

ISBN 978-0-9924254-8-7 (print)

ISBN 978-0-9924254-9-4 (digital)

ISBN 978-0-9943687-0-6 (HTML)

© Commonwealth of Australia 2015

All material presented in this publication is provided under a Creative Commons Attribution 3.1 Australia licence (creativecommons.org/licenses) with the exception of the Commonwealth Coat of Arms, the Australian Research Council logo, images, signatures and where otherwise stated. For the avoidance of doubt, this means this licence only applies to material as set out in this document. The details of the relevant licence conditions are available on the Creative Commons website as is the full legal code for the CC BY 3.0 AU licence creativecommons.org/licenses.

Requests and enquiries regarding this licence should be addressed to ARC Legal Services on +61 2 6287 6600.



Australian Government
Australian Research Council

2015

2016

State of Australian
University Research
Volume 1 ERA National Report

MINISTER'S FOREWORD



I am pleased to present the *State of Australian University Research 2015–16: Volume 1 ERA National Report (ERA 2015)*, a comprehensive assessment, by discipline, of the quality of research conducted in Australia's higher education institutions.

In Australia, and around the world, high quality research is driving innovation that saves lives, answers social and environmental imperatives, improves economic productivity and growth, and creates the jobs of the future. The Australian Government will invest \$9.7 billion in 2015–16 into research across education, industry, health, defence, environment and agriculture that will help ensure the Australia of the future is agile, creative and innovative, and able to compete with the best in the world.

ERA 2015's internationally benchmarked data shows that Australia's research effort, conducted in universities across the nation and in every broad discipline group, continues to perform well—above world standard.

It also showcases the rich research diversity, strength and excellence across the spectrum of Australian universities.

With ERA 2015, Australia now has longitudinal data on our research effort since 2003 — an invaluable resource for universities, industry and other users of research, and policymakers.

This will be used to help map progress in meeting the Australian Government's Science and Research Priorities, and corresponding Practical Research Challenges.

ERA is also a quality assurance mechanism for Australia's universities, which reported \$9.9 billion in research income between 2011 and 2013.

Encouraging stronger incentives for research–industry collaboration and better translating research into commercial outcomes — as promoted by the Government's Boosting the Commercial Returns from Research strategy — is a high priority so as to maximise the economic and social outcomes of Australia's high–quality research.

I congratulate the Australian Research Council and all of the universities that contributed to ERA 2015 for their commitment to Australian research investment, performance, and discovery.

A handwritten signature in blue ink, which appears to read "Simon Birmingham".

Senator the Hon Simon Birmingham
Minister for Education and Training

CEO'S FOREWORD



This is the inaugural *State of Australian University Research 2015–16*.

In the past, the ARC has released the ERA results through an ERA National Report and Volume 1 of this *State of Australian University Research 2015–16* continues that tradition. It comprehensively details the quality of Australian university research benchmarked against world standards.

With three rounds of ERA now complete, this unique dataset covers all Australian university research outputs, staffing and activity from 2003 to 2013, and research income and research application data from 2006 to 2013.

Over the coming year the ARC will produce additional volumes based on analyses of this longitudinal data, which will provide further insights into the state of Australian university research. Volume 2 will be released in April 2016.

ERA is the primary mechanism to assure Government of its research investment in Australian universities.

ERA 2015 results clearly demonstrate that Australian universities are diverse and that much of their research meets world standard or better.

This report identifies the excellence in research across a broad range of universities and the outstanding performances in areas of specialisation. Overall the quality of Australian university research continues to improve.

The data also shows solid growth of the sector from the previous ERA round. For ERA 2015 data for over 430,000 unique research outputs and 67,000 researchers was collected from the 41 participating universities. There were 2,460 units of evaluation assessed, including 1,802 four-digit and 658 two-digit disciplines.

ERA would not be possible without the support the ARC receives from the sector. In addition to sector-wide consultations to help refine the ERA 2015 process and the work of all universities during the submission stages, there were 155 Research Evaluation Committee members and about 1,300 peer reviewers from Australia and overseas appointed to conduct the evaluations.

This strong sector engagement maintains the confidence that ERA is the most rigorous and effective measure of research quality in Australia's universities. I would like to take this opportunity to thank all those involved at various stages of the ERA process and in particular the ARC ERA staff.

I strongly encourage universities, industry and other research users to make use of the valuable information that ERA provides.

A handwritten signature in black ink, appearing to read 'Aidan Byrne'.

Professor Aidan Byrne
Chief Executive Officer
Australian Research Council

CONTENTS

Minister's Foreword	ii
CEO's Foreword	iii
Abbreviations	xii
Guide to the Report	xiii

INTRODUCTION 1

Objectives of ERA	2
Use of Information from ERA	2
Definition of Research	3
Fields of Research (FoR) Codes	3
ERA 2015 Reference Periods	3
ERA 2015 Evaluation Process	4
ERA 2015 Discipline Clusters	4
ERA 2015 Indicators	4
Unit of Evaluation	5
Low Volume Threshold	5
ERA Rating Scale	6
Additional Reporting for ERA 2015	8
Key ERA 2015 Documents	8
Use of the ERA National Report	9

SECTION 1: ERA 2015 NATIONAL OVERVIEW 11

Research Quality	12
Assessed Units of Evaluation	25
National ERA Volume at a Glance	27
Comparison of ERA 2010, ERA 2012 and ERA 2015	35
Percentage Contribution to the National Landscape	37
Discipline Growth	41
Multi-disciplinary Research	47
Contribution by Employment Level	57
Non-Traditional Research Outputs	66
Employment Function	67
Contribution of Non-salaried Staff	70
Co-authorship by ERA Authors	71
Patents and Applied Income Sources	72

Additional Reporting on ERA 2015	75
Diversity within Institutions	75
Gender	80
Open Access	82

SECTION 2: OVERVIEW BY TWO-DIGIT FIELDS OF RESEARCH CODE

85

Research Outputs	86
HERDC Research Income Summary (All Categories)	87
HERDC Category 1 – Australian Competitive Grants Research Income	88
HERDC Category 2 – Other Public Sector Research Income	90
HERDC Category 3 – Industry and Other Research Income	92
HERDC Category 4 – CRC Research Income	94
FTE Staffing Profile	96
Esteem Measures	97
Patents Granted	98
Registered Designs	99
Plant Breeder's Rights	100
National Health and Medical Research Council (NHMRC) Endorsed Guidelines	100
Research Commercialisation Income	101

SECTION 3: RESULTS BY FIELDS OF RESEARCH CODE 103

01 Mathematical Sciences	104
0101 Pure Mathematics	108
0102 Applied Mathematics	109
0103 Numerical and Computational Mathematics	109
0104 Statistics	109
0105 Mathematical Physics	110
0199 Other Mathematical Sciences	110
02 Physical Sciences	111
0201 Astronomical and Space Sciences	115
0202 Atomic, Molecular, Nuclear, Particle and Plasma Physics	116
0203 Classical Physics	116
0204 Condensed Matter Physics	116
0205 Optical Physics	117
0206 Quantum Physics	117
0299 Other Physical Sciences	117

03 Chemical Sciences	118
0301 Analytical Chemistry	122
0302 Inorganic Chemistry	123
0303 Macromolecular and Materials Chemistry	123
0304 Medicinal and Biomolecular Chemistry	123
0305 Organic Chemistry	124
0306 Physical Chemistry (Incl. Structural)	124
0307 Theoretical and Computational Chemistry	124
0399 Other Chemical Sciences	125
04 Earth Sciences	126
0401 Atmospheric Sciences	130
0402 Geochemistry	131
0403 Geology	131
0404 Geophysics	131
0405 Oceanography	132
0406 Physical Geography and Environmental Geoscience	132
0499 Other Earth Sciences	132
05 Environmental Sciences	133
0501 Ecological Applications	136
0502 Environmental Science and Management	137
0503 Soil Sciences	137
0599 Other Environmental Sciences	137
06 Biological Sciences	138
0601 Biochemistry and Cell Biology	142
0602 Ecology	143
0603 Evolutionary Biology	143
0604 Genetics	143
0605 Microbiology	144
0606 Physiology	144
0607 Plant Biology	144
0608 Zoology	145
0699 Other Biological Sciences	145
07 Agricultural and Veterinary Sciences	146
0701 Agriculture, Land and Farm Management	151
0702 Animal Production	151
0703 Crop and Pasture Production	151
0704 Fisheries Sciences	152
0705 Forestry Sciences	152
0706 Horticultural Production	152
0707 Veterinary Sciences	153
0799 Other Agricultural and Veterinary Sciences	153

08 Information and Computing Sciences	154
0801 Artificial Intelligence and Image Processing	159
0802 Computation Theory and Mathematics	159
0803 Computer Software	159
0804 Data Format	160
0805 Distributed Computing	160
0806 Information Systems	160
0807 Library and Information Studies	161
0899 Other Information and Computing Sciences	161
09 Engineering	162
0901 Aerospace Engineering	169
0902 Automotive Engineering	169
0903 Biomedical Engineering	169
0904 Chemical Engineering	170
0905 Civil Engineering	170
0906 Electrical and Electronic Engineering	170
0907 Environmental Engineering	171
0908 Food Sciences	171
0909 Geomatic Engineering	171
0910 Manufacturing Engineering	172
0911 Maritime Engineering	172
0912 Materials Engineering	172
0913 Mechanical Engineering	173
0914 Resources Engineering and Extractive Metallurgy	173
0915 Interdisciplinary Engineering	173
0999 Other Engineering	174
10 Technology	175
1001 Agricultural Biotechnology	179
1002 Environmental Biotechnology	180
1003 Industrial Biotechnology	180
1004 Medical Biotechnology	180
1005 Communications Technologies	181
1006 Computer Hardware	181
1007 Nanotechnology	181
1099 Other Technology	182
11 Medical and Health Sciences	183
1101 Medical Biochemistry and Metabolomics	190
1102 Cardiovascular Medicine and Haematology	190
1103 Clinical Sciences	190
1104 Complementary and Alternative Medicine	191
1105 Dentistry	191
1106 Human Movement and Sports Science	191

1107 Immunology	192
1108 Medical Microbiology	192
1109 Neurosciences	192
1110 Nursing	193
1111 Nutrition and Dietetics	193
1112 Oncology and Carcinogenesis	193
1113 Ophthalmology and Optometry	194
1114 Paediatrics and Reproductive Medicine	194
1115 Pharmacology and Pharmaceutical Sciences	194
1116 Medical Physiology	195
1117 Public Health and Health Services	195
1199 Other Medical and Health Sciences	195
12 Built Environment and Design	196
1201 Architecture	200
1202 Building	200
1203 Design Practice and Management	200
1204 Engineering Design	201
1205 Urban and Regional Planning	201
1299 Other Built Environment and Design	201
13 Education	202
1301 Education Systems	205
1302 Curriculum and Pedagogy	205
1303 Specialist Studies in Education	205
1399 Other Education	206
14 Economics	207
1401 Economic Theory	210
1402 Applied Economics	210
1403 Econometrics	210
1499 Other Economics	211
15 Commerce, Management, Tourism and Services	212
1501 Accounting, Auditing and Accountability	217
1502 Banking, Finance and Investment	217
1503 Business and Management	217
1504 Commercial Services	218
1505 Marketing	218
1506 Tourism	218
1507 Transportation and Freight Services	219
1599 Other Commerce, Management, Tourism and Services	219
16 Studies in Human Society	220
1601 Anthropology	223
1602 Criminology	224
1603 Demography	224

1604 Human Geography	224
1605 Policy and Administration	225
1606 Political Science	225
1607 Social Work	225
1608 Sociology	226
1699 Other Studies in Human Society	226
17 Psychology and Cognitive Sciences	227
1701 Psychology	230
1702 Cognitive Sciences	230
1799 Other Psychology and Cognitive Sciences	230
18 Law and Legal Studies	231
1801 Law	234
1802 Maori Law	234
1899 Other Law and Legal Studies	234
19 Studies in Creative Arts and Writing	235
1901 Art Theory and Criticism	240
1902 Film, Television and Digital Media	240
1903 Journalism and Professional Writing	240
1904 Performing Arts and Creative Writing	241
1905 Visual Arts and Crafts	241
1999 Other Studies in Creative Arts and Writing	241
20 Language, Communication and Culture	242
2001 Communication and Media Studies	247
2002 Cultural Studies	247
2003 Language Studies	247
2004 Linguistics	248
2005 Literary Studies	248
2099 Other Language, Communication and Culture	248
21 History and Archaeology	249
2101 Archaeology	252
2102 Curatorial and Related Studies	252
2103 Historical Studies	252
2199 Other History and Archaeology	253
22 Philosophy and Religious Studies	254
2201 Applied Ethics	258
2202 History and Philosophy of Specific Fields	258
2203 Philosophy	258
2204 Religion and Religious Studies	259
2299 Other Philosophy and Religious Studies	259

SECTION 4: NATIONAL PROFILES BY FIELDS OF RESEARCH CODE 261

Research Outputs by Type	267
Research Outputs by Year	276
HERDC Category 1 – Australian Competitive Grants Research Income	283
HERDC Category 2 – Other Public Sector Research Income	290
HERDC Category 3 – Industry and Other Research Income	297
HERDC Category 3 – Industry and Other Research Income (Australian)	304
HERDC Category 3 – Industry and Other Research Income (International A)	311
HERDC Category 3 – Industry and Other Research Income (International B)	318
HERDC Category 4 – CRC Research Income	325
Staffing Profile	332
Esteem	339
Patents Granted	347
Registered Designs	352
Plant Breeder's Rights	353
NHMRC Endorsed Guidelines	354
Research Commercialisation Income	355

SECTION 5: ERA 2015 INSTITUTION REPORT 363

01 Mathematical Sciences	364
02 Physical Sciences	366
03 Chemical Sciences	368
04 Earth Sciences	370
05 Environmental Sciences	372
06 Biological Sciences	374
07 Agricultural and Veterinary Sciences	376
08 Information and Computing Sciences	378
09 Engineering	380
10 Technology	382

11 Medical and Health Sciences	384
12 Built Environment and Design	386
13 Education	388
14 Economics	390
15 Commerce, Management, Tourism and Services	392
16 Studies in Human Society	394
17 Psychology and Cognitive Sciences	396
18 Law and Legal Studies	398
19 Studies in Creative Arts and Writing	400
20 Language, Communication and Culture	402
21 History and Archaeology	404
22 Philosophy and Religious Studies	406

GLOSSARY AND APPENDICES 409

Glossary	410
Appendix 1 – Eligible Institutions	415
Appendix 2 – ANZSRC Fields of Research (FoR) Codes	416

ABBREVIATIONS

AIATSIS	Australian Institute of Aboriginal and Torres Strait Islander Studies
ANZSRC	Australian and New Zealand Standard Research Classification (ANZSRC) 2008
ARC	Australian Research Council
BB	Biological and Biotechnological Sciences discipline cluster/Research Evaluation Committee
CRC	Cooperative Research Centre
EC	Economics and Commerce discipline cluster/Research Evaluation Committee
EE	Engineering and Environmental Sciences discipline cluster/Research Evaluation Committee
EHS	Education and Human Society discipline cluster/Research Evaluation Committee
EPO	European Patent Office
ERA	Excellence in Research for Australia
FoR	Fields of Research (ANZSRC)
FTE	Full-Time Equivalent
HCA	Humanities and Creative Arts discipline cluster/Research Evaluation Committee
HERDC	Higher Education Research Data Collection
HESDC	Higher Education Staff Data Collection
JPO	Japan Patent Office
MHS	Medical and Health Sciences discipline cluster/Research Evaluation Committee
MIC	Mathematical, Information and Computing Sciences discipline cluster/Research Evaluation Committee
NHMRC	National Health and Medical Research Council
NTRO	Non-traditional research outputs
PBRs	Plant Breeder's Rights
PCE	Physical, Chemical and Earth Sciences discipline cluster/Research Evaluation Committee
REC	Research Evaluation Committee
SRE	Sustainable Research Excellence
UoE	Unit of Evaluation
USPTO	United States Patent and Trademark Office

GUIDE TO THE REPORT

The *State of Australian University Research 2015–16: Volume 1 ERA National Report* presents a comprehensive assessment by discipline of the quality of research activity conducted in Australia's higher education institutions. This volume provides information on the discipline-specific research activity of each eligible Australian higher education institution (see **Appendix 1: Eligible Institutions**), and the contribution of each discipline to the national landscape.

The *ERA National Report* is divided into six sections which are listed below:

- › The **Introduction** provides an overview of the ERA framework and methodology
- › **Section 1: ERA 2015 National Overview** provides a national summary of world standard research performance, a summary of all data submitted for the purposes of the ERA evaluation, some comparative data for ERA 2010, ERA 2012 and ERA 2015, and some preliminary analysis of the ERA 2015 submission data
- › **Section 2: Overview by Two-Digit Fields of Research (FoR) Code** provides a summary of two-digit FoR codes for the suite of indicators presented in ERA
- › **Section 3: Results by Fields of Research (FoR) Code** provides a summary of evaluation outcomes and data for each FoR code, including key volume and activity information and ERA rating outcomes
- › **Section 4: National Profiles by Fields of Research Code** provides a detailed breakdown of ERA data by two- and four-digit FoR codes
- › **Section 5: ERA 2015 Institution Report** provides the ERA ratings for each assessable Unit of Evaluation (UoE) for each of the 41 institutions eligible for ERA.

Enquiries about the *State of Australian University Research 2015–16: Volume 1 ERA National Report* should be directed to:

Leanne Harvey

Executive General Manager

Australian Research Council

Tel +61 (02) 6287 6755

Email era@arc.gov.au

This report is available on the ARC website at: arc.gov.au/excellence-research-australia

If you have issues with obtaining any information or document on our website, please contact the ARC on +61 (02) 6287 6600 or web@arc.gov.au.