European Commission

JRC TECHNICAL REPORTS

The research performance of the European Commission's Science and Knowledge Service, Joint Research Centre (2007-2015)

A bibliometric analysis

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Foreword

This report was requested in support of an interim evaluation of the JRC's research activities under Horizon 2020: the EU Framework Programme for Research and Innovation to be carried out with the assistance of independent experts.

Acknowledgments

This report is a follow up to a previous report prepared by Thomson Reuters. Peter Fako provided assistance in the micro-level publication analysis. The report has been internally reviewed by Pieter van Nes and Göran Lövestam. Professor Robert Tijssen from the Centre for Science and Technology Studies at Leiden University validated the methodology and reviewed the document as external bibliometric expert.

Executive summary

This report presents an assessment of the JRC's scientific and technical research activities in the period 2007-2015, focusing on research outputs and citation impact. It complements a 2014 report drafted by Thomson Reuters. The aim of the report is to inform a panel of independent experts, who will carry out an implementation review of the JRC half way the EU Framework Programme for Research and Innovation, Horizon 2020.

The report provides information on the number of JRC research publications and the scientific impact of those publications, based on data and metrics derived from Thomson Reuter's *InCites* platform and the Web of Science database.

The total number of JRC publications during the period under study was 6 970. Of these publications, 1 362 ranked in the world's top 10 % highly cited publications as categorised per scientific field, which means a 20 % ratio of highly cited papers. This is almost twice the world-average performance. A notable increase in the number of highly cited publications gives an indication of an improved JRC performance.

The JRC's share of top 1 % highly cited publication per field is more than three times the world average in recent years. A considerable number of JRC publications thus have a major impact in the scientific literature. The high score on this metric may be related to the regulatory science role of the JRC.

The five fields of science in which the JRC produces most publications are: Environmental Sciences, Nuclear Science & Technology, Material Science, Analytical Chemistry, and Meteorology & Atmospheric Science.

The field-normalised citation impact (FNCI) is 65 % above the average world level. For some fields, high productivity and impact overlap. These areas of excellence include: Ecology, Energy & Fuels, Environmental Studies, Environmental Sciences, Toxicology, Applied Physics and Meteorology & Atmospheric Sciences. There are also some fields of large JRC publication productivity with relatively low citation impact. Very few of those fields have an FNCI score below world average.

Around 81 % of the JRC's highly cited publications are the result of international co-operation. For 39 % of the highly cited publications, a JRC researcher is the corresponding author. This indicates that, to a significant extent, the highly cited publications are the result of JRC research activities.

In terms of the shares of highly cited publications, the JRC performs at a similar level as top level 'basic science organisations' such as leading research universities and public research centres. The same can be said for the FNCI metric, where the JRC outperforms most of its comparator organisations in fields of major research activity like Environmental Sciences and in Geosciences.

As for JRC's outreach to industry, the share of JRC research publications that are co-produced with private-sector partners (business enterprises and industry) may provide some indication of the contribution to innovations and future socioeconomic impacts. With 3.5 % of its peer-reviewed scientific articles published together with private sector partners, the JRC has a percentage score on par with EPA and NIST in the US or the CEA in France. While the score is lower than that of typical research and technology organisations (RTOs), such as Fraunhofer (DE), TNO (NL) and VTT (SF) for which working with industry is a core part of their mission, it is significantly higher than for most of the academic science organisations, such as Oxford University and the Max Planck Society.

1 Introduction

As the European Commission's science and knowledge service, the Joint Research Centre's (JRC) mission is *'to support EU policies with independent evidence throughout the whole policy cycle. Its work has a direct impact on the lives of citizens by contributing with its research outcomes to a healthy and safe environment, secure energy supplies, sustainable mobility and consumer health and safety'*.

In 2014, the JRC carried out an evaluation of its research performance as part of a broader effort by the EC to evaluate and monitor the outcome of the FP7. For this purpose, *Thomson Reuters* (TR)[1], an international media conglomerate and data provider, prepared a data analytical report[2] responding to a list of open questions that were designed to measure the quantity and quality of JRC research publication outputs. Traditional 'bibliometric' data – i.e. publication counts, scientific references to publications ('citations'), as well as the institutional affiliations of the authors[3] – were extracted from the TR-owned *Web of Science* database (WoS) and analysed to provide a clearer picture of the international comparative state of research at the JRC.

Against this background, the current document provides an update of the abovementioned *Thomson Reuters* report. This assessment of the JRC's scientific and technical research activities in the period 2007-2015 solely focuses on research outputs and citation impact.[4]

A grand total of 6 970 publications were identified within the WoS[5], for the publication years 2007-2015, where the author address list on each publication mentions at least one JRC affiliation. This is the core bibliographical dataset that was used for the 'bibliometric' data analysis underlying this report.[6] A corresponding set of publications for a group of comparator organisations was extracted

1 The Thomson Reuters division that owned the Web of Science, and related information products such as the InCites™ platform and *Essential Science Indicators*, was sold to a new company *Clarivate Analytics* in late 2016. Given the fact that our data refer to earlier years, and for the sake of internal consistency with the prior report, we will keep referring throughout this report to Thomson Reuters as the owner of the information source.

2 Thomson Reuters (2014) "Evaluation of the Research Performance of the Joint Research Centre of the European Commission during the 7th Framework Programme (2007-2013)." https://ec.europa.eu/jrc/sites/jrcsh/files/thomson-reuters-study-2007-2013.pdf

3 The field of 'bibliometrics' is devoted to the measurement of science and research performance based on information retrieved from (online) published scientific documents, especially research articles in scientific and technical journals, contributions to conference proceedings, and academic books. The most well-known measures are based on publication outputs and citation-based scientific impact.

4 The report focus is thus solely on research outputs and impacts and does not consider inputs (such as researcher FTE or funding). It will therefore not include measures of productivity or effectiveness. The main methodological problem which underlies this decision is the lack of information on the amount of time and funding devoted to fundamental research. This issue holds for both the JRC as well as for the comparator organisations to which it will be benchmarked. No reliable assessment or comparison was deemed possible.

5 Both the Web of Science (WoS) database and Scopus database provide powerful analytical tools for advanced citation analysis. Both include many thousands of scholarly journals. Although the journal inclusion criteria in Scopus are similar to the Web of Science, and the databases are similar in their coverage of the world's science (Moya-Anegon et al. 2007, p. 76), coverage differences between the two remain. While Scopus includes more trade journals and national language journals, the world's major 'core' journals are thought to be sufficiently covered in both databases. If the bibliometric analyses would have been based on Scopus, somewhat different results would have been found, but general patterns and trends – at the aggregate level of the studied large research-active organisations - would most likely have been the same.

6 To understand how representative WoS-indexed research publications are for JRC publication productivity the records kept of JRC publication output as presented in the PRIME report are explored. Across all fields, the WoS-indexed publications represent 61 % of all JRC publications. The Scopus database, produced by the publisher *Elsevier*, has a somewhat broader coverage – 4 % of JRC publications are covered in *Scopus* and not in the WoS. Other publications contributed to books or periodicals comprise another 32 % of publications which are not covered by these two main databases. Monographs and books represent 2 % and PhD theses another

for this time period in order to benchmark the JRC research performance. The analysis comprises two levels: (1) all fields of science in total and (2) selected fields.

The aim of this report is to inform a qualitative expert peer assessment of the JRC performance across all JRC research fields by analysing the scientific output and impact of JRC research (as measured by the number of publications and an analysis of the citations these publications received).

1 % of JRC publication output (JRC Productivity and Impact Report, Results from PRIME 2015 (2016), Ref. Ares(2016)2889992 - 22/06/2016). This provides some indication of the relative representativeness of the WoS database.

2 Methodology

In general, most methodological choices were made in order to produce an updated report that is as similar and comparable to the previous report as possible. To this end, the analysts used the TR-owned *InCites™* platform which produces publication metrics and citation indicators based on the *Web of Science* (WoS) database. Some methodological improvements have, however, been made. This section discusses the methodological choices that were made and explains how this analytical report differs from the TR 2014 report.

2.1 Field definitions

Each of the research publications selected from the WoS were assigned to one or more fields of science. These fields were defined in two ways, according to:

(1) TR's 22 *Essential Science Indicators (ESI)* categories. This has the advantage that each publication is assigned to a single broad, mutually-exclusive category. In principle the report thus covers (almost) all JRC research through this approach and does not engage in double counting: i.e. the results from the different '*ESI fields*' can be added to attain the total volume of JRC-produced publications.

(2) TR's WoS *Journal Subject* categories, which allows for a much more fine grained analysis of fields of research activity at the level of 256 (overlapping) fields. A publication can be assigned to multiple '*WoS fields*', depending on the cross-field coverage of the journal in which the publication appeared.

It is difficult to represent the JRC research profile for all 256 'WoS fields'. The selection was therefore restricted to the 35 fields with the highest publication volume. The number of publications in each of the categories is sufficiently large to ensure statistically robust data for each selected field. Both sets of fields (ESI fields and WoS fields) are presented in the report.

2.2 Normalising name variants

In consultation with TRs' InCites team, a few minor improvements were made in the harmonisation of JRC's organisation name variants as they appear in the author addresses in WoS-indexed research publications. These minor adaptations will not have had a major effect on the analyses carried out by TR in 2014. For the comparator organisations, to be discussed in the next section, TR has carried out a similar process of organisational name harmonisation in the InCites platform.

2.3 Time frame

One of the most significant differences in the current report compared to the 2014 report is that the analysis goes up to the year 2015[7]. To explore trends it was decided to provide an analysis covering the entire FP7 timespan (2007-2013) and the first part of Horizon 2020 (2014 and 2015).

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[7] The time frame applied within the Thomson Reuters' study did not extend beyond 2013.

2.4 Comparator organisations

This report takes the 16 organisations, identified by the JRC and TR for the TR 2014 report. It compares the JRC's performance with the performance of these organisations. When comparing it is important to realise that the nature of these organisations can be quite different from the JRC[8]. The TR group of comparators (see **Table 1**) includes some major research universities which, apart from having substantial resources for basic 'discovery-oriented' research, also have an important teaching and training function. Although the JRC also has a training role, it is less of a core activity than at universities. Like the JRC, these universities may play a role in 'supporting policymakers with independent evidence throughout the whole policy cycle', but this is not their core objective. The same can be said for large public research organisations such as the Max-Planck-Gesellschaft (MPG) (Germany), the Consiglio Nazionale delle Ricerche (CNR) (Italy) and the CNRS (France).[9] These organisations tend to be focused more on basic research and have a different relationship with policy-making bodies than the JRC has.

Table 1. Comparator organisations

1.	Commissariat à l'énergie atomique et aux énergies alternatives (CEA), France
2.	Centre national de la recherche scientifique (CNRS), France
3.	Max-Planck-Gesellschaft (MPS), Germany
4.	Oak Ridge National Laboratory (ORNL), United States
5.	Argonne National Laboratory (ANL) United States
6.	Consiglio Nazionale delle Ricerche (CNR),Italy
7.	VTT Technical Research Centre of Finland (VTT),Finland
8.	University of Oxford (OX), United Kingdom
9.	National Institute of Standards and Technology (NIST), United States
10.	National Physical Laboratory (NPL), United Kingdom
11.	University of Cambridge (CAM), United Kingdom
12.	Austrian Research Centre (AIT/ARC), Austria
13.	Fraunhofer-Gesellschaft (FG), Germany
14.	Netherlands Organisation for Applied Scientific Research (TNO), Netherlands
15.	Environmental Protection Agency (EPA), United States
16.	Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
17.	Rikagaku Kenkyūsho (RIKEN), Japan
18.	Chinese Academy of Science (CAS), China
19.	Institut national de la recherche agronomique (INRA), France

[8] As the European Commission's science and knowledge service, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

[9] Cruz Castro, Bleda, Jonkers, Derrick, Martinez, Sanz Menendez, (2011), 'OECD IPP actor brief, public research organisations'.

The list of organisations selected by the JRC for the TR report underwent some adaptation. Firstly, instead of including only the policy advice unit of the US Environmental Protection Agency (US EPA) the total organisation was included for analysis. This was done because the policy advice unit produces only a handful of publications a year. The Spanish organisation CIEMAT, a network of Research and Technology Organisations (RTOs), has been excluded for methodological reasons, as its string of organisational name variants were not harmonized in the *InCites* information platform. In addition, a few additional organisations, such as CSIRO in Australia were added. CSIRO was considered to have a degree of similarity to the JRC both in its development history and its current mission. Other additional organisations include INRA in France, the Chinese Academy of Sciences in China and RIKEN in Japan. The list of organisations has been validated by Pieter van Nes, the Chief Evaluating Officer of the JRC.

2.5 Metrics and research performance indicators

The set of performance measures comprises the following six metrics[10],[11]:

Number of publications: frequency count of research publications (co-)authored by the JRC or the comparator organisations.[12]

Number of highly cited publications: frequency count of publications falling within the top 10 % and top 1 %[13] highly cited publications per field produced worldwide.[14]

Share of highly cited publications[15]: percentage of JRC publications that falls within the top 10 % and top 1 % highly cited publications produced worldwide.

Share of non-cited publications: percentage of publications that had not received any citations in the period 2007-2015 from other Web of Science indexed publications.

Field-normalised citation impact (FNCI)[16]: number of citations per publication received up until April 2017 normalised by the world-average citation rate per field and publication year. The FNCI score allows comparisons between organisations of different sizes and research portfolios. An FNCI value

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10 The definitions of these indicators is derived from the *InCites* Indicator Handbook: http://researchanalytics.thomsonreuters.com/m/pdfs/indicators-handbook.pdf

11 A ‘metric’ is a measurement or a measurement scale related to a specific observable phenomenon, whereas an ‘indicator’ is usually defined as a (composite) ‘proxy’ score that reflects a higher-level or more abstract phenomenon.

12 *InCites* uses absolute counting to calculate this metric. This means that a publication which is co-authored by two (or more) organisations is counted as 'one' publication for each organisation.

13 The number and share of top 1 % most highly cited publications is reported because even if the numbers involved are small, these publications are especially interesting given the skewedness of citation distributions. Such publications can have a disproportionate influence.

14 The definition of highly cited publication used in this report follows international common practice (e.g. Hicks et al., 2015) and diverges from the indicator used in the 2014 Thomson Reuters report in which they select publications with a FNCI value larger than 4.

15 In its report, Thomson Reuter uses an alternative definition of highly cited publications, namely those publications with an average citation impact of four or more. This report follows common practice in the field by selecting the top 10% most highly cited publications indicator (Tijssen et al., 2002).

16 "The FNCI of a document is calculated by dividing the actual count of citing items by the expected citation rate for documents with the same document type, year of publication and subject area. When a document is assigned to more than one subject area, an average of the ratios of the actual to expected citations is used. The FNCI of a set of documents, for example the collected works of the JRC is the average of the FNCI values for all the documents in the set". (*InCites* indicator handbook). Note that TR presents a different indicator the "average impact factor" which leads to different results.

of 1 represents performance at par with world average, values above 1 are considered above average and values below one are considered below average. An FNCI value of two is considered twice the world average.

Percentage industry co-publications[17,18]: An industry co-publication is a co-publication in which at least one of the author's affiliation is listed as 'corporate'. The percentage of industry co-publications is thus the number of industry co-publications for an entity divided by the total number of documents for the same entity represented as a percentage.

2.6 Task description

The guiding research questions are: how many publications has the JRC published in total, and how many of those are highly cited publications? How does the JRC compare to the comparator organisations in terms of research publication output and highly cited publications? And is the citation impact of JRC above world average in key fields of science?

2.7 Methodology

In line with TRs' 2014 report, the steps listed below are followed to complete the data analysis and address those three questions:

1) The total number of publications citations and derived indicators were collected for the JRC and its comparator organisations for the years 2007-2015;
2) The number of publications, citations and derived indicators in each of the 22 ESI fields were collected for the JRC and its comparator organisations for the years 2007-2015;
3) The number of publications, citations and derived indicators in each of the largest WoS fields by number of JRC publications are collected for the JRC and its comparator organisations for the years 2007-2015.
4) In these ESI and WoS fields, the JRC's performance is compared with the performance of the comparator organisations;
5) The individual publications were downloaded from the online version of the Web of Science. These publications were analysed to identify those in which JRC researchers are the corresponding author and those which were 'internationally co-authored'.[19] [20]

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17 Note that Thomson Reuter cautions that 'It is not possible to unify the data for every single affiliation of all the publications in *InCites*, therefore only those entities that have been unified will have an organization type. There will be corporate affiliations that have not yet been unified, will not have an organization type and therefore will not be identified as an industrial collaboration.'

18 Tijssen, R.J.W., (2012) Co-authored research publications and strategic analysis of public-private collaboration, Research Evaluation, 21, 204-215.

19 This refers to co-publications with researchers based in research organisations in a country other than the JRC research facility in which JRC authors are employed: e.g. a publication by a researcher in Petten, the Netherlands, with a researcher in France. Co-publications between JRC researchers based in different geographical sites are not included. Arguably, JRC co-publications with researchers in other domestic organisations could also be considered as international co-publications given the special status of the JRC as being part of an international organisation. However, this decision was not taken in the following instance: e.g. a co-publication between JRC researchers in Petten and those at Delft University (Netherlands) is not considered as an international co-publication.

20 Note that the volume of publications found for the JRC in all years is larger than reported in the Thomson Reuters (2014) report. Plausible explanations include 1) that in this report 'letters and notes' were included alongside 'articles' and 'reviews'. This can account only for a minor increase however. 2) The WoS database grows over time and the publications from newly included journals

3 Results

3.1 Analysis of JRC research performance

Table 2 provides the evolution in the number of publications (co-)authored by JRC staff ('total JRC publication output') per year. It also shows the number and share of the top 10 % highly cited publications, the share of non-cited publications and the field normalised citation impact metric.

One observes a steady upward trend in publication output. This indicates an increase in production, and may also reflect improved levels of productivity - if the output growth surpassed the increase of research-active staff at JRC. The JRC has also improved its performance in terms of highly cited publications, which are now double the expected amount in the world's top 10 % highly cited (the JRC's share was more than 20 % from 2012 onwards), and three times more than expected in the top 1% highly cited (JRC shares exceed 4 % in recent years, i.e. 4 times the world average of 1%). The share of JRC publications cited in the international scientific literature is high: more than 90 %. The declining share in more recent years (2013-2015) results from the fact that most publications take at least 4 to 5 years to reach their full potential in terms of citation impact.[21] The citation impact profile is summarized by the FNCI score, which has increased quite significantly since 2007-2008 (with an impact 27-38 % above world average) to scores in 2012-2013 that are 75-94 % above world average. The scores in the two most recent years (2014-2015) confirm this upward trend. The share of co-publications with industry fluctuates annually around 3.5 per cent. This metric will be placed into context in the comparison with other research organisations in section 3.4.

Table 1. JRC research performance trends: publication output and citation impact

Publication year	Total JRC publication output	Percentage JRC publications in the world's top 10 % highly cited	Percentage JRC publications in the world's top 1 % highly cited	Percentage publs cited	FNCI	Percentage industry copublication
2007	641	16.5	1.6	95.8	1.27	3.74
2008	690	14.2	0.9	95.8	1.38	4.35
2009	650	20.2	2.2	92.5	1.36	2.77
2010	729	18.4	2.9	94.0	1.58	4.25
2011	791	19.7	2.9	94.6	1.48	4.05
2012	784	20.2	4.1	92.0	1.94	2.17
2013	854	21.9	4.7	91.2	1.75	3.51
2014	923	21.9	4.6	87.1	1.71	3.79
2015	908	20.9	4.1	78.9	2.14	3.08
Overall	6 970	19.5	3.2	90.8	1.65	3.52

are included retro-actively. This may account for a larger share of the observed increase. 3) A third explanation for the observed difference is that the TR search algorithms for finding JRC publications (the name and address variants included) increases: i.e. recall has increased.

21 Note that the validity and statistical robustness of a publication's citation impact score declines as the time frame for the accumulation of citations shortens. The citation impact scores for 2014 and 2015 publications, with a citation window of 3 years or less, should be interpreted with caution.

Figure 1 provides a graphical overview of JRC publications according to the number of highly cited publications (top 1% and top 10%) per year.[22] Annual publication output increased from 641 in 2007 to around 900 per year in 2015.

Figure 1. JRC publication output: total, top 10 % and top 1 % highly cited publications

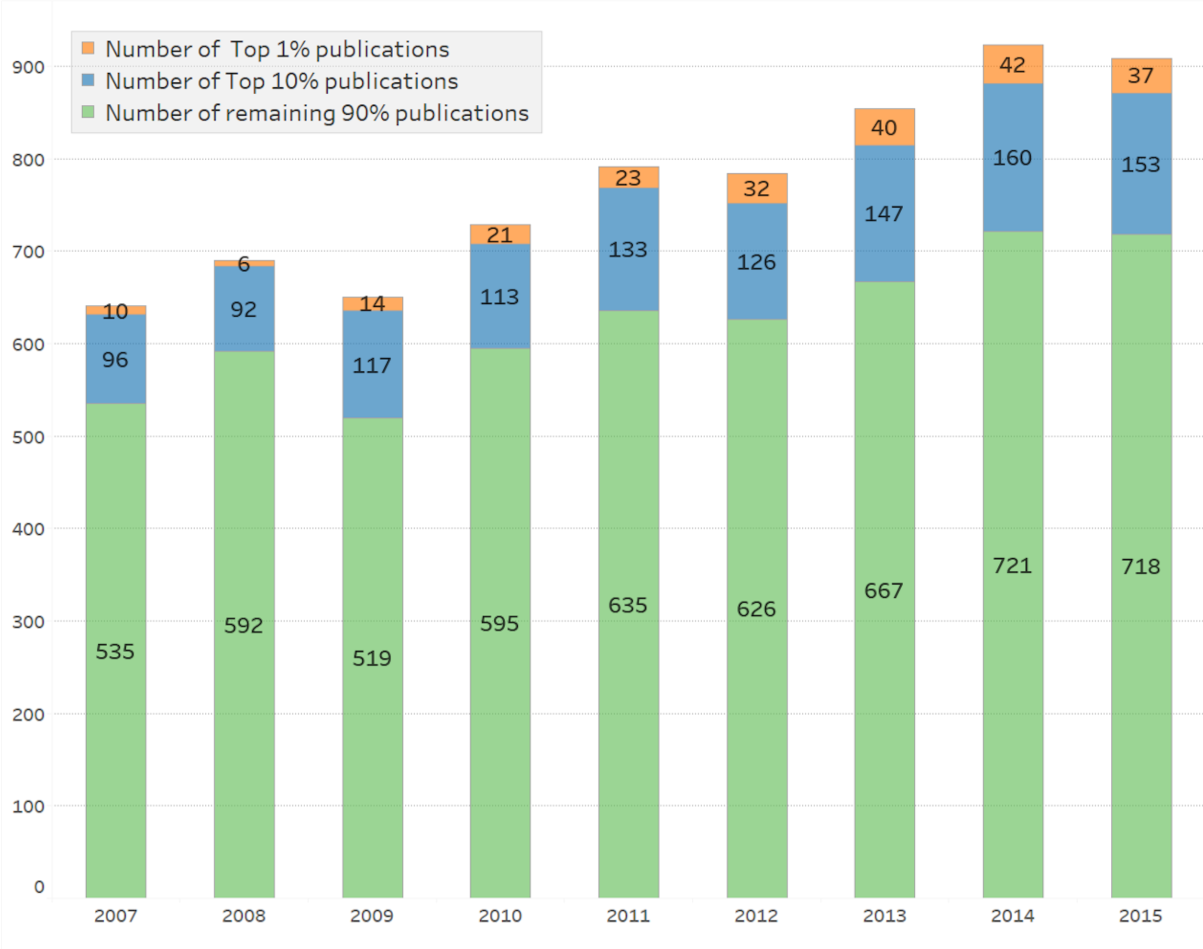
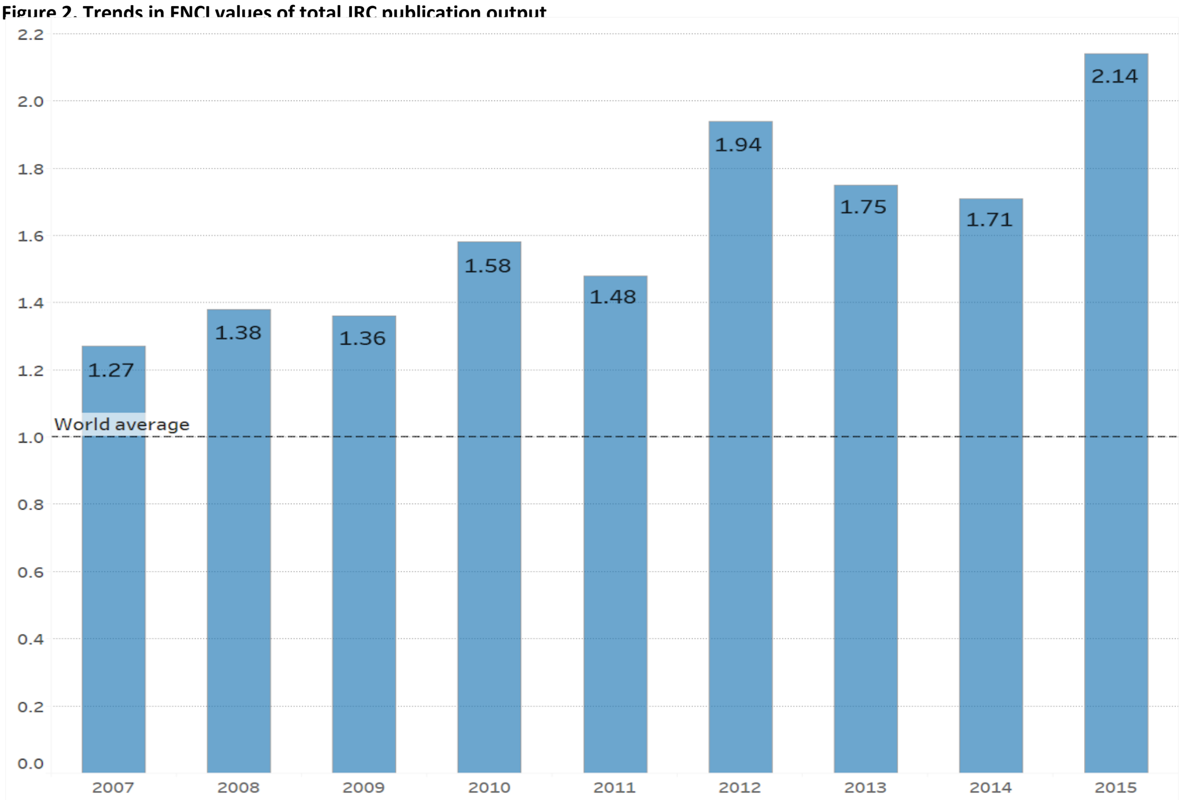


Figure 2 shows the annual trends according to the FNCI value for the JRC's total publication output. In most years, JRC publications receive well over the world average number of citations when normalised by citation intensity in the different fields. The 'over-performance' among the highly cited papers, especially among the top 1% publications, is higher than the over-performance for the whole portfolio of research publications.

[22] The number of top 1% and top 10% most highly cited publications in Figure 1 is based on the WoS field classification scheme. Different numbers of highly cited publications would have been found using the broader ESI classification scheme reported in section 3.2., but the overall pattern across all fields of science will not change significantly.

Figure 2. Trends in FNCI values of total JRC publication output



Digging deeper into the collaborative patterns responsible for JRC's top 10 % highly cited publications, **Table 3** shows the share of publications that result from external research cooperation.[23] That is, co-publications with an 'external researcher' affiliated with, or based at, another research organisation abroad. The table shows that international collaboration occurs in 81 % of all top 10 % highly cited JRC publications. This high share was expected as international co-publications are known to receive a relatively high number of citations on average. However, the excellent performance levels are not solely the result of JRC authors making (potentially minor) contributions to publications produced by large international research projects or R&D consortia. There is ample evidence that they are (also) based on substantive JRC research efforts. This becomes clear by zooming in on the share of top 10 % highly cited publications with a JRC-affiliated 'corresponding author'. Being nominated a corresponding author on a research publication tends to reflect project leadership. The share of publications with a JRC corresponding author is 41 %. Hence, JRC-affiliated authors are the leading authors in almost half of the JRC publications that are among the top 10 % highly cited publications.

Table 2. JRC publication distribution by research contribution

JRC as research partner (publications co-authored with non-JRC researchers abroad)	
Share of all top 10 % cited JRC publications	81 %
JRC as research leader (international co-publications with JRC-affiliated 'corresponding author')	
Share of all top 10 % cited JRC publications	39 %

[23] The micro-data publication analysis that was performed to construct this table led to the identification of another few misclassified organisational addresses which will be communicated to the *InCites* team

3.2 Analysis of JRC research performance - ESI fields

As explained in the methodological section, the first part of the field analysis has split the JRC publication output in journal-based categories. The ESI classification system[24] is not perfect, as it was not possible to allocate 257 JRC publications.

Figure 3. Number of publications by ESI field

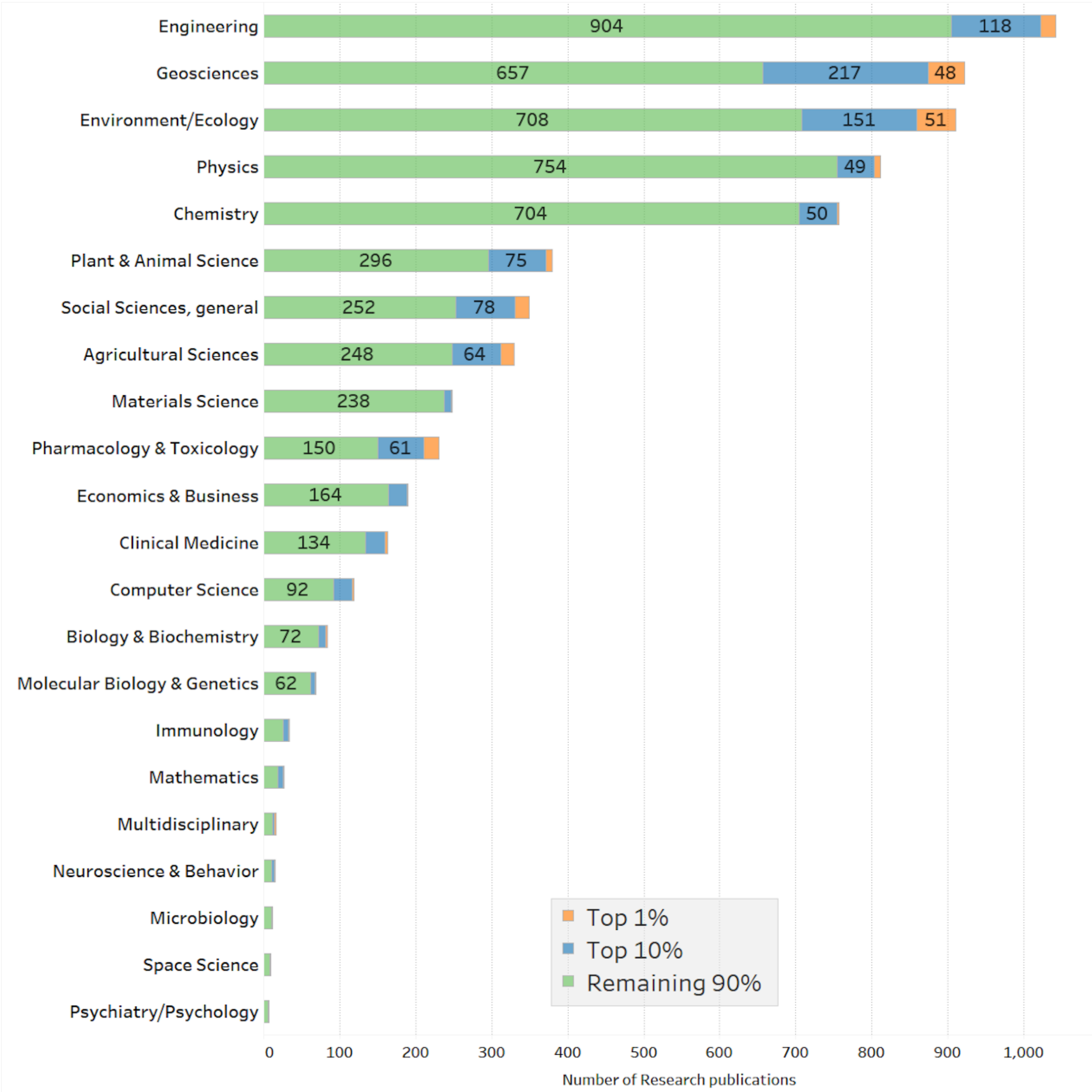


Figure 3 shows the number of publications in the different ESI fields. One observes that the majority of the JRC output is classified in five broad fields: Engineering (15.5 %), Geosciences (13.7 %), Environment &Ecology (13.6 %), Physics (12.1 %) and Chemistry (11.3 %). The figure also shows that in some of these categories a relatively large share of publications belong to the publications which are among the top 10 % or even top 1 % highly cited publications in the world. This is especially true for Pharmacology & Toxicology, Geosciences, Environment & Ecology, General Social Sciences (which

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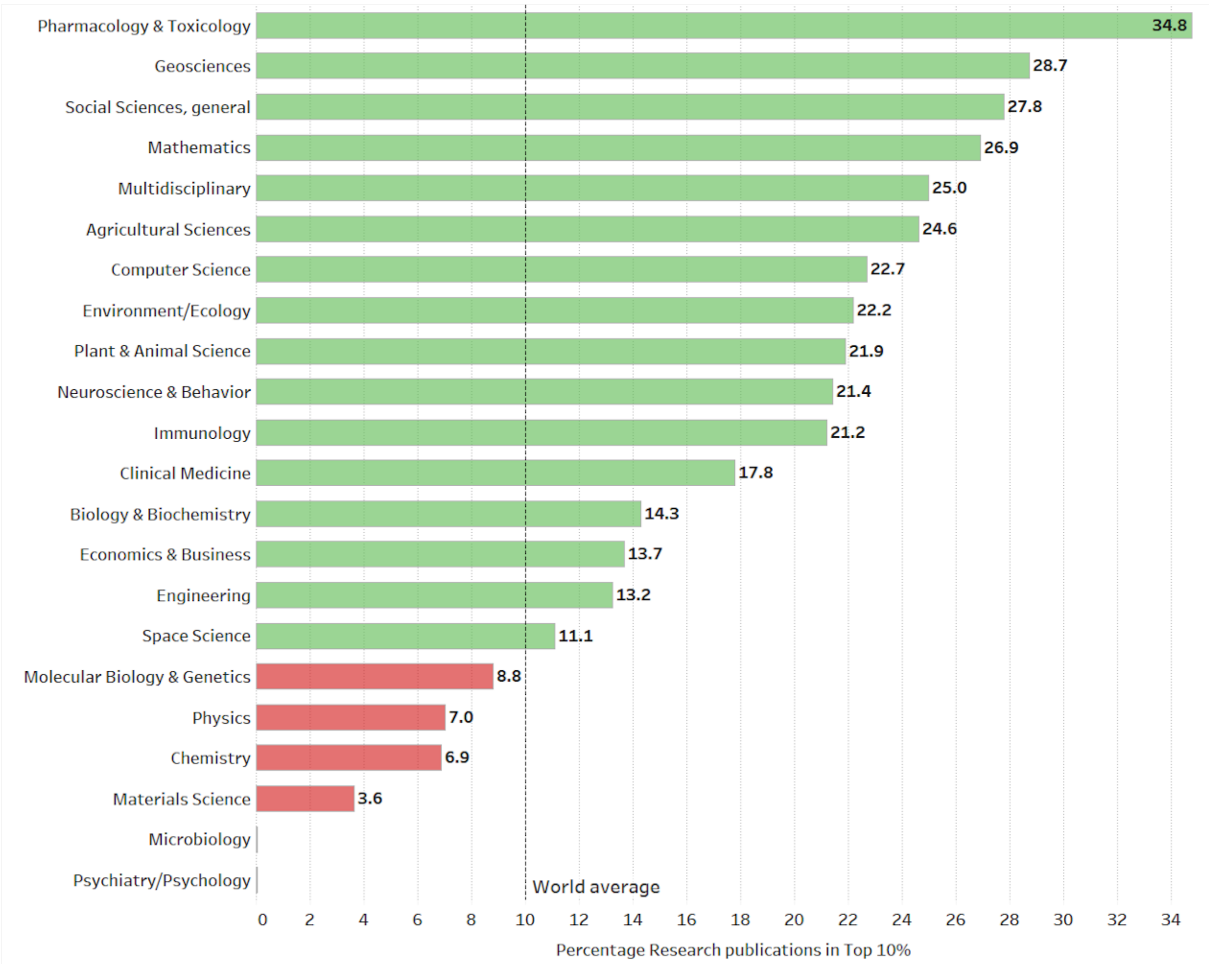
[24] These ESI fields are derived from TRs' *Essential Science Indicators* information product.

does not include Economics & Business), Agricultural Sciences, Computer Sciences and Plant & Animal Science.[25]

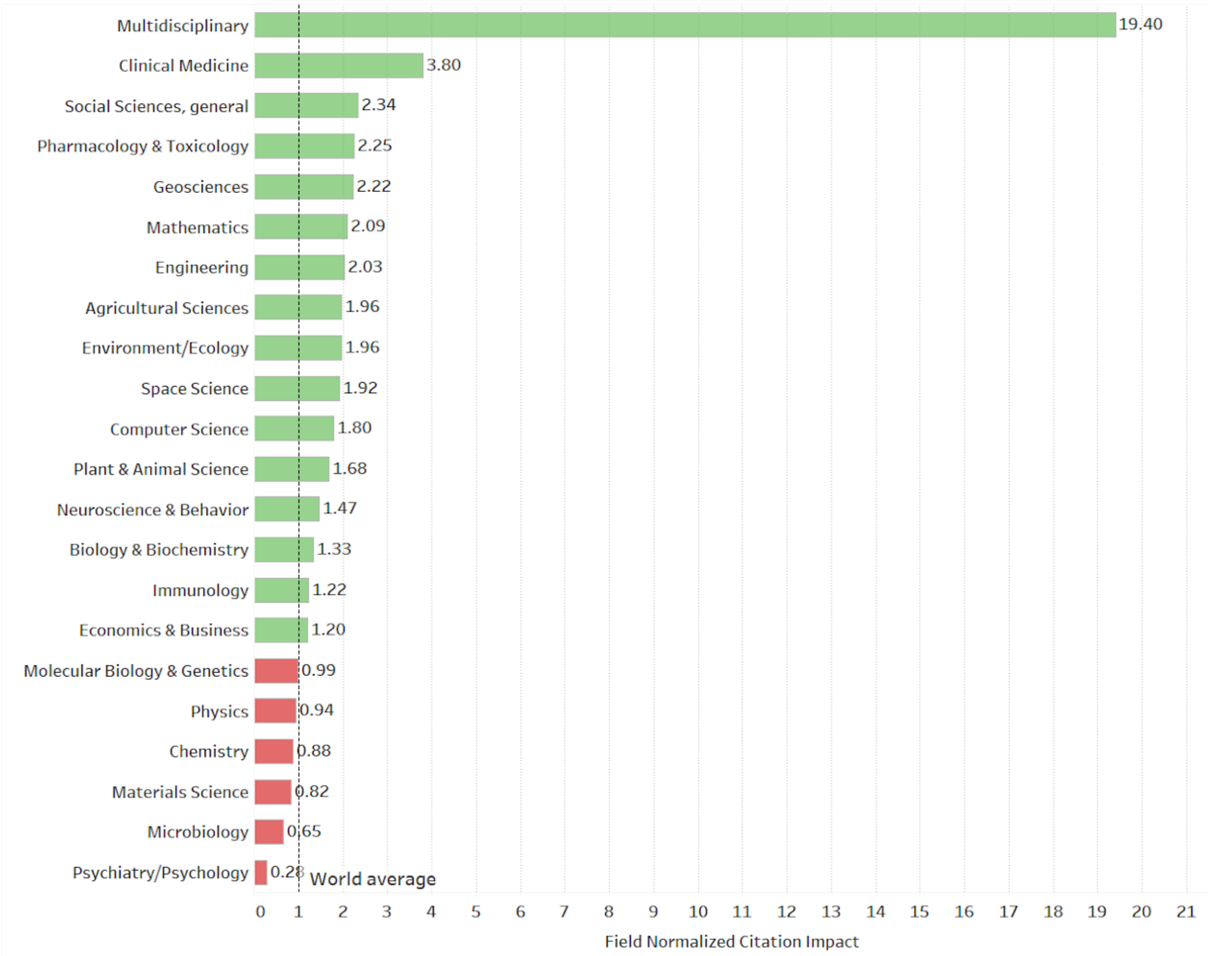
Figure 4 expands on the latter observation by showing the share of top 10 % highly cited publications one observes that the JRC performs well above the world average of 10 % in most fields of publication activity. This also holds for fields in which a large share of its publication activity is concentrated - such as the Geosciences, Social Sciences, Pharmacology & Toxicology, and Environment/Ecology. The share of the JRC's publications that is among the 'top 10 % highly cited publications', is below the world average in Molecular Biology & Genetics, Physics, Chemistry, and Materials Science.

Figure 4. Share of top 10% publications by ESI field



[25] As well as some small field of publication activity: Immunology, Neuroscience & Behaviour and Mathematics

Figure 5. Citation impact scores (FNCI) by ESI field



This brings one to the analysis of the field-normalised citation impact (FNCI) scores in **Figure 5**. This metric indicates how many citations an average JRC publication receives relative to the world average in a specific field[26]. We observe that in most fields the JRC performs well above the world average value of 1. In some fields of large JRC activity - including Geosciences, Environment/Ecology, Pharmacology & Toxicology, the General Social Sciences, and Engineering - the JRC receives more than double the world average of citations per publication. The 'multidisciplinary' field stands out. This is due to the inclusion of broad scope 'multidisciplinary' journals, like *Nature*, *Science* and *PNAS* in this category alongside other lower impact journals. Again the JRC performs under the world average in the same fields as in the previous figure. As was shown in Figure 3 Physics, Chemistry and Materials Science are fields of substantial JRC publication output, which means these fields have an influence on overall JRC performance on this metric. This is less the case for the remaining (smaller) fields which score low on this metric.

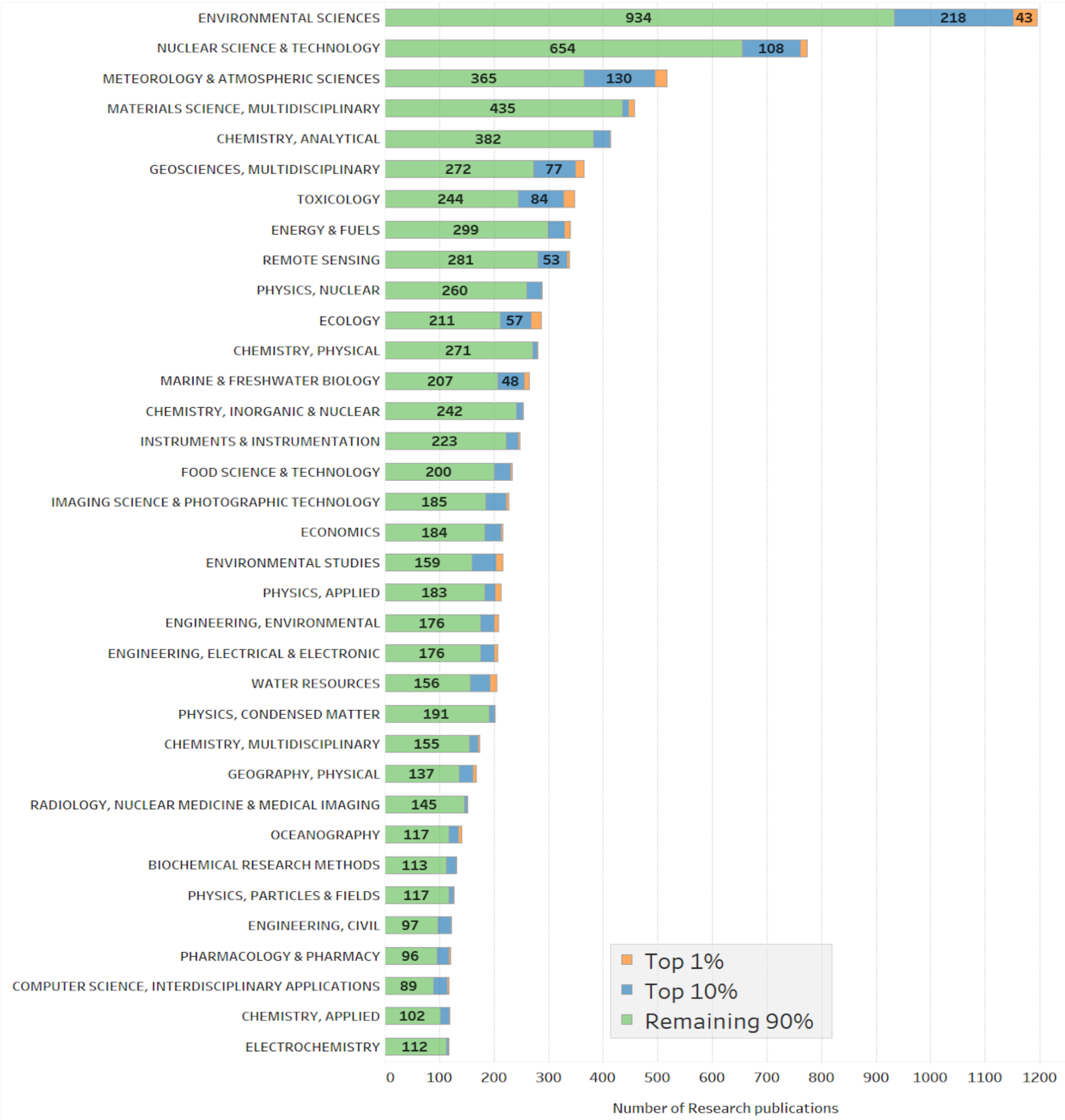
3.3 Analysis of JRC performance - WoS fields

Figure 6 shows the relative share in JRC output of the main research WoS fields, which was limited to the top 35 fields in terms of publication volume in the period 2007-2015. As explained in the

[26] A FNCI score of 1.5 would signify that the JRC receives 50% more citations than the world average. A score of 0.5 signifies that an average JRC publication in this field receives 50% less citations than world average.

methodological section, these fields overlap making it impossible to compute a de-duplicated JRC total output. Also, not all JRC publications will be represented in these categories as there are smaller fields which could not be presented in this figure. Nonetheless, these WoS fields provide additional, finer-grained information on JRC performance supplementary to the previous ESI-based figures (3 to 5).[27] The figure reveals that Environmental Sciences is the largest field of JRC publication activity, followed by Nuclear Science & Technology, Meteorology & Atmospheric science, Materials Science, Analytical Chemistry, and Geosciences.

Figure 6. JRC publication output by WoS field



For some of these fields, most notably Environmental Sciences and Meteorology & Atmospheric Sciences, one observes a relatively large number of publications in the top 10 % and top 1 % highly cited publications. Further insight in this observation is provided by looking at the share of top 10 %

[27] The WoS field based data is also included in this report to ensure consistency with Thomson Reuter's 2014 report.

highly cited publications in **Figure 7**. The world average of this share is 1:10. One thus sees that the JRC performs above the world average in most fields. An especially strong performance is observed in the fields Toxicology, Meteorology & Atmospheric Sciences, Ecology, Environmental Studies, Geosciences, Water Resources, Marine & Freshwater Biology, Computer Science (interdisciplinary applications) and the Environmental Sciences. In all these fields the JRC has more than double the world average number of highly cited papers. In a few fields the JRC has a share of highly cited publications below the world average of 1:10. This includes fields of substantial JRC publication activity, like Materials Science, Analytical Chemistry, Physical Chemistry, Nuclear Physics, Condensed Matter Physics, and Instruments & Instrumentation.

A word of warning is in order. For example, the latter statistics could lead to the wrong conclusion that e.g. the nuclear branch of the JRC is performing below the world average. While 1:10 in the field Nuclear Physics is indeed just at the world average, the JRC registered three times more publications in the field Nuclear Science & Technology, which with a 1:6 result, scores much higher than world average.

Figure 7. Share of Top 10% highly cited publications by WoS field

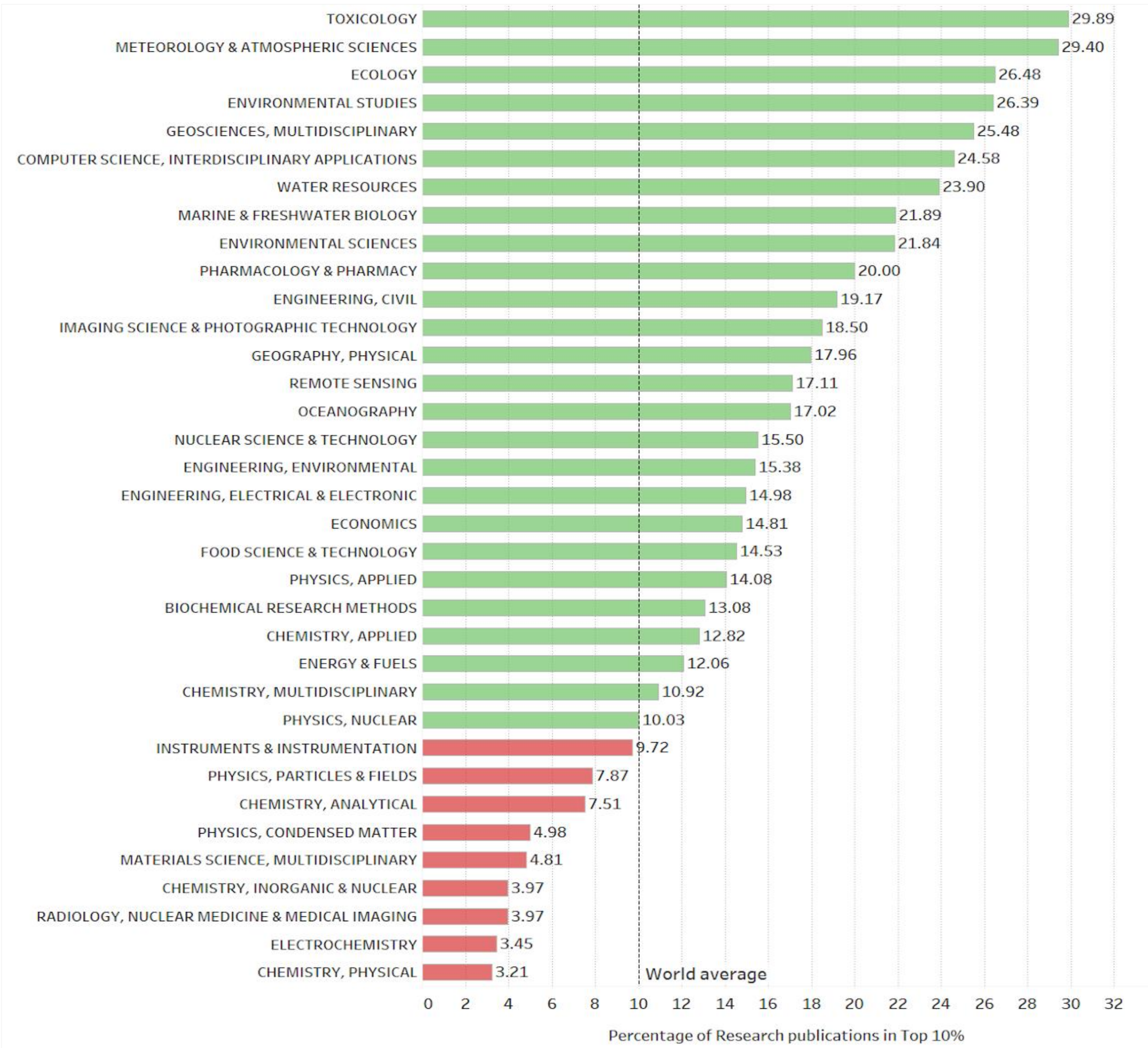
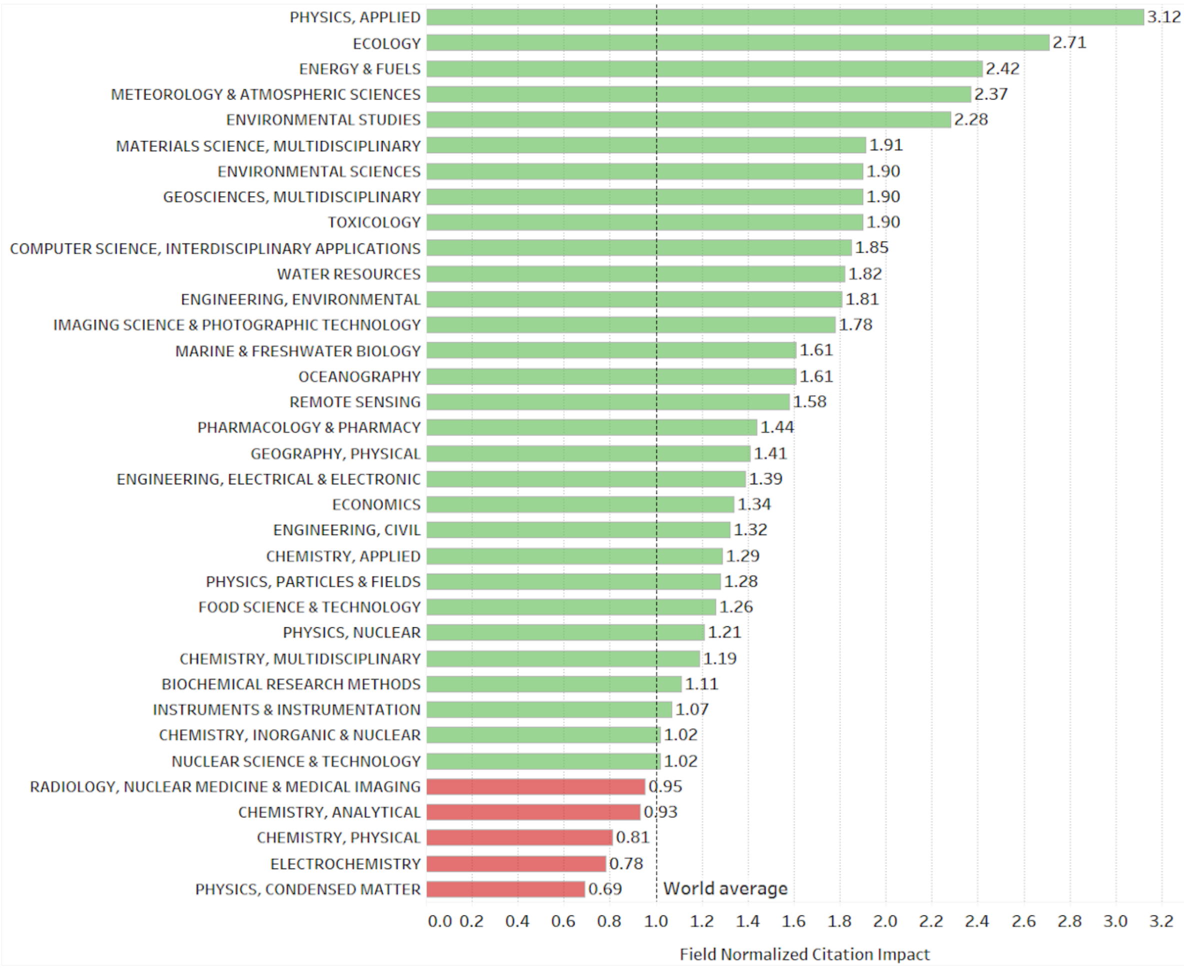


Figure 8 shows again the FNCI scores. In some fields marked by large JRC research activity – notably Toxicology, Geosciences, Ecology, Energy & Fuels, Environmental Studies, Environmental Sciences and Meteorology & Atmospheric Sciences - JRC publications receive more than double the world average of citations per paper. Only a few fields perform below the world average of 1.

Figure 8. Citation impact scores (FNCI) by WoS fields



3.4 Comparator analysis: JRC versus benchmark organizations

Table 5 compares the JRC research profile to that of the selected comparator 'benchmark' organisations. The table also shows data on field-normalised citation impact and the share of highly cited (top 1 % and top 10 %) publications. In terms of the shares of highly cited publications, one observes that the JRC performs at a similar level as top-level 'basic science organisations' such as the leading research universities and public research centres considered. The same can be said for the field-normalised citation impact metric. Another metric of potential interest in relation to societal impact is the share of JRC publications, which are made together with private sector partners (business enterprises and industry). With 3.5 % of its peer-reviewed scientific articles published together with industrial partners, the JRC has a percentage score on par with NIST and EPA in the US or the CEA in France. While it is lower than that of typical RTOs such as Fraunhofer (DE), TNO (NL) and VTT (SF) for whom an industry focus is central to their mission, it is significantly higher than for Australia's CSIRO and most of the academic science organisations, such as Oxford University and the Max Planck Society. Hence this share indicates a substantial degree of interaction with industrial R&D and business sector partners.

Table 4. Comparator analysis: research performance profiles

	Total publication output	Citation Impact (FNCI)*	% publ. cited	% publ. in world Top 1% cited	% publ. in world Top 10% cited	% industry co-publ.
CNRS	263 142	1.29	91.2	1.7	14.9	2.3
CAS	239 602	1.18	89.1	1.8	14.2	0.9
MPS	90 337	1.78	93.9	3.3	22.5	1.9
OX	76 908	1.92	85.8	3.7	21.7	2.7
CAM	69 716	1.81	86.9	3.5	21.5	3.8
CNR	43 253	1.17	92.5	1.4	12.9	1.5
CEA	42 339	1.60	93.0	2.8	18.7	3.5
INRA	34 181	1.42	92.7	2.1	16.8	2.1
CSIRO	25 455	1.54	93.1	2.9	19.1	1.4
RIKEN	22 276	1.48	92.6	2.4	17.4	2.0
ORNL	15 373	1.71	93.2	3.5	21.2	3.9
ANL	14 864	1.88	93.4	3.8	23.1	2.2
NIST	11 798	1.58	92.9	2.7	19.1	3.3
EPA	8 741	1.42	92.2	2.4	17.8	3.7
FG	8 434	1.23	88.4	1.7	14.1	4.5
JRC	**6 970**	**1.65**	**90.8**	**3.2**	**19.5**	**3.5**
TNO	5 005	1.30	92.0	1.5	16.0	7.5
VTT	4 193	1.47	85.9	2.0	15.5	5.2
NPL	2 099	0.98	88.9	1.0	9.8	3.7
ARC	1 287	1.25	89.6	1.6	14.9	2.7

* World average performance: FNCI=1. Above average FNCI > 1; below average FNCI < 1.

Figure 9 provides an overview of the publication output of the comparator organisations. It clearly shows that several organisations - especially CNRS, MPG and CEA - publish considerably more publications than JRC.

The actual degree of comparability between organisations is a critical issue that needs careful consideration and determines the margin for drawing strong conclusions.[28] When comparing JRC with such broad organisations, sufficient attention should be paid to how 'economies of scale and scope' may beneficially affect the research performance of large organisations. Further analysis suggests that these organisations do not only differ in size but also in terms of research specialisation.[29] Hence, due caution is needed when interpreting the results of figures 9-11. The findings are best seen as a high-level proxy of institutional differences in research performance levels.

Figure 9. Comparator analysis: total publication output and highly cited publications

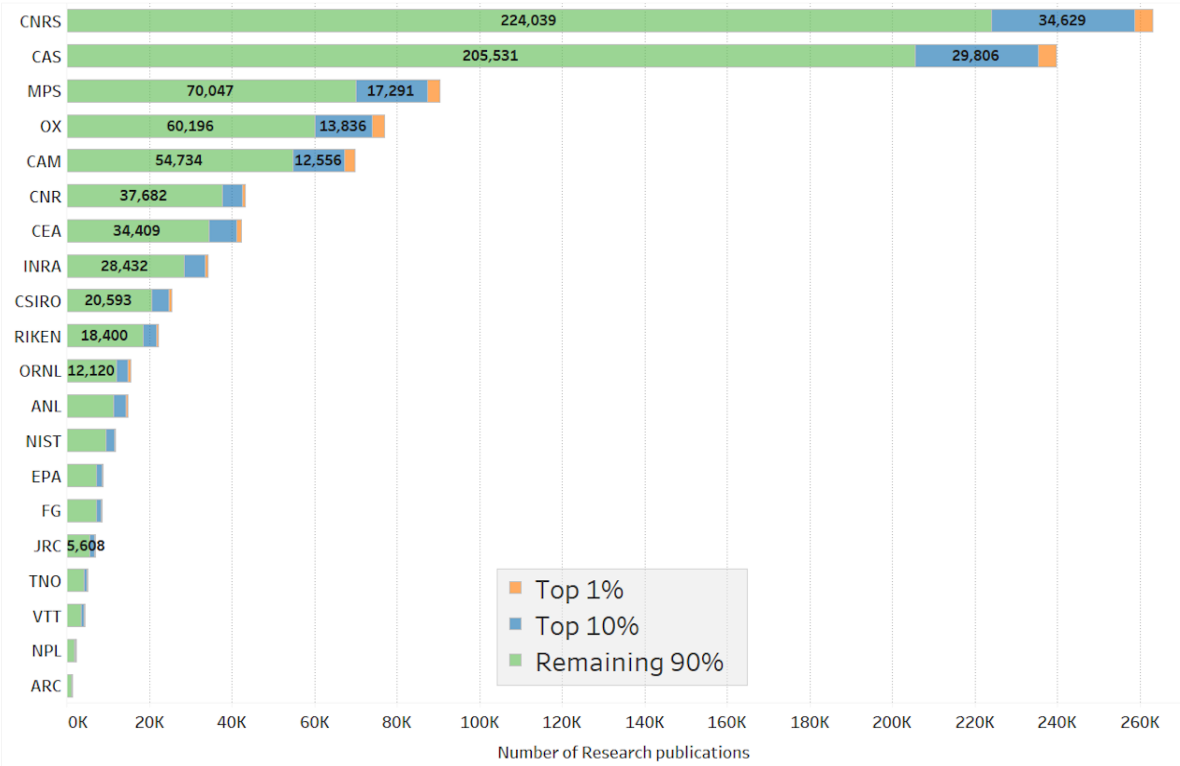


Figure 10 zooms in on the share of top 10 % highly cited publications. JRC is among the top performers, surpassed only by Oak Ridge National Laboratory, the Max Planck Society, Oxford University, Cambridge University and Argonne National Laboratory. Considering the relatively small

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28 The JRC, as well as all comparators mentioned in this report, are unique 'one of a kind' organisations because of their specific mission, history, funding sources, specialisation profiles, country of location, and other distinctive features. When interpreting the results of cross-organisational comparisons one needs to take these inherent differences into account. For example, the effects of sheer size, due to economies of scale and scope, can influence the relative performance in terms of research collaboration (both within the organisation and with external partners), this can then affect international visibility and scientific impact as measured by citation indicators. This may limit the comparability between the JRC and organisations that are substantially larger, such as the CEA, CNRS, the Max Planck Society and the Chinese Academy of Science. Ideally, one should opt for 'like-with-like benchmarking' exercises that involve similar organisations or 'aspirational benchmarking' with pre-selected organisations that exhibit desirable performance levels. However there are few, if any, research organisations that are similar to the JRC in nature and mission.

29 Additional data and figures on the detailed comparison between organizations can be provided upon request.

numbers of publications concerned, small differences in performance between organisations like the JRC, CNRS and the Max Planck Society, should not be over-interpreted.

Figure 10. Comparator analysis: top 10% highly cited publications

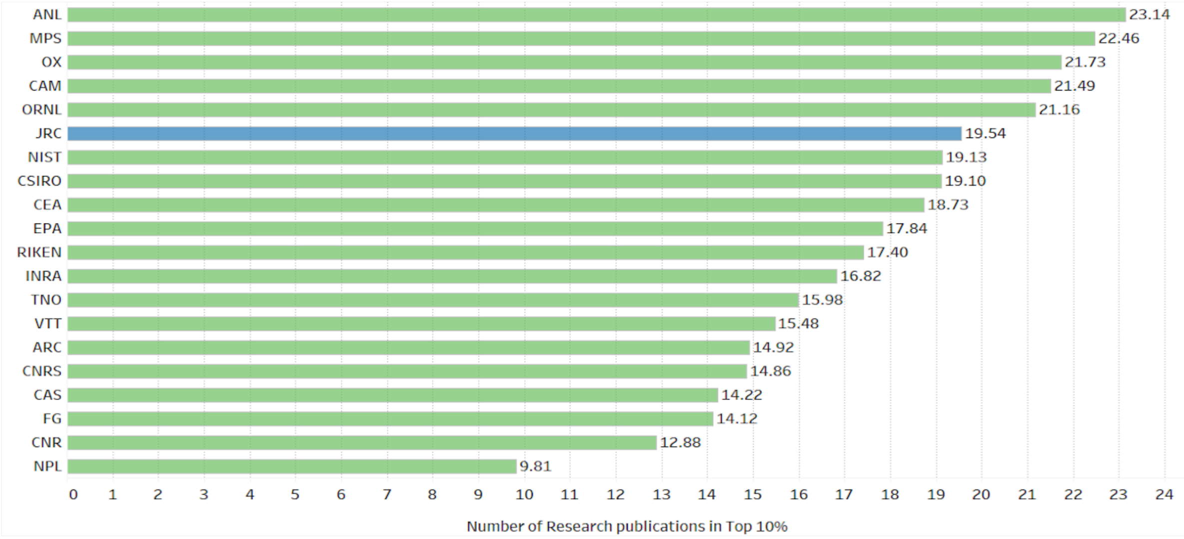
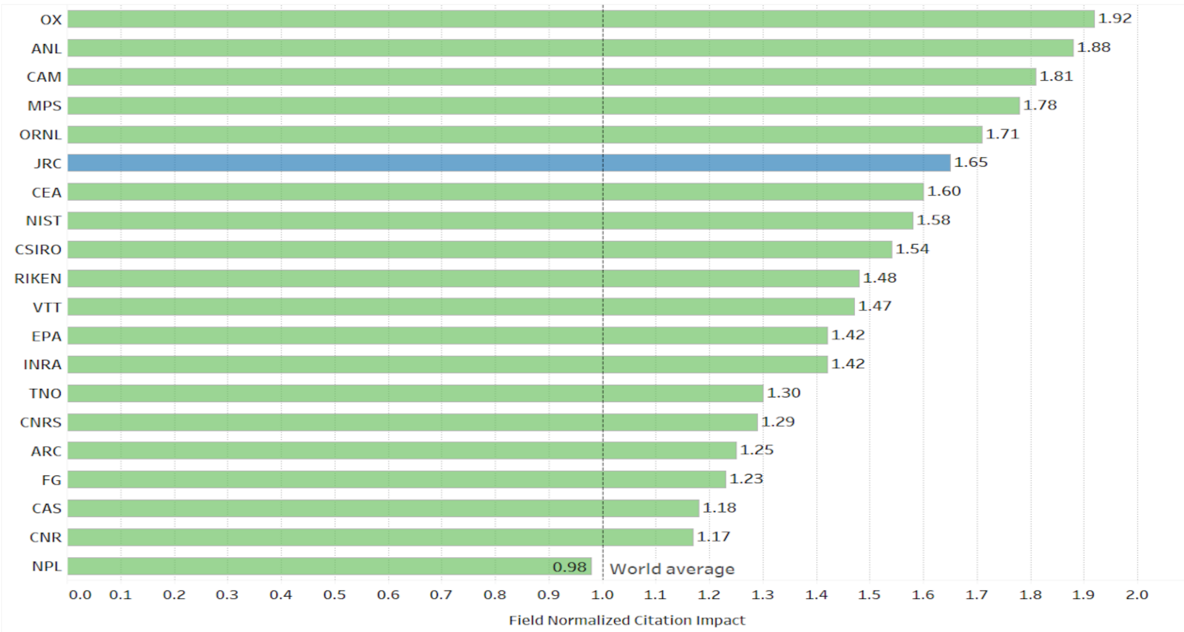


Figure 11 shows the comparison in terms of FNCI. JRC has a FNCI score of 1.68 indicating that an average JRC publication receives 68 % more citations than an average paper published worldwide. That of Argonne (ANL) is similar to the JRC, whereas publications by the Max Planck Society, Cambridge University, Oxford University and the US Oak Ridge National Laboratory receive a higher number of citations per paper than those by the JRC. Nonetheless, the JRC clearly remains in the top group of performers on this metric as well.

Figure 11. Comparator analysis: Field-normalised Citation Impact



* The full name of each comparator organisations is mentioned in Table 1.

4 Discussion and conclusions

This bibliometric analysis of *JRC* research publication output was guided by some general considerations to which such quantitative research evaluations should adhere. In principle, the analysis should be replicable by any data analyst who has access to the *InCites* platform or the underlying *Web of Science* (WoS) database. As the citation metrics are calculated at a specific point in time (in our case in March-April 2017), there will be changes, especially in the citation metrics for recent years where more recent citations to publications are accumulated.

The metrics used are standard performance measures and widely accepted as such within the international bibliometric community[30]. This should ensure the credibility of the analysis and these findings. Given that 62 % of JRC's published output is captured in the WoS and that this publication set comprises the bulk of the research publications having international scientific impact, the report argues that the analysis has a sufficient level of accuracy and representativeness within an international comparative setting. The performance levels and trends observed for the JRC are largely in line with many comparator organisations worldwide; there are no major deviations or fluctuations, nor unexplainable observations within the JRC research performance patterns. This adds to the credibility of the results of the analysis.

Given the nature of this study and the depth of the data analysis too strong general conclusions are avoided. Instead the next section repeats some of the most noteworthy findings and possible explanations:

- In terms of scientific impact, the analyses established that JRC researchers produce around 95 % more top 10 % highly cited publications than the world average. The share of top 1 % highly cited publications, is, at 3 %, three times the world average. In recent years, the share of top 1 % highly cited publications increased to 4%. This indicates that JRC researchers succeed in producing a relatively large number of publications with a major influence on the scientific literature. The high score on these metrics may be related to the regulatory science role of the JRC. The JRC's field-normalised citation impact score is around 65 % above the world average. This high level performance also seems to have improved even further in recent years. The JRC performs considerably better than many of the other organisations considered, and at a similar level as organisations with a basic science mission. This finding is potentially remarkable given the broad mission of the JRC which includes much more than producing research for peer reviewed journals.
- The JRC also has a relatively high share of industrial co-publications compared to many comparator organisations These co-authored publications are an indication of close research collaboration and interaction with the business sector, which in turn could be a precursor of science-related innovations and socioeconomic impacts in future years.
- International co-publications, with research partners located in other countries, comprise 81 % of the high-impact JRC NST publications. In 39 % of the high-impact publications, JRC researchers are the lead researchers and 'corresponding authors'. Thus, the high-impact publications are not solely the result of (potentially minor) JRC participation in large research

[30] See for example: Tijssen et al., 2002; De Bellis, 2009; OECD, 2013.

consortia. To an important extent they are thought to be the outcome of substantial JRC research activity.

- In most fields JRC publications achieve an above average number of citations and have a relatively large share of high citation impact publications. Fields in which the JRC has both a large output and a high impact include: Ecology, Energy & Fuels, Environmental Studies, Environmental Sciences, Toxicology, Applied Physics and Meteorology & Atmospheric Sciences. The JRC citation impact levels in these fields are high in comparison to most of the comparator organisations.

The JRC, as well as all comparators mentioned in this report, are unique 'one of a kind' organisations because of their specific mission, history, size, funding sources, funding per researcher, time researchers devote to research, specialisation profiles, country of location, and other distinctive features. When interpreting the results of cross-organisational comparisons one needs to take these inherent differences into account. In spite of this caveat, the analysis shows that the JRC performs well in comparison to the other organisations on all metrics considered. Over time its performance appears to be improving.

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Annex 1. Annual trends in publication output of the comparator organisations

Table A1 shows the evolution (growth or decline) in publications for the comparator organisations. Whereas there are notable year-on-year fluctuations, in general the relative ranking of the organisations in terms of scientific output remains fairly stable over time.

	Web of sciences documents									
Organisation	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
CNRS	23134	26365	28460	29558	29901	30206	31365	31762	32391	263,142
CAS	17736	19396	20633	22652	24867	28326	32288	35349	38355	239,602
MPS	8473	8796	9481	9973	10598	10730	10853	10776	10657	90,337
OX	6332	6873	7370	7910	8663	9135	10116	9856	10653	76,908
CAM	6266	6514	6925	7161	7797	8548	8684	8837	8984	69,716
CNR	5454	4963	5118	4724	3891	4074	4647	4919	5463	43,253
CEA	3936	4219	4508	4665	5034	4842	5046	5087	5002	42,339
INRA	3210	3496	3517	3634	4031	3959	4176	4168	3990	34,181
CSIRO	1946	2256	2402	2805	3033	3077	3232	3321	3383	25,455
RIKEN	2330	2401	2432	2387	2333	2514	2677	2583	2619	22,276
ORNL	1356	1378	1418	1571	1829	1812	2034	1959	2016	15,373
ANL	1394	1266	1354	1391	1602	1831	2013	1989	2024	14,864
NIST	1245	1297	1307	1232	1384	1348	1347	1352	1286	11,798
EPA	1056	1004	1032	950	1021	970	922	937	849	8,741
FG	533	672	807	859	1012	1004	1116	1218	1213	8,434
JRC	641	690	650	729	791	784	854	923	908	6,970
TNO	525	515	553	569	582	594	572	577	518	5,005
VTT	343	313	444	449	513	471	558	630	472	4,193
NPL	205	187	165	227	248	249	235	277	306	2,099
ARC	139	126	162	162	164	119	124	136	155	1,287

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