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NATIONAL SURVEY OF RESEARCH, INNOVATION AND ENTERPRISE IN SINGAPORE

2022

NATIONAL RESEARCH FOUNDATION
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SINGAPORE

Agency for Science, Technology and Research
SINGAPORE

NATIONAL SURVEY OF RESEARCH, INNOVATION AND ENTERPRISE 2022

Expenditure on R&D rose in 2022

All types of R&D expenditure increased for private and public sector in 2022

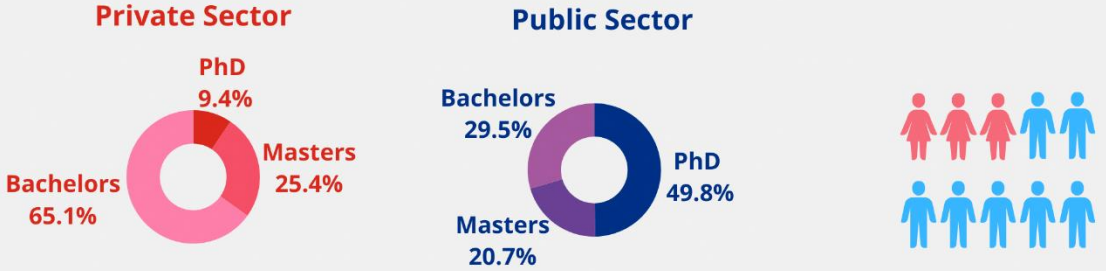
R&D-related Employment Up in 2022

59,752 jobs* associated with R&D in 2022, up from 55,510 in 2021

	Private Sector					Public Sector				
	2020	2021	2022	% Change (2020 - 2021)	% Change (2021 - 2022)	2020	2021	2022	% Change (2020 - 2021)	% Change (2021 - 2022)
Researchers[1]	24,237	23,786	**27,136**	-1.9%	**+14.1%**	21,878	23,719	**24,710**	+8.4%	**+4.2%**
• Researcher Scientists and Engineers (RSE)[2]	22,219	21,778	**24,727**	-2.0%	**+13.5%**	16,609	18,144	**18,639**	+9.2%	**+2.7%**

Bachelor degree holders made up the highest share of RSEs in Private Sector while PhD degrees was the most prevalent qualification type among Public Sector in 2022

31.2% of all RSEs were females in 2022



* Includes researchers, technicians and other supporting staff.
[1]Comprises Research Scientists and Engineers, non-degree researchers and full-time postgraduate students.
[2]Refers to those who hold formal qualifications at university degree level, and excludes full-time postgraduate students.

CONTENTS

Introduction

Singapore's sustained investments in Research, Innovation and Enterprise (RIE) over the past three decades have cultivated an increasingly vibrant RIE ecosystem. Our institutes of higher learning, industry partners, public sector agencies and research institutes collaborate closely on research and development (R&D) to generate innovative products, services, and solutions. The Government has supported these efforts strongly through various RIE Plans, with the latest being the RIE 2025 Plan[1]. Collectively, these efforts will continue to develop a critical mass of capabilities and talent, enhance Singapore's economic competitiveness as a knowledge-based and innovation-driven economy and also tackle national strategic challenges.

In 2022, Singapore's Gross Expenditure on R&D (GERD) increased by 11.7% to reach $12,689.4 million from $11,365.1 million in 2021. Singapore's GERD as a percentage of GDP was 1.8% in 2022. The increase in GERD was due to the increase in both Business Expenditure on R&D (BERD), by 11.9% between 2021 and 2022, and the increase in Public Expenditure on R&D (PUBERD) by 11.3% over the same period. The BERD/PUBERD ratio in 2022 increased slightly to 1.79, from 1.78 in 2021.

R&D investments enable job creation. In 2022, a total of 59,752 jobs were associated with R&D activities. Among these, Research Scientists and Engineers (RSEs) accounted for the majority at 72.6%, or 43,366 jobs. The bulk of RSEs were Bachelor's degree holders (49.8%), followed by PhD (26.8%) and Master's degree holders (23.4%). The number of RSEs in the private sector increased by 13.5% between 2021 and 2022, bouncing back from the decline of 2.0% in 2021. Among the public sector, the number of RSEs grew by 2.7% between 2021 and 2022, a sustained increase from the 9.2% growth observed in 2021. Overall, the total number of RSEs grew by 8.6% in 2022.

The RIE survey data provides insights about Singapore's R&D ecosystem, from the expenditure of organisations to the impact on manpower. This survey would not be possible without the support of participating organisations in both the public and private sectors. We thank all participant organisations for their important contributions.

National Research Foundation,
Agency for Science, Technology and Research

[1] The Research, Innovation and Enterprise (RIE) 2025 Plan was announced in Dec 2020, with the Government's commitment of $25 billion for RIE efforts from 2021 to 2025. In Budget 2024, the Government invested a further $3 billion in RIE 2025, bringing the total to $28 billion.

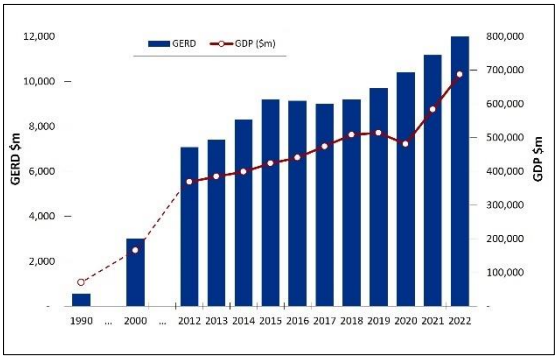
1. OVERVIEW OF R&D IN SINGAPORE

1.1. Gross Expenditure on R&D (GERD)

GERD in Singapore increased by 11.7% from $11,365.1 million in 2021 to $12,689.4 million in 2022. Singapore's GDP[2] (at current market prices) increased by 17.8% from $583.2 billion to $687.2 billion over the same period.

In 2012, GERD was $7,074.3 million and GDP was $368.8 billion. The Compound Annual Growth Rate (CAGR) of GERD from 2012 to 2022 was 6.0%.

Fig.1.1 Gross Expenditure on R&D and GDP (1990-2022)

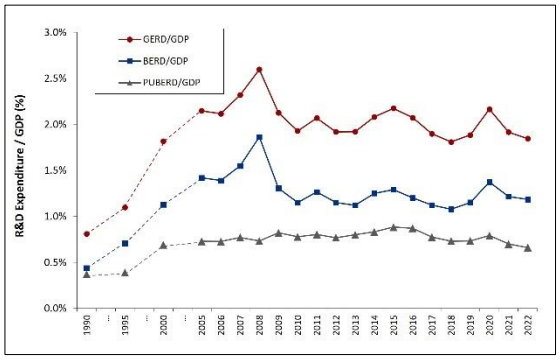


1.2. Ratio of Public Expenditure on R&D (PUBERD) to Business Expenditure on R&D (BERD)

Due to strong GDP growth, GERD as a percentage of GDP decreased slightly from 1.9% in 2021 to 1.8% in 2022. Of this, both Business Expenditure on R&D (BERD) and Public Expenditure on R&D (PUBERD) as a percentage of GDP was at 1.2% and 0.7% respectively in 2022, unchanged from 2021.

For every $1 spent on research in the public sector, $1.79 was spent by businesses in 2022.

Fig.1.2 Gross Expenditure, Business Expenditure and Public Expenditure on R&D as a percentage of GDP (1990-2022)

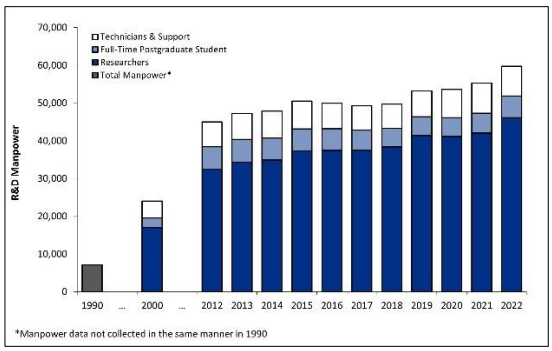


1.3. Manpower

Total R&D Manpower (including researchers, full-time postgraduate students, technicians and support staff) increased by 7.6% from 55,510 persons in 2021 to 59,752 persons in 2022. This represents a CAGR of 2.9% from a base of 44,986 persons in 2012.

The number of researchers (excluding full-time postgraduate students) increased by 9.2% from 42,268 in 2021 to 46,139 in 2022. The CAGR from 2012, with 32,497 researchers, to 2022 was 3.6%. The total number of researchers (including full-time postgraduate students) was 51,846 in 2022.

Fig.1.3 R&D Manpower (1990-2022)



[2] GDP figures were extracted from Department of Statistics in Dec 2024.

2. BUSINESS EXPENDITURE ON R&D (BERD)

2.1 Overview

In 2022, 1,025 private sector companies indicated that they performed R&D in Singapore. The total BERD of these companies amounted to $8,141.1 million, corresponding to 1.2% of Singapore's GDP in 2022. This represents an increase of 11.9% compared to the BERD in 2021 at $7,277.4 million. The CAGR from 2012 to 2022 was 6.7%, from a base of $4,238.0 million in 2012.

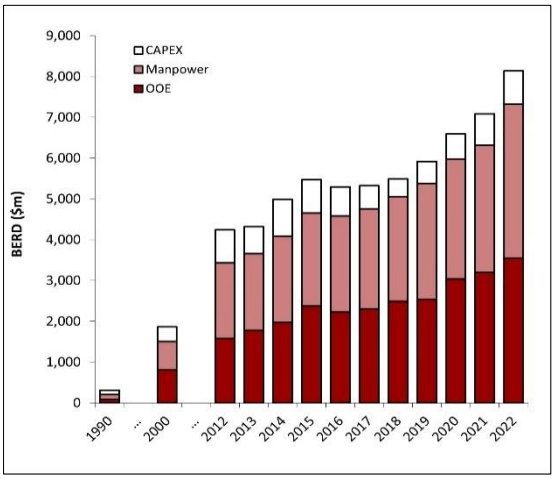
2.2 Type of Expenditure

Capital expenditure (CAPEX) increased by 5.5% from $774.6 million in 2021 to $817.1 million in 2022. From a base of $803.9 million in 2012, the CAGR for 2012 to 2022 was 0.2%.

Manpower expenditure increased by 20.1% to $3,771.7 million in 2022 from $3,141.2 million in 2021. From a base of $1,853.4 million in 2012, the CAGR for 2012 to 2022 was 7.4%.

Other operating expenditure (OOE) rose by 5.7% to $3,552.3 million in 2022 from $3,361.6 million in 2021. From a base of $1,580.7 million in 2012, the CAGR for 2012 to 2022 for OOE was 8.4%.

Fig.2.1 Business Expenditure on R&D by type of cost (1990-2022)



2.3 Type of R&D

The types of R&D conducted in private sector companies are classified into 3 categories.

a) **Basic research** (both experimental or theoretical work undertaken without any particular application or use in view);
b) **Applied research** (original investigation directed primarily towards a specific practical aim or objective); and
c) **Experimental development** (systematic work directed to producing or subtantially improving materials, products and devices; or installing new processes, systems and services).

Basic research expenditure in the private sector increased by 43.3% from $ 1,118.4 million in 2021 to $1,602.7 million in 2022. From a base of $422.9 million in 2012, the CAGR for 2012 to 2022 was 14.3%.

Applied research by private sector companies increased by 15.5% from $2,128.8 million in 2021 to $2,458.7 million in 2022. This represents a CAGR of 6.0% from 2012 when it was $1,374.3 million.

In 2022, business expenditure on experimental development rose by 1.2% from $4,030.2 million in 2021 to $4,079.7 million in 2022. CAGR for the period 2012 to 2022 was 5.3% as business expenditure on experimental development by private sector companies in 2012 was $2,440.8 million.

Fig.2.2 Type of Business Expenditure on R&D (1990-2022)

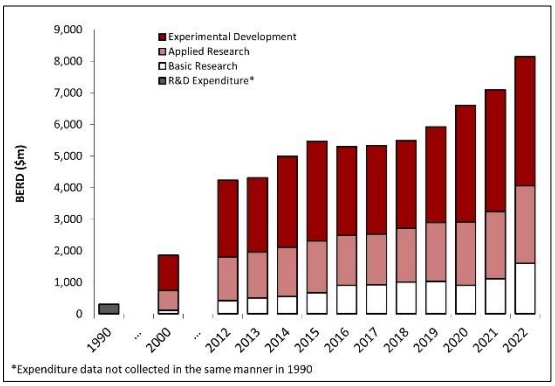
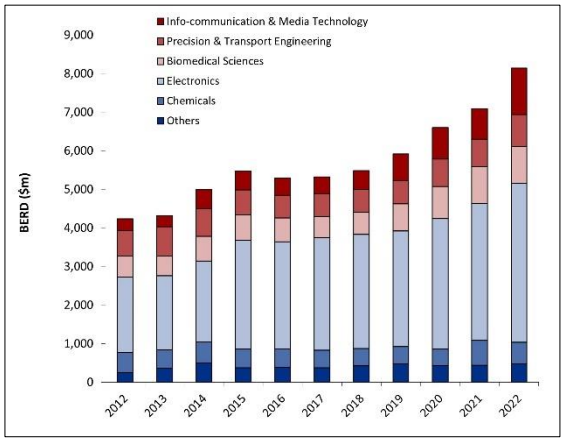


Fig.2.3 Business Expenditure on R&D by fields of science and technology (2012-2022)



2.4 Fields of Science and Technology

In the private sector, research expenditure in Info-communication & Media Technology increased by 34.5% from $896.6 million in 2021 to $1,205.6 million in 2022. This represents a CAGR of 14.5% from 2012 when it was $310.9 million.

Expenditure in Precision and Transport Engineering research increased by 14.8% from $713.7 million in 2021 to $819.7 million in 2022. Between 2012 and 2022, the CAGR was 2.3%, from a base of $650.2 million in 2012.

Research expenditure on Biomedical Sciences increased slightly by 0.4% from $952.4 million in 2021 to $956.1 million in 2022. This represents a CAGR of 5.6% from 2012 when it was $552.6 million.

Research expenditure in Electronics grew by 13.7% from $3,631.5 million in 2021 to $4,129.2 million in 2022. This represents a CAGR of 7.8% from 2012 when it was $1,956.1 million.

Spending in Chemicals research decreased by 13.9% from $645.4 million in 2021 to $555.5 million in 2022, following the strong growth of 51.8% between 2020 and 2021. Nevertheless, the CAGR was still positive at 0.7% from 2012 when it was $517.9 million.

The types of R&D conducted are classified by Fields of Science and Technology are as follows:

a) **Biomedical Sciences**; Comprising: Biomedical & Related Sciences, and Biomedical Engineering.
b) **Chemicals**; Comprising: Material Sciences & Chemical Engineering, and Chemical Sciences.
c) **Electronics**; Comprising: Electrical & Electronics Engineering, and Computer Engineering.
d) **Info-communication & Media Technology**; Comprising: Info-communication & Media Technology, and Computer & Related Sciences.
e) **Precision & Transport Engineering**; Comprising: Aeronautical Engineering, Civil & Architecture Engineering, Marine Engineering, Mechanical Engineering, and Metallurgy & Metal Engineering.
f) **Others**; Comprising: Agricultural Sciences, Food Sciences, Earth & Related Environmental Sciences, Environmental Engineering, Physical Sciences & Mathematics, Energy, and Other Areas.

3. PUBLIC EXPENDITURE ON R&D (PUBERD)

3.1 Overview

In 2022, 59 [3] public institutions, including government agencies, public research institutes, institutes of higher learning, academic medical centres and hospitals, indicated that they performed R&D in Singapore.

These organisations reported a total R&D expenditure of $4,548.3 million in 2022, making up 0.7% of Singapore's GDP, unchanged from 2021. The total expenditure by public sector in 2022 was higher than the $4,087.7 million in 2021. From a base of $2,836.2 million in 2012, the CAGR for 2012 to 2022 was 4.8%.

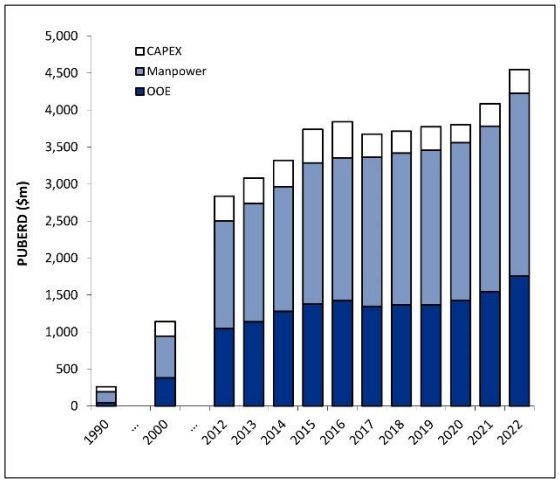
3.2 Type of Expenditure

Amongst public institutions, CAPEX increased by 5.5% from $305.2 million in 2021 to $321.9 million in 2022. From $333.4 million in 2012, the CAGR for 2012 to 2022 for CAPEX decreased by 0.4%.

Manpower expenditure increased by 10.2% from $2,240.5 million in 2021 to $2,469.4 million in 2022. From a base of $1,453.7 million in 2012, the CAGR for 2012 to 2022 for manpower expenditure was 5.4%.

OOE increased by 13.9% from $1,542.0 million in 2021 to $1,757.0 million in 2022. From a base of $1,049.1 million in 2012, the CAGR for 2012 to 2022 for OOE was 5.3%.

Fig.3.1 Public Expenditure on R&D by type of cost (1990-2022)



3.3 Type of R&D

The types of R&D conducted in public sector research organisations are as follows:

a) **Pure basic research** (primarily focused on the advancement of knowledge, rather than to solve a specific problem or to seek long-term economic or social benefits);
b) **Strategic basic research** (carried out with the expectation that it will produce a broad base of knowledge likely to form the basis of the solution to current or future problems or possibilities);
c) **Applied research** (original investigation directed primarily towards a specific practical aim or objective); and
d) **Experimental development** (systematic work directed to producing or substantially improving materials, products and devices; or installing new processes, systems and services).

[3] This was a decline from the 78 public institutions in 2021 as the research institutes under the Agency for Science, Technology and Research has been amalgamated into 1 legal entity.

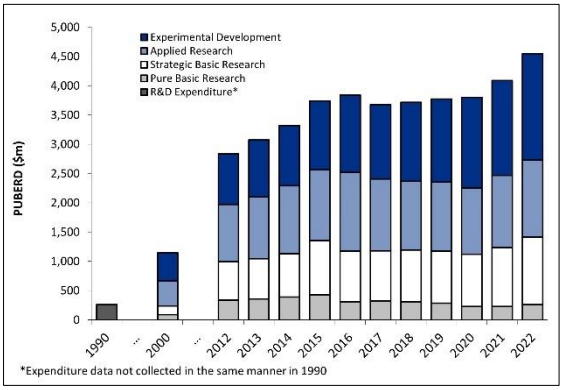
Pure basic research expenditure in public institutions increased by 15.3% from $228.6 million in 2021 to $263.5 million in 2022. From a base of $339.7 million in 2012, the CAGR for 2012 to 2022 showed a decline by 2.5%.

Strategic basic research expenditure in public institutions increased by 14.1% from $1,009.3 million in 2021 to $1,151.4 million in 2022. This represents a CAGR of 5.8% from 2012 when it was $655.1 million. Together, pure basic research and strategic basic research registered a CAGR of 3.6% from 2012 to 2022.

Applied research expenditure in public institutions increased by 7.2% from $1,228.9 million in 2021 to $1,316.8 million in 2022. This represents a CAGR of 3.0% from 2012 when it was $ 979.5 million.

Experimental development expenditure in public institutions increased by 12.1% from $1,621.0 million in 2021 to $1,816.5 million in 2022. This represents a CAGR of 7.7% from 2012 when it was $861.9 million.

Fig.3.2 Type of Public Expenditure on R&D (1990-2022)



3.4 Fields of Science & Technology

In public institutions, R&D expenditure on Info-communication & Media Technology increased by 8.5% from $409.8 million in 2021 to $444.6 million in 2022. This represents a CAGR of 5.6% from 2012 when it was $257.4 million.

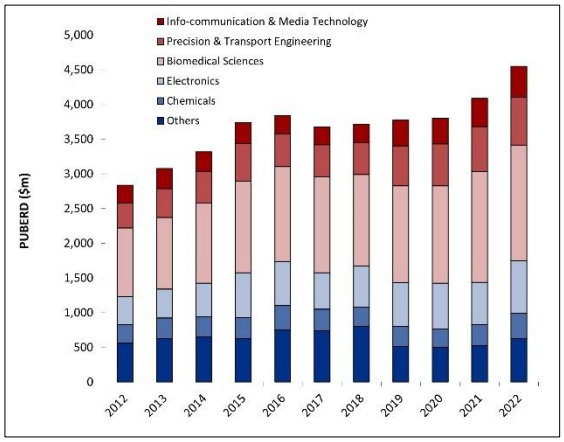
The expenditure for Precision and Transport Engineering research increased by 7.8% from $640.5 million in 2021 to $690.3 million in 2022. Between 2012 and 2022, the CAGR was 6.7%, from a base of $360.7 million in 2012.

Expenditure on R&D in Biomedical Sciences increased by 4.1% from $1,601.8 million in 2021 to $1,667.9 million in 2022. This represents a CAGR of 5.4% from 2012 when it was $987.1 million.

Expenditure on R&D in Electronics increased by 24.2% from $608.6 million in 2021 to $755.9 million in 2022. This represents a CAGR of 6.5% from 2012 when it was $402.5 million.

Expenditure on R&D in Chemicals increased by 19.0% from $306.5 million in 2021 to $364.7 million in 2022. Between 2012 and 2022, the CAGR was 3.1%, from a base of $269.0 million in 2012.

Fig.3.3 Public Expenditure on R&D by fields of science and technology (2012-2022)



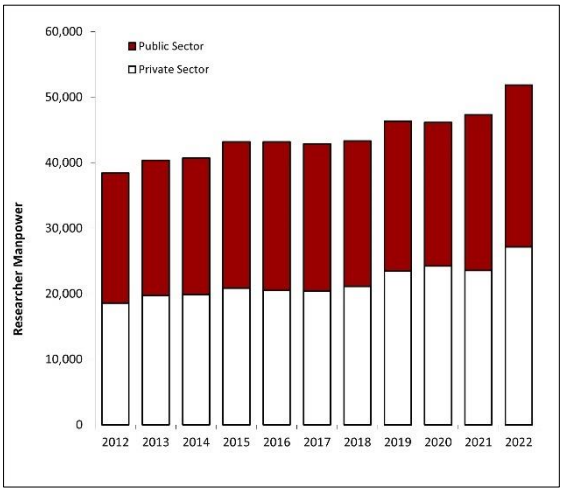
4. R&D TALENT

4.1 Total Researchers[4]

The total number of researchers (comprising Research Scientists and Engineers (RSEs), non-degree researchers and full-time postgraduate research students) increased by 9.1% from 47,505 in 2021 to 51,846 in 2022. This represents a CAGR of 3.0% from a base of 38,421 in 2012.

Researchers in the private sector grew by 14.1% from 23,786 in 2021 to 27,136 in 2022, while researchers in the public sector increased by 4.2% from 23,719 in 2021 to 24,710 in 2022. Between 2012 and 2022, both private and public sectors registered growth in researchers, with CAGR of 3.9% and 2.2% respectively.

Fig.4.1 Researcher Manpower (2012-2022)



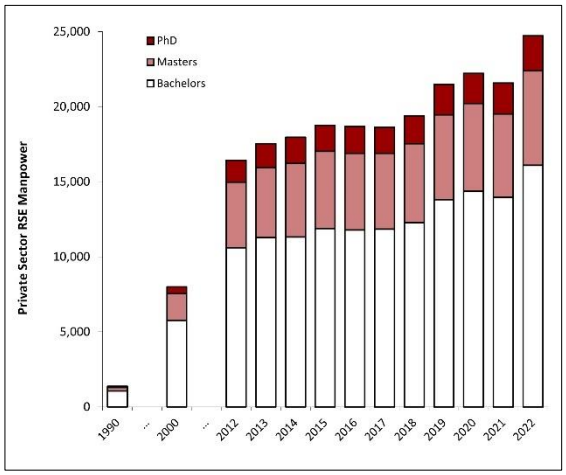
4.2 Total Research Scientists & Engineers

RSEs comprise researchers who hold formal qualifications at the university degree level. RSEs exclude full-time postgraduate research students.

In 2022, the number of RSEs grew by 8.6% from 39,922 in 2021 to 43,366 in 2022. This represents a CAGR of 3.7% from a base of 30,105 in 2012.

In the private sector, the number of PhD RSEs increased by 12.1% from 2,079 in 2021 to 2,330 in 2022. This represents a CAGR of 4.8% from 1,463 in 2012. RSEs with a Master's degree grew by 12.0% from 5,618 in 2021 to 6,293 in 2022. This was a of CAGR of 3.7% from 4,359 in 2012. The number of RSEs with a Bachelor's degree increased by 14.4% from 14,081 in 2021 to 16,104 in 2022. This represents a CAGR of 4.3% from 10,600 in 2012.

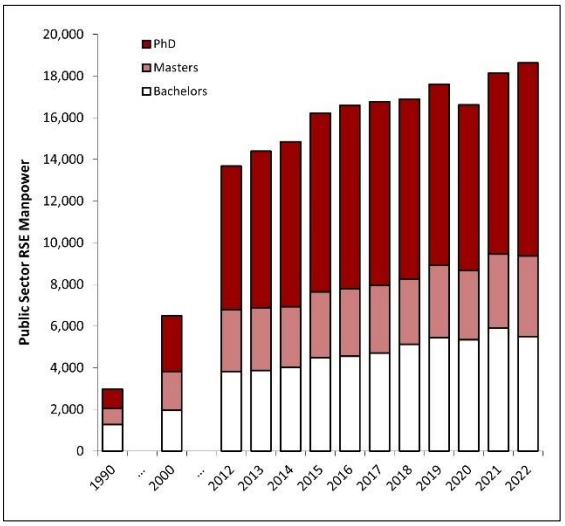
Fig.4.2 Private Sector Research Scientists & Engineers (1990-2022)



In the public sector, the number of PhD RSEs increased by 6.8% from 8,689 in 2021 to 9,279 in 2022. This represents a CAGR of 3.0%, from a base of 6,902 in 2012. RSEs with a Master's degree increased by 8.3% from 3,560 in 2021 to 3,857 in 2022. There was a CAGR growth of 2.7% from a base of 2,959 in 2012. RSEs with a Bachelor's degree decreased by 6.6% from 5,895 in 2021 to 5,503 in 2022. There was nevertheless a positive CAGR of 3.7% from a base of 3,822 in 2012.

[4] Data on all R&D manpower (including non-researchers) can be found in the manpower tables under the List of Tables appended at the end of the report.

Fig.4.3 Public Sector Research Scientists & Engineers (1990-2022)

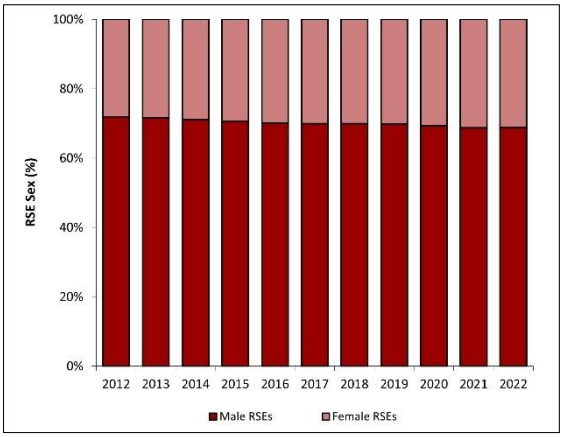


4.3 Profile of Research Scientists & Engineers

Sex

There were 13,532 female RSEs in 2022, making up 31.2% of all RSEs, slightly lower than the 31.3% in 2021. This represents a CAGR of 4.8% from 8,461 female RSEs in 2012.

Fig.4.4 Sex of Research Scientists & Engineers (2012-2022)

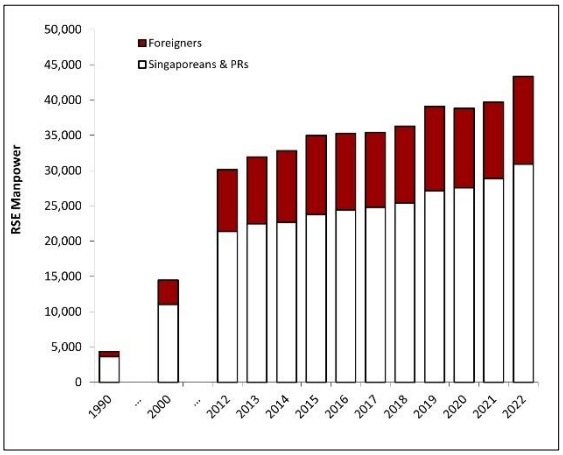


Citizenship

The number of Singaporean and Permanent Resident (PR) RSEs increased by 6.6% from 28,993 in 2021 to 30,908 in 2022. This represents a CAGR of 3.8% from a base of 21,377 RSEs in 2012.

The number of foreign RSEs saw an increase of 14.0% from 10,929 in 2021 to 12,458 in 2022, after seeing declines of 5.6% in 2020 and 3.1% in 2021. This represents a positive CAGR of 3.6% from a base of 8,728 foreign RSEs in 2012.

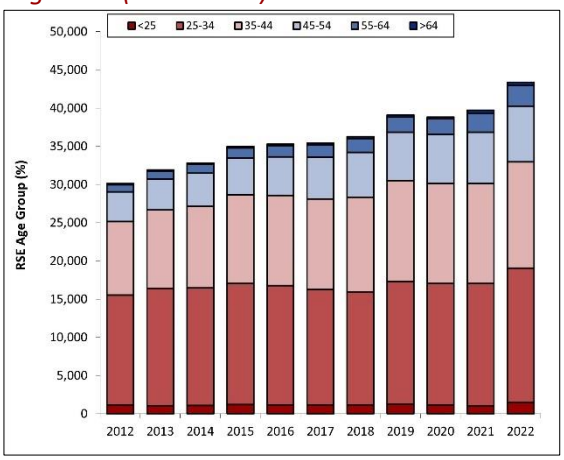
Fig.4.5 Citizenship of Research Scientists & Engineers (1990-2022)



Age-Bands

In 2022, 44.0% of all RSEs were under the age of 35 and 76.0% of all RSEs were under the age of 45. Compared to 2012, these proportions had fallen from 51.6% and 83.5% respectively, as there were now more RSEs in the higher age-bands.

Fig.4.6 Age-Bands of Research Scientists & Engineers (2012-2022)



5. PATENTS

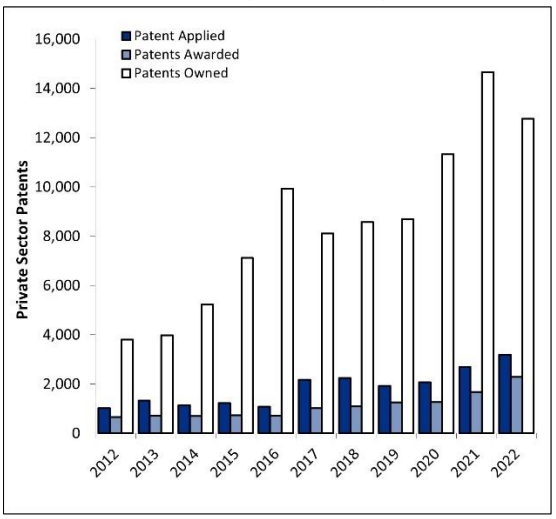
5.1 Patents Applied

In 2022, the total number of primary patent applications (first filings) as a result of R&D conducted in Singapore, stood at 4,107. This was an increase of 12.7% from the 3,644 patents filed in 2021, and a CAGR of 9.1% from the 1,722 patents filed in 2012.

In the private sector, 3,192 patents were filed in 2022, showing a 18.6% increase from the 2,692 patents filed in 2021, and a CAGR of 12.0% from the 1,024 patents filed in 2012.

In the public sector, the number of patent applications decreased by 3.9% from 952 in 2021 to 915 in 2022. Nevertheless, there was positive CAGR of 2.7% from the 698 patents filed in 2012.

Fig.5.1 Patents Applied, Awarded and Owned in the Private Sector (2012-2022)

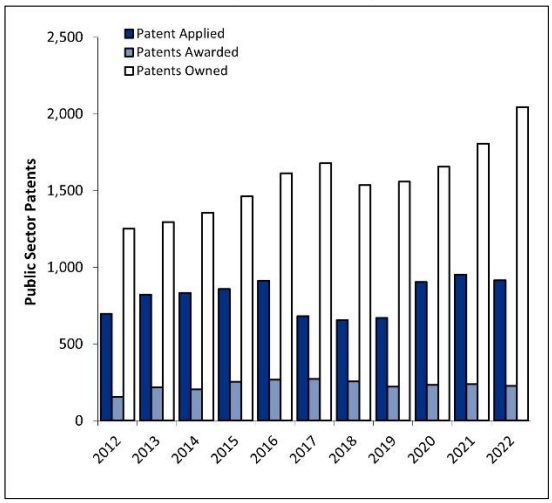


5.2 Patents Awarded

In 2022, the total number of patents awarded (first grants) as a result of R&D conducted in Singapore was 2,518. This represents an increase of 31.2% from 1,919 patents awarded in 2021 and a CAGR of 11.9% from the 817 patents awarded in 2012.

The number of patents awarded to private sector companies increased by 36.3% from 1,681 patents awarded in 2021 to 2,291 in 2022 at a CAGR of 13.2% from the 662 patents awarded in 2012. In the public sector, the number of patents awarded decreased by 4.6% from 238 in 2021 to 227 in 2022. There was nevertheless a positive CAGR of 3.9% from the 155 patents awarded in 2012.

Fig.5.2 Patents Applied, Awarded and Owned in the Public Sector (2012-2022)



6. INTERNATIONAL COMPARISON OF R&D

6.1 Research Intensity in Selected Countries/Regions

According to OECD Main Science and Technology Indicators 2024/07, the United States of America remained the country with the highest GERD, which is the sum of business and public expenditure on R&D, with US$923 billion spent on research in 2022. China remained in second position, having spent US$812 billion, while Japan remained in third position having spent US$201 billion. Normalised as a percentage of GDP, GERD/GDP was 3.6% in the United States, 2.6% in China and 3.4% in Japan.

Singapore's GERD/GDP was 1.8% in 2022, comparable to 2021 (1.9%). The top 3 most research-intensive countries/regions in the world, as measured by GERD/GDP, were Israel (6.0%), Republic of Korea (5.2%), and Taiwan (4.0%).

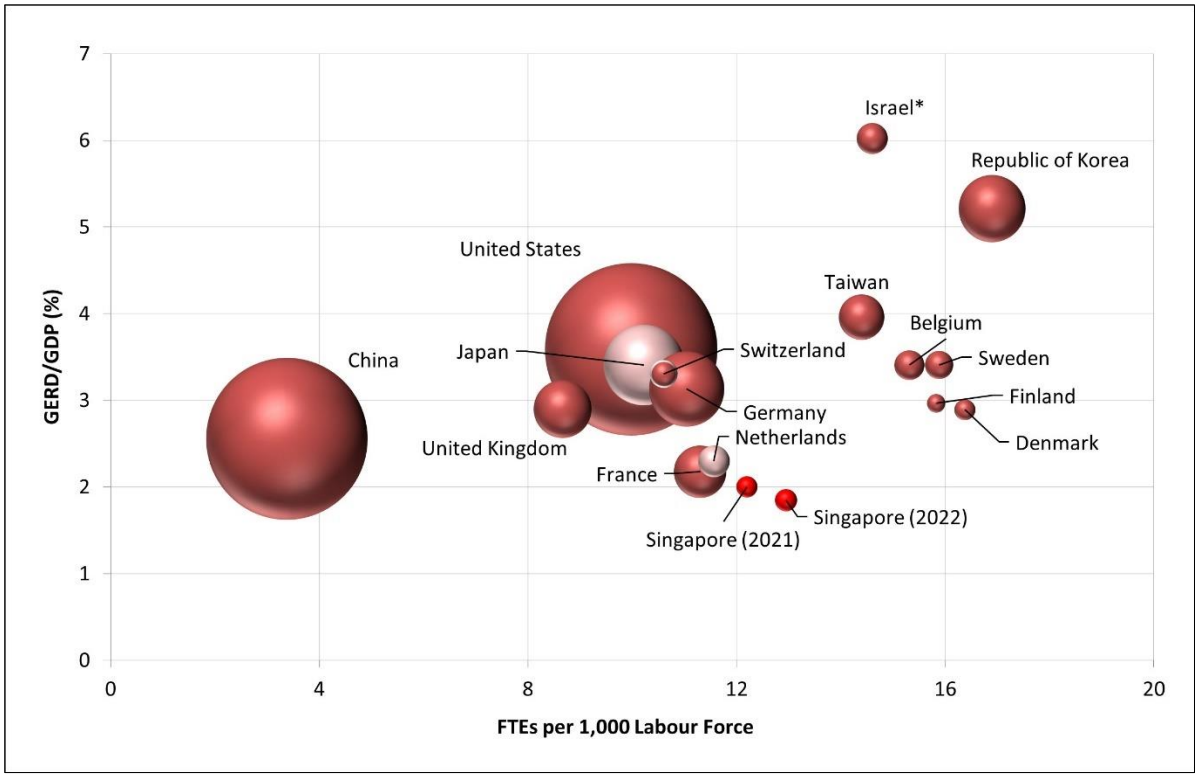
6.2 Researcher Intensity in Selected Countries/Regions

Researcher intensity is measured by Full-time Equivalents (FTEs) as a percentage of the labour force. Researcher FTEs in Singapore rose by 9.9% from 44,226 in 2021 to 48,599 in 2022, outpacing the rate of growth of the labour force (4.1%) over the same period.

Singapore's researcher intensity (FTEs/1,000 Labour Force) was 12.3 in 2021 and 12.9 in 2022.

The top 3 countries in terms of researcher intensity in 2022 are Republic of Korea (16.9), Denmark (16.4) and Sweden (15.9).

Fig.6.1 Comparison of Selected Countries/Regions by Research & Researcher Intensity (2022)



Bubble size indicates GERD.
**Researcher intensity for Israel is as of 2012.*
Source: OECD, Main Science and Technology Indicators 2024/07
Data for most countries are for 2022, otherwise based on latest available in OECD MSTI.

7. EXPLANATORY NOTES AND DEFINITIONS

7.1 DEFINITION OF R&D

7.1.1 Research and development (R&D) comprises creative work undertaken on a systematic basis in order to increase the stock of knowledge and the use of this stock of knowledge to devise new applications. R&D covers three activities: basic research, applied research and experimental development, which are defined and described in Section 7.5. The scope of the definition of R&D for this Survey extends to R&D in science and technology only and excludes the social sciences and humanities.

7.1.2 R&D is related to a number of other activities with a scientific and technological basis, which are often very closely linked to R&D through flows of information or in terms of operations, institutions and personnel. The basic criterion for distinguishing R&D from related activities is the presence of an appreciable element of novelty and the resolution of scientific or technological uncertainty, i.e. when the solution to a problem is not readily apparent to someone familiar with the basic stock of common knowledge and techniques for the area concerned.

7.2 R&D MANPOWER

7.2.1 R&D manpower comprises all persons directly employed on R&D and those providing direct services. It includes persons who are mainly or partially engaged in R&D. It comprises the three occupation groups defined and described below: researchers; technicians; and other supporting staff.

7.2.2 Researchers are professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems, or in the management of the projects concerned.

7.2.3 Researchers are further sub-classified as follows:

(a) **Research scientists and engineers (RSEs)** comprise the researchers, excluding the full-time postgraduate research students, who hold formal qualifications at the university degree level. RSEs are classified into three subcategories according to the highest level of the formal qualifications: PhD; master degree; and bachelor degree.

(b) **Non-degree researchers** comprise the researchers, excluding the full-time postgraduate research students, who hold formal qualifications below the university degree level.

(c) **Full-time postgraduate research students (FPGRSs)**.

We define also TRSEs (“total” RSEs) to be the category comprising the RSEs and FPGRSs.

7.2.4 **Technicians** are persons whose main tasks require technical knowledge and experience in one or more fields of science and technology. They participate in R&D by performing scientific and technical tasks involving the application of concepts and operational methods, normally under the supervision of researchers. The tasks of technicians include: preparing computer programmes; carrying out experiments, tests and analyses; preparing materials and equipment for experiments, tests and analyses; and recording measurements, making calculations and preparing charts and graphs.

7.2.5 **Other supporting staff** comprise other persons who participate in or are directly associated with R&D projects. Managers and administrators dealing mainly with financial and personnel matters and general administration, skilled and unskilled craftsmen, and secretarial and clerical staff,

are included in this heading, insofar as their activities are a direct service to R&D. Persons providing an indirect service should be excluded (but their wages and salaries should be included as an overhead costs when measuring expenditure on R&D).

7.2.6 The Survey's reporting convention for the headcount of those engaged in R&D is the number of persons as at the last day of the one-year reporting period.

7.2.7 One full-time equivalent (FTE) unit may be thought of as one person-year. A person who spends 30% of his time on R&D and the rest on other activities during the one-year reporting period should be considered as 0.3 FTE. If a full-time R&D worker is employed for only six months during the one-year reporting period, this results in a 0.5 FTE.

7.2.8 R&D manpower is also classified by the following:

(a) **Nationality**, categorised by "Singapore citizens and Singapore permanent residents" as well as "non-PR foreign citizens".

(b) **Age group**, categorised by the following: (i) under 25 years; (ii) 25-34 years; (iii) 35-44 years; (iv) 45-54 years; (v) 55-64 years; and (vi) above 64 years.

(c) **Sex**.

7.3. R&D EXPENDITURE

7.3.1 The (intramural) R&D expenditures for an organisation comprise all expenditures on R&D performed *within the organisation* during the reporting period. They include non-R&D expenditures made outside the organisation but in support of the R&D performed within the organisation. It excludes extramural R&D expenditures, which are the sums an organisation paid or committed to pay to another organisation for the performance of R&D (e.g., acquisition of R&D performed by others and grants given to others for performing R&D).

7.3.2 Intramural R&D expenditures comprise current and capital expenditures.

(a) **Current expenditures** comprise manpower and other operating expenditures:

(i) **Manpower expenditures** comprise annual wages and salaries and all associated expenditures for R&D manpower. The manpower expenditures on persons who provide an indirect service to R&D and are not categorized as R&D manpower are included as other operating expenditures on R&D and not as manpower expenditures on R&D.

(ii) **Other operating expenditures (OOE)** include non-capital purchases of materials, supplies and equipment to support R&D performed by the organisation. Administrative and other overhead expenditures are included and prorated if necessary. Expenditures on indirect services are included. Rents and fees associated with R&D are included.

(b) **Capital expenditures (CAPEX)** are the annual gross expenditures on fixed assets used in the R&D programmes of the organisation, i.e. on (i) land, buildings and other structures, and on (ii) vehicles, plant, machinery and equipment. They are reported in full for the reporting period when they took place rather than registered as an element of depreciation.

7.3.3 Sources of R&D funds are reported by the performers of research. The surveyed organisation reports the sums which it received or will receive from various sources for the performance of (intramural) R&D during the one-year reporting period. Funds

received for R&D performed during earlier periods or for R&D not yet started are excluded. The categories of sources of R&D funds are:

(a) Within Singapore:
  (i) Private sector;
  (ii) Government sector;
  (iii) Institutes of Higher Learning.

(b) Abroad:
  (i) Foreign-based companies;
  (ii) Foreign governments and international organisations.

7.3.4 All monetary amounts in this report are in Singapore dollars. Monetary amounts that are reported by survey respondents in foreign currency units are converted to Singapore dollars based on the average exchange rates for the relevant year, as published by the Monetary Authority of Singapore.

7.4. INSTITUTIONAL CLASSIFICATION

7.4.1 Sectors. The Survey classifies organisations into four sectors:

(a) **Private sector**. This comprises all business enterprises, excluding institutions of higher learning.

(b) **Government sector**. This comprises all government organisations, including government ministries, statutory boards and public research institutes. It excludes institutes of higher learning, which are classified under a separate sector.

(c) **Institutes of Higher Learning**. This comprises institutions of higher learning, including the universities and polytechnics.

7.4.2 Industrial classification. The enterprises in the private sector are further sub-classified into industry groups and subgroups according to their classification by the Singapore Standard Industrial Classification (SSIC) 2020.

7.4.3 The enterprises in the private sector are also sub-classified by ownership and size:

(a) A company with at least 30% local equity is classified as a local company, and with less than 30% local equity a foreign company.

(b) A local company is classified as a small/medium-sized enterprise (SME) if it satisfies the following criteria (following Enterprise Singapore), and a large enterprise (LE) otherwise:

  (i) Annual sales turnover of not more than $100 million; or
  (ii) Employment size of not more than 200 workers.

7.5. FUNCTIONAL DISTRIBUTION

7.5.1 Type of R&D. Three types of R&D are distinguished:

(a) **Basic research** is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.

The performer of the research may not know about actual applications when doing the research, and therefore does not have them in view: such research is basic according to the definition. Research that is undertaken with the goal of a broad range of applications in the future, but which does not have a particular use in view, is basic according to the definition.

Thus, two types of basic research are distinguished:

(i) **Pure basic research** is carried out primarily for the advancement of knowledge, rather than to solve a specific problem or to seek long-term economic or social benefits or to transfer the results to sectors responsible for their application.

(ii) **Strategic (or oriented) basic research** is carried out with the expectation that it will produce a broad base of knowledge likely to form the basis of the solution to recognised or expected, current or future problems or possibilities.

(b) **Applied research** is also original investigation undertaken in order to acquire new knowledge. However, it is directed primarily towards a specific practical aim or objective. Applied research is undertaken either to determine possible uses for the findings of basic research or to determine new methods or ways of achieving specific and predetermined objectives. It involves considering the available knowledge and its extension in order to solve particular problems. The results of applied research are intended primarily to be valid for a single or limited number of products, operations, methods or systems. Applied research gives operational form to ideas.

(c) **Experimental development** is systematic work, drawing on knowledge gained from research and practical experience, that is directed to producing new materials, products and devices; to installing new processes, systems and services; or to improving substantially those already produced or installed.

7.5.2 Fields of science and technology (S&T). The areas of R&D are classified by the following S&T fields:

Natural sciences (excluding biological sciences)

- Computer and related sciences [computer programming, computer studies, electronic data processing, information sciences, system analysis, and areas related to software development]
- Physical sciences and mathematics [astronomy and space sciences, physics and related sciences]
- Chemical sciences [chemistry and related sciences]
- Earth and related environmental sciences [geology, geophysics, mineralogy, meteorology, physical geography and other geosciences, other atmospheric sciences including climate research, oceanography, vulcanology, palaeoecology and related sciences]

Engineering and technology

- Civil and architecture engineering [architecture engineering, building sciences and engineering, construction engineering, municipal and structural engineering]
- Mechanical engineering
- Metallurgy and metal engineering
- Aeronautical engineering
- Marine engineering
- Electrical and electronics engineering [electrical engineering, electronics, communication engineering and systems]
- Computer engineering [hardware only]
- Info-communication and media technology
- Materials science and chemical engineering
- Environmental engineering
- Biomedical engineering

Biomedical and related sciences

- Basic medicine [anatomy, cytology, physiology, pharmacy, pharmacology, toxicology, immunology and

immunohaematology, pathology, neuroscience]
- Clinical medicine [anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology, oncology, geriatrics, cardiovascular, dermatology, urology, infectious diseases]
- Health sciences [public health services, social medicine, hygiene, nursing, epidemiology]
- Pharmaceutical sciences and manufacturing
- Biological sciences [biochemistry, biology, biophysics, genetics, microbiology, molecular biology, bioengineering, bioinformatics]
- Other related biomedical sciences

Agricultural sciences, food sciences [Agronomy, agrotechnology, animal husbandry, fisheries, forestry, horticulture, bacteriology related to animals, veterinary medicine, botany, zoology, food and other related sciences]

Energy
[Clean energy systems; solar energy; wind energy]

Other areas

7.6. OTHER DATA

7.6.1 The following R&D-related data are also collected by the Survey:

(a) **Patenting activities** arising from R&D performed in Singapore:

(i) Number of primary patent applications during the reporting period. Only first filings of patent applications are counted, and patent applications for the same invention in more than one country are entered as one.

(ii) Number of patent awards during the reporting period. Patent awards for the same invention in more than one country are entered as one.

(iii) Number of patents owned as at the last day of the calendar year.

(b) **Revenue data**:

(i) Licensing revenue from patents and new technologies developed in Singapore;

(ii) Sales revenue from commercialized products/processes attributed to R&D performed in Singapore.

7.6.2

(a) The following classification data are also collected in the Survey:

(i) Total number of employees;

(ii) Total sales revenue over the one-year reporting period;

(iii) Information on local and foreign equity in the company.

(b) The industrial classification of private sector enterprises by the SSIC 2020 is obtained from the Department of Statistics.

7.6.3 The convention for reporting data such as sales revenue may differ across organisations.

7.7 LIST OF ABBREVIATIONS:

BERD	Business Expenditure on R&D
CAPEX	Capital Expenditure
CAGR	Compound Annual Growth Rate
EDB	Economic Development Board
FPGRS	Full-time Postgraduate Research Student
FTE	Full-time Equivalent
GDP	Gross Domestic Product
GERD	Gross Expenditure on R&D
IPOS	Intellectual Property Office of Singapore
OOE	Other Operating Expenditure
PG	Post Graduate
PUBERD	Public Expenditure on R&D
RIE	Research, Innovation and Enterprise
R&D	Research & Development
RSE	Research Scientists and Engineers
SME	Small & Medium Enterprise
SSIC	Singapore Standard Industrial Classification
S&T	Science and Technology
UEN	Unique Entity Number

8. METHODOLOGY

8.1. METHODOLOGY

8.1.1 The National Survey of Research, Innovation and Enterprise (RIE) in Singapore is conducted under the Statistics Act 1973 (Chapter 317), which makes the submission of returns mandatory. Individual returns received are kept in confidence with the Statistics Act. The Act is available on the Singapore Department of Statistics' website (www.singstat.gov.sg).

8.1.2 The approach is to survey all organisations that are known to perform R&D. A register of R&D performing organisations is maintained. The Survey form is sent to the organisations on the register. The register comprises all organisations that had reported previously to the Survey that they performed R&D, after excluding those that subsequently reported that they did not perform R&D or ceased operations. The register is updated annually through a Preliminary Survey of organisations that are potentially performing R&D but are not on the register. The list of organisations surveyed in the Preliminary Survey is compiled annually from various sources, and includes all companies that are in receipt of government R&D grants.

8.1.3 From 2019, the register has expanded to include organisations that perform innovation activities (other than R&D). This is in line with the expansion of the survey to include returns on innovation activities performed by organisations in Singapore.

8.2. RESPONSES

8.2.1 The organisations that reported to the Survey that they performed innovation and/or R&D in 2022 comprised private sector enterprises, government organisations, institutions of higher learning and the public research institutes. A total of 1,025 private sector enterprises reported that they performed R&D in 2022.

8.2.2 Approximately 14,200 survey forms were sent out in the Preliminary Survey. Subsequently, close to 3,000 survey forms were sent out to private sector enterprises in the 2022 register of innovation and/or R&D-performing organisations. From these, nearly 2,000 private sector enterprises responded, out of which about 1,600 (80%) reported that they performed innovation (including R&D), up from 1,500 in the previous reference period. The remaining 20% reported that they did not perform innovation and/or R&D in 2022 or had ceased business operations.

8.2.3 In 2022, the top 150 private sector enterprises (by R&D expenditure in 2021) accounted for 81% ($6.6 billion) of private sector R&D expenditure. 142 (95%) reported that they performed R&D in 2022 and their returns were either reported under their own name or under a parent or subsidiary and 8 (5%) either reported that they did not perform R&D in 2022 or had ceased business operations or did not respond to us.

8.2.4 81% of all the government organisations, institutions of higher learning and government research institutes that were surveyed in 2022 responded.

8.2.5 The 2022 National RIE Survey publication continues to report the aggregated findings of organisations that perform in-house R&D. Findings of innovation activities performed by organisations in Singapore may be included in future editions of the publication.

8.3. CONVENTIONS

8.3.1 The reporting period of the Survey is one year in length. The actual period may vary across Survey respondents but it would usually be the calendar or fiscal year.

8.4. HISTORICAL NOTES

8.4.1 The National Survey of R&D in Singapore was conducted by the Singapore Science Council on a triennial basis from 1978 to 1987. Since 1990, it has been conducted and published annually by the Agency for Science, Technology and Research (formerly the National Science and Technology Board). In 2019, the National Survey of R&D has been renamed the National Survey of Research, Innovation and Enterprise (RIE), which includes innovation as well.

8.4.2 Postgraduate research students (at the master degree and PhD levels) have been reported as R&D manpower only since the 2000 Survey. In the 2000 Survey, both full-time and part-time postgraduate research students were counted. Since the 2001 Survey, only full-time postgraduate research students (FPGRSs) have been included.

8.4.3 In 2000 and 2001, the Survey published data on patents applied and awarded that combined data from the Survey with data from the public databases of the Intellectual Property of Singapore (IPOS). Specifically, the published data combined the patenting data of the Survey respondents with the patenting data in the IPOS databases of locally-based companies (and individuals) that were not among the Survey's respondents. (The IPOS data contributed an additional 128 patents applied and 46 patents awarded in 2000, and an additional 193 patents applied and 51 patents awarded in 2001.) Since 2002, the Survey publishes only the patenting data of Survey respondents.

8.4.4 Since the 2002 Survey, (a) the industrial classification of enterprises in the private sector by industry groups was revised to ensure overall consistency of the classifications with SSIC 2000 and to align the definitions of the industry groups in the manufacturing industries with EDB's new definitions; (b) basic research in the private sector was not sub-classified into the subtypes of pure and strategic basic research; (c) "licensing revenue from acquired patents and new technologies" and "sales revenue from commercialised products and processes attributed to R&D performed in Singapore within the last 2 years" ceased to be published; (d) the Survey asked additionally for the age group and sex of R&D manpower to be reported; (e) the Survey included "computer engineering", "info-communication & media technology", "biological sciences", "basic medicine", "clinical medicine", "health sciences", "pharmaceutical sciences & manufacturing" and "other biomedical related sciences" as disaggregated options under the fields of science & technology category for both researchers and R&D expenditure; and (f) the Survey asked for the disaggregation of reported R&D expenditure in each field of science & technology by the type of R&D.

8.4.5 Prior to 2005, the classification of survey respondents from the private sector was based on the SSIC 2000. In 2005, it was updated to SSIC 2005, in 2010, to SSIC 2010, in 2015, to SSIC 2015, in 2017, to SSIC 2015 (version 2018), and in 2020, to SSIC 2020. In 2017, the aggregation of manufacturing activities into the EDB-defined manufacturing subsectors was also updated with EDB's revised classification. These revisions have some but limited impact on the comparability of the published R&D statistics in the 2017 survey report relative to those in the preceding survey reports.

8.4.6 Hitherto, organisations which were known to have performed R&D in the survey period, but which did not submit a survey return or submitted an incomplete survey return, have been excluded from the published survey results. With effect from the 2006 survey report, such organisations would be captured in the published survey results through a mechanism of imputation,

where this is feasible. The imputed data would be based on the previous year's survey returns and/or the current year's incomplete returns. The impact on the published statistics was marginal considering the survey already had a high response rate. Imputation was used for 7 (0.2%) of the 4,121 entities surveyed in 2021.

8.4.7 With effect from the 2007 Survey, an exercise would be undertaken on a yearly basis to update any changes made by the Department of Statistics to an organisation's Unique Entity Number (UEN) which could in turn impact its SSIC code. This is to capture any changes in the organisation's core activity so as to ensure that the organisation is placed in the correct industry classification.

8.4.8 With effect from the 2021 Survey, breakdowns for Capital Costs into the separate components "*Land, Building & Other Structures"*, and "*Vehicles, Plant, Machinery & Equipment"* are no longer collected to reduce respondent burden.

LIST OF TABLES

Data tables can be accessed at: https://www.a-star.edu.sg/News/national-survey-of-rie.

Data for full time series can be obtained at SingStat Table Builder (i.e. At SingStat Table Builder, choose Industry → Research and Development (R&D))