outcomes as seen from patents and papers

As PGC Visayas was established in 2019, it has not yet achieved any major outcomes.

Representative research projects and the details thereof

As stated above, the Center has not realized any clear outcomes. It is working on research concerning variations of COVID-19 together with the Philippines' Insurance Commission and national research institutions, and the team anticipates that this will become representative research.

Issues associated with facility maintenance and operations

PGC Visayas' budget for purchasing and maintaining research equipment cannot be said to be adequate, and its top issue is acquiring funding. Another issue is obtaining and training experienced technicians who can handle newly added equipment.

### 5.4.3 University of the Philippines – Philippine Genome Center Mindanao (PGC Mindanao)

Purpose of establishing facility

The Philippine Genome Center Mindanao of the University of the Philippines (PGC Mindanao) is also an omics research center, similar to PGC Visayas. In addition to engaging in research as a center, it was established to provide a research environment for researchers and organizations in need of research infrastructure. External researchers and others can use its facilities and equipment by signing an MOU with PGC Mindanao.

Assignment of personnel for facility operations

PGC Mindanao has approximately 10 regular staff members; managers are assigned to each piece of equipment and are responsible for overseeing the equipment in question. Research staff are hired from outside the Center as needed in accordance with the characteristics of its research projects. Research staff are considered to be irregular members of staff.

Fostering human resources associated with facility operations and the use of equipment

Equipment training is provided for undergraduates so they can learn how to use the equipment. Researchers who are engaged in joint research with PGC Mindanao and other facility users may participate in these programs if they wish to.

Similar to PGC Visayas, equipment users must attend training in advance.

Current state of equipment (major research equipment)

PGC Mindanao's major research equipment is listed below, in no particular order.

・Next-generation sequencer (NGS) (Illumina (US); NextSeq 1000)
・Next-generation sequencer (NGS) (Illumina (US); iSeq 100)
・DNA sequencer (Thermo Fisher Scientific (US); SeqStudio)
・Real-time PCR (Thermo Fisher Scientific (US); QuantStudio)
・Flow cytometer

Form and scope of sharing

PGC Mindanao was established as a facility, and one of its aims is to share its research infrastructure with the area. There are no limits to the scope of sharing, but its equipment is mainly used by Filipino universities, research centers, and government institutions (agricultural, biotechnology, etc.) It is open to researchers who are members of private companies or foreign research institutions, but the effects of COVID-19 have caused its use by foreign researchers to decline sharply.

If a researcher wants to use PGC Mindanao's facilities and research equipment, their affiliated institution must sign an MOU or a contract concerning research cooperation with PGC Mindanao.

Developing rules for shared use

With regard to the application process to use PGC Mindanao's facilities, after the MOU, etc. is signed, the person who wants to use the facilities must send an application form to and obtain permission from the person in charge of PGC Mindanao (its director); the form includes their research goals, an overview, and information on the research equipment, etc. required. Applications are generally sent by email, but there are no particular restrictions, so it is possible to apply by speaking to the director face-to-face.

The signing of an MOU is the basic condition for the use of facilities and research equipment, but PGC Mindanao does sometimes receive requests to use equipment to handle short-term research projects or to create reports. In these cases, researchers can use the equipment without an MOU, but this is not the norm.

When it comes to rules of use, there are safety regulations for the facility as a whole, which must be observed. In addition, there are rules of use for each piece of equipment, and so researchers must attend an explanation of these rules from the manager of the equipment and ensure they are followed.

Amount of money given and income/expenditure

This differs every year, but in the first half of this year PGC Mindanao received around 30 million PHP. If there are no unusual fluctuations, it will receive the same amount in the second half of the year. Around 10% of the money received is used to purchase and maintain research equipment. Very little time has passed since the Center was established, so its expenses are large compared to its income from external use.

Facility operation KPI

PGC Mindanao's KPI have not been made public, but its major aims are as follows:

・To contribute to the nation's focus fields for research and to undertake research projects;
・To foster and produce the researchers of the future;
・To work with many different researchers by sharing the Center's infrastructure.

Implementation of personnel exchanges

There are no particular exchanges, but vendors regularly hold training for equipment, and staff are sent to these sessions.

Research outcomes as seen from patents and papers

・International patents: 0; Total papers published: 3
・The top three papers by number of citations are shown below.

**Table 5-4: Representative examples of papers from PGC Mindanao**

| Title | Authors | Year published | Number of citations | Publication |
|---|---|---|---|---|
| Pilot Fecal DNA Barcoding on Selected Fruit Bats in Davao City, Philippines | Michael G. Bacus (PGC-Mindanao), Sammer C. Burgos, Hannah G. Elizagaque, Kameela Monique A. Malbog, Mae A. Responte, Lief Erikson D. Gamalo (PGC-Mindanao), Marion John Michael M. Achondo, and Lyre Anni E. Murao (PGC-Mindanao) | 2021 | 2 | Philippine Journal of Science |
| Critical factors influencing biotech corn adoption of farmers in the Philippines in relation with the 2015 GMO Supreme Court ban | Clarisse M.Gonzalvo, Ma. Stella C.Tirol, Mildred O.Moscoso, Nelson J.V.B.Querijero, Wilson F.AalaJr. (PGC-Mindanao) | 2020 | 3 | Journal of Rural Studies |
| Genome-based local dynamics of canine rabies virus epidemiology, transmission, and evolution in Davao City, Philippines, 2018-2019 | Michael G.Bacus (PGC-Mindanao), Sheryl Grace C.Buenaventura, Allan Michael C.Mamites, Hannah G.Elizagaque, Christian C.Labrador (PGC-Mindanao), Frederick C.Delfin, Ma. Noreen J.Eng, Arlene P.Lagare Gloria N.Marquez, Lyre Anni E.Murao (PGC-Mindanao) | 2021 | 1 | Infection, Genetics and Evolution |

(Created by the authors based on RISS. Information accurate as of March 30, 2022)

<u>Issues associated with facility maintenance and operations</u>

There are issues with acquiring government funding that can be used to purchase equipment. Compared to its sister facilities on the main island, PGC Mindanao has a poorer budget and equipment, so there is a desire to enrich its facilities and equipment as joint infrastructure.

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# 6. Country survey: Republic of Singapore

## 6.1 Basic information on science and technology policies

The Republic of Singapore (Singapore) has no resources, and science and technology have traditionally been acknowledged as the keys to national success and survival. The National Science and Technology Board (NSTB) was established in 1991, and launched the first five-year National Technology Plan; in January 2002, NSTB was renamed the Agency for Science, Technology and Research (A*STAR). A*STAR's mission is to develop Singapore's science, technology and engineering capabilities to promote economic growth in the country, and it is assigned some of the National Science and Technology Plan budget to achieve this. The Research, Innovation and Enterprise Council (RIEC) was set up in 2006, taking over the function of drafting the strategic direction of national research and development. Moreover, the National Research Foundation (NRF), also set up in that same year (2006), was established as a funding institution that coordinates between relevant institutions and provides capital for strategic research and development initiatives, with the goal of realizing the national research strategy set by the RIEC.

The Research, Innovation and Enterprise Plans (RIE) created every five years serve as guidelines to promote a knowledge-intensive economy led by innovation, with the aims of building a strong base of scientists, engineers, and technicians; promoting economic and corporate change; and creating economic value chains. Currently, activities are being developed in accordance with RIE2025 (2021–2025).

Singapore's science and technology investment has a limited budget; to make maximum use of this, the country emphasizes practicality as an output. Thus, priority areas are decided based on whether they will lead to future promotion of industry, whether there is a possibility of creating high-added-value employment, and similar considerations. The government's basic policy is to provide concentrated research funding as an incentive, and, at the same time, ensure policy support to encourage investment from foreign-funded companies and excellent human resources. As a result, their presence has been established in areas such as the biomedical and electronics fields, and both industry promotion and job creation have become a reality.

There are also cases in which needs and opportunities not anticipated in the national science and technology plans have suddenly become apparent as a result of the rapidly changing business environment and evolution of technology. To deal with these opportunities, the government has incorporated a White Space funding framework in its investment plans, making it possible to respond rapidly when new priority matters arise. Examples of this include the use of White Space funding for cybersecurity and investment in the production of foodstuffs to improve the degree of self-reliance.

The priority issues of Singapore's national science technology plans and changes in priority investment fields are shown in the table below.

**Table 6-1: Changing national science and technology plans/Research, Innovation and Enterprise plans**

| | National Technology Plan 1995 | Science and Technology plan 2000 | Science and Technology plan 2005 | Science and Technology plan 2010 | Research, Innovation and Enterprise 2015 | Research, Innovation and Enterprise 2020 | Research, Innovation and Enterprise 2025 |
|---|---|---|---|---|---|---|---|
| Period of plan | 1991-1995 | 1996-2000 | 2001-2005 | 2006-2010 | 2011-2015 | 2016-2020 | 2021-2025 |
| Total R&D investment | 2 billion SGD | 4 billion SGD | 6 billion SGD | 13.5 billion SGD | 16 billion SGD | 19 billion SGD | 25 billion SGD |
| Priority issues | ・Promoting research that focuses on output | ・Attracting R&D centers of multinational corporations<br>・Fostering human resources that can support R&D centers | ・Fostering human resources in Singapore and securing global human resources<br>・Promoting industry-academia collaboration through cooperation with A*STAR and EDB | ・Supporting corporate R&D activities<br>・Strengthening industry-academia collaboration<br>・Developing capabilities for research-intensive/autonomous universities | ・Investing in basic research for future innovation<br>・Attracting and fostering human resources<br>・Strengthening competitive funding<br>・Specializing in research that is likely to produce economic results and strengthening industry-academia collaboration through support for technology transfer | ・Creating jobs by continuing research and development in accordance with industrial needs, and creating high-added-value products and services<br>・Continuing cooperative relationships to deepen collaboration with industry | ・Expanding capabilities to tackle a broader spectrum of national needs and enhance Singapore's competitive advantage in the long term<br>・Producing large numbers of excellent researchers by supporting basic research<br>・Supporting deep technology research to launch and commercialize emergent technologies |
| Priority investment fields | ・Manufacturing technology<br>・ICT<br>・Electronics<br>・Materials<br>・Energy | Same as left | ・Biomedical added | ・Environment and water added<br>・ Digital media added | ・Electronics<br>・Biomedical sciences<br>・ICT<br>・Engineering<br>・Clean tech | ・Advanced manufacturing and engineering<br>・Health and biomedical sciences<br>・Services and digital economy<br>・Urban solutions and sustainability | ・Manufacturing, trade, and connectivity<br>・Human health and potential<br>・Urban solutions and sustainability<br>・Smart nation and digital economy |

(Created by the authors based on national science and technology plans/ Research, Innovation and Enterprise plans)

In the most recent plan, RIE2025, there are no changes in policies for concentrated funding for strategic fields that aim to create new growth opportunities in light of national needs and future issues. On the other hand, there are some researchers who have raised doubts concerning research and investment policies that are too skewed toward utilitarianism; RIE2025 also includes points concerning handling a wider range of research needs and strengthening basic research.

Based on RIE2025, the Singapore government's R&D investment should be around 1% of its annual gross domestic product (GDP) between 2021 and 2025. The aim is to realize 25 billion SGD of R&D investment during the period covered by the plan by making the most of the outcomes of government investment incentives. The amount Singapore spends on R&D increases each year; the breakdown is generally 60% private and 40% public. The amount of R&D investment from the government is increasing as a proportion of total R&D spending.

On the other hand, looking at investment in assets, including research equipment, the team found that in about 2010 the amount spent was over 10% of R&D investment, but since 2017 it has stayed in the range of around 7%. Although the amount of R&D investment is increasing, asset investment is not changing a great deal, so the proportion of asset investment is decreasing as a percentage of the whole.

An overview of RIE2025 and its different statistics are shown in the figures below.

[Overview of RIE2025]

**RIE2025**

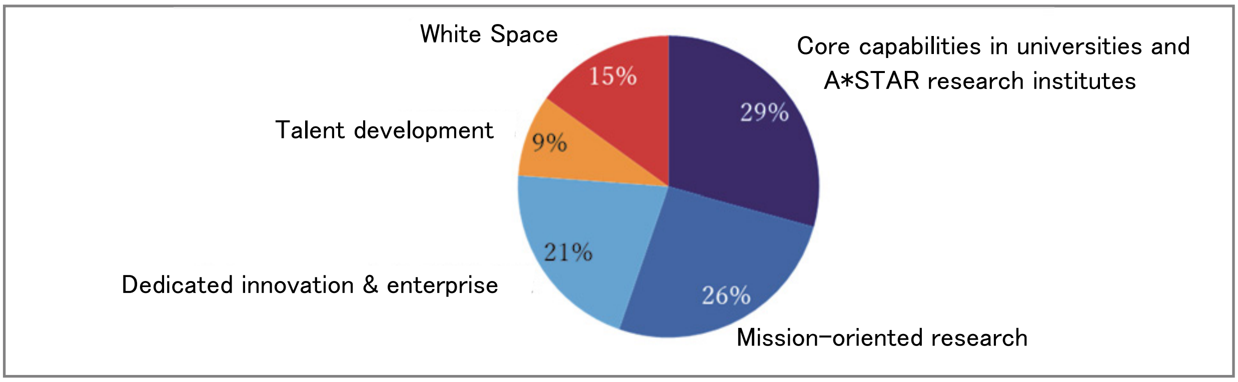
| Manufacturing, trade, and connectivity | Human health and potential | Urban solutions and sustainability | Smart nation and digital economy |
|---|---|---|---|
| Strengthen Singapore's position as a global business innovation hub for advanced manufacturing and connectivity through research and development. | Transform and protect health, advance human potential and create economic value for Singapore. | Revitalize and build a city that is livable, resilient, sustainable and economically vibrant for the future. | Develop technology leadership to drive Smart Nation ambitions and reinforce Singapore' s position as a trusted digital innovation hub. |

**Academic research**
Construct a robust research base and research hubs of international excellence

**Research manpower**
Develop a research talent pipeline for strong research and innovation

**Innovation and enterprise**
Accelerate corporate innovation

[Breakdown of the RIE2025 investment plan]




[Changes in Singapore' s research and development costs and facility investment]

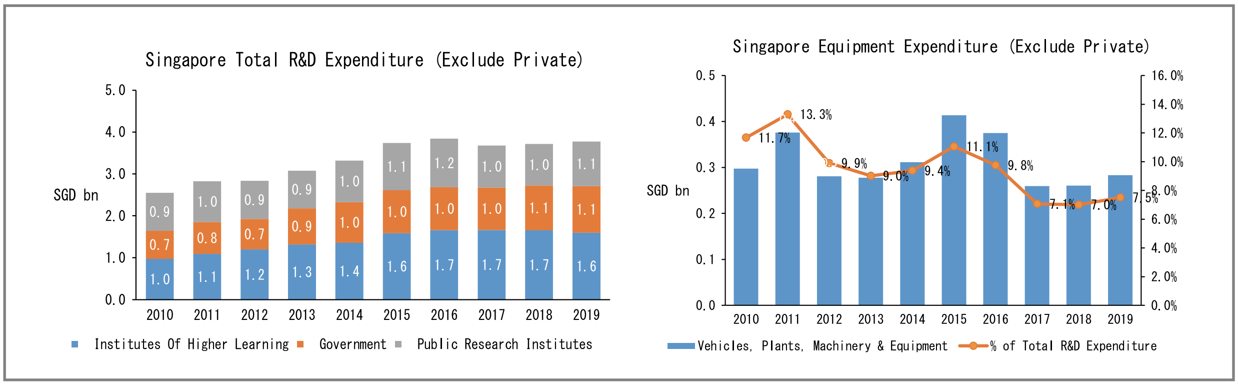



**Figure 6-1: Overview of RIE2025**
(Created by the authors based on RIE2025 and data from the Department of Statistics, Singapore)

## 6.2 Policy/funding survey

There are three broad categories for obtaining and maintaining advanced research equipment: equipment installations that make use of the independent budgets of universities and public research institutions, equipment installations based on funding obtained by researchers, etc., and equipment installations based on money received from the private sector.

The first of these, equipment installations that make use of the independent budgets of universities and public research institutions, refers to the six autonomous universities in Singapore and research institutions that fall under A*STAR; these each possess research facilities. Although the autonomous universities fall under the Ministry of Education, they are responsible for their own independent management, and obtain and maintain research equipment based on their own efforts in accordance with university strategy, maintaining facilities through collaboration with other public institutions, private institutions, and organizations. The research institutions under A*STAR obtain and maintain equipment in a similar fashion. In some cases, facilities with advanced research equipment, especially those with versatile equipment, are open to external researchers and to private institutions, as well as to researchers within the same organization. As this equipment is obtained from contributions arising from the organization's own efforts, they are not forced to make the equipment openly available by the government or a funding institution, but each institution independently ensures that its facilities are open from the perspective of giving back to the local community and promoting collaboration with other institutions.

The second category is equipment installations based on funding obtained by researchers, etc. Some funding institutions, including NRF, run large-scale grant programs. Researchers, etc. can make use of these programs and utilize part of their costs for equipment. The basic approach to budget allocation means that it is divided between programs derived from the four areas set out in RIE2025. Each program accepts public applications and allocates its grant money to promising research. Some grant programs do not generally publicize information, so it is difficult to grasp the details of each program and their budgets from public information. Examples of programs with elements covering advanced research equipment are given in the table below. Policies and programs associated with shared facilities are explained in the next section.

**Table 6-2: Examples of programs associated with advanced research equipment**

| | Research Centres of Excellence | Mid-sized Grants | National Medical Research Council Centre Grant |
|---|---|---|---|
| Funding institution | National Research Foundation | Same as left | National Medical Research Council Centre |
| Goals | To create Research Centres of Excellence (RCE) on an international level in universities to spur research excellence. | To consolidate research activities across departments, faculties and universities to create a critical mass of leading researchers in strategic research areas for Singapore | To provide funding support to public healthcare institutions/clusters to build up their core research capabilities in terms of common research platforms, shared resources and core manpower to enhance their collaborative and transdisciplinary research productivity in achieving progress towards the RIE2025 goals. |
| Overview of program | Carries out world-class investigator-led research aligned with the long-term strategic interests of Singapore<br>・Attract, retain and support world-class academic investigators;<br>・Train quality research manpower;<br>・Create new knowledge in the specific areas of focus of each centre. | Same as above | Encourages collaboration and coordination of research efforts across the different healthcare entities focusing on the same area of research to disseminate research findings for the benefits of the community. |
| Period of funding | Unknown | 10 years (CA2DM) | 4 years |
| Institutions in receipt of grants | ・Earth Observatory of Singapore (EOS)<br>・Centre for Quantum Technologies (CQT<br>・Cancer Science Institute of Singapore (CSI)<br>・Mechanobiology Institute (MBI Singapore)<br>・Singapore Centre for Environmental Life Sciences Engineering (SCELSE)<br>・Institute for Functional Intelligent Materials (I-FIM) | ・Centre for Advanced<br>・Singapore Centre for<br>・Singapore Hybrid-Integrated Next-generation μ Electronics Centre | ・Memory Ageing and Cognition Centre<br>・Saw Swee Hock School of Public Health<br>・Khoo Teck Puat Hospital<br>・Singapore Gastric Cancer Consortium<br>・National University Cancer Institute Singapore |

(Created by the authors based on RIE2025 and information from each program)

The third category is equipment installations based on money received from the private sector. NRF runs The Corp Lab @ University programme, which establishes company laboratories within universities and encourages public-private research and development partnerships between universities and companies. To date, this program has invited over 10 private companies to set up facilities and research equipment in universities. Examples from The Corp Lab @ University programme are listed below.

**Table 6-3: Examples from The Corp Lab @ University programme (in no particular order, excluding legal status and titles)**

| Name of facility | University | Collaborating company | Investment (SGD) | Research fields |
|---|---|---|---|---|
| Rolls-Royce@NTU Corporate Laboratory | Nanyang Technological University | Rolls-Royce (UK) | 75 million | Electrical power and control systems, manufacturing and repair technologies, and computational engineering |
| Keppel-NUS Corporate Laboratory | National University of Singapore | Keppel (Singapore) | 75 million | Offshore and marine lab |
| ST Engineering-NTU Corporate Laboratory | Nanyang Technological University | ST Engineering (Singapore) | 53 million | Advanced robotics and autonomous systems |
| Sembcorp-NUS Corporate Laboratory | National University of Singapore | Sembcorp (Singapore) | 60 million | Energy, water and waste-to-resource |
| HP-NTU Digital Manufacturing Corporate Lab | Nanyang Technological University | Hewlett-Packard (US) | 84 million | Digital manufacturing technologies, including 3D printing |

(Created by the authors based on NRF program information)

A*STAR, as a public research institution, also maintains its research facilities through collaboration with private companies. The IMCB-Nikon Imaging Centre (NIC) is a typical example of one of its facilities. NIC is a light microscopy facility jointly established by Nikon's Singaporean subsidiary and the Institute of Molecular and Cell Biology (IMCB), which falls under A*STAR's umbrella. The facility has the following missions, and provides cutting-edge microscopes and imaging equipment to all researchers.

NIC's missions

- Promote biological research by providing access to cutting-edge equipment;
- Provide training courses for the regional research community;
- Develop new techniques in response to feedback from users.

NIC's major research equipment

- Confocal laser microscope (made by Nikon; A1R+si Confocal)
- Super-resolution microscope (made by Nikon; N-STORM/TIRF + Live Cell)
- Upright microscope (made by Nikon; Ni-E: Upright Microscope)

In Singapore, although there are many facilities that are open access, shared research facilities equipped based on clear policy support and programs are limited in number. There are numerous cases of equipment installations that use the independent budgets of universities and public research institutions, as mentioned above, being made open access based on universities and public research institutions' own volition.

There are three main categories of shared research facilities in Singapore. The first is facilities that are equipped based on policies and programs. The second is facilities that universities and public research institutions have equipped independently, and the third includes facilities led by the private sector and those with joint labs (e.g. private sector-university labs) that are open access. This survey focused on investigating shared research facilities based on the policies of the first category.

The categories of shared research facilities in Singapore and examples of major institutions in each category are as follows.

**Table 6-4: Categories of shared research facilities and examples of institutions (in no particular order, excluding legal status and titles)**

| Category of shared use facility | Policy support for shared use | Example of institution |
|---|---|---|
| 1. Available for shared use with facilities and systems equipped based on policies and programs | Yes | ・St. John's Island National Marine Laboratory (National University of Singapore)<br>・SingaScope (A*STAR)<br>・SIgN (A*STAR) |
| 2. Available for shared use; facilities independently equipped by universities/public research institutions | No. However, shared use is encouraged based on the social significance of each organization. | ・Nanyang NanoFabrication Centre (Nanyang Technological University)<br>・Advanced Remanufacturing and Technology Centre (Science and Engineering Research Council) |
| 3. Private-led facilities or facilities with private sector-university/public institution joint labs that are generally open access | No | ・IMCB-Nikon Imaging Centre (Nikon)<br>・Advance Manufacturing Transformation Centre (Siemens (Germany)) |

(Created by the authors)

When it comes to policies designed to promote shared use, NRF has NRI and SIS. NRI is a program established in 2015, through which NRF gives money to facilities that need large-scale investment but are struggling to procure funding through conventional funding programs on the condition that the facility allows shared use, etc. NRI does not have a clear set budget on any roadmap. Consequently, funding from NRI comes from the White Space budget.

Meanwhile, SIS is a program that was set up at around the same time as NRI, but rather than supporting the maintenance, etc. of individual facilities, it aids the creation of platforms to promote the shared use of existing facilities and equipment. Generally, the details of the SIS program are not made public, so the content of this report was created based on press releases from institutions in receipt of grants and interviews with relevant parties who have received SIS grants.

Policies with elements concerning shared use did exist before 2015 (when NRI was established), but the conditions for shared use were not robust. For example, the supercomputing facility that received grants from 2010 to 2015 had elements of shared use. However, shared use was limited to recommendations, making it very different to NRI and SIS, which enforce the promotion of shared use with an obligation for open access facilities.

The table below contains an overview of NRI and SIS.

**Table 6-5: Overview of policies related to shared use**

| | National Research Infrastructure (NRI) | Shared Infrastructure Support grant (SIS) |
|---|---|---|
| Objectives | Coordinate infrastructure investments and maximize their value by ensuring the possible sharing of specified research facilities operated as national resources open to all researchers in Singapore. | Support the maintenance and renewal of advanced research equipment that can be easily shared and provide value to many researchers. Increase operating rate of equipment and make effective use of expensive equipment through shared use. |
| Funding institution | NRF | NRF |
| Overview of program | Candidate programs are identified based on strategic value, cost, size, and potential user base; funds from NRF are allocated for operational costs such as facility acquisition and upgrade costs, personnel costs, maintenance, equipment replacement, and operating costs. It is desirable for NRI to be under the management of a host institution such as the National University of Singapore or Nanyang Technological University. | Research organizations with existing infrastructure that would greatly benefit the research community through equipment upgrades or replacement are selected for grants. Equipment purchased with grant funding may be shared or provided as a service, depending on the value of the equipment and the complexity of its operation. |
| Program features | ■Open access<br>Facilities must be made available in an equitable manner to all Singaporean public and private research institutions, including the use of all equipment and technical support.<br>■Billing model<br>Users will be charged according to the use and the type of service required. Charging not only covers operating costs but also prevents unnecessary or misuse of shared equipment.<br>■Collaborative platforms<br>The facility should act as a platform for national and international, public and private sector researchers to collaborate on interdisciplinary research and create synergies to promote new approaches and the development of new technologies. | ■Open access<br>Same as left<br>■Billing model<br>Same as left<br>■Contribution to the research community<br>Contributes to the research community through effective use of infrastructure, including private multinational companies and start-ups. |
| Funding | From 10 million SGD (In some cases, over 100 million SGD) | From 5 million SGD |
| Period of funding | Maximum of 5 years per program | Around 5 years |

(Created by the authors based on information on NRF programs and the content of interviews)

# 6.3 tate of development based on policies, etc.

## 6.3.1 Shared research facilities that use NRI

Two facilities are publicly listed on the NRF website as facilities that use NRI: St. John's Island National Marine Laboratory (SJINML), which carries out marine research, and the National Supercomputing Centre (NSCC), which is equipped with supercomputers. Moreover, although the details have not been disclosed, according to interviews with NRF, the Singapore Synchrotron Light Source (SSLS), which possesses a synchrotron, and the SingAREN-Lightwave Internet Exchange (SLIX), which has a high-speed optical fiber network, also use NRI.

SJINML is Singapore's only marine research institution with access to the ocean, and was established in 2002 as a research facility for the Tropical Marine Science Institute of the National University of Singapore (NUS); it was designated an NRI facility in 2016. More details about SJINML are introduced in the next section, so here the report provides information about NSCC. NSCC is Singapore's first petascale computing facility with high performance computing (HPC) functions, and was set up in 2015. It was designated an NRI facility in 2019. Its major equipment is its supercomputers, and it has none of the research equipment included in the aims of this survey.

An overview of NSCC is provided in the table below.

**Table 6-6: Overview of the National Supercomputing Centre (NSCC)**

| | | |
|---|---|---|
| Year established | | 2015 |
| Location | | Fusionopolis (Singapore) |
| Host institution | | A*STAR |
| Members | Researchers | 16 (made up of staff for systems, cybersecurity, software projects & applications, network, facilities & services, etc.) |
| | Staff | 10 (made up of those for strategy, planning & engagement, corporate services, and other staff) |
| Goals | | To leverage HPC to advance Singapore's strategic interests, boost national initiatives and facilitate industry transformation in areas like visualization, modelling, simulation, big data analytics and artificial intelligence.<br>NSCC encourages the use of HPC in all relevant fields such as computational science, analytics, engineering, advanced manufacturing, genomics, biomedicine and healthcare, among many others, and supports the enhancement of its competitive advantage. |
| Research field | | Supports research needs using high performance computing |
| Form of sharing | | Open to all researchers (charges apply) |
| Grant | | 200 million SGD |
| Year selected | | 2019 |
| Main equipment | | Supercomputers (2): HPC usage support for climate and environment research, etc.<br>AI platform: Novel AI research support |

(Created by the authors based on public information on NRF and NSCC)

### 6.3.2 Shared research facilities that use SIS

As noted above, information about SIS grant programs is not made public. Information about institutions in receipt of SIS grants is also not disclosed. However, some research institutions have published press releases stating they have been selected for an SIS grant. From press releases and similar media, the team were able to confirm four platforms that have received SIS grants: SingaScope, the Singapore Immunology Network (SIgN), the Singapore National Laboratory for MASS Spectrometry (SingMass) and the Translational Pathology Consortium (TPC). All of these are research institutions under A*STAR.

Overviews of these four institutions are given below. Further details concerning SingaScope and SIgN are given in the next section.

**Table 6-7: Overview of SingaScope**

| | |
|---|---|
| Facility overview | SingaScope is a Singapore-wide microscopy infrastructure network in the biomedical domain. It gathers information concerning facilities that offer shared use of microscopes on its platform, and provides an environment that enables the research community to access advanced research equipment and related services. |
| Aim of establishment | For scientists to easily search for the equipment they need through SingaScope’s online database, and to ensure an environment that enables access to equipment and consultation with relevant specialists. |
| Research field | Biomedical |
| Staff | Stated below |
| Main installations | Microscopes (80+) |
| Form of shared use | Researchers can book to use microscopes belonging to platforms using the SingaScope website |
| Scope of shared use | Available for all researchers in Singapore |
| Funding | Stated below |

(Created by the authors based on public information on SingaScope and the content of interviews)

**Table 6-8: Overview of SIgN**

| | |
|---|---|
| Facility overview | SIgN is a cutting-edge immunity monitoring platform with integrated functions, including flow cytometry, multiplex analysis of proteins, and computational immunology. |
| Aim of establishment | To broaden and strengthen immunology research in Singapore. |
| Research field | Biomedical (immunity) |
| Staff | Stated below |
| Main installations | Flow analyzer & sorter, cytometer, genomics chromium equipment, multiplex analysis system for proteins, etc. (Some of the equipment is available for shared use. The majority is provided for testing services) |
| Form of shared use | Open |
| Scope of shared use | Available for researchers in Singapore and overseas. However, foreign researchers must have a usage agreement with the facility |
| Funding | Stated below |

(Created by the authors based on public information on SIgN and the content of interviews)

**Table 6-9: Overview of SingMass**

| | |
|---|---|
| Facility overview | The Singapore National Laboratory for Mass Spectrometry (SingMass) is made up of three mass spectrometry centers. |
| Aim of establishment | To offer mass spectrometry users in Singapore and the larger Southeast Asian region a comprehensive solution for mass spectrometry applications and technology development. |
| Research fields | Proteomics, small molecule analysis, structural mass spectrometry |
| Staff | 19 |
| Main installations | Mass spectrometry (9 types) |
| Form of shared use | Access to equipment registered on three partner platforms in Singapore |
| Scope of shared use | Available for all researchers in Singapore |
| Funding | Unknown |

(Created by the authors based on public information on SingMass)

**Table 6-10: Overview of the Translational Pathology Consortium (TPC)**

| | |
|---|---|
| Facility overview | Singapore's only GLP-accredited laboratory providing histopathology and in vitro and in vivo toxicological pathology services. |
| Aim of establishment | To provide high-quality and timely data using cutting-edge technology to support academic and industrial research. It is also the primary provider of diagnostic pathology services for veterinary clinics and hospitals in Singapore. |
| Research field | Pathology |
| Staff | Unknown |
| Main installations | Tissue processor, microtome, laser-capture microdissection, IHC analyzer |
| Form of shared use | Open |
| Scope of shared use | Available for all researchers in Singapore |
| Funding | Unknown |

(Created by the authors based on public information on TPC)

## 6.4 Survey of major shared research facilities

The team interviewed people associated with SJINML, which receives grants from NRI, and with SingaScope and SIgN, which receive grants from SIS, gaining an overview of each facility and surveying the current state of affairs. All of these facilities have high-level research equipment; they have created structures and systems for shared use, and this equipment is used by large numbers of external researchers, including those from universities and private companies. These organizations have established KPI for operations, including the operating rate of equipment, the percentage of external users, the diversity of users, and user satisfaction, and are obligated to create annual reports (that include these KPI) for NRF, their funding institution. The achievement of their KPI affects whether their grant funding continues and the amount they receive, so serious discussions take place as to how to achieve KPI. In Singapore, there is an awareness of the issues and limits of shared research institutions, so this is accepted as an effective function.

### 6.4.1 St. John's Island National Marine Laboratory (SJINML)

Purpose of establishing facility

SJINML was established as a facility for interdisciplinary marine research in 2002, as an institution of NUS. SJINML's focus is on research associated with sustainability and on conservation activities, aiding Singapore in fulfilling its environmental responsibilities as a developed country. Singapore is a key maritime port, and an urbanized state, and as such faces numerous challenges, including the destruction of the marine ecosystem, climate change, and the issue of coastal protection. In 2016, SJINML was designated an NRI to tackle these challenges in an interdisciplinary way, in collaboration with numerous other institutions within the country. This facility is the only institution in Singapore with direct access to the ocean. Thus, there is an expectation that it will strengthen Singapore's position as a key leader in marine research and support the nation's marine environment and economy in the medium and long term.

Generally, the costs for facilities such as research vessels and water tanks and advanced research equipment, which are required for marine research, are large, but as this is not an area that lends itself to commercialization or monetization, it is a field with little joint research with companies and few influxes of corporate funds. Thus, the government and funding institutions hope that making SJINML's equipment into a shared resource will enable more effective and efficient use of researchers' research funding. They also anticipate synergistic outcomes such as increased research capabilities from joint, interdisciplinary research through the use of shared facilities. The key research fields of this facility are:

・Coastal ecological engineering
・Marine ecosystems and biodiversity
・Environmental impact and monitoring
・Marine technology and platforms

<u>Assignment of personnel for facility operations</u>

SJINML's personnel structure is as follows.

・Managers: 3 (director of the facility and management staff)
・Full-time researchers: 11
・Lab managers: 5
・Operations and field support: 8
・Outreach and education staff: 2

The responsibilities of staff associated with the facility are:

・Facility operations
・Strategic research on marine science ecosystems
・Participation in the international research community
・Guiding and fostering interdisciplinary researchers of the next generation
・Giving advice on marine research

<u>Fostering human resources associated with facility operations and the use of equipment</u>

The lab managers and staff responsible for operations and field support have the required specialist knowledge for fieldwork and to use the research equipment; they are able to provide necessary support when researchers are using equipment or are engaged in fieldwork.

Many of Singapore's marine researchers are young—in their 30s or younger—and in some cases they lack practical experience and experience using equipment. In this context, this facility sees more cases in which researchers need support from staff than other organizations. As a result, facility operations are carried out with particular consideration for safety. For example, all full-time research staff are obligated to attend safety information sessions run twice a year by SJINML, and undergo continuous training.

In addition, all researchers who use SJINML are required to have valid safety training certificates when they enter the facility, and must complete any necessary training before they start working. SJINML only considers chemical substance safety training certificates from A*STAR, NUS, the Singapore Institute of Technology (SIT), Nanyang Technological University (NTU), and SingHealth to be valid. When researchers require training, the lab manager makes arrangements so they can participate in safety training courses that will enable them to access the equipment they need, and issues NUS certificates.

Current state of equipment (major research equipment)

SJINML's major research equipment is listed below. Its other expensive equipment includes a research vessel, water tanks, and a biohazard room.

■ Microscopy equipment

・Confocal laser microscope (ZEISS (Germany); LSM 900)

・Inverted microscope (ZEISS (Germany); Axio Observer 7)

■ Material analysis equipment

・High performance liquid chromatography (Agilent Technologies (US); Agilent 1260)

■ Biotechnology analysis equipment

・Cell sorter (BioRad (US); S3e cell sorter)

・Flow cytometry (Yokogawa Fluid Imaging Technologies; Flowcam 8400)

The majority of equipment purchases and operational costs are taken care of by NRF based on the NRI scheme. When equipment and facilities are used, the user is charged; the user pays part of the operating costs of the facility in question.

Form and scope of sharing

SJINML was acknowledged as a shared research facility as one of NUS' existing facilities. Since it was recognized as an NRI in 2016, SJINML has supported the research of over 250 scholars and students from Singapore and from overseas, who are affiliated with 16 institutions and organizations.

SJINML's facilities and installations are basically all open access, and can be used by any research institution, including private companies. In accordance with NRI's concept, fair access and use of its facilities, including equipment use and technical support, is available to everyone. Researchers who are members of Japanese universities and similar organizations can also use them. SJINML's typical users (excluding full-time researchers) are as follows:

・Ad-hoc researchers (80-90% of users)

These are researchers and students who are members of universities or research institutions. They visit SJINML once or twice a month to carry out fieldwork or to use research equipment.

・Other (10-20% of users)

This covers guest research staff from foreign research institutions, business and industrial users, other stakeholders (people with a connection to the ocean, environmental activist groups, etc.) and members of the public (citizen scientists, volunteers, etc.).

Developing rules for shared use

SJINML has published a Researcher Handbook, which includes all its rules, including facility usage fees. Facility users must follow this handbook. Around five years have passed since SJINML became a shared research facility, and a lot of time and effort has been put into developing common rules. In Singapore, universities and public research institutions are acknowledged to have a high degree of autonomy, and each institution sets its own rules for operating its facilities. As a result, how to determine SJINML's rules became an issue—should they be based on those of NUS, the host institution? And how should they be modified? A great deal of thought also went into handling regulations. For example, there is a regulation stating that any pharmaceuticals used by researchers must be supplied by the institution to which they belong, meaning that pharmaceuticals provided by SJINML cannot be used by anyone other than researchers from NUS. This has caused many related parties to become involved in creating operations that ensured the effective running of the facility while adhering to regulations. This was partly due to the fact that SJINML was Singapore's first fully fledged shared research facility, and the situation was unprecedented.

SJINML expects facility users to publish research outcomes. It also recommends that credit is given to SJINML when it comes to research outcomes. If a private company or similar organization is using the facility and has no intention of publishing research outcomes, they are charged a different amount (a higher fee) to the normal billing fee, in consideration of the fact that there will be minimum ripple effect from research outcomes. As there is an assumption that this facility will be available for shared use, private companies and researchers may not monopolize it.

Amount of money given and income/expenditure

SJINML has received a total of 9.5 million SGD over three years. Its income and expenditure has not been made public.

Facility operation KPI

SJINML, which was established using NRI funding, receives grants from NRF through NUS, its host institution. SJINML's expenditure is evaluated and approved by a management committee that includes the government and marine-related institutions. Its achievements are assessed based on the following KPI.

・Usage of facility and equipment (usage rate of equipment and facilities)
However, this is more than just the usage rate; the diversity of users (affiliated institutions, researchers, students, etc.) is also important.

・Education and fostering human resources

Providing learning and research opportunities. Fostering research personnel in the marine sciences field through this.

・Collaboration with local researchers

Organic collaboration with local researchers and research institutions

The KPI of a facility that uses NRI are set by each facility, based on the idea that the direction for which each facility aims is different. Based on the direction for which SJINML aims, its KPI are reviewed every 5 years, when they are discussed in a management committee in which stakeholders come together. SJINML' s KPI are monitored in a regularly held management committee. No KPI have been set concerning research achievements. The research achievements and outcomes accomplished at SJINML are published extensively on its website, but as it is difficult to track the number of papers and citation records, and it is acknowledged that these are simply outcomes and SJINML' s strategic mission is to develop Singapore' s marine research capabilities, the research outcomes themselves do not serve as KPI.

<u>Implementation of personnel exchanges</u>

SJINML is a major institution for marine research, and as such is responsible for fostering the next generation of marine scientists. Its main initiatives are as follows.

・Giving the Young Marine Scientist Research Award

Students who are undergraduate/diploma/junior college level (17-25 years old) are given funding support for exploratory marine science research through practical work overseas.

・Young Marine Scientist Symposium

Serves as a platform for students to share their research outcomes and aspirations for the marine environment.

・International Collaboration Fellowship

This post-doctoral international collaborative fellowship is for research associated with the ocean or sustainable cities to strengthen scientific talents.

・Regular seminars and training to educate the public and foster talent

Since 2017, SJINML has trained 51 polytechnic students.

For the future, SJINML is considering outreach to the region, in addition to Singapore, and building partnerships with foreign research institutions. Creating a network with research institutions will help promote exchange activities for students and researchers. It will also make it easy to collaborate if cooperating parties are needed in the host country when carrying out marine surveys outside of Singapore. SJINML is considering four stages of outreach to the region.

・Stage 1: Information exchange. Creating connections with other marine research institutes and facilitating communication.

・Stage 2: Joint research. Carrying out joint research with other marine research institutes and increasing research capabilities in the region. Such cross-national initiatives will enable effective functionality from a funding perspective.

・Stage 3: Develop platforms. Make the most of the convenience of regional transport to promote marine science education and create opportunities for learning, forming an environment that enables researchers to come together for study and research.

・Stage 4: Government-government level cooperative relationships.

Research outcomes as seen from patents and papers

Singapore's Marine Science Research and Development Programme (MSRDP) has published 163 papers; SJINML contributed to many of these. Representative examples of papers are listed below.

**Table 6-11: Representative examples of papers**

| Title | Authors | Year published | Publisher | Number of citations |
|---|---|---|---|---|
| Fate of nanoplastics in marine larvae: A case study using barnacles, Amphibalanus amphitrite | Samarth Bhargava<br>LEE SIEW CHEN SERINA<br>YING SHU MIN, LYNETTE<br>NEO MEI LIN<br>Teo, S.L.M.<br>VALIYAVEETTIL, SURESH | 2018 | American Chemical Society | 62 |
| Sub-annual fluorescence measurements of coral skeleton: relationship between skeletal luminescence and terrestrial humic-like | Kaushal, Nikita<br>Yang, Liudongqing<br>Tanzil, Jani Thuaibah Isa<br>Lee, Jen Nie<br>Goodkin, Nathalie Fairbank<br>Martin, Patrick | 2020 | Coral Reefs | 11 |

(Created by the authors based on Google Scholar. Information accurate as of March 31, 2022)

Representative research projects and their content are also shown in the table below.

**Table 6-12: Major projects**

| Project | Members | Period |
|---|---|---|
| Adaptation And Resilience Of Coral Reefs To Environmental Change In Singapore | NUS: Danwei Huang (PI), Peter A Todd (Co-I)<br>SJINML: Jani TI Tanzil (Co-I)<br>NTU: Scott Rice (Co-I), Nathalie F Goodkin (Co-I), Diane McDougald (Co-I) | 2016 to 2020 |
| Tropical Model Marine Organisms For Experimental Marine Science | SJINML: Serena LM Teo (P-I), Mei-Lin Neo (Co-I)<br>NUS: Suresh Valiyaveetil (Co-I) | 2016 to 2020 |
| Biota Effects On The Environment | NUS: Seng Keat Ooi (PI), Nhan Phan-Thien (Co-I), Boo-Cheong Khoo (Co-I) | 2018 to 2019 |
| Microbe-Sediment Interactions In The Coastal Marine Environment | TU: Stefan Wuertz (PI)<br>SJINML: Maria Yung (Co-I) | From 2017 |

(Created by the authors based on public information on SJINML)

Issues associated with facility maintenance and operations

SJINML has two major acknowledged issues:

・Developing rules

Although this is gradually being solved over time, as noted above, how to develop common rules among multiple key institutions with different rules, and how to ensure effective operations while supporting regulations is a big issue.

・Initiatives and integration with KPI

Over the last 5 years, the time and efforts of staff have been used for many public education events and outreach, based on acknowledgement that these are important to SJINML's role. On the other hand, because the KPI that evaluate these initiatives are not heavily weighted, the effort invested in them is not equal to their KPI outcome; this is a dilemma. SJINML is cognizant of the challenge involving both the importance of regularly reviewing KPI and the necessity of operations that are not too closely bound to KPI so as to ensure that the truly important things are achieved.

### 6.4.2 SingaScope

Purpose of establishing facility

SingaScope is a microscopy infrastructure network in the biomedical science field, established in April 2019. A*STAR serves as its host institution, and it manages seven microscopy platforms (facilities equipped with microscopes) in Singapore: the NUSCam at Life Sciences Institute, NUS-MBI Singapore Microscopy and Bioimage Analysis, NUS Centre for Bioimaging Science, AIEML at Life Sciences Institute, NTU Optical Bio-Imaging Centre, A*STAR Microscopy Platform at Research Support Centre, and Advanced Bioimaging. SingaScope's foundational goals are:

- Facilitating access to microscopy equipment for all Singapore researchers.
- Increasing the usage rate of equipment by increasing the number of microscope users and reducing duplicated equipment.
- Encouraging information exchanges within the microscope-using research community.
- Providing training for users concerning how to use microscopes and other related courses.
- Enhancing research capabilities and participating in global initiatives such as Global Bioimaging and the Network of European BioImage Analysts (NEUBIAS).

SingaScope's reasons for obtaining an NRI SIS grant are thought to be as follows:

- It is a cross-cutting initiative in which multiple organizations with biomedical research objectives (currently 7 facilities) participate;
- The merits of the initiative are obvious, including increased funding efficiency and increased researcher access to equipment;
- It is an actual and accomplished initiative that is based on existing facilities and equipment.

Assignment of personnel for facility operations

SingaScope is an infrastructure network that manages each platform, so it doesn't have assets, offices, or operational functions of its own. Each platform under SingaScope has its own staff, but SingaScope itself does not have any full-time staff, and portal site development and operations are outsourced to external operators.

Fostering human resources associated with facility operations and the use of equipment

SingaScope provides training concerning knowledge of microscopy equipment and how to use it, as well as courses that ensure researchers use facilities and equipment safely.

The latter refers to courses that must be taken by users who hope to utilize microscopy equipment through a platform. The usage rules are set by each platform, so the course content differs for each, meaning that even if a user has completed similar training at another institution in the past, if they have not undergone training at the facility they are now using, they must be retrained.

Current state of equipment (major research equipment)

SingaScope does not have any clear rules, but the price range for the main research equipment registered as shared equipment is 150,000 to 1.3 million SGD.

When SIS grant proposals are made, the purpose of use of the money is included. The assumption is that around half of the grant is used for equipment. Prior consultation between platforms takes place as to what new equipment to acquire, and SingaScope holds discussions to ensure that duplication of equipment is minimized and equipment is used effectively after considering the needs of each platform.

Equipment registered and shared on SingaScope is the core equipment of each platform; equipment that requires advanced expertise and special equipment used for limited purposes are not handled by SingaScope. Equipment for shared use on each platform is listed in the table below.

**Table 6-13: Equipment for shared use on each SingaScope platform (in no particular order, excluding legal status and titles)**

| Platform | Main category | Medium-level category (equipment) | Manufacturer | Model |
|---|---|---|---|---|
| NTU NOBIC | Microscopy equipment | SEM | Hitachi High-Tech Corporation | FlexSEM 1000 II |
| | | Laser microscope | Olympus | FV1200 |
| | | | ZEISS (Germany) | LSM 780 |
| | | | | LSM 800 Airy |
| | | | | LSM800 |
| | | | ZEISS (Germany) | ELYRA PS.1 + LSM 780 |
| | | Other | GE (US) | High Content Screening Microscope - IN Cell 2200 |
| A*STAR - AMP | Microscopy equipment | TEM | JEOL | JEM2200FS |
| | | | Thermo Fisher Scientific (US) | Talos 120c |
| | | SEM | JEOL | JSM-6701F |
| | | Laser microscope | Olympus | FV3000 |
| | | | | FV3000RS |
| | | | Leica (Germany) | Leica Stellaris |
| | | | LaVision (Germany) | Trim II Multiphoton |
| | | | Multiple manufacturers | Nikon TiE + Yokogawa CSU22 |
| SingHealth - ABI | Microscopy equipment | TEM | JEOL | JEM2100 |
| | | Laser microscope | ZEISS (Germany) | LSM710 (inverted) |
| | | | | LSM710 (upright) |
| | | | Nikon | NSTORM |
| | | | Leica (Germany) | TCS SP8 Confocal and STED 3x |
| | | | ZEISS (Germany) | Elyra PS.1 SIM |
| | | Other | Leica (Germany) | Light Microscopy: Leica LMD7000 Laser Microdissection |
| NUS - CBIS | Microscopy equipment | Cryo-electron microscope | Thermo Fisher Scientific (US) | FEI Titan Krios |
| | | TEM | Thermo Fisher Scientific (US) | FEI Tecnai T12 |
| | | | | FEI Titan S/TEM |
| | | | JEOL | JEM 2010F |
| | | | | JEM-2200FS |
| | | SEM | Thermo Fisher Scientific (US) | Helios 600 DualBeam |
| | | | JEOL | JSM 6510 |
| | | Laser microscope | Leica (Germany) | SP8 Stellaris Confocal |
| | | | Olympus | FV3000 |
| | | | ZEISS (Germany) | LSM 900 with airyscan II |
| | | | PerkinElmer (US) | UltraView VoX |
| NUS - MBI | Microscopy equipment | SEM | JEOL | JSM 6010LV |
| | | Laser microscope | Nikon | A1R |
| | | | | A1Rsi |
| | | | Olympus | FV3000NIR |
| | | | ZEISS (Germany) | LSM710 |
| | | | | LSM980_FLIM |
| | | | Multiple manufacturers | Perkin Elmer UltraVIEW VoX + Olympus IX81 + Yokogawa CSU-X1 |
| | | | | Yokogawa CSU-W1 + Nikon TiE |
| | | | | Yokogawa CSU-W1 + Nikon TiE + Gataca iLas Ablation system |
| NUS - CMA | Microscopy equipment | Laser microscope | Olympus | FV1000 |
| | | | | FV3000 |
| | | | ZEISS (Germany) | LSM710 |
| | Biotechnology analysis equipment | Flow cytometer | Becton, Dickinson and Company (US) | LSR Fortessa |
| | | | Beckman Coulter (US) | Cytoflex LX |
| | | | | Moflo Astrios Sorter |

(Created by the authors based on public information on SingaScope)

Form and scope of sharing

The platforms that participate in SingaScope are fundamentally open access. Each platform agrees that all researchers from research institutions can use their facilities and installations, including private research institutions in Singapore.

Platforms are currently open to users within Singapore, but SingaScope is a member of the Global Bioimaging network, and it is conceivable that it will become open to foreign users in the future.

Developing rules for shared use

SingaScope has common rules, and there are also rules for each platform. Areas that can be coordinated developed as common rules, but in some cases the university or organizational policy is prioritized, and so platform rules also developed. SingaScope does not interfere with the rules and policies of the platforms under its umbrella, and users are made aware of the gist of any changes to rules and policies.

・Booking system

The same system is used by everyone, regardless of whether they have an internal or external relationship with a platform. All users must book equipment using the same booking system, and all users have equal access to equipment.

・Equipment usage fee

Depending on the type of user (public institution or private institution, etc.), the same equipment may have different set prices. Prices are based on discussions between platforms, and similar usage prices are set for similar equipment, but the final decision on pricing is left to each platform. The amount billed comes to the platform in question.

・Usage rules and training

As noted above, the details of usage rules are similar across facilities, but policies are determined by each platform and users must follow the rule book for each facility. Thus, in different facilities users must undertake training in accordance with that facility's rules.

・Research credit

There is no obligation to give any credit for research outcomes regarding the use of research equipment in partner platforms accessed through SingaScope, but it is recommended. A trial scheme for educating people about credit for research outcomes and tracking credit is being run on SingaScope's system.

Amount of money given and income/expenditure

Over the five years of the grant period, from 2019 to 2024, SingaScope's grant money will total 10 million SGD. The purpose of the grant money is, based on the content of the grant application form, to purchase equipment (around 50%) and operation costs (around 50%). The grant money is distributed to each platform in roughly equal amounts.

Facility operation KPI

SingaScope and the platforms under its umbrella are appraised based on the following KPI. SingaScope's grant is a grant for infrastructure development, to make equipment use more efficient, so research achievements are not set as KPI. However, SingaScope itself is experimenting with tracking achievements.

・Usage rate (operation rate of equipment)

Monitoring the usage rate, the usage records across platforms, and the records of external users who are not members of any platforms are all important KPI. SingaScope is a single system that covers both internal and external use of the platforms under its umbrella, so it is easy to monitor the usage rate and the membership affiliations of users.

・Cost recovery rate

This refers to how much of the grant is recovered during the grant period through open access and the effective use of equipment.

・User satisfaction

SingaScope users are surveyed each year, and their satisfaction levels are measured. This confirms whether they were able to use equipment without any issues, whether they gained specialist knowledge concerning equipment use, and whether they obtained desirable results through this use.

Institutions in receipt of SIS grants are obligated to submit an annual report that includes designated KPI outcomes to NRF each year.

Implementation of personnel exchanges

SingaScope is the only microscopy infrastructure network in Singapore, and it aims to contribute to the local community (in Singapore) and to construct a network and ensure knowledge exchange between scientists on a global scale.

From the perspective of local contribution, SingaScope provides training courses so that participants can gain knowledge of microscopy, including courses on the use of microscopy equipment and image analysis courses, so that local researchers can increase their capabilities. These are currently being held for researchers inside Singapore, but it is possible that they will expand to include researchers from neighboring countries in the future. SingaScope also holds events and networking sessions to encourage knowledge exchange in local microscopy communities.

From the perspective of international exchange, SingaScope is a member of the Global Bioimaging network (imaging infrastructure), and held an international conference in this capacity in 2019. In addition, as it is a member of this global network, its staff visit facilities equipped with microscopes in other countries, learn about techniques and operations, and run initiatives to give back the knowledge they have gained to the community.

Research outcomes as seen from patents and papers

In SingaScope, research outcomes do not serve as KPI, and there is no rigid monitoring of users' research outcomes. However, when a researcher publishes a paper, they are asked to credit SingaScope. In addition, when a researcher accesses SingaScope's systems, an alert is displayed asking whether they have recently published any papers, and if they have they are encouraged to enter the information of that paper. This is an attempt to understand the relationship between SingaScope and research outcomes.

Representative research projects and the details thereof

SingaScope' s main aim is always to make equipment use more efficient, so there is no awareness of any large projects launched due to the creation of SingaScope, nor of it driving any research.

Issues associated with facility maintenance and operations

・Effects of COVID-19

SingaScope was launched in September 2019, and was immediately subject to the movement restrictions imposed due to COVID-19, meaning that it was not used as assumed by its KPI. However, as the movement restrictions were gradually eased, improvements in usage rates, etc. were confirmed.

・Complications when accessing non-affiliated platforms

When accessing platforms to which a user is not affiliated, there are additional procedures and additional time is needed; for example, users must clear security to enter institutions and undergo training for each facility.

・Difficulties developing common rules in relation to safety and health, etc.

There are policies for each platform, and these can be subject to change, so SingaScope cannot declare common rules (connected with no. 2).

・Difficulties regarding independence associated with expensive facilities and equipment costs

Expensive research equipment such as microscopy equipment also costs large amounts of money to procure, operate (specialist personnel) and maintain, so it is difficult to cover costs, even when receiving some usage costs from users, making it difficult for facilities to have economic independence. Thus, based on the awareness that they cannot operate without support from the country and affiliated institutions, they must consider optimal operations.

Other

The concept of shared use is applied to expensive research equipment with a certain versatility. Singapore is a small country with a particular environment, and is thinking that the concept of shared use can also be used effectively even over some distance and across national boundaries; SingaScope is considering open access for researchers from neighboring countries as a realistic option. However, there are difficulties moving dangerous or delicate items.

SingaScope' s concept was created with reference to research infrastructure networks in Australia.

### 6.4.3 Singapore Immunology Network (SIgN)

Purpose of establishing facility

The immune system plays a key role as the main cause of illnesses and deaths due to infectious diseases, cancer, diabetes, and autoimmune disorders, so SIgN was established within A*STAR in 2006 as a research institution for the immune system that supports research and clinical studies across Singapore. In addition to research, SIgN' s goals are:

・Fostering human resources to strengthen Singapore' s research and development ecosystem by providing training;

- Connecting and fostering science and business through joint research in Singapore and overseas;
- Supporting multinational corporations and local biotechnology companies through SIgN's research and installation capabilities;
- Holding events and seminars to encourage knowledge exchange in the community.

The Immunomonitoring Service Platform (ISP), which falls under SIgN, seeks to strengthen flow cytometry, multiplex analysis of proteins (MAP), and bioinformatic functions, and received an NRF SIS grant to foster human resources with expertise in cutting-edge technology in 2019.

<u>Assignment of personnel for facility operations</u>

SIgN has 191 researchers, including 15 principal investigators (PI). On the management side, it has 14 members of staff.

<u>Fostering human resources associated with facility operations and the use of equipment</u>

One of SIgN's important roles is training researchers, etc. in how to use advanced research equipment. Researchers who hope to use research equipment are provided with training by SIgN operators.

<u>Current state of equipment (major research equipment)</u>

The main advanced research equipment available for shared use in ISP is listed below.

■ Flow cytometry

- Becton, Dickinson and Company (US); FACSymphony
- Cytek Biosciences (US); Cytek Aurora

■ MAP

- Agilent Technologies (US); Extracellular Flux Analyzer Seahorse XFe96
- Mabtech (Sweden); IRIS reader

Moreover, when it comes to equipment needed for advanced techniques, SIgN provides testing services with its own operators using the equipment. The main services are as follows:

■ Flow cytometry

- Full service, including guidance for research design, sample preparation, dyeing, data acquisition, sorting, and analysis

■ MAP

- Simultaneous measurement of multiple analytes using Luminex (US) equipment

■ Computational immunology

- Analysis using a next generation sequencer (NGS)

■ Mass cytometry

- Analysis of high dimension data obtained from single cell flow and mass cytometry measurements using Cytofkit

■ Immunogenomics

- Analysis services using equipment from 10x Genomics (US)

ISP' s research equipment purchases, maintenance, and updates are covered by the NRF SIS grant and A*STAR funding. Moreover, all research equipment maintenance is outsourced to the vendors from which the equipment was purchased.

Form and scope of sharing

ISP was established as a national shared platform through an SIS grant, and some of its equipment can be used by Singaporean and foreign users from all research institutions, including private companies, based on open access. However, foreign users must have a user agreement in order to make use of the equipment.

Currently, around half of shared equipment bookings are made by internal users, and half by external users. Regardless of their affiliation, all users book the equipment through the same system, allowing all users equal use of equipment.

However, as noted above, only some of ISP' s equipment is available for shared use; the other equipment is expensive or requires advanced techniques to use it, and so it is provided via a testing service rather than via shared use.

The aims of users of SIgN' s services are varied. Multinational companies ask for testing in anticipation of high-quality analysis based on SIgN' s experience and expert knowledge. On the other hand, start-up companies, including start-ups in the biological sciences, etc., often do not have their own facilities or equipment, and thus make use of SIgN' s equipment and services.

Developing rules for shared use

Users who hope to book and use shared flow cytometry equipment or MAP equipment must first attend a training course run by SIgN operators and receive certification from this. During the training process, users are made aware of the rules and policies for facility and equipment use.

Usage costs for research equipment and services are set based on the cost-plus method (combining equipment purchase costs, maintenance costs, personnel costs, etc.). Costs do not differ greatly between internal and external users, but the method for calculating personnel costs is different, so prices are cheaper for internal users. However, SIgN does not aim to make a profit through these services, so even the costs for external users are cheap compared to similar private services.

Amount of money given and income/expenditure

The SIS grant period covers the five years from 2019 to 2024, with a total grant amount of 5 million SGD. The purpose of the grant is the purchase of research equipment and fostering human resources with expertise in the operation of research equipment.

Facility operation KPI

ISP's core functions are becoming stronger thanks to the SIS grant, and with this it is required to fulfill KPI.

SIgN is obligated to submit an annual report, including its KPI, to NRF. The main KPI are listed below. The KPI concerning the number of papers is not connected to the joint users of equipment. It measures output from people associated with SIgN, created through the introduction of advanced equipment.

■ Number of papers

・The number of research papers created in a year

■ Collaboration with industry

・Company involvement in SIgN's ecosystem

・The establishment and spin-off of new companies and businesses

・Marketing activities to publicize SIgN. More specifically, running symposiums and roadshows

・Patents and licenses. More specifically, the number of patents and licenses created in a year

Implementation of personnel exchanges

SIgN runs the following initiatives for external researchers, etc.

・The construction of a personnel pipeline

To foster excellent research personnel, SIgN offers programs such as student programs, PhD programs, and internships; it provides young scientists with learning opportunities under the guidance of principal investigators.

・Promoting the commercialization of research outcomes

SIgN runs programs that collaborate with industry and use science and technology in accordance with industrial needs. For example, the T-UP Programme sends SIgN scientists to start-up companies; the scientists support the improvement of industrial processes and the development of products while gaining experience in the world of industry. SIgN's achievements to date are as follows:

・Active industry collaborations with pharmaceutical companies/biotechnology companies (research cooperation agreements and service contracts): 24

・Joint studies with clinicians and clinician scientists from Singapore and overseas: 40

・Joint labs with private organizations and companies: 3

・Spin-off companies created by SIgN research staff: 3 (2016-2018)

・Initiatives to increase SIgN's recognition

・Building relationships with potential partners and research institutions by introducing SIgN's capabilities;

・Proactively participating in exhibitions, seminars, and symposiums;

・Publishing a newsletter introducing new initiatives, equipment, and services provided by SIgN.

Research outcomes as seen from patents and papers

SIgN does not monitor output from shared use of research equipment.

Overall, since 2007, researchers affiliated with SIgN have published 1,646 peer-reviewed papers; 50% of these have an impact factor of 5 or more, and 20% have an impact factor of 10 or more. The table below lists representative papers.

**Table 6-14: Representative examples of papers**

| Title | Authors | Year published | Publisher | Number of citations |
|---|---|---|---|---|
| Developmental Analysis of Bone Marrow Neutrophils Reveals Populations Specialized in Expansion, Trafficking, and Effector Functions | MaximilienEvrard, Immanuel W.H.Kwok, Shu ZhenChong, Karen W.W.Teng, EtienneBecht, JinmiaoChen, Je LinSieow, Hweixian LeongPenny, Goh ChiChing, SapnaDevi, José MariaAdrover, Jackson L.Y.Li, Ka HangLiong, LeonardTan, ZhiyongPoon, ShihuiFoo, Jia WangChua1I-HsinSu, Lai GuanNg | 2018 | Immunity | 283 |
| Hepatitis B virus-specific T cells associate with viral control upon nucleos(t)ide-analogue therapy discontinuation | Laura Rivino, Nina Le Bert, Upkar S. Gill, Kamini Kunasegaran, Yang Cheng, Damien Z.M. Tan, Etienne Becht, Navjyot K. Hansi, Graham R. Foster, Tung-Hung Su, Tai-Chung Tseng, Seng Gee Lim, Jia-Horng Kao, Evan W. Newell, Patrick T.F. Kennedy, and Antonio Bertoletti | 2018 | American Society for Clinical Investigation | 134 |
| Checkpoint blockade immunotherapy reshapes the high-dimensional phenotypic heterogeneity of murine intratumoural neoantigen-specific CD8+ T cells | M. Fehlings, Y. Simoni, H. L. Penny, E. Becht, C. Y. Loh, M. M. Gubin, J. P. Ward, S. C. Wong, R. D. Schreiber & E. W. Newell | 2017 | Nature Communications | 95 |

(Created by the authors based on Google Scholar. Information accurate as of March 31, 2022)

Issues associated with facility maintenance and operations

SIgN's shared research facilities and testing services are used by plenty of external users as well as internal users, and the facility is not aware of any major issues regarding operations. From the perspective of facility operation, SIgN acknowledges the importance of obtaining and retaining human resources who can operate highly specialized advanced research equipment, and of training and fostering these.

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# 7 Country Survey: Kingdom of Thailand

## 7.1 Basic information on science and technology policies

The Kingdom of Thailand (Thailand) has developed as a typical industrialized nation amongst the ASEAN countries. However, while it is developing economically, freeing itself from an economic structure skewed towards outsourced manufacturing in factories and plants has become an issue. The government has raised the "smartification" of industry, enterprise, human resources, and infrastructure as a key theme, and aims to realize smartification that combines science and industry as a long-term goal for science, technology, and innovation.

Thailand is increasing investment in research and development each year as it works towards changing its industrial structure, and its GERD (Gross Expenditure on R&D) as a percentage of GDP went from 0.2% in 2004 to over 1.1% in 2019. Since 2020, a decline in GERD has been predicted as a consequence of COVID-19, but the government aims for GERD as a percentage of GDP to reach 2% in 2027.

In 2014, the Thai government established the National Reform Council, and selected higher education, science, research, and innovation as one of its reform agendas. In accordance with this, the Ministry of Higher Education, Science, Research and Innovation (MHESI) was formed as the successor to the Ministry of Science and Technology (MOST), and the Science, Technology and Innovation Act was passed in May 2019. MHESI is the main organization currently responsible for determining and managing Thailand's science and technology policy.

Moreover, Thailand has a long-term plan for science and technology, Thailand 4.0, which includes economic development models and a roadmap for the approximately 20 years between 2014 and 2032. There is an awareness that adding value and promoting innovation are major issues, and so the key focus is on applying ICT technology to the economy and society as a whole to foster smart industry and start-ups, and on promoting the creation of human capital and infrastructure.

Moreover, Thailand creates medium-term plans every five years; the 12th National Economic and Social Development Plan (2017–2021) noted areas such as creating future industries, building infrastructure, developing economic zones, constructing energy businesses, and expanding educational platforms, based on ten strategies. Strategy no. 8 included research, technology, and innovation, and set the following goals:

- Increasing R&D investment as a percentage of GDP to 1.5%;
- Ensuring that the ratio of private sector R&D investment to public sector R&D investment is 70 private: 30 public (in 2019, it was around 80% private);
- Ensuring that the research and development investment ratio for key industries, basic research and infrastructure/human resources/standardization is 55:25:20;
- Increasing the number of research and development personnel to 25 per 10,000.

## 7.2 Policy/funding survey

This survey was not able to identify any specific policies or programs to encourage the procurement/maintenance of advanced research equipment or the shared use of equipment. However, Thailand does have the National Science Technology and Innovation Master Plan 2012–2021 (STI Plan), which was mainly determined by the National Science Technology and Innovation Policy Office (STI), an independent institution under MOST. This plan includes the construction of a fully national innovation system that aims to harmonize science, technology, and innovation policies among public institutions, and to strengthen collaboration between the private sector, institutions in the world of academia, and others.

In addition, Strategy no. 5 of the STI Basic Plan references the development of infrastructure for science, technology, and innovation, and describes the strengthening of infrastructure, the provision of one-stop services, and the promotion of the effective use of infrastructure. Moreover, the Thai government has selected representative organizations to promote STI, and the institutions chosen are expected to actively promote joint research and the shared use of equipment. Some of the interview subjects for this survey also commented that their selection as an STI organization led to the opening of their facilities and the start of shared use.

## 7.3 State of development based on policies, etc.

The following are facilities in which the team could confirm actual shared use, based on the STI Basic Plan mentioned in the previous section.

**Table 7-1: List of shared research facilities in Thailand (in no particular order)**

| | Facility name | Research field |
|---|---|---|
| 1 | Mahidol University | Multidisciplinary |
| 2 | Khon Kaen University | Multidisciplinary |
| 3 | King Mongkut's University of Technology Thonburi | Multidisciplinary |
| 4 | Chiang Mai University | Multidisciplinary |
| 5 | Thammasat University | Multidisciplinary |
| 6 | Suranaree University of Technology | Multidisciplinary |
| 7 | Chulalongkorn University | Multidisciplinary |
| 8 | Prince of Songkla university | Multidisciplinary |
| 9 | Thailand Institute of Scientific and Technological Research (TISTR) | Multidisciplinary |
| 10 | National Center for Genetic Engineering and Biotechnology (BIOTEC) | Life science |
| 11 | National Metal and Materials Technology Center (MTEC) | Material engineering |
| 12 | National Electronics and Computer Technology Center (NECTEC) | Electrical and electronic engineering |
| 13 | National Nanotechnology Center (NANOTEC) | Nano-engineering |
| 14 | National Energy Technology Center (ENTEC) | Energy |

(Created by the authors)

## 7.4 Survey of major shared research facilities

From among the shared research facilities in Thailand, the team interviewed people from Khon Kaen University (KKU), the Thailand Institute of Scientific and Technological Research (TISTR), and the National Nanotechnology Center (NANOTEC), gaining an overview of each shared research facility and surveying the current state of affairs.

### 7.4.1 Khon Kaen University (KKU)

Purpose of establishing facility

KKU is a multidisciplinary national university established in 1964 with the goals of research and education. The Research Instrument Center of this university was set up as a shared research facility that supports highly specialized research. Equipment for eight faculties—Medicine, Science, Engineering, Pharmaceutical Sciences, Agriculture, Associated Medical Sciences, Dentistry, and Technology—is managed by the Research Instrument Center.

Assignment of personnel for facility operations

Around 30 people are assigned to the Research Instrument Center. The breakdown of staff is as follows:

・Management staff: 14 (chair, Vice Chairman, director, Secretary, etc.)

・Equipment instructors and equipment scientists: 13 (responsible for each piece of equipment)

Fostering human resources associated with facility operations and the use of equipment

There are no programs to train operators for research equipment or fixed programs to train researchers in how to use equipment.

Current state of equipment

An overview of representative equipment for shared use and usage prices are listed in the table below.

**Table 7-2: Overview of representative equipment for shared use and usage prices (in no particular order)**

| Broad category | Medium-level category (equipment) | Manufacturer | Model | Prices for external users (baht) (Internal/external/private company) |
|---|---|---|---|---|
| Microscopy equipment | TEM | Thermo Fisher Scientific (US) | Tecnai G2 20 | 1,800/3,500/- per hr |
| | FE-SEM | TESCAN (Czech Republic) | MIRA | 300/300/- per hr |
| | AFM | PARK (S. Korea) | XE-120 | 1,500/3,000/- Per time |
| | CASA | Hamilton Thorne (US) | CEROS II | -/-/500 |
| | FIB-SEM | Thermo Fisher Scientific (US) | Helios Nanolab G3 CX | -/-/3,000 |
| Material separation equipment | NMR (400 Mhz) | Bruker (US) | Ascend-400 | 575 / 725 / 875 per hr |
| | Spectroscopy equipment | JASCO | J-815 | 200/400/- per hr |
| | XRD | Bruker (US) | D8 Advance | 200 / 300 / - |
| | High-pressure homogenizer | Microfluidizer (US) | M-110P | 200 / 400 / 600 per hr |
| | Raman spectroscopy equipment | Horiba | SploRA Plus | 500 / 1,000 / 1,000 per hr |
| | LC/MS-MS | Bruker (US) | Easy-nLC-microOTOF, etc. | (Tryptic Digestion) 300/400/-<br>(Short Gradient Test) 1,000/1,600/-<br>(Long Gradient Test) 3,000/4,000/-<br>※Per sample / fraction |
| | Gas chromatography (GC) | Shimadzu | GC-2014 | 200/300/300 per hr |
| | UV-Vis spectrophotometer | Agilent Technologies (US) | AL-SYS-UV-6000-M | 400/800/- per hr |
| | Total Organic Carbon (TOC) | Analytik Jena (Germany) | Multi N/C 2100sla | 150/300/- Per minimum rate |
| Powder analysis equipment | Particle Size Analyzer | Malvern PANalytical (Netherlands) | Nano S90 | 400/600/800 per hr |
| | Zetasizer | Malvern PANalytical (Netherlands) | Nano ZS | 400/600/800 per hr |
| Biotechnology analysis equipment | Real-time PCR | BIORAD (US) | CFX96 | 300/500/500 per minimum rate |
| | In Cell Analyzer | GE (US) | IN Cell Analyzer 2000 | 300/600/600 Per minimum rate |
| | Flow cytometry | Becton, Dickinson and Company (US) | FACSCanto II | 900/1,350/1,350 per hr |
| Other | Dispensing Platform | Biodot (US) | BD-XYZ-3210 | 700/1,400/- per hr |
| | Clamshell Lamination Module | Biodot (US) | BD-LM-5000 | 200/400/- per hr |
| | Guillotine Cutter | Biodot (US) | BD-CM-5000 | 300/600/- per hr |
| | Assembly Roller | Biodot (US) | BD-AR-3000 | 200/400/- per hr |
| | Solid Inker (continuous sealer for printing) | Brother | SN-FRD-1000W | 150/300/- per hr |
| | Freeze dryer | CHRIST (Germany) | GAMMA 2-16 LSC | 750-1,000/1,000-1,250/1,500-1,750 per hours/day(business-after hours) |
| | Mini spray dryer | BUCHI (Switzerland) | B-290 | 120/225/450 per hr |

(Created by the authors based on public information on KKU)

Form and scope of sharing

KKU's sharing is open access. In the past, the University did not consider shared use. However, the Research Instrument Center was established approximately 10 years ago, as a result of KKU's selection for the Thai government's conceptual framework of the National Science, Technology and Innovation Policy and Plan in 2011. An awareness of the idea of sharing facilities and equipment and the merits thereof has spread during the process of operating this facility. Since last year, it has been managed as a platform that anyone can use.

The scope of sharing allows all researchers, including members of universities and companies in Thailand and in other countries, open access. People who want to use the facilities can check equipment usage schedules online and send a usage application. Information concerning facility users, including external researchers, is managed by the University's human resources department. Since 2016, the use of its research equipment has consisted of the following. Most use is internal, with use by external researchers and private companies making up around 20% of the total use.

- By category: Internal (865 cases, 81%); external researchers (188 cases, 18%), private companies (11 cases, 1%)
- By affiliation: Master's students (304 cases, 29%); doctoral students (272 cases, 26%); undergraduates (189 cases; 18%), researchers (118 cases; 11%), etc.

Developing rules for shared use

KKU's main rules are as follows:

- It is possible to book any equipment for up to seven consecutive days.
- When using equipment, researchers must enter their actual start and finish times (to understand accurate usage times for equipment).
- If a researcher is not using equipment on the day they have booked it, they must cancel the booking. (If a researcher does not use the equipment on the day it is booked and does not cancel the booking, they may be ineligible to use equipment for a 14-day period).
- If a researcher breaks two or more regulations, they may be banned from using any equipment.
- Researchers must consult their supervisor before booking to use equipment.
- Researchers must print out their booking information and bring it with them when using equipment.
- Usage fees may differ from those listed on the website, so researchers should check this with a representative in advance.

Amount of money given and income/expenditure

A breakdown of KKU's R&D budget shows that 25% of its funds are obtained from the government, 25% from the University, and the remaining 50% from joint research and funding institutions. Around 10% of the research budget covers purchasing research equipment and management fees for equipment. Those responsible consider 10% to be inadequate, and believe that 20% is needed.

Facility operation KPI

KKU has set the following KPI, and monitors their outcomes. However, only usage fees from shared research facilities are directly related to shared use.

- Usage fees from shared use;
- Procurement of external funds;
- Number of projects implemented;
- Number of papers

Implementation of personnel exchanges

KKU does not run any initiatives to encourage shared use. When it comes to exchanges in a broader sense, KKU is promoting stronger relationships with universities with which it has an MOU. More specifically, exchanges take place between Hokkaido University and the University of Tsukuba in Japan, the University of Cambridge in the UK, as well as universities in countries such as Australia, Myanmar, Cambodia, and Vietnam.

Research outcomes as seen from patents and papers

KKU does not monitor research outcomes derived from shared use.

Representative research projects and the details thereof

As a university, KKU's strength lies in agriculture, foodstuffs, and pharmaceuticals (medicine); its top-cited paper is about rice. The fields of agriculture and foodstuffs are focus areas for the country, not just KKU.

Issues associated with facility maintenance and operations

Advanced research equipment is expensive, and it is not easy to purchase or update the latest equipment from a budgetary perspective.

### 7.4.2 Thailand Institute of Scientific and Technological Research (TISTR)

Purpose of establishing facility

TISTR is a research institution under the umbrella of MHESI. It was founded based on the following four aims:

- To contribute to the country through research and development in science, technology and innovation;
- To transfer the benefits of technology and innovation to industry and local communities;
- To raise industrial standards and competitiveness through analysis, testing, and quality certification systems;
- To develop an effective organizational management system based on good governance.

Assignment of personnel for facility operations

TISTR employs around 1,200 people; of these, around 70% are personnel involved in science and technology and/or R&D. It has 11 departments, each of which manages facilities and equipment. Obtaining and maintaining equipment is also carried out by the different departments, but in many cases equipment maintenance is left to external vendors.

Fostering human resources associated with facility operations and the use of equipment

TISTR provides personnel education programs to ensure that participants learn how to use research equipment. Moreover, in addition to holding study sessions to which research equipment manufacturers are invited, TISTR informs people within the institution of educational programs run by manufacturers and encourages them to participate.

Current state of equipment (major research equipment)

TISTR's major research equipment is listed in the table below:

Table 7-3: Representative equipment for shared use (in no particular order)

| NO | Equipment | Manufacturer | Model |
|---|---|---|---|
| 1 | Ion chromatography | Shimadzu | Prominence HIC-SP |
| 2 | High-performance liquid chromatography (HPLC) | Shimadzu | CTO-10A |
| 3 | Energy dispersive spectrometry (EDS) | Bruker (US) | ESPRIT 2 |
| 4 | Total organic carbon analysis equipment | Shimadzu | TOC-V CPH |
| 5 | Surface roughness measuring device | Tokyo Seimitsu | Handysurf E-35A |
| 6 | Actuator | Samyeon Tech (S. Korea) | STC Samyeon M42905 |
| 7 | Machine testing system | MTS (US) | 810 |
| 8 | Universal testing machine (200 tons) | INSTRON (US) | 5596-B1-E2-F3-G2 |
| 9 | Universal testing machine (250 kN) | INSTRON (US) | 5985 |
| 10 | Universal testing machine | INSTRON (US) | 1123 |
| 11 | Vibration testing machine | Spectral Dynamics (US) | SD-11000-17 DA-50 ACU153 |
| 12 | Vibration testing machine | MTS (US) | 840.3 |
| 13 | Micro-mechanical tester | Bruker (US) | UMT TriboLab |
| 14 | Inverted microscope | ZEISS (Germany) | 405M |
| 15 | Inverted microscope | ZEISS (Germany) | 200M MAT |
| 16 | Stereo microscope | ZEISS (Germany) | Stemi SV11 |
| 17 | Scanning Electron Microscope (SEM) | Thermo Fisher Scientific (US) | Prisma E |
| 18 | Electron Back-Scattered Diffraction (EBSD) | Bruker (US) | E-FlashFS |
| 19 | 3D optical microscope | Bruker (US) | Contour GT-K |
| 20 | Ion milling equipment | Musashino Denshi | Model 1061 SEM Mill |
| 21 | Inductively coupled plasma spectrometer | Perkinelmer (US) | Optima 7000 |
| 22 | FT-IR | Bruker (US) | Vertex 70 |
| 23 | Portable X-ray stress measurement equipment | Rigaku | SmartSite RS |
| 24 | X-ray stress measurement equipment | Rigaku | PSF-3M |

(Created by the authors based on public information on TISTR)

Form and scope of sharing

Sharing takes the form of open access, and facilities and equipment can also be used by people outside TISTR. The goal of this open access is to contribute to the development of Thailand's science and technology, and the qualitative improvement of its research. As this institute has been open for some time, the team could not determine when this began and the trigger for it. Anyone can make use of TISTR's facilities and equipment, regardless of whether they are Thai or foreign, or from a public or private institution.

Developing rules for shared use

For foreign researchers, the process of applying for shared use first involves contacting the Department of International Relations through their website, and then receiving permission for research use from the Governor. The researcher will be guided by one of the 11 departments depending on the content of the research; they discuss the content of their research, including its aims and the tests required, with their assigned department, and are then permitted to use facilities, equipment, etc.

There are basic usage regulations that cross departments and a common manual for equipment use, but detailed rules are left to each department, and differ accordingly.

Amount of money given and income/expenditure

Maintenance and management of equipment is paid for from the regular budget. On the other hand, the budget for infrastructure, including purchasing equipment, is organized separately and received from the national government. TISTR' s annual budget, including money for infrastructure, is approximately 1 billion THB, and around half of this is used for equipment.

Facility operation KPI

TISTR has no KPI concerning the use or sharing of equipment. As an organization, its main KPI are:

- How many projects are being carried out;
- How well research outcomes are leading to commercialization;
- Whether the budget is being managed appropriately, and whether there is any waste, etc.

Implementation of personnel exchanges

TISTR does not run any personnel exchanges or events connected with shared use. However, when it comes to research, it does carry out exchanges with universities, research institutions, and companies in Thailand and in other countries, and is also engaged in joint research with Japan.

Research outcomes as seen from patents and papers

As a research institute, TISTR' s output consists of the following:

- International patents: 1
- Total papers published (academic journals, direct and indirect): 40

Issues associated with facility maintenance and operations

There are no issues with research equipment, but TISTR does have problems with human resources. It wants to hire excellent human resources with expert knowledge, but things are not going according to its hiring plan.

### 7.4.3 National Nanotechnology Center (NANOTEC)

Purpose of establishing facility

Established in 2003, NANOTEC is a public research institution that falls under the umbrella of the Thailand National Science and Technology Development Agency (NSTDA); it aims to carry out research on nanotechnology, offer research support, transfer technology to the world of industry, and disseminate it to society.

Assignment of personnel for facility operations

NANOTEC has 260 members of staff; the Nano Characterization Research Team are the department responsible for obtaining/maintaining and managing installations and equipment. Of this team, around 20 members serve as equipment maintenance staff, and two as administrative staff.

Fostering human resources associated with facility operations and the use of equipment

The Nano Characterization Research Team fosters human resources (tool keepers) who manage and operate equipment. In addition to equipment management, tool keepers also take on the role of instructors for external users, etc. Tool keepers have set levels, and their equipment and the scope of their responsibilities are decided in accordance with these levels.

Current state of equipment (major research equipment)

Below is a list of the main research equipment of one of NANOTEC's facilities, the National Advanced Nano-characterization Center (NANC); this facility provides shared use of equipment and testing services.

**Table 7-4: Representative equipment for shared use (in no particular order)**

| Equipment category | Equipment |
|---|---|
| Microscopy equipment | TEM |
| | E-SEM |
| | FIB and FE-SEM |
| | Confocal Raman spectroscopy equipment |
| | AFM |
| Material analysis equipment | Infrared spectrograph (FT-IR) |
| | X-ray diffraction equipment (XRD) |
| | GC/MS |
| | LC/MS |
| | HPLC |
| | Inductively coupled plasma mass spectrometry equipment (ICP-MS) |
| Powder analysis equipment | Particle distribution analyzer |
| | Nano particle analysis equipment |
| | Specific surface area/pore size distribution measuring device |
| Thermal analysis equipment | TGA |
| | DSC |

(Created by the authors based on public information on NANOTEC)

Form and scope of sharing

NANOTEC is a research facility situated within Thailand Science Park, an open hub whose facilities and equipment can be used by tenant companies, external researchers, private companies, and more. The scope of sharing is wide, and includes universities, private companies, and research institutions in Thailand and other countries; its equipment can also be used by Japanese researchers.

Developing rules for shared use

External researchers have three options for facility use. The first is joint research; the institution with which the researcher is affiliated signs an MOU with NANOTEC and a joint research project is set up. External research members engaged in joint research can book and use equipment through their joint project members.

The second option is rental use of facilities and equipment. People who hope to use equipment can log in from the NANOTEC website and apply to book the equipment they wish to use. If the equipment coordinator approves the details of their application and it is their first time using such equipment, arrangements will be made for them to receive training on how to use the equipment from a tool keeper or an expert in equipment use (a super-user). Having participated in the training and obtained permission to use the equipment in question, the person can make a formal booking online.

The third option is to use the testing services provided by NANOTEC. Applicants can make paid requests for the tests they want carried out.

Amount of money given and income/expenditure

NANOTEC's budget is made up of funding from money received from the government, funding from research projects, equipment usage fees, and income from licensing. The 2020 budget was 528.29 million THB, and around 15% of this was used for equipment purchase and maintenance.

Facility operation KPI

NANOTEC has no KPI for the use of facilities and equipment. NANOTEC's KPI are divided into two categories: research output and technology transfer. Research output refers to the international publication of papers, the creation of prototypes, the number of patents, different sorts of commendations and rewards, etc. Meanwhile, technology transfer involves the number of R&D contracts based on requests from companies, the number of joint studies with companies, the number of licenses, and the current status of intellectual property use.

Implementation of personnel exchanges

NANOTEC does not run any particular exchanges or events on the topic of facilities or research equipment.

Research outcomes as seen from patents and papers

・International patents: 929; Total papers published: 1,126 (of these, 9 papers are listed on SCI)

・The top three papers by number of citations are shown in the table below:

**Table 7-5: Representative examples of papers from NANOTEC**

| Title | Authors | Date published | Number of citations | Publication |
|---|---|---|---|---|
| A dye sensitized solar cell using natural counter electrode and natural dye derived from mangosteen peel waste. | Maiaugree W, Lowpa S, Towannang M, Rutphonsan P, Tangtrakarn A (Nanotec-KKU Center of Excellence), Pimanpang S, Maiaugree P, Ratchapolthavisin N, Sang-Aroon W, Jarernboon W, Amornkitbamrung V (Nanotec-KKU Center of Excellence) | 2015 | 127 | Scientific Reports |
| Evaluation of Microencapsulation Techniques for MICP Bacterial Spores Applied in Self-Healing Concrete | Pungrasmi W (Research Network of NANOTEC-CU), Intarasoontron J, Jongvivatsakul P, Likitlersuang S, | 2019 | 47 | Scientific Reports |
| Oxidized Carbon Black: Preparation, Characterization and Application in Antibody Delivery across Cell Membrane. | Amornwachirabodee K, Tantimekin N, Pan-In P (Nanotec-Chulalongkorn University Center of Excellence), Palaga T, Pienpinijtham P, Pipattanaboon C, Sukmanee T, Ritprajak P, Charoenpat P, Pitaksajjakul P, Ramasoota P, Wanichwecharungruang S | 2018 | 26 | Scientific Reports |

(Created by the authors based on RISS. Information accurate as of March 31, 2022)

Issues associated with facility maintenance and operations

When purchasing equipment, NANOTEC must submit a proposal and obtain permission. As this is subject to a strict review, the proposal must demonstrate the necessity of and basis for the equipment, and if this is not convincing, permission is not granted. In 2022, new equipment purchases went ahead (e.g. Raman spectroscopy equipment), so there is no awareness of any issues concerning the current status and operation of equipment.

The majority of NANOTEC's budget is based on government grants, but the effects of COVID-19 have meant that external income such as equipment usage fees has fallen. However, NANOTEC has recently begun joint research with companies, and income based on opportunities for external cooperation has started to increase.

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# 8 Country Survey: Socialist Republic of Vietnam

## 8.1 Basic information on science and technology policies

The Socialist Republic of Vietnam (Vietnam) is engaged in attracting foreign companies' plants and factories by leveraging its people's high awareness of education and low personnel expenses as its strength, and is continuing sustainable economic development by maintaining a high economic growth rate. On the other hand, Vietnam is seeking ways to free itself from its current economic system—centered on foreign investment, the manufacturing industry, and state-run companies—and to create new industry related to the Fourth Industrial Revolution and a private-sector-led economy.

Vietnam's GERD (Gross Expenditure on R&D) as a percentage of its GDP came to less than 0.2% before 2011, but this has gradually increased, and has been recorded as 0.53% as of 2017. Moreover, while the proportion of government spending is high among many ASEAN countries, in Vietnam, the proportion of private investment was around 25% in 2011, and reached over 70% in 2017. When looking at investment by industry, the proportion given to the manufacturing and technology fields is also approximately 70%. (All based on UNESCO data.)

Diverse stakeholders contribute to the planning and promotion of Vietnam's science and technology policies. The Ministry of Science and Technology (MOST) leads the way when determining the country's science and technology development strategy and policy, but the Ministry of Planning and Investment (MPI) is also involved when it comes to national strategy. After policies are decided, MOST spearheads the planning, but it is MPI that confirms the plans made. With regard to implementation, relevant projects go ahead after the budget is obtained from the Minister of Finance (MOF). In addition, ministries other than MOST, including the Ministry of Education and Training (MOET), the Ministry of Industry and Trade (MOIT), and the Ministry of Information and Communications (MIC), decide science and technology policies in connection with their own areas.

Under MOST, the National Foundation for Science and Technology (NAFOSTED), the State Agency for Technology Innovation (SATI), and the National Technology Innovation Foundation (NATIF) contribute to the promotion of science and technology in universities, etc. Overviews of each of these are given below.

・NAFOSTED

A funding and fellowship program for basic research; offers assistance for people to participate in international conferences, etc.

・SATI

Responsible for policy research and planning, including science and technology plans, and supports MOST. Also responsible for technology management systems, evaluating technology levels, and supporting industrial technologies, etc.

・NATIF

Provides research funds and favorable loan guarantees, etc. for organizations and companies engaged in research and development.

Until 2020, science and technology policies and their implementation were carried out based on Vietnam's Socio-Economic Development Strategy for the period of 2011–2020 and its Strategy for Science and Technology Development for the 2011–2020 period. These strategies emphasized areas in research on new materials, Earth sciences, marine sciences, environmental energy, telecommunications, space sciences, biotechnology, and others. The key fields to date are listed in the table below.

**Table 8-1: Key industries and development policies for science and technology**

| Key industries | Development policies |
|---|---|
| Electric power | Expand power generation facilities and distribution networks to ensure stable provision of electric power. Promote cooperation with the electricity grids of neighboring countries to increase the competitiveness of the electric power market. |
| Coal | Coal is used in thermal power generation, cement production, fertilizer production, the creation of materials for construction, and as a fuel for everyday life in farming villages and mountain regions, with the aim of sustained development. |
| Oil and gas | Proactively attract foreign investment with the aim of introducing relevant boring technology and refining technology for the sustained development of resources. |
| Iron and steel | Demand is continually rising; continue industrial development to meet this demand. |
| Metals | Develop strategic export mineral commodities such as aluminum and foster associated processing industries. |
| Cement | Continue to foster cement production and the processing industry to meet the continuously increasing demand of the construction industry sector and improve product quality. |
| Paper manufacturing | Reduce dependence on imports of pulp/manufactured paper and aim to make paper for low-grade use and wrapping a domestic industry. |
| Machinery | Expand the production base for high value-added machinery such as automobiles, motorbikes, and machine tools. |
| Electronics and telecommunications | ICT: Concentrate on the manufacturing of electronic parts and electronic products for industry. Information processing: Concentrate on software for management, education, and training, and on e-commerce. |

(Created by the authors based on Vietnam's Socio-Economic Development Strategy)

The country has also determined its next long-term plan: Vietnam 2035. This sets out the following visions. Based on these, its key themes include proactively introducing advanced technology from other countries, selecting key fields, and concentrated investment.

・Leading and modernizing the economy through a competitive private sector
・Enhancing national technology and innovation capabilities
・Reviewing urban policies, creating more dynamic cities, and investing in urbanization
・Considering sustainability vis-à-vis the changing climate and environment
・Developing a harmonious middle class society and promoting equality
・Establishing a modern nation ruled by law and a democratic society

## 8.2 Policy/funding survey

Expensive and advanced research equipment in Vietnam's state and national universities is mainly obtained and maintained by grants from the government. NAFOSTED, under the umbrella of MOST, runs the Applied Research Program & Emergent Breakthrough Program, which can be used for expensive equipment; the details are given in the table below.

The team were not able to find any policies or programs that enforce the shared use of facilities and equipment. However, shared use is practiced in public universities and public high-tech park facilities. The former of these support research by offering facility use and testing services to other universities and private companies that do not have sufficient access to research environments as one of their missions as universities. The latter engage in shared use from the perspectives of joint research and joint development, etc.

**Table 8-2: NAFOSTED' s Applied Research Program & Emergent Breakthrough Program**

| | |
|---|---|
| Objective | Funding to tackle national science and technology challenges |
| Funding organization | National Foundation for Science and Technology Development (NAFOSTED) |
| Program overview | Grants for promising projects that can also be used to improve research facilities and research equipment |
| Program features | ■Differences to past support policies<br>In the past, there were programs that could be used to purchase research equipment, but the size of the grants was small and their use was limited. This program allows proposals to include the research equipment required for the project (with the possibility of subsidizing the purchase of expensive research equipment if the research is recognized as promising).<br>■Evaluation method<br>NAFOSTED will evaluate the proposal as well as the facilities and equipment required to implement the proposal.<br>■Evaluation criteria<br>1) Research capacity (research team, representatives, facilities and equipment, etc.)<br>2) Research plan (scientific value and feasibility)<br>3) Research results (applicability and plans for practical application) |
| Grant amount | 5.2 million USD (cumulative total) |
| Grant period | No relevant provisions (depends on project) |

(Created by the authors based on NAFOSTED program information)

## 8.3 State of development based on policies, etc.

The team was able to confirm that the following nine facilities have functions for shared use.

**Table 8-3: List of Vietnam' s shared research facilities (in no particular order)**

| | Facility name | Research field |
|---|---|---|
| 1 | Vietnam National University, Hanoi | Multidisciplinary |
| 2 | Hanoi University of Science and Technology | Multidisciplinary |
| 3 | Vietnam National University, Ho Chi Minh City | Multidisciplinary |
| 4 | Ho Chi Minh City University of Technology | Multidisciplinary |
| 5 | The University of Da Nang | Multidisciplinary |
| 6 | Hue University | Multidisciplinary |
| 7 | Can Tho University | Agriculture |
| 8 | Hoa Lac Hi-Tech Park | Material engineering/biology |
| 9 | Saigon Hi-Tech Park | Multidisciplinary |

(Created by the authors)

An example of an overview of a shared research facility at a high-tech park is given below. University facilities are introduced in the next section.

Sai Gon High-Tech Park

Sai Gon High-Tech Park has five R&D centers, for nanotechnology, biotechnology, automated precision equipment, semiconductors, and IT technologies, and carries out joint research with public institutions and private companies, both Vietnamese and foreign, as well as its own independent research. It also lets out facility space and provides training programs for equipment use. Although this facility does have certain conditions for use, it is open to other researchers, and functions as a shared research facility.

# 8.4 Survey of major shared research facilities

## 8.4.1 Ho Chi Minh City University of Technology (HCMUT)

Purpose of establishing facility

Ho Chi Minh City University of Technology (HCMUT) is the largest and oldest engineering research university in the south of Vietnam. In addition to its focus on education and research, the University supports research by providing facility sharing and testing services for other universities and private companies that do not have sufficient facilities or research equipment. It does not have independent facilities for shared use; rather, it shares the equipment in its existing facilities.

Assignment of personnel for facility operations

As stated above, HCMUT does not have facilities for shared use; each research department manages its own facilities and research equipment, and there are operators for each facility. Those responsible for each research department are also responsible for its facilities.

Fostering human resources associated with facility operations and the use of equipment

Although the necessity of programs to foster human resources for facility operations and the use of research equipment is understood, such programs do not currently exist. If someone from outside the University hopes to use research equipment, HCMUT sets up lectures and training sessions on equipment operation. After attending these, external users are able to use the research equipment.

Current state of equipment

HCMUT's major research equipment is listed below (in no particular order).

■ Refinery and Petrochemicals Technology Research Center (RPTC)

・Crystallization device
・Microwave reactor
・Continuous steam explosion device
・Liquid gas absorption device
・Supercritical Separator
・Bioreactor
・Liquid phase reactor
・Gas distillation equipment

・High pressure reaction equipment
・Supercritical CO2 device
■ Asian Center for Water Research (CARE; water-themed lab)
・Electrical Resistivity Tomography (IRIS Instruments (France); SYSCAL PRO 96)
・Time Domain Electromagnetics (AEMR company (Netherlands); TEMFAST 48)
・Frequency electromagnetic profiling (IRIS Instruments (France); PROMIS)

Form and scope of sharing

In terms of the form of sharing, HCMUT's existing facilities are open access, but there are no clear rules or mechanisms for shared use; currently, any external requests are handled case-by-case.

The scope of sharing is such that if there is a request to use a facility or piece of equipment, regardless of whether it is from a public institution, university, or private company, it will be considered.

Developing rules for shared use

There are no clear rules; hopeful users send in an application, and an agreement (contract) is signed between the relevant parties. On top of this, the applicant must attend lectures or training on operating equipment before using it. This includes an understanding of laboratory usage rules, usage simulations, and simple tests.

Amount of money given and income/expenditure

The budget for facility operation consists entirely of grants from the government. There are no details regarding facilities and equipment in the budget. As the required money differs based on the research department or project, the necessary amount is assigned from the total budget so these can operate.

Facility operation KPI

As there are no independent facilities or clear mechanisms for shared use, there are no KPI for shared use.

As a university, HCMUT's most important KPI is raising its position in the QS World University Rankings. There is a particular focus on increasing its rank in the South-east Asian rankings. The University is aware of the importance of joint research, particularly joint research with foreign researchers, to increase its university ranking. Upping its university ranking will enhance the presence of the University, offering more research opportunities and enabling HCMUT to gather more excellent students, leading to a larger budget.

Implementation of personnel exchanges

The University does not run any particular initiatives to encourage shared use, but it proactively holds conferences to introduce research details so as to strengthen its international joint research.

Research outcomes as seen from patents and papers

There are no particular outcomes for papers or patents with regard to the shared use of research equipment. Currently, there are no mechanisms to track outcomes with regard to shared use.

Representative research projects and the details thereof

This has no connection to shared use, but representative examples of HCMUT's international projects include a project on sustainable agriculture carried out between 2009 and 2013 with JICA and JST, as well as a project on agriculture with the University of Sydney, supported by the Australian government.

Issues associated with facility maintenance and operations

The costs of maintaining research facilities and equipment are high, and the current budget is not enough. As a university, HCMUT must set budget details for research facilities and equipment after calculating the budget needed.

Moreover, foreign public institutions and universities have systems for inexpensively sharing advanced facilities and research equipment, but in Vietnam, there is an awareness that standards are inferior (for example, universities' research infrastructure is old), and that there isn't a lot of research equipment that will appeal to users. In addition, there aren't any established mechanisms or systems for sharing.

People are cognizant of the importance of first developing infrastructure such as research facilities and research equipment to enable more advanced research. They also believe that they should use systems, etc. to establish mechanisms for sharing equipment. In Vietnam, although shared use takes place, the mechanisms behind it are immature.

### 8.4.2 Vietnam National University of Hanoi (VNU)

Purpose of establishing facility

Vietnam National University of Hanoi (VNU) is a state university that represents Vietnam. Its mission is to innovate the country's advanced science and technology, and it fulfills the role of a pioneer of Vietnam's higher education system. Although VNU's facilities are open to outsiders, most external use is based on joint research projects.

Assignment of personnel for facility operations

The main research equipment available for shared use is situated in different laboratories. The equipment is managed by technicians sent to each laboratory and by a department that ensures the cross-cutting management of University facilities and equipment.

Any research equipment that cost 5,000 USD or more is assigned two technicians each. The technicians provide training sessions for equipment users, and are responsible for handling things when the equipment is in use as well as for simple equipment management.

The department that ensures the cross-cutting management of facilities and equipment consists of four engineers and two members of staff. If an equipment fault or failure occurs and the technicians assigned to each laboratory cannot handle it, the department is responsible for contacting the equipment vendor or a specialist repair firm.

Fostering human resources associated with facility operations and the use of equipment

When the technicians who manage research equipment are newly hired, they undergo training for, on average, two to three months. This training is mostly online. Moreover, the technicians of each laboratory also provide training for people who hope to use the equipment, as mentioned above.

Current state of equipment (major research equipment)

VNU's main research equipment is listed below (in no particular order).

- SEM (Thermo Fisher Scientific (US); FEI NovA NanoSEM)
- Raman microscope (Horiba; LabRAM HR)
- FT-IR
- XRD (Bruker (US); D8 ADVANCE)
- GC/MS (Agilent Technologies (US); HP 6890GC-HP5973 MSD)
- LC/MS (Shimadzu; LCMS-QP8000)
- LC/MS (Shimadzu; LCMS-2010)
- Real-time PCR (Biometra (Germany); Analytik Jena TAdvanced 96 SG)

Form and scope of sharing

Each research laboratory has been open since its establishment, and has functions for shared use. The scope of sharing is wide, and includes possible use by research institutions, educational institutions, and private companies in Vietnam and in other countries. Equipment, etc. is used by research institutions and educational institutions in Vietnam and in other countries, but is mostly used by private companies in Vietnam, such as Vingroup. There are no actual records of use by a foreign private company.

The main assumption is that external equipment use will consist of use by institutions and companies carrying out joint research with VNU, but it is also possible to pay set usage fees to rent equipment (by the hour). However, educational use is the main priority, with research goals, including joint research, as the second priority; rental use is a lower priority.

Developing rules for shared use

The process of applying to use equipment or facilities differs depending on whether it is for joint research goals or rental use.

If it is for joint research goals, there is an assumption that an MOU has been signed. The content of the agreement differs somewhat depending on whether it is signed with a private company or a public institution. After the MOU is signed, anyone hoping to use facilities can phone the representative of the relevant laboratory and make a usage application.

On the other hand, if it is for rental use, the usage application goes to the department responsible for the University's financial affairs. Based on the content of the application, a status check will be carried out, and if the checker judges that there are no issues, the applicant can use the facilities or equipment.

Amount of money given and income/expenditure

There are two budget categories when it comes to obtaining equipment: the first is money assigned from the University budget, and the other is procurement using research project budgets. The money allocated for equipment operation is not public information, but money roughly equivalent to equipment depreciation costs is allocated by the University, and the equipment is operated based on this cost.

Facility operation KPI

The University's KPI for equipment use concerns the number of users of each piece of equipment; when it comes to said equipment, students, graduate students, and researchers record and report how many times they use it. They give detailed reports on their usage of newly procured research equipment in particular, so that the University can gain an understanding of its actual use.

Implementation of personnel exchanges

There are no particular initiatives to encourage shared use.

Research outcomes as seen from patents and papers

As a university, VNU's outcomes are shown below. However, these do not grasp research outcomes from the perspective of shared use.

International patents: 1

Total papers published: 1,286; Number of these listed on SCI: 38

Issues associated with facility maintenance and operations

Since FY2015, VNU has continued funding activities to procure necessary equipment, and is gradually developing its research equipment based on the money received.

On the other hand, the number of equipment users (undergraduate students, graduate students, external users, etc.) is a KPI, so it is important for more people to make use of the equipment. The University is always considering how to increase the usage rate of its equipment.

### 8.4.3 Hanoi University of Science and Technology (HUST)

Purpose of establishing facility

Hanoi University of Science and Technology (HUST) is a national university established in 1956 with the aim of contributing to the improvement of Vietnam's science and technology standards and the development of its higher education. It has 10 research institutes and centers under its umbrella, and each of these engages in joint research and offers the shared use of equipment. Its facility and equipment use is wide open, and use by private companies in Vietnam is particularly common.

Assignment of personnel for facility operations

As this is left to the discretion of each research institute and center, the details differ for each, but fundamentally there are people who are responsible for and manage each piece of research equipment.

The number of pieces of equipment managed by a single person varies.

In addition to those assigned to each research institute and center to be responsible for equipment management, there is also a department that manages University facilities and installations; four engineers are responsible for handling failures and external communications.

Fostering human resources associated with facility operations and the use of equipment

HUST has no fixed programs to foster equipment management personnel. It also has no programs to teach or train facility users in how to use equipment.

Current state of equipment (major research equipment)

HUST's major research equipment is listed below (in no particular order).

- TEM (Thermo Fisher Scientific (US); FEI Tecnai G2 F20)
- SEM (JEOL; JSM7600F)
- SEM (different to above)
- XPS
- Micro-Raman spectroscopy equipment
- XRD
- HPLC (Agilent Technologies (US); 1100 Series)
- RF sputtering equipment

Form and scope of sharing

All research equipment in HUST is available for shared use. Its research institutes and centers have been open since they were established.

Users of the facilities and equipment of research institutes and centers are broadly divided into internal associates and external associates. Usage by external associates is further divided into use as part of joint research and rental use based on the payment of usage fees. Around 40% of users are internal users, and around 60% of users are external users. Among the external users, approximately 20% use the facilities and equipment as part of joint research, and around 80% as rental use.

The scope of sharing is wide, with research institutions, educational institutions, and private companies in Vietnam and in other countries being able to make use of facilities and equipment. Domestic companies use equipment, etc. the most frequently. On the other hand, foreign private companies barely use it at all.

Developing rules for shared use

Use is dependent on the signing of an MOU with HUST. After the MOU is signed, the applicant contacts the relevant research institute or center to coordinate which equipment they will use and the usage schedule. There is no set way of communicating with the research institute or center, nor is there a set application form.

Manuals have been created covering how to handle each piece of equipment, and users must be familiar with the manual when using the equipment. People who want to use equipment take a test on the equipment in question, and if they pass they are issued with a qualification to use that equipment. As the test also includes practical skills, it takes place on-site rather than online.

Internal associates and external associates both have to pay usage fees when using equipment. However, the fee is different for internal and external users. Discounts apply to internal users. Moreover, internal users' research outcomes and achievements in publishing papers can lead to further discounted usage fees.

Amount of money given and income/expenditure

There are two budget categories when it comes to obtaining equipment: the first is money assigned from the University budget, and the other is procurement using research project budgets. Sometimes, the University budget receives money from the government, and on other occasions it receives money from organizations such as the World Bank. To purchase new equipment with the University budget, researchers must submit a proposal to the University and obtain approval.

The necessary costs for equipment operation and management are taken from the rental fees of equipment users. Around 30% of the equipment usage fees paid by users are given to the research institute or center, and this quota is used for equipment operation and management.

Facility operation KPI

HUST has no KPI concerning shared use and the use of research equipment.

Implementation of personnel exchanges

There are two relevant policies to encourage joint research and shared use. The first is building relationships with exchange destinations by sending affiliated researchers on foreign exchanges. The other is accepting researchers who are members of private companies and collaboration with private companies. The former refers to regular foreign exchange systems; the latter can take diverse forms, including E-learning, surveys, training, equipment sponsors, and financial support regarding the 52 companies with partnerships with HUST.

Research outcomes as seen from patents and papers

As a university, HUST's outcomes consist of the following. However, these do not grasp research outcomes from the perspective of shared use.

International patents: 20 (published by the University)

Total papers published: 1,232; Number of these listed on SCI: 30

Issues associated with facility maintenance and operations

Shared use has been carried out for some time, and there is currently no awareness of any particular issues or challenges.

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# 9 Country Survey: Kingdom of Cambodia

## 9.1 Basic information on science and technology policies

The Kingdom of Cambodia (Cambodia) has one of the lowest GDPs per capita among the ASEAN countries, and relatively high importance is placed on agriculture and the tourism industry. The Cambodian government's spending on R&D—its GERD (Gross Expenditure on R&D) as a percentage of GDP— is 0.1% (2015). By field, the humanities, medical sciences, and agriculture are the key recipients of R&D spending. In Cambodia, due to its history, there are few researchers, and the development of its facilities and equipment is limited as a result of its economic capacity. It has few systems and policies to support research and development when compared to other ASEAN countries. The main role of its universities is strongly believed to be education, so research and development in universities is also limited.

In the past, Cambodia had no clear governmental organizations or related institutions responsible for the promotion of science and technology. However, in December 2019, the prime minister approved the National Science, Technology and Innovation Policy 2020–2030, and the Ministry of Industry and Handicrafts was renamed the Ministry of Industry, Science, Technology and Innovation (MISTI) in March 2020. Under MISTI, the General Department of Science, Technology and Innovation (GDSTI) created a report on the science, technology, and innovation ecosystem of Cambodia with the cooperation of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). There is an expectation that MISTI and the National Council of Science, Technology and Innovation (NCSTI) will take the lead on future science, technology, and innovation (STI) policies based on this report.

As Cambodia's research policies have only just started, the team could not find any current specific policies or funding programs concerning the development of advanced research equipment. The direction of the country's science and technology promotion and its main initiatives are given in the table below.

**Table 9-1: The direction of Cambodia's science and technology promotion and main initiatives**

| | Goal | Main initiatives |
|---|---|---|
| Governance | ・Constructing a governance system for STI. Selecting MISTI and NCSTI as the organizations responsible for STI policies, and determining the direction of STI policies and the research agenda by 2021. | ・Determining national innovation plans for each sector<br>・Continuously collecting data on STI to determine policies<br>・Evaluating and reviewing the roadmap every three years |
| Education | ・Fostering STI human resources, and ensuring that 50% of university students are in STEM (science, technology, engineering, and math) education by 2030. 40% of these should be female. | ・Continuing and continuously monitoring previously decided measures |
| Research | ・Improving the quality and quantity of research. Spending 1% of GDP on research and development by 2030. | ・Establishing roadmaps by field for key fields (ICT, agriculture, healthcare)<br>・Establishing roadmaps by university<br>・Establishing a national certification program for research institutions |
| Collaboration | ・Strengthening collaboration between STI organizations, etc., and building three innovation clusters in 2025. | ・Establishing industry-academia collaboration offices in universities |
| Construction of an ecosystem | ・Attracting companies and encouraging the acceptance of STI investment, gaining half of R&D expenditure from the private sector by 2030. | — |

(Created by the authors)

## 9.2 Policy/funding survey

As stated above, Cambodia's research policies have only just started, and the team could not find any current specific policies or funding programs concerning the development of advanced research equipment. On the other hand, there is a program for shared use: the Capacity Building Research and Development Fund (CBRD). This program aims to support the construction of foundational infrastructure for education, training, research and development, and innovation, as well as innovation centers, laboratories, and testing facilities, with a focus on the fields of telecommunications and ICT. Those eligible for funding are:

・Telecommunication operators who fall under Article 17 of the Law on Telecommunications;
・Public institutions responsible for education, training, research and development, and innovation in the fields of telecommunications and ICT;
・Qualified persons who meet the goals specified in Article 13 of the Law on Telecommunications.

Although the above policy encourages shared use, its main target research field is telecommunications, and its intentions differ from the shared research facilities equipped with high-level advanced research equipment that are the targets of this survey.

## 9.3 State of development based on policies, etc.

Cambodia has established three shared research facilities in the organizations below based on the policy noted in the previous section. All of these are shared research facilities in the field of ICT, and do not have the advanced research equipment that is the focus of this survey.

・Institute of Technology Cambodia
・National University of Management
・A Network Laboratory Room and An Innovation Center (an annex within the National University of Management)

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# 10 Country Survey: Lao People's Democratic Republic

## 10.1 Basic information on science and technology policies

The Lao People's Democratic Republic (Laos) has a GDP of around 2,500 USD per capita (2000), which is low among the ASEAN countries, and a high national poverty rate of approximately 18% (2018). Its budget for education is small and it lacks basic educational facilities; science and technology statistics have not yet been developed, and there is no recent data concerning the development of research investment even among the statistics of international institutions.

In March 2021, the Laos government dissolved its Ministry of Science and Technology and transferred its functions to five ministries: the Ministry of Industry and Commerce; the Ministry of Education and Sports; the Ministry of Post, Telecom and Communications; the Ministry of Agriculture and Forestry; and the Ministry of Energy and Mines. Consequently, it is now unclear which organization sets and controls science and technology policy.

Laos does have national research centers. The National Agriculture and Forestry Research Institute, for example, falls under the umbrella of the Ministry of Agriculture and Forestry; the government provides research funding, and the Institute engages in research in accordance with themes of national importance. As one key national theme is the reduction of poverty, improving Laos' food self-sufficiency rate is a major theme of the research carried out at the Institute. High-level research that requires advanced research equipment is limited in terms of research themes and budgetary constraints. Moreover, while Laos does have national universities (including the National University of Laos) and private higher educational institutions, their main role is that of education, and the development and use of high-level research equipment using advanced research equipment is limited.

In Laos, there are currently no policies to encourage the development of advanced research equipment or shared use, and the team were not able to find any facilities that allow the shared use of advanced research equipment.

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# 11 Country Survey: Republic of the Union of Myanmar

## 11.1 Basic information on science and technology policies

The Republic of the Union of Myanmar (Myanmar) has achieved rapid economic growth since its economic reforms. However, its GDP per capita is still around 1,400 USD (2020), which is the lowest level within ASEAN. There has been political instability in recent years, and this, as well as the effects of COVID-19 and other factors, have caused economic growth to stagnate.

According to data from 2017, Myanmar's government spending on R&D—it's GERD (Gross Expenditure on R&D) as a percentage of GDP—is less than 0.05%, meaning that contributions to research and development are extremely low. Its science and technology policies are decided and controlled by the Ministry of Science and Technology, and the key science and technology fields connected to its national economic development plan are listed below.

- Agriculture, forestry, livestock (especially biotechnology)
- Resources and related materials
- Preserving water quality and developing water and sewage services
- Telecommunications
- Construction and transport
- Renewable energy
- Medicine and pharmaceutical development

However, in light of the current economic and social situation, the government's priority items are areas directly connected to social issues, such as the reduction of poverty and the development of agricultural infrastructure, rather than high-level research. In FY2017, it was announced that the country's first government-led funding program for research and development in the medical/healthcare field was to be organized, and that it would receive 740,000 USD from the government. This program was expected to be used for research on education, food safety, and pharmaceutical production, but no outcomes have been made public, and the team couldn't confirm its current operating status.

Myanmar currently has no policies to encourage the development of its advanced research equipment or shared use, and the team could not find any facilities that offer the shared use of advanced research equipment.

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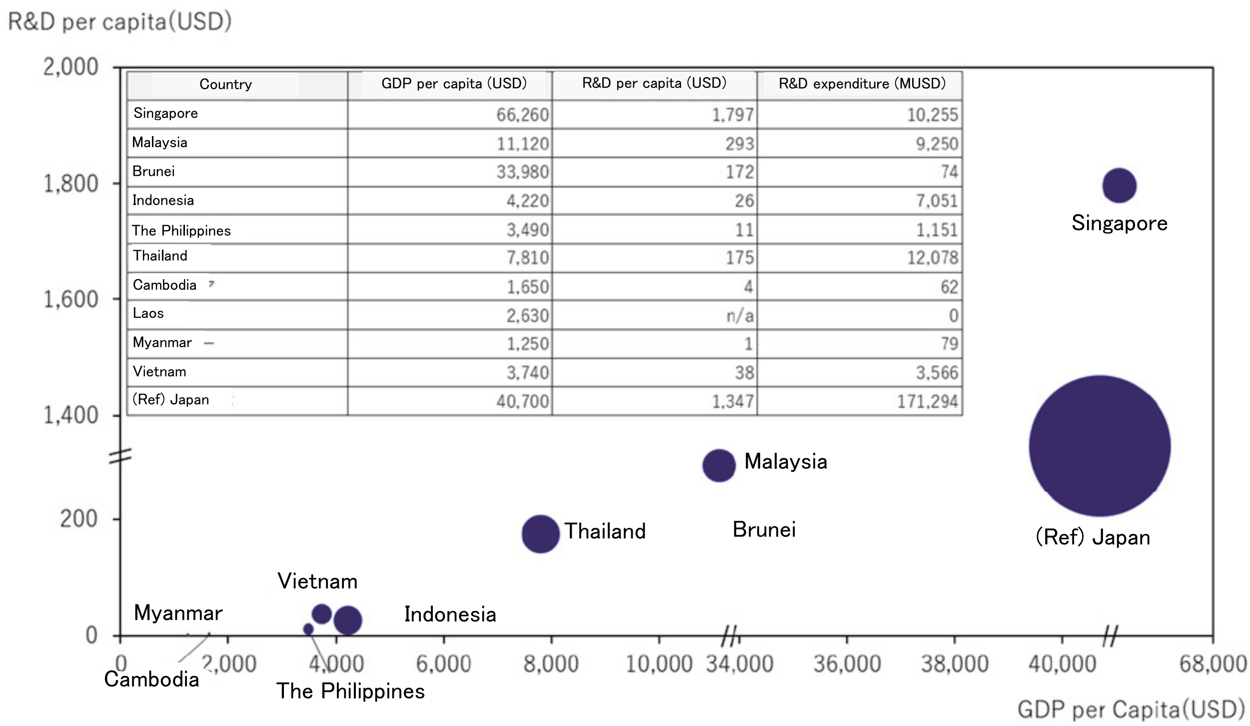
# 12 Summary

## 12.1 Comparison of advanced research equipment and shared research facilities in ASEAN countries

From a geographical perspective, there is a tendency to group the ASEAN countries together, however, as seen in the table below, there is significant economic disparity between these nations, as well as major differences in their research investment and initiatives to promote science and technology. There were also visible differences between the advanced research equipment and shared research facilities surveyed for this report.

The concept of shared use is not necessarily a new idea among the ASEAN countries; since access to high-level research equipment is limited, especially in emerging countries, equipment rentals and the provision of testing services are commonly provided as part of the social responsibilities of public research institutions and public universities.

**Table 12-1: GDP per capita and investment in research in each country**




| Country | GDP per capita (USD) | R&D per capita (USD) | R&D expenditure (MUSD) |
|---|---|---|---|
| Singapore | 66,260 | 1,797 | 10,255 |
| Malaysia | 11,120 | 293 | 9,250 |
| Brunei | 33,980 | 172 | 74 |
| Indonesia | 4,220 | 26 | 7,051 |
| The Philippines | 3,490 | 11 | 1,151 |
| Thailand | 7,810 | 175 | 12,078 |
| Cambodia | 1,650 | 4 | 62 |
| Laos | 2,630 | n/a | 0 |
| Myanmar | 1,250 | 1 | 79 |
| Vietnam | 3,740 | 38 | 3,566 |
| (Ref) Japan | 40,700 | 1,347 | 171,294 |

(Created by the authors based on data from the IMF and UNESCO)

The table below indicates the form and scope of sharing among the 20 institutions interviewed as part of this survey. As it shows, many of the shared research facilities surveyed offer open access for equipment use and testing services for national and international researchers. The team also found many institutions with few obstacles to shared use, including no established conditions for use.

**Table 12-2: Form and scope of sharing of the 20 facilities surveyed**

| | | | Brunei | Indonesia | | | Malaysia | | | | The Philippines | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CAMES | LIPI (biotech) | BB Biogen | UI (medicine) | MIMOS | SIRIM | UMT | KIMIA | ASTI | UP-Visayas | UP-Mindanao |
| Area | | | New energy, etc. | The IGF is for biotechnology | Agriculture | Medicine | Industry in general | Industry in general | Oceans | Chemistry | Electronic materials and digital research | Biotechnology (genomics) | Biotechnology (genomics) |
| Form of sharing | | | Open access | Open access | Open access | Open access | Open access | Open access | Open access | Open access | Open access | Shared facility | Shared facility |
| Scope of sharing | National | Universities, etc. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | Private sector | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | Conditions | Shared use is for joint research partners only. Testing services are open access | Some equipment that is difficult to use is offered via testing services | In flux due to the integration with BRIN | Conditions may vary from facility to facility | | | Evaluation required | | | Generally, an MOU with the user's institution is required | In principle, an MOU with the user's institution is required |
| | International | Universities, etc. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | Private sector | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | Conditions | | | | | | | | | | | |
| Usage rules for shared use | | | Yes | Yes (subject to rules developed by BRIN) | Yes (subject to rules developed by BRIN) | Yes (subject to rules developed by BRIN) | No (but NSFE rules must be followed) | Yes | Yes (based on ISO17025) | Yes | No | Yes | Yes (with rules for each facility and piece of equipment) |
| Shared use system | | | No | Common system (ELSA) | Common system (ELSA) | Common system (ELSA) | Common system (NSFE) | Common system (NSFE) | Common system (NSFE) | Common system (NSFE) | No | No | No |

| | | | Singapore | | | Thailand | | | Vietnam | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | SJINML | SingaScope | SIgN | KKU | TISTR | NANOTEC | HUMUT | VNU | HUST |
| Area | | | Oceans | Biotechnology (microscopy) | Immunology | Multidisciplinary | Multidisciplinary | Nanotechnology | Industry in general | Multidisciplinary | Industry in general |
| Form of sharing | | | Open access | Information hub | Open access | Open access | Open access | Open access | Open access | Open access | Open access |
| Scope of sharing | National | Universities, etc. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | Private sector | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | Conditions | | | Some equipment that is difficult to use is offered via testing services only | | | | Usage contract with user's institution required | | Conditional on an MOU with the user's institution |
| | International | Universities, etc. | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | Private sector | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | Conditions | | | Contract required | | | | | | |
| Usage rules for shared use | | | Yes (stipulated in the Researcher Handbook) | Yes (SingaScope and other facilities have rules) | Yes | Yes | Yes | Yes | No | Yes | Yes |
| Shared use system | | | Online booking system | Online booking system | Online booking system | Online booking system | Online booking system | Online booking system | No | No | No |

(Created by the authors based on the outcomes of interviews)

However, a comparison of policies supporting the development of shared research facilities, the specifications of advanced research equipment in those facilities, mechanisms for shared use, and systems to operate them revealed major differences between countries. The team organized their characteristics based on the survey outcomes by classifying the countries into five groups according to the state of development of advanced research equipment, whether they set policies, and their mechanisms of operation.

- Advanced: Higher GDP per capita and R&D investment than in Japan, with policies and operational arrangements (including systems) in place for the efficient use of advanced research equipment.

- Independently developed: GDP per capita and R&D investment are below Japan's, but policies and operational mechanisms are in place to ensure efficient use of advanced research equipment within a limited research budget.
- In transitional period: Although advanced research equipment is available for shared use, the supporting policies and mechanisms for operation are still in the process of being developed.
- Under consideration: Advanced research equipment is available for shared use, but supporting policies are inadequately developed, and operation is haphazard and not efficiently and effectively managed.
- Premature: The availability of advanced research equipment is limited, as is shared use; there are no policies or mechanisms for this.

An overview of these classifications is shown in the table below.

**Table 12-3: Classifications based on the state of research investment, installation of advanced research equipment, and policies in each country**

| | SG | MY | ID | TH | VN | PH | BN | LA | KH | MM | JP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GDP per capita (USD) | 66,260 | 11,120 | 4,220 | 7,810 | 3,740 | 3,490 | 33,980 | 2,630 | 1,650 | 1,250 | 40,700 |
| R&D per capita (USD) | 1,797 | 293 | 26 | 175 | 38 | 11 | 172 | n/a | 4 | 1 | 1,347 |
| Advanced research equipment *1 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | × | × | × | ○ |
| Shared use of advanced research equipment *2 | ○ | ○ | ○ | ○ | ○ | ○ | △ | × | × | × | ○ |
| Policies for shared use *3 | ○ | ○ | ○ | △ | △ | △ | × | × | × | × | ○ |
| Operational mechanisms and systems *4 | ○ | ○ | ○ | ○ | × | × | × | × | × | × | △ |
| Classification | Advanced | Independently developed | | In transition | Under consideration | | | Premature | | | - |

Legend
*1 ○ In several locations × Unable to confirm (limited)
*2 ○ In several locations △ In some locations × Unable to confirm
*3 ○ There is a policy foundation for shared use △There is a related policy, but not a direct one × No supporting policy can be found
*4 ○ Multiple sites have systems for booking and management △ Some sites have systems or functions × Unable to confirm

(Created by the authors based on the outcomes of interviews)

(Created by the authors based on the outcomes of interviews)

Advanced (Singapore)

Both Singapore's GDP per capita and its research investment are higher than Japan's, and there is a lot of advanced research equipment in the country. Moreover, this advanced research equipment, especially versatile equipment, is proactively made available for shared use regardless of policy support. Funding institutions also have policies to promote shared use, and when facilities and equipment are being developed based on these policies, KPI are set and strictly monitored. Depending on the outcomes of these KPI, grants may cease or be reduced, so facility operators are also aware of KPI and carry out activities for improvement on a day-to-day basis while checking the relevant figures. When promoting shared use, the country aims to ensure effective operations by setting rules and making effective use of booking and management systems.

Independently developed (Malaysia and Indonesia)

Although these two countries are lacking in research investment and equipment when compared to Singapore and Japan, some facilities have high-specification research equipment made in the US, Europe, or Japan. To make effective use of its research equipment, Malaysia mandates that research facilities in public research institutions and public universities are designated as shared research facilities. In Indonesia, all public institutions are being integrated into BRIN, with the aim of ensuring that all public institutions under BRIN's umbrella are available for shared use and operate based on one set of rules and one system. As many research facilities become available for shared use, the governments of these countries are developing common platforms—KRSTE. My (Malaysia) and ELSA (Indonesia)—to ensure their efficient operation. All of the equipment in each facility is managed via these systems, and efforts are being made to ensure that facility bookings can be completed on these systems too. As management data is accumulated on one system, it is possible to obtain equipment in a way that takes the development of each locality and the operational status of equipment into account when acquiring new research equipment.

In transitional period (Thailand)

The country's representative research institutions and universities have high-specification equipment made in the US, Europe, or Japan. There are measures in place for shared use, and shared use does actually take place, but the country's policies are not noted in any specific programs. As a result, no KPI have been established even at shared research facilities. Moreover, although there are basic rules when operating and using shared research facilities, as well as systems for operation, it is assumed that in the future further policy development and mechanism creation will be needed.

Under consideration (Vietnam, the Philippines, and Brunei)

Although there is advanced research equipment in research institutions and universities in Vietnam and the Philippines, there is not enough, or the equipment is old. In some cases, public research institutions and public universities offer shared use as part of their responsibilities, but no supporting policies or specific programs exist. Consequently, if an institution receives a request to use equipment from another university or a private operator, it will be considered internally on a case-by-case basis, along with any fees. There are no KPI for operating shared research facilities, and no clear operational rules or systems for efficient management.

Brunei's economic standards are high among the ASEAN countries, but its population is small and therefore the numbers of researchers and research facilities are also small. There is only one facility with shared use functions, and this facility and its equipment are mainly open to joint research partners. Due to this situation, it cannot be said that Brunei's policies for shared use and its mechanisms for operating shared research facilities are adequate.

Actual use of shared research facilities takes place in each of these countries, and it is thought that policies and mechanisms will be developed in the future.

Premature (Laos, Cambodia and Myanmar)

These countries have low economic levels and their research and development investment is limited. There is little development in terms of advanced research equipment, and plans to promote science and technology are immature or, in some cases, nonexistent. The development of advanced research equipment in these countries is limited, and it is thought that time will be needed to equip facilities; the team believes that establishing these as shared research facilities when they are founded will be helpful.

## 12.2 Challenges and proposals for the development of advanced research equipment and shared research facilities in ASEAN countries

In the previous section, this report confirmed the presence or absence of shared research facilities in each country, and that there are various states of development. This section presents hints gained from surveying these various shared research facilities in different ASEAN countries.

<u>Hints for Japan</u>

There are unique initiatives among the ASEAN countries that Japan can learn from. For example, in Singapore, not only is there an evaluation when applying for a grant, KPI are set and are strictly monitored after the grant is provided, and penalties or rewards are applied in accordance with the outcomes. Although this strict control places a burden on the controller and controlee, the expectation is that this initiative would be effective in ensuring the efficient and effective operation of shared research facilities.

Moreover, in Singapore's shared research facilities, the cost of the development of systems to book facilities and manage their use, as well as the development of mechanisms, is included as an item of expenditure from the grant application stage, in order to realize efficient operations. Grants cover more than personnel expenses and the costs of purchasing equipment; there is a focus on overall optimization, with grants also including the cost of system development, leading to the more effective operation of shared research facilities, more convenience for users, and making their actual usage status more apparent.

In Malaysia and Indonesia, policies mandate that public research institutions and universities are designated as shared research facilities, creating an environment that gives national and international researchers access to facilities and equipment. Moreover, these countries are developing common, cross-facility platforms online, through which anyone can easily check the equipment and services provided at each facility, and building mechanisms that enable online booking. On top of this, they are leveraging the data accumulated by these platforms so that government officials can consider which research equipment should be installed in which area based on the state of research equipment and its use. It isn't easy to ensure that all research institutions allow shared use, or to manage all research equipment using one system, but from the perspective of efficiently and effectively operating shared research facilities, the impact when this is realized will be huge.

<u>Areas to which Japan can collaborate to help build a foundation for science and technology cooperation</u>

This survey has led to an understanding of the state of development of advanced research equipment in the ASEAN countries, the reality of shared research facilities, and unique initiatives connected to their operation. Meanwhile, it has also shed light on the challenges associated with obtaining/maintaining and operating advanced research equipment. By supporting problem-solving in each country, it is conceivable that Japan could collaborate to building a foundation for science and technology cooperation in each country. As stated above, the state of development of advanced research equipment and the maturity of shared research facilities is different in different countries, so problem-solving approaches will also differ.

■ Issues associated with the development of advanced research equipment, and responses

Advanced research equipment is expensive, and so to many developing countries, there is a large financial burden involved in installing equipment in multiple facilities and continuously updating that equipment. Moreover, maintenance and management costs, such as consumables for equipment operation, He gas for cooling, and electricity costs, as well as the necessary burden of regular maintenance, are significant. Among the institutions surveyed, some are not going ahead with equipment installation due to lack of budget, and comments were also made concerning machinery that cannot used because a budget for repairs cannot be secured, equipment that continues to be used without regular maintenance, and the use of cheap imitation consumables.

There is a tendency for researchers to continue to use the equipment they are used to using when it comes to higher-level research equipment. Consequently, supporting the installation of equipment from Japanese manufacturers in shared research facilities and grasping the gateway to the use of research equipment could contribute to helping Japan build a foundation for science and technology cooperation; it could also contribute to expanding opportunities for joint research between Japan and the country in question, increase the user base for Japanese-made advanced research equipment, and expand the businesses of Japanese manufacturers in the future. Thus, supporting the installation of equipment for shared use and the provision of consumables to shared research facilities in each country is worthy of consideration.

■ Issues associated with equipment management and human resources development, and responses

Matters concerning advanced research equipment do not end with its purchase; operational know-how to ensure it is used appropriately is needed, including training for external users, and equipment management, including regular maintenance to ensure it can be used for a long period of time, is vital. The survey confirmed comments noting the existence of equipment that cannot be used because facilities are unable to provide sufficient maintenance. For equipment vendors, installing the equipment, as well as fostering human resources who can manage and operate it in each facility, is important to building a foundation for science and technology cooperation. Thus, in addition to the abovementioned support for installing equipment, supporting the development of human resources who can manage this equipment is also an area to which Japan could conceivably collaborate.

■ Issues associated with policy development, and responses

When it comes to policy, there are countries like Singapore, Malaysia, and Indonesia, which have clear measures and policies to maintain shared research facilities. On the other hand, there are countries like Vietnam and the Philippines, which continue sharing based on past customs and do not have any clear policy support. Shared research facility maintenance should be effective and efficient to enable the effective use of advanced research equipment, and supporting policies are vital to maintaining these facilities. It is possible that Japan could aid target countries in determining policies by telling them what it has understood through its previous policy development and advising them on which policies the countries should develop based on their own situation.

■ Issues associated with mechanisms and systems, and responses

Together with policy development, forming individual rules for operations as well as systems (online booking systems and common platforms, etc.) contributes to more efficient operations. There are numerous external users in shared research facilities, so the development of clear rules that guide everyone is key. Moreover, system development supports the reduction of analogue duties associated with bookings and management, as well as the determination of plans for future equipment development based on an understanding of the circumstances of equipment operation and accumulated data.

Providing rules developed in Japan, sharing issues that became apparent when the rules were enacted, and providing the structure and specifications of systems could help support mechanism and system development in each country.

■ Areas to which Japan can collaborate and approaches to collaboration

When supporting problem-solving in different countries, approaches to individual problems and full-package approaches can be considered in response to the issues of each country. The issues of each country and suggested approaches are listed in the table below.

In Laos, Cambodia, and Myanmar, where shared research facilities are not developed, providing everything from the concept of shared research facilities to equipment and mechanisms for its operation in one package could be considered an effective way of supporting improved research capabilities. On the other hand, in the case of Malaysia and Indonesia, which have policies and mechanisms, as well as issues in procuring and managing equipment, providing support for individual issues could be effective.

It is assumed that ensuring appropriate support after gaining an understanding of the structure of each country' s issues will lead to improved research capabilities in each country and to the greater presence of Japanese research in ASEAN countries.

**Table 12-4: Areas to which Japan can collaborate to help build a foundation for science and technology cooperation with each country**

| Area to which Japan can collaborate | | SG | MY | ID | TH | VN | PH | BN | LA | KH | MM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Individual support | Installing advanced research equipment | | ✓ | ✓ | ✓ | ✓ | ✓ | | | | |
| | Equipment management and human resources development | | ✓ | ✓ | ✓ | ✓ | ✓ | | | | |
| | Policy support | | | | (✓) | ✓ | ✓ | ✓ | | | |
| | Mechanism and system development | | | | (✓) | ✓ | ✓ | ✓ | | | |
| Full-package support | | | | | (✓) | (✓) | (✓) | | ✓ | ✓ | ✓ |

*Legend: ✓Priority approach (✓) Option for approach

(Created by the authors based on the outcomes of interviews)

# Persons and organizations who cooperated with the survey


Brunei

| | |
|---|---|
| Lim Chee Ming | Universiti Brunei Darussalam (UBD) |

Indonesia

| | |
|---|---|
| Robertus Heru Triharjanto | Badan Riset dan Inovasi Nasional (BRIN) |
| Ratih Asmana Ningrum | Badan Riset dan Inovasi Nasional (BRIN) |
| Sofia Yunai Sani | Lembaga Ilmu Pengetahuan Indonesia (LIPI) |
| Anugerah Yuka Asmara | Lembaga Ilmu Pengetahuan Indonesia (LIPI) |
| Aqwin Polosoro | Balai Besar Penelitian dan Pengembangan Bioteknologi dan Sumber Daya Genetik Pertanian (BB Biogen) |
| Bambang Budi Siswanto | Universitas Indonesia (UI) |

Malaysia

| | |
|---|---|
| Ts. Ir. Nordin Ramli | MIMOS Berhad |
| Mohd Fadzil Bin Mohd Akhir | Universiti Malaysia Terengganu (UMT) |
| Hasnul Akmal Haron | SIRIM Berhad |
| Raja Subramaniam | Jabatan Kimia Malaysia (KIMIA) |

The Philippines

| | |
|---|---|
| Bayani Benjamin R. Lara | Advanced Science and Technology Institute (ASTI) |
| Victor Marco Emmanuel Ferriols | University of the Philippines Visayas |
| Jo-Hannah Llames | University of the Philippines Mindanao |

Singapore

| | |
|---|---|
| Jasbir Singh | National Research Foundation (NRF) |
| Ren Min Oh | National Research Foundation (NRF) |
| Serena Teo | St John's Island National Marine Laboratory (SJINML) |
| Graham Wright | SingaScope |
| Fariyal Ahmed | Singapore Immunology Network (SIgN) |

Thailand

| | |
|---|---|
| Wilawan Ungsunantawiwat | Khon Kaen University (KKU) |
| Boonritr Saovapruk | Thailand Institute for Scientific and Technological Research (TISTR) |
| Wannee Chinsirikul | National Nanotechnology Center (NANOTEC) |

Vietnam

| | |
|---|---|
| Pham Tan Thi | Ho Chi Minh City University of Technology (HCMUT) |
| Vu Thi Thom | Vietnam National University of Hanoi (VNU) |
| TS. Nguyễn Đức Trung Kiên | Hanoi University of Science and Technology (HUST) |

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Research Report

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