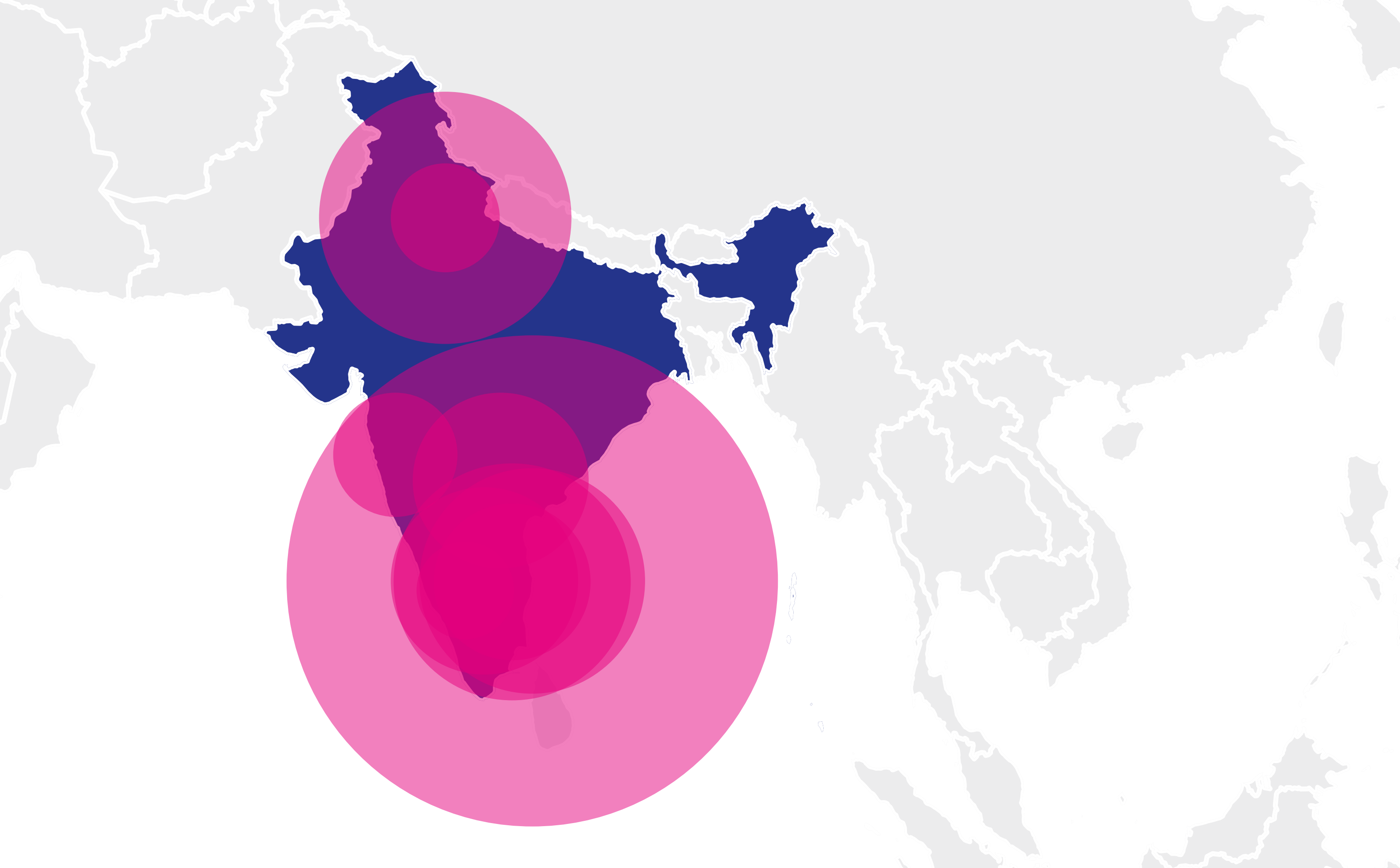

Policy brief: Co-publishing patterns of EU-India

The international dimension of co-publishing in India with special regard to the European Union

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Definitions and abbreviations

Affiliation: A unique author-institution combination related to one record. The same author can be affiliated with several institutions within one single record. If this is the case, the different affiliations are also counted. Therefore, publications with one author, but two affiliations, one in India and one in for example Norway, are included in the analysis and considered co-publications.

BRIC: Grouping acronym that refers to Brazil, Russia, India and China. These are countries all deemed to be at a similar stage of newly advanced economic development.

Co-publication: International scientific publications, indexed in literature databases, with the participation of at least two institutions/organisations located in at least two different countries. In the context of the present study, the term co-publication therefore is used only for international co-publications involving at least one author affiliated to an Indian institution. There are two counting methods:

Full: The number of total co-publications of a country is obtained by counting each publication in which the name of the given country appears at least once among the addresses of the affiliated organisations of the authors. Here, for a publication to be considered a co-publication, at least one author affiliated to another country has to be involved. Double counting is avoided in that if more than one author of a given country appears on a paper, the publication is only counted once for the country.

Fractional: The number of co-publications of a country is obtained by allocating each organisation on a paper an equal fraction of the publication. The sum of all fractional paper counts across countries adds up to the number of the total number of co-publications.

ERA: This is the European Research Area (ERA). It consists of the 28 EU Member States of the European Union and countries associated to the EU's Framework Programme 7 (FP7)[1]. These include, in addition to EU candidate countries: Turkey, Montenegro and Macedonia; Switzerland, Israel, Norway, Iceland, Liechtenstein, as well as western Balkan countries. In this publication, EU+ is used as a synonym to the ERA.

EU28: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom

1 For Horizon 2020 (the current European Framework Programme from 2013–2020) negotiations with most of the countries to be associated are still ongoing. Therefore the list of countries associated to FP7 was used.

Impact: This is the citations per record; that is the number of cases in which the respective publication is cited by a different, more recent publication. There are also two methods for counting citations: full and fractional counting; similar to methods of counting co-publications (see "co-publication" above).

Record: An entry in the database containing the metadata of a uniquely identified publication. In the case that the same publication appears in both data sources (Scopus and Web of Science), it is still dealt with as one record.

Science Metrix classification: A multi-lingual three-level journal subject classification system, developed by a Canada-based company "Science Metrix". The main difference between the Science Metrix ontology and classification systems used by Scopus and Web of Science is the disjunctive classification, i.e. each journal is attributed to one subject category. Whenever Science Metrix fields and/or sub-fields are referred to in this publication, they are italicised (e.g.: *Energy*). All other expressions indicating scientific areas or specialisations are explained in the respective methodology sections and do not refer to the Science Metrix definitions (e.g.: ICT).

1 Introduction

This reports analyses the patterns of scientific international co-publications between India and EU Member States and countries associated to the EU's Seventh Framework Programme for Research (FP7) between 2003 and 2012.

Co-publications are regarded as one indicator for measuring cooperation and are used as one of many proxies for the assessment of the current state of bi-regional collaboration in science. Thus, this report is a basic component for the monitoring of bi-regional cooperation and its impact.

The aim of INDIGO Policy, an FP7 funded coordination and support action project with India, is to support and coordinate bilateral activities and initiatives between Europe and India in order to build mutual areas of interest in the Scientific, Technological and Innovation (STI) fields. This report elaborates the impact dimension of the S&T cooperation between the EU28 and countries associated with the FP7 programme [together, the so called European Research Area (ERA)] and India, by looking at co-publications in which at least one author is affiliated in an ERA-country and one author affiliated in India. Furthermore, the analysis is narrowed down to topics selected in the *India-EU Strategic Roadmap for Innovation and Research:* "energy", "health" and "water" including their respective sub-topics.

The study aims at providing an overview and analysis of the recent trends of EU-India research cooperation in these fields. It also seeks to recognise gaps in which cooperation between the two areas could be intensified. The report is not to be seen as an assessment or a concrete priority setting recommendation, but rather, the results should inspire and give input to discussions on the visions of future STI cooperation between the two regions.

In 2012, the Department of Science and Technology (DST) of the Government of India commissioned two comprehensive studies on India's scientific publication outputs: the *Bibliometric Study of India's Scientific Publication Outputs from 2001 to 2010* and the *International Comparative Performance of India's Scientific Research.* This policy brief aims at complementing these reports but at the same time deviates from these reports with regard to its geographical and thematic foci and the data used. Unlike in the two previous studies mentioned above, this study employs data from both Elsevier's Scopus database and Thomson Reuter's Web of Science.

The report is structured as follows: it begins with an introduction of the data and methods used in this study. This is followed by setting the scene for co-publishing in the thematic areas of energy, health and water. In order to do so, the report describes the publication and co-publication patterns in India. The core of this report, chapter 3, is an analysis of different dimensions of co-publication activity in the selected thematic areas. Based on this analysis, conclusions are drawn and an outlook is deduced.

1.1 Data and methodology

1.1.1 Data sources and data consolidation

The data analysed in this study was retrieved in January and February 2014 from the two best known and most comprehensive multi-disciplinary

academic citation databases: Elsevier's Scopus database (Scopus) and Thomson Reuter's Web of Science (WoS).

The data covers a 10-year-period from 2003 to 2012 and is limited to international co-publications with at least one author affiliated with an institution in India and at least one author affiliated to another country. Data of all document types was retrieved, but restricted to citable material published in scientific journals or conference proceedings (excluding letters, articles in press etc.) for the impact analysis. For further processing, the data was restricted to eight thematic areas in fields of energy, water and health research which was assigned through key-word sets (annex):

- **Energy:** biomass, photovoltaic and smart grids
- **Water:** drinking water, waste water and urban water management
- **Health:** diabetes and affordable health

On the basis of the retrieved data, raw data tables containing records and affiliations from Scopus and WoS were created separately. A combined data set[2] was then created using a series of processing steps in an SQL database and with a specifically developed web interface for a multi-stage data cleaning process (e.g. duplicate detection, raw data correction) including both, automatic and manual steps:

- **Unification of journal names:** the number and set of journals registered by Scopus and Web of Science are different, with many records appearing in both databases, but partially with different spellings, institutions and/or author notations etc. The unification is done by normalising syntax and spelling of journal names detected as identical and linking journals with the same Document Object Identifiers (DOIs).

- **Detection of duplicates:** The identification of records from both sources describing the same publication is done by searching for conformities in the following variables: DOI, title, year, begin page, ISBN, journal ID or ISSN and author. The majority of duplicates are identified and unified automatically with a specific algorithm. Ambiguous cases are checked manually.

- **Raw data correction:** The raw data check is conducted automatically with regular expressions (e.g. invalid values for DOI, space between characters and in fields) and possible raw data errors are corrected manually.

- **Classification of journals:** WoS and Scopus classify each listed journal with one or more journal subject categories: 249 categories in WoS and 334 categories in Scopus. To achieve a classification each journal is assigned a Science-Metrix sub-field.

- **Data unification:** A complex matching algorithm identifies and unifies the datasets from WoS and Scopus from normalised data sets. Merging the two data sources typically leads to an enlargement of data stock by around 20 %.

- **Manual affiliations correction:** The aim of cleaning affiliations is to make identical institutions available in a standardised format and combine them with the exact geographical coordinates.

2 The combined use of both databases increases data coverage and quality and exceeds common practice in benchmarking studies (cf. Royal Society (2011) only uses one of the two sources. For a discussion on advantages and disadvantages of using either of the data sources see Fraunhofer ISI/Idea Consult/SPRU (2009) or Neuhaus/Daniel (2006).

Retrieved, corrected and unified data are in a further step displayed in a so-called "results tree", classifying the information by regions (several selections), years and Science-Metrix subfields. The data unification and cleaning steps lead to a significant increase in data quality and remarkable gain in data coverage. After the unification process 128,882 co-publications could be identified as unique. 90,069 co-publications were listed in WoS only and 94,481 in Scopus only. Nevertheless the method and data used has certain restrictions:

- **Caution with impact measures** (average times cited counts) because the data can only give punctual snapshots (February 2014 in this study) and the times cited counts are naturally constantly changing. Also subject areas with a small number of co-publications should be treated with caution because low number of records can skew the results.
- **Control of duplicates:** In case a specific piece of research is published via multiple channels in similar ways, there is no way of identifying control for this kind of duplicates at the meta-level too.
- **Limitations due to the general validity of bibliometric data** and limitations inherent to the data source (with regards to the amount and coverage of journals and the quality of the data source e.g. misspellings, ambiguity in subject classification etc.) exist and have to be accepted. Despite considerable efforts in data processing and cleaning, there is always a certain margin of error in the data (a rough analysis of possible errors points to an error probability of 1–5 %) to be considered.
- **Limitations in benchmarks:** The data set is unique and therefore hardly comparable with total sums published in other studies as they usually only use one data source.
- **Comparability of research fields:** The number of average authors per (co-)publication is typically significantly higher in some fields (e.g.: Physics) than in others.

2 Setting the scene

2.1 India and the world: comparison of publication output

Between 2003 and 2012, the worldwide scientific publication output was 20,794,653 publications (Scopus). In the same period, Indian authors published 606,709 scientific publications. Thus, India produced 3 % of the worldwide publication output.

With the share of 3 %, India does not compare favourably to many developed economies: the US with 23 % total publications in this time frame, ERA with 34 %, China with 12 % and Japan with 6 %. These countries produce a much bigger share of the worldwide publication output (figure 1). India has a similar publication output as Canada (749,500) and Australia (537,024). Compared to the total number of publications of the BRIC countries between 2003 and 2012, India ranks second behind China; which is one of the world major players.

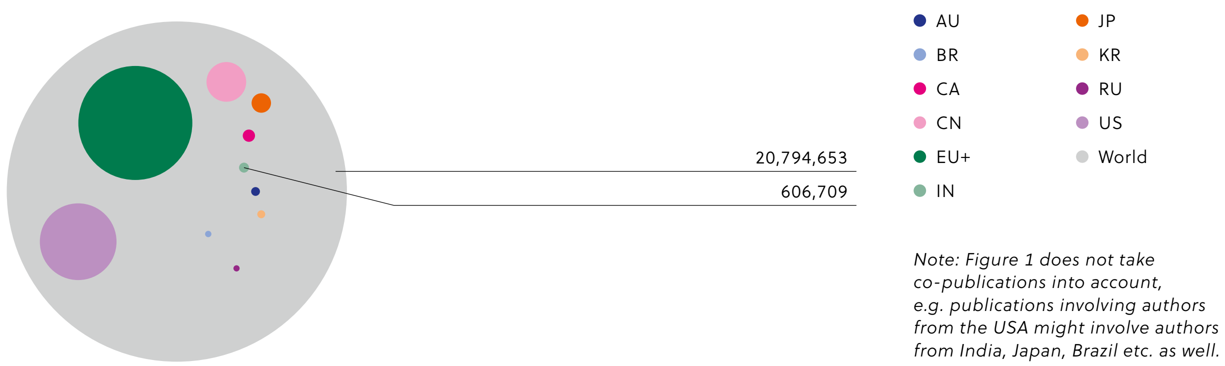

Figure 1: Worldwide publication output between 2003 and 2012 compared to the share of publications of selected countries. Source: Scopus

From 2003 to 2012, Indian annual publication output grew each year, with a particularly high increase of annual publications from 2009 to 2011. India's publication output is growing faster than that of most of the BRIC countries. However, the publication output of Brazil and South Korea is also growing faster than the worldwide average and only the Russian Federation is lagging behind in the context of the BRIC countries. Whereas the annual growth of the publication output of ERA-countries is quite similar to the worldwide annual growth, the publication output of Japan and the USA is growing slower (see figure 2).

As table 1 below shows, relative positioning of India with respect to other developed economies and BRICS countries in scientific publications could be traced to among other reasons policy-derived causes. Indeed, although public R&D expenditure in India is relatively high, there are only a few universities among the world's top universities, even when the GDP is taken into account.

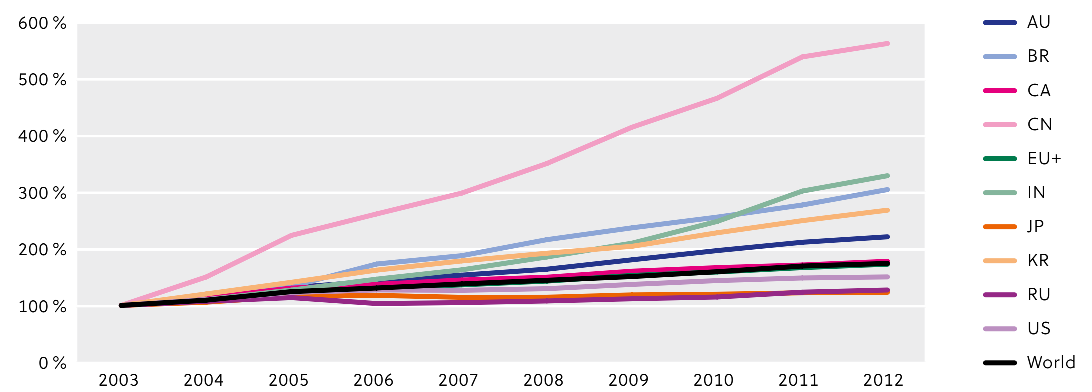

Figure 2: Distribution of growth rates of publication output, 2003–2012. Source: Scopus

	Science base			Human resources
Country	Public R&D expenditures (per GDP)	Top 500 universities (per GDP)	Publications in the top-quartile journals (per GDP)	S&T occupations in total employment (%)
Brazil	66.8	29.3	17.6	8.4
China	55.1	31.8	22.9	−39.3
India	60.3	2.2	10.4	−32.4
Russian Federation	52.6	6.5	−3.3	111.4
South Africa	37.3	51.4	26.1	18.7
OECD sample med.[3]	100	100	100	100

Table 1: STI indicators. Source: OECD Statextracts (extracted 15 October 2014)

Comparing the worldwide distribution of publications in different subject areas (Scopus), the Indian publication output is above the worldwide average in *Pharmacology, Toxicology and Pharmaceutics, Chemistry, Materials Science, Agricultural and Biological Sciences, Physics and Astronomy, and Environmental Science.* According to Thomson Reuters (2011) materials, physics and astronomy, and medicine are especially significant subject areas because each represents a high share of the total Indian output and have grown by more than 7 % per year from 2006 to 2010. Furthermore, India has four subject areas which demonstrate above world average citation impact: *Energy*, *Chemical Engineering*, *Engineering* and *Materials* science. Energy stands out as the subject area in which India has the highest world normalised citation impact and also as the fastest growing subject area in India (Thomson Reuters 2011).

2.2 India and the EU: international co-publishing in India

With its diversity and capacity, it seems a surprise that India does not collaborate more. The collaborative network does now seem to be expanding, and it is expanding eastwards towards other new and emerging research economies and not to the traditional trans-Atlantic research axis, although these countries account currently for a greater proportion of India's current collaborative research. (Thomson Reuters 2011: 13)

3 Normalised index of performance relative to the median values in the OECD area (index median = 100)

According to Thomson Reuters (2011: 8), international collaboration is less frequent in India than for many established economies. Of the 606,709 publications from 2003 to 2012 involving at least one author affiliated in India, only 17 % (103,496) involve an additional author from a different country i.e. are international co-publications (Scopus). 42 % (43,159) of these Indian international co-publications involve at least one author affiliated in one of the ERA-countries (see figure 3).

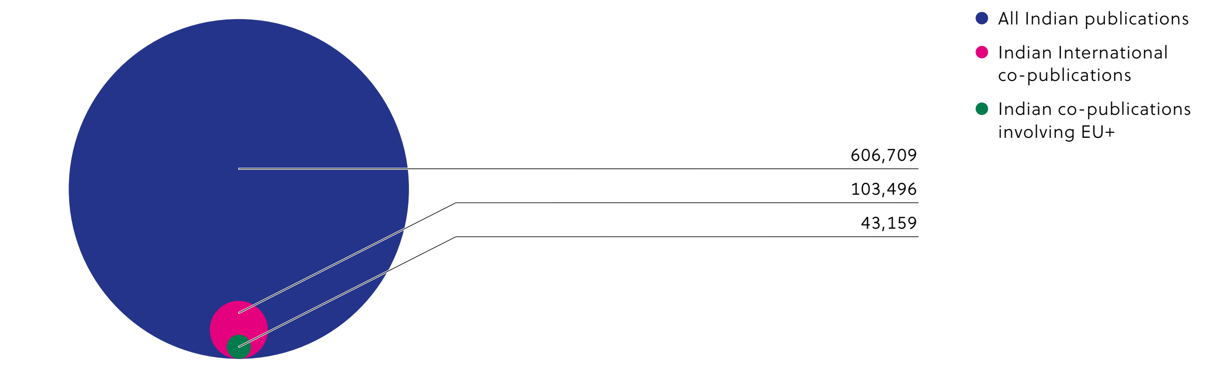

Figure 3: Indian publications, international co-publications and co-publications with EU+, 2003–2012. Source: Scopus

Figure 4 compares the growth rates of Indian publications, Indian-international co-publications and Indian-ERA co-publications from 2003 to 2012. All display steady growth rates with a higher increase from 2009 to 2011. However, the overall Indian publication output seems to be growing much quicker than the Indian-international co-publication output and the India-ERA co-publication output. The Indian-international publication output and the ERA co-publication output show a slower growth especially from 2009 onwards.

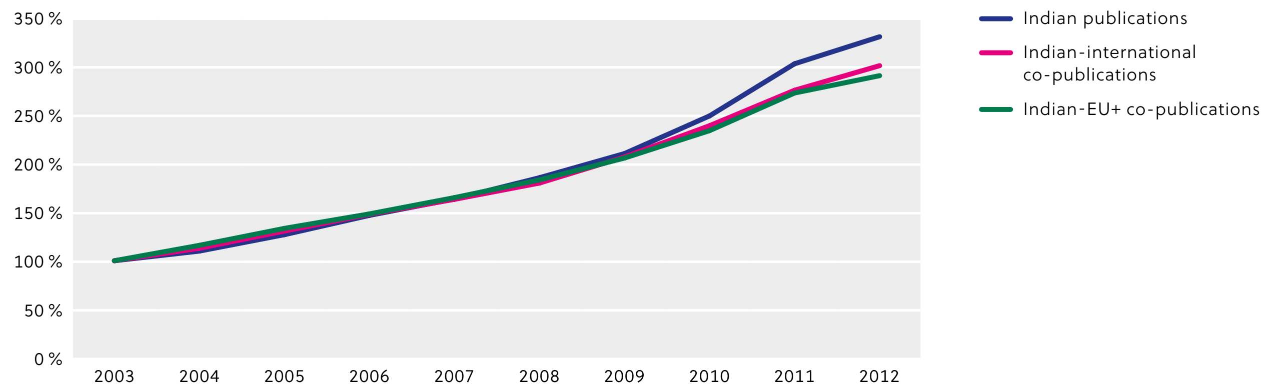

Figure 4: Distribution of growth rates, 2003–2012. Source: Scopus

Authors from the USA are most frequently involved in Indian-international co-publications surprisingly followed by authors from Germany and only after that, by authors from the United Kingdom. Japan, France, South Korea, Canada, Australia, Italy and China are among the top 10 partner countries for Indian international co-publications (see figure 5).

As figure 6 on the next page shows, comparing the worldwide distribution of publications in different subject areas (Scopus), the involvment of authors affiliated in other countries in Indian publications in the field of physics and astronomy is, not surprisingly, rather frequent. For *Materials Science, Earth and Planetary Science, Biochemistry, Genetics, Molecular Biology* and to some extent for *Chemistry* this is the case too. Where India has a lower share of publications than the world share (for example in *Medicine*, *Engineering*, *Arts and Humanities*, *Psychology*, *Social Sciences)*, most of the time the international co-publications or India-ERA co-publications have an even lower share in this subject area.

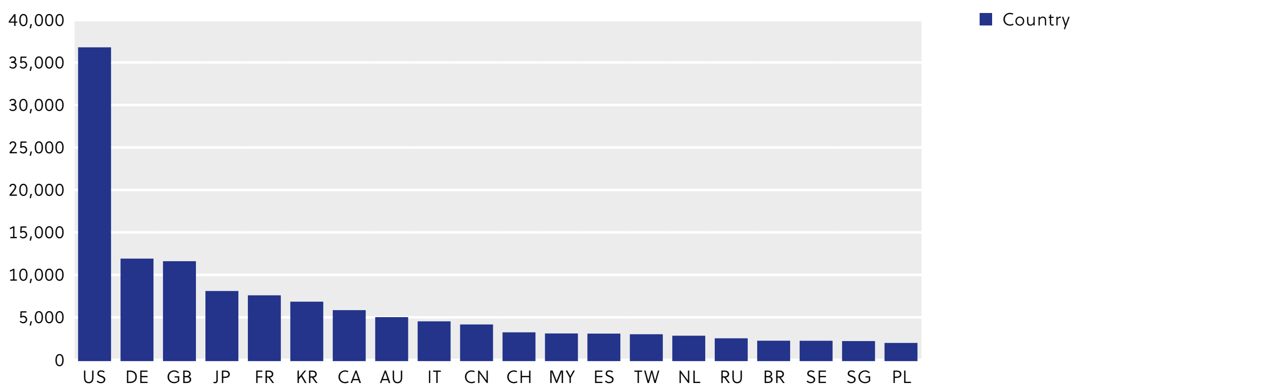

Figure 5: Most frequently involved countries in Indian-international co-publications, 2003–2012. Source: Scopus

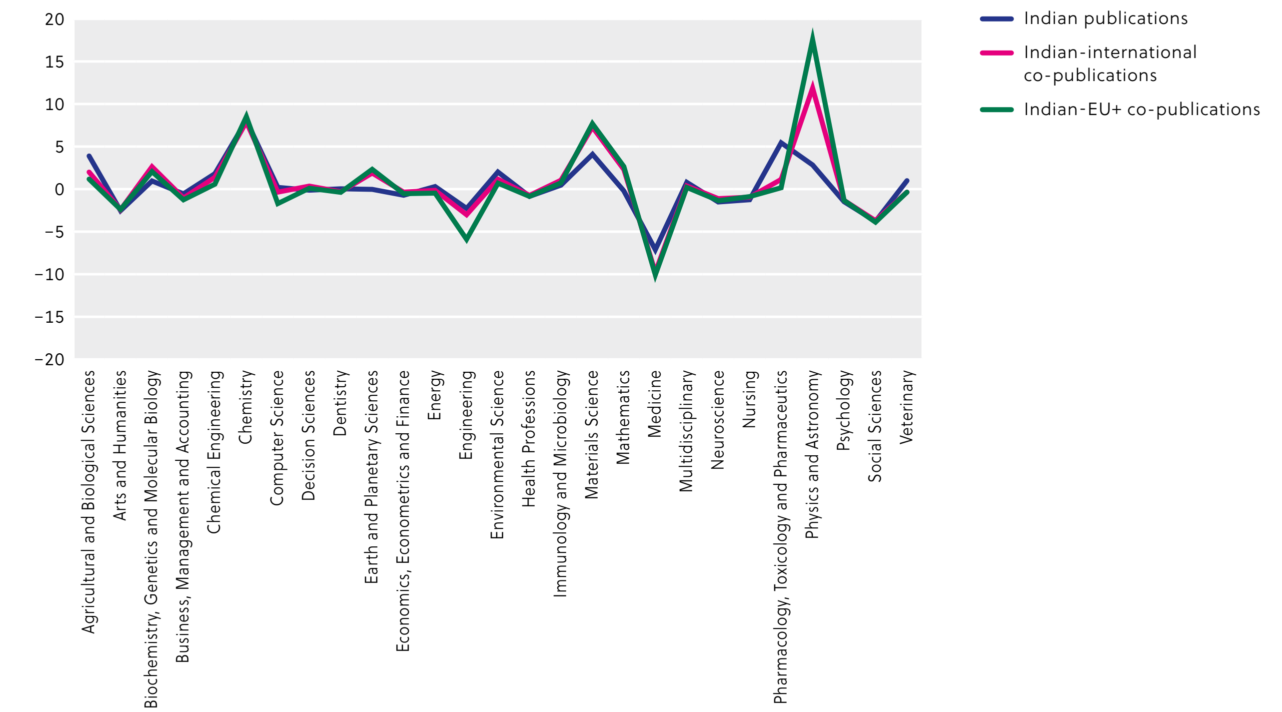

Figure 6: Distribution of thematic categories compared to the distribution of thematic categories worldwide, 2003–2012. Source: Scopus[4]

4 Scopus might assign one publication to several different thematic categories.

3 Areas of mutual interest: Water, Health, Energy[5]

3.1 Water

- From 2003 to 2012, India was involved in 588 co-publications on drinking water, 150 on urban water management and 430 on waste water. From 2003 to 2012, authors from European Research Area were involved in 37 % of the co-publications with India on drinking water, 41 % on waste water and 46 % on urban water management.
- In terms of output levels, from 2003 to 2012, Indian international collaboration in water seemed to be increasing faster than on average across the thematic fields. In this context, drinking water was the strongest cooperation topic and urban water management the weakest. Co-publishing on drinking water also shows more active growth in recent years than the other two water topics.
- The USA is India's most frequent collaborating partner in water topics. However, if the involvement of ERA-countries in this topic is summed up, the collaboration is more frequent than with the USA. Whereas Australia was the most important collaboration partner after the USA and ERA, there were some variations in other frequent publishing partners depending to the topic.
- ERA-countries and India have not only been co-publishing actively in waste water but the co-publications were also ERA-country centred ERA-countries were less involved in publications in the other two topics.
- The United Kingdom is India's most frequent European collaboration partner in all three water topics being one of the top three most frequent collaborating partners in each topic. The collaboration with the United Kingdom shows strong growth.
- Germany and France are among the top five most frequent collaborators in all three fields. Whereas the UK demonstrates above average citation impact in all three fields, France and especially Germany are less significant in terms of citations.
- ERA-countries have linked up with most of the internationally active Indian organisations for example University Kalyani when publishing on drinking water and Indian Institute of Technology when publishing on waste water. However, some opportunities for collaboration were underutilised. For example ERA-countries did not collaborate on drinking water with Javadpur University, which was internationally significant in terms of output.
- The most significant thematic field was *Environmental Engineering and Environmental Sciences* for all three topics.

3.1.1 Drinking water

In time frame of 2003 to 2012, India produced 508 co-publications on drinking water. 216 of the publications or 37 % of all publications involved an author based in the ERA-countries.

5 If not otherwise stated, in chapter 3 all data is based on Scopus and WoS.

As the figure 7 below shows, the USA is the most frequent collaborating partner for India in drinking water. However, if the involvement of all ERA-countries is added up, it is an even more frequent collaborating partner than the USA. Looking at the top collaborating partners from ERA-countries for India individually in this sub-field, the United Kingdom, Germany, France and Sweden are among the top six countries. More interestingly, it looks like the top co-publishing partner countries are growing in importance in this sub-field, notably, the United Kingdom and France which are growing the fastest. India co-published already in 2003 with all these most frequent co-publishing partner countries.

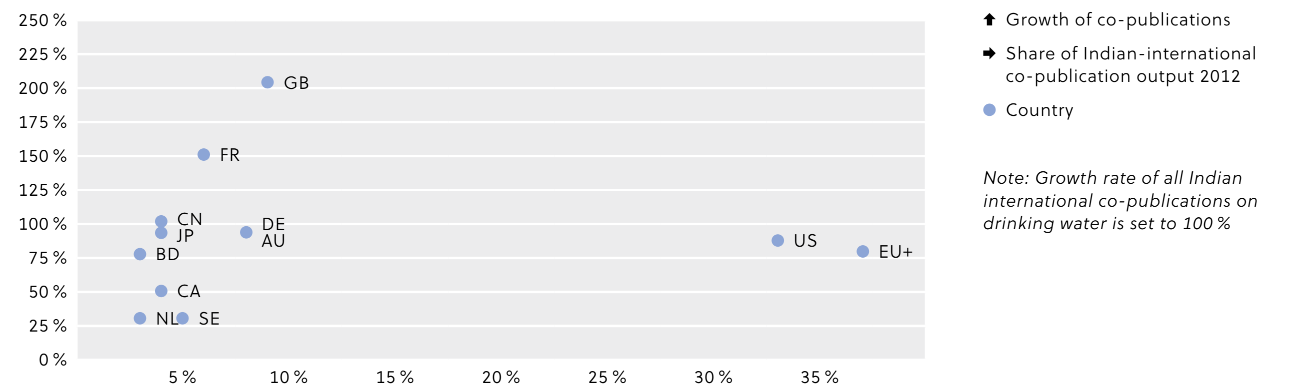

Figure 7: Most frequent collaboration partners for India in drinking water, 2003–2012

When partnering up with the USA, the co-publications were more USA centred than when partnering up with ERA-countries. When looking at the fractional counts, the USA had produced 90 full publications and ERA countries only 65. Although part of this difference could be explained by Indian authors being affiliated and actively based in the USA, it cannot be explained with the different size of author networks publishing together[6]. Indeed, there was no significant difference in the number of countries or authors involved in the publications. On average, there were 5 authors from 2 countries involved in a single co-publication[7] in the sub-field drinking water. However, publications involving Sweden, China and Australia had generally 2 more authors while those with the United Kingdom 1 less author on average.

Following the overall trend of increasing annual (co-)publication output, the Indian co-publication output grew from 2003 to 2012 in the sub-field of drinking water by almost 500 percent. When looking at the real growth in the co-publication output in the field of drinking water of the top eight co-publishing partners, it can be seen that the growth was overall stable but speeded up slightly in 2007 and again in 2010 (figure 8). Nevertheless, when looking at the annual growth rates, it can be seen that the growth of collaboration with the most frequent collaboration partners, the USA, and the UK, slowed down from around 70 to 80 % annual increase in the first years to around 20 % towards the end of the period. At the same time, the collaboration with Australia, China and Canada but also with Sweden started to grow faster towards the end of the period.

6 Fractional counting allocated an equal share of the co-publication to each involved organization. Therefore, if there are a small number of organisations involved, each organisation is allocated a higher share, for example if only two organisations co-publish together, each is allocated 50 % of the co-publication but if three organisations co-publish together, each count only for 30 % of the co-publication.

7 Indian international co-publications have on average 12 authors from two different countries.

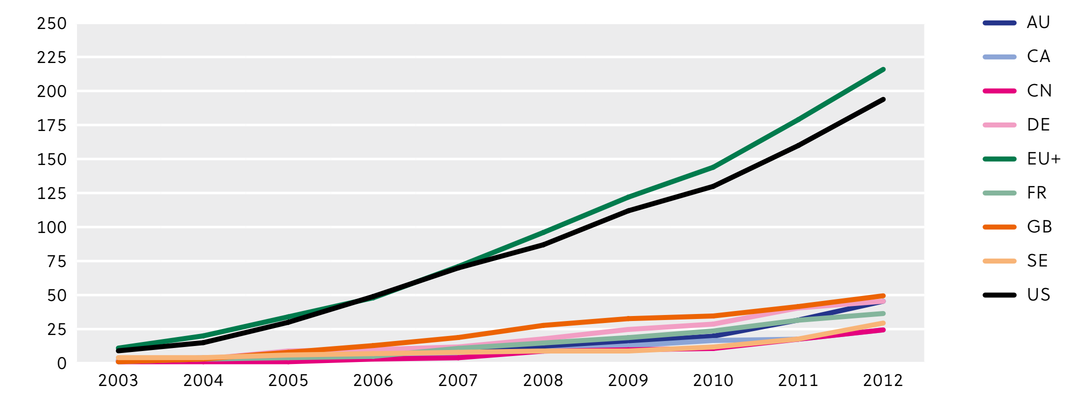

Figure 8: Cumulative annual growth (real) of the output, most frequently collaborating partners in drinking water

Only few ERA-countries collaborated frequently with India, namely the UK, Germany and France. However, in these countries, not only one or two institutions had a close collaboration relationship with India, but a wide spread of organisations. On the other hand there was a wide mix of organisations collaborating with India, although the five most active organisations counted for around a quarter of the total affiliations (figure 9). The most active institution did not come from the most active country, the UK, but was the KTH Royal Institute of Technology from Sweden. In the United Kingdom, Germany, and France there were many organisations collaborating with India, whereas in Sweden the collaboration was almost solely done by KTH Royal Institute of Technology and in Turkey by Fırat University. Similarly, the most involved authors were also affiliated to these institutions; Prosun Bhattacharya affiliated to the KTH Royal Institute of Technology was the most productive author with 14 publications. The other active authors had around four publications each: Gisela Degen and Manoj Aggarwal (University Dortmund), and Thomas Grischek (University of Applied Sciences Dresden).

Figure 9: Most active European countries and organisations involved in India-ERA co-publications on drinking water

In India, international co-publishing on drinking water was concentrated around Kolkata and Delhi. The most active organisations were the University of Kalyani with 105 records and Javadpur University with 68 records, both located in the state of West Bengal. These were followed by Javaharlar Nehru University in Delhi and Indian Institute of Technology in Roorkee. Also CSIR institutes in different geographical locations, such as the Indian Institutes of: Veterinary Research, Chemical Biology, Toxicology Research and National Environmental Engineering Research Institute played an important role.

The two most active authors, Bibhash Nath and Debashis Chatterjee, came from University of Kalyani, both being involved in around ten publications each. The authors collaborated internationally, actively with ERA countries and were often affiliated to two or more institutions in India and Europe.

With regard to cooperation with the ERA-countries, the University of Kalyani was the most active organisation, followed by the Indian Institute of Veterinary Research and the Indian Institute of Technology in Roorkee. What is interesting here is that Jadavpur University, which was the second most active institution in international collaboration in general, did not collaborate with Europe at all. Furthermore, with regard to India-ERA collaboration, organisations less significant in India-international co-publishing demonstrated a larger importance: TERI University, Indian Institute of Technology Delhi, Indofrench Centre for Groundwater Research and Central Salt and Marine Chemical Research Institute of CSIR.

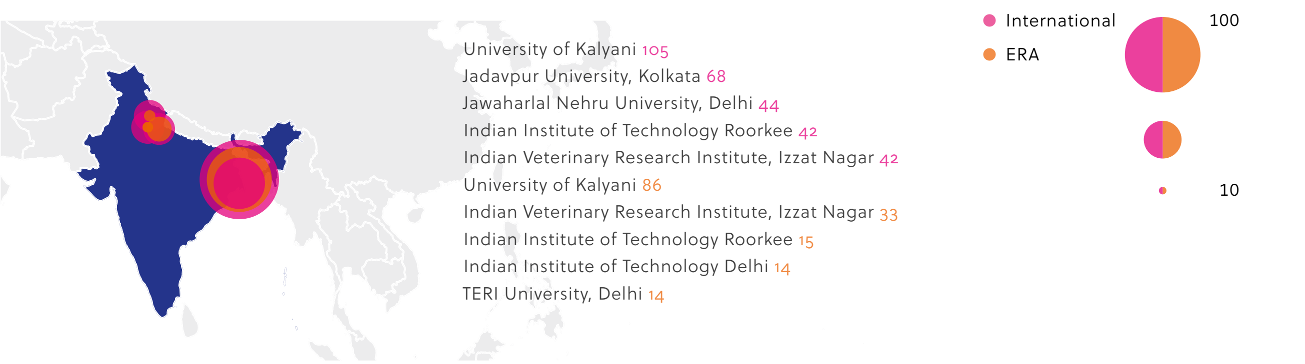

Figure 10: Most active Indian organisations involved in India-International and India-ERA co-publications on drinking water

When looking at the mean citations of India-international co-publications on drinking water, it seems that the most relevant countries are Bangladesh and Sweden. However, the low record numbers cause large variance in the data and therefore skew the results. Looking at figure 11, it can be noticed that from the important partner countries in terms of co-publication output, the USA, Sweden, the United Kingdom and France have an above average citation impact. On the other hand, the citation impact of China, Canada, Australia and Germany is low despite them being important partners in terms of output. Similarly as with the output, if one looks just at the fractional citation counts, the USA becomes a more significant collaboration partner than the ERA.

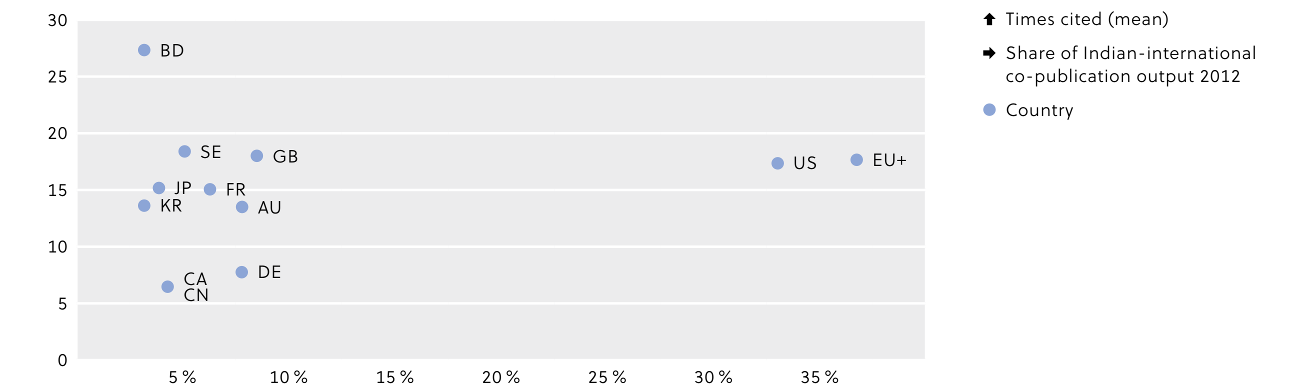

Figure 11: Most significant collaboration partners for India in drinking water, 2003–2012

Among India-international co-publications on drinking water, the most significant were the co-publications in the overarching field of *Environmental Sciences*[8], with 21 % of the publications and 21 citations on average. The publications in the field of *Environmental Engineering* were cited only 6 times on average but were still important in terms of output (18 %). The same areas dominated co-publishing with the ERA-countries. However, in field of *Environmental Sciences* the ERA-India co-publications were cited much more frequently and in *Environmental Engineering* less than on average. Looking at the most common author keywords, thematic foci of drinking water publications was on toxins, groundwater and water quality (figure 12).

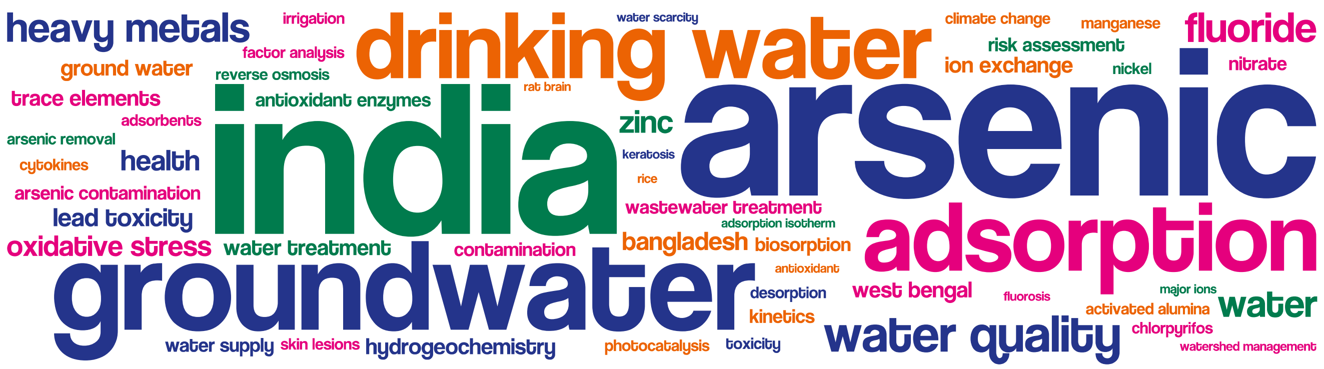

Figure 12: Most prominent author key words in Indian international co-publications on drinking water

3.1.2 Urban water management

In the period from 2003 to 2012, India produced 150 international co-publications on urban water management. 68 publications or 46 % of these co-publications involved an author based in one of the ERA-countries.

India's annual international co-publication output on urban water management grew from 6 in 2003 to 22 in 2012. India collaborated most frequently with the USA (29 %) and the United Kingdom (21 %). Authors from ERA-countries were involved in 68 of the urban water management co-publications, with three countries, the UK, Germany and France among the five most frequent collaborating partners (figure 13).

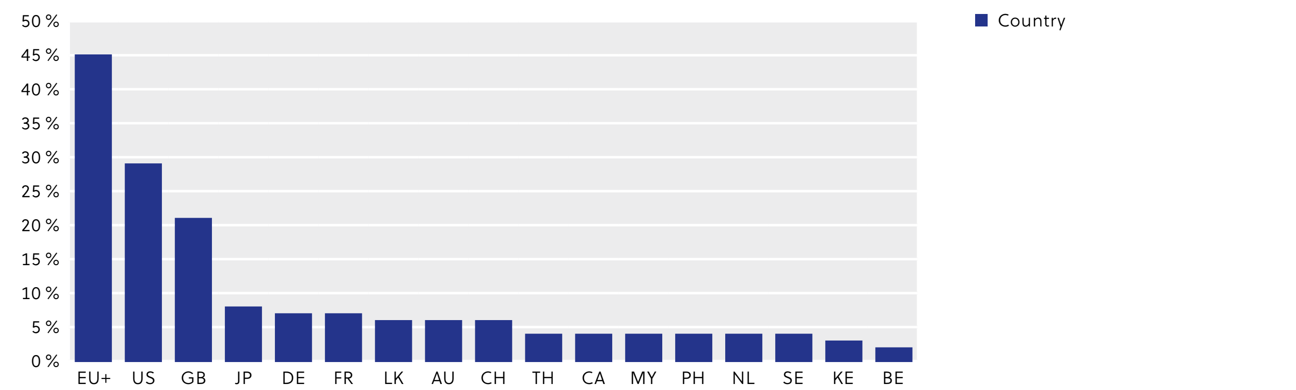

Figure 13: Most frequent collaboration partners for India in urban water management, 2003–2012

8 Science Metrix classification

When assigning each author on a paper an equal fraction of a publication, USA and the ERA-countries together are equally active in collaborating with India. This means that the organisations from ERA-countries played a less central role in the co-publications with India than the USA based organisations. For individual countries except for the USA, the fractional counting does not make a significant difference compared to counting with absolute numbers, when each involved country is allocated one "full" publication.

The India-international co-publication output grew from 2003 to 2012 in the sub-thematic area of urban water management by 370 %. Despite the small scale collaboration in the urban water management field, as figure 14 shows, the number of India-ERA co-publications grew each year, fastest from 2006 to 2008 and from 2009 to 2011. Although India started to collaborate with the ERA-countries later than with the USA, the collaboration grew faster, especially from 2004 to 2007. In 2011 and 2012, when the collaboration with ERA-countries slowed down, the collaboration with the USA continued to grow in the same pace as in the previous years.

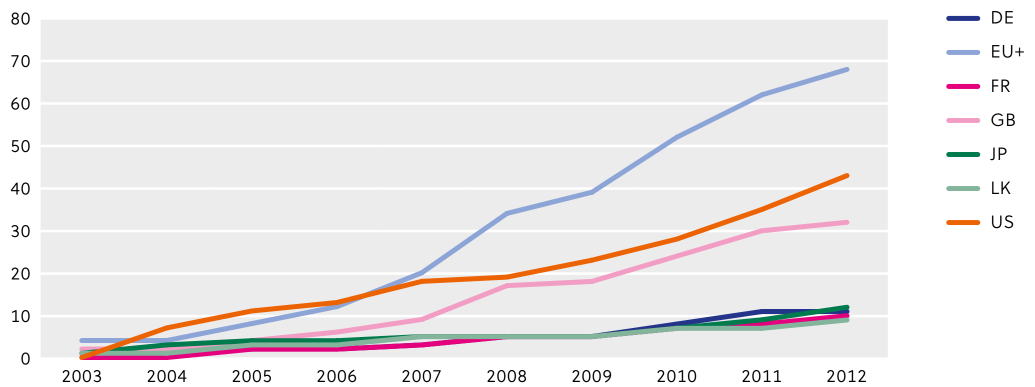

Figure 14: Cumulative annual growth (real) of the output, most frequently collaborating partners in urban water management

As the publishing activity has remained low, it is not concentrated in specific countries but it is rather carried out by a few organisations in a few of the ERA-countries. The 6 most active collaborating organisations count for 40 % of records. The single most active organisation was the World Health Organization based in Geneva, Switzerland, followed by the London School of Hygiene and Tropical Medicine. The most active European authors, J. H. J. Ensink (London School of Hygiene and Tropical Medicine) and Fiona Marshall (University of Sussex), with 3 co-publications each, were UK-based.

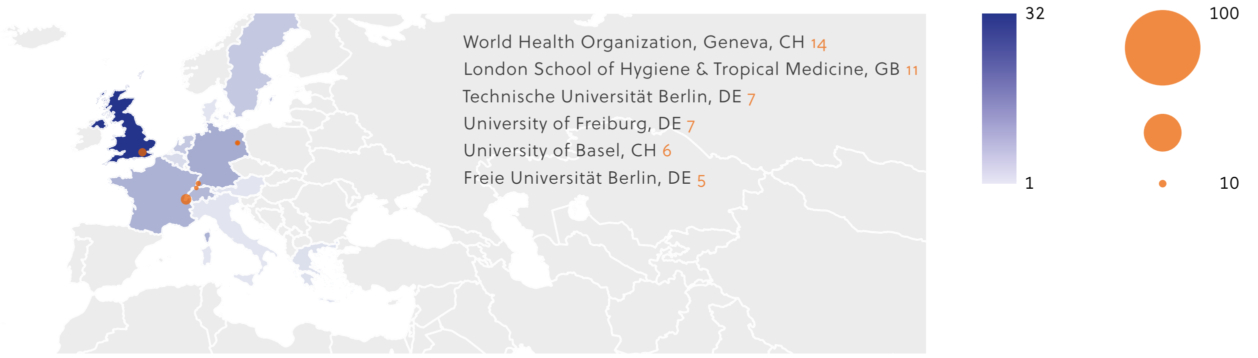

Figure 15: Most active European countries and organisations involved in India-ERA co-publications on urban water management

In India, organisations collaborating altogether internationally on urban water management were concentrated in Delhi, Bangalore, Hyderabad and Vellore. The most active institutions were Christian Medical College in Vellore, Indian Institute in Technology, Banaras Hindu University, Ashoka Trust for Ecology and the Environment and National Environmental Engineering Research Institute. These same organisations were also the most active in collaborating with the ERA-countries. The two most active authors collaborating internationally and specifically with Europe, both being involved in 3 publications, were Madhoolika Agrawal from the Banaras Hindu University and Rajesh Kumar Sharma from the Ecological Research Laboratory.

Figure 16: Most active Indian organisations involved in India-International and India-ERA co-publications on urban water management

On average, Indian international co-publications on urban water management were cited 10 times. ERA-countries and the USA were as significant collaborating partners for India in terms of citation impact (figure 17). However, as the publications involving organisations from the USA were also USA centred, the USA had higher fractional citation impact than the ERA-countries. From the less significant countries in terms of publication output, the publications involving Switzerland and Sri Lanka were cited most frequently. On the other hand, the citation impact of publications involving Germany, France and Australia was well below the average.

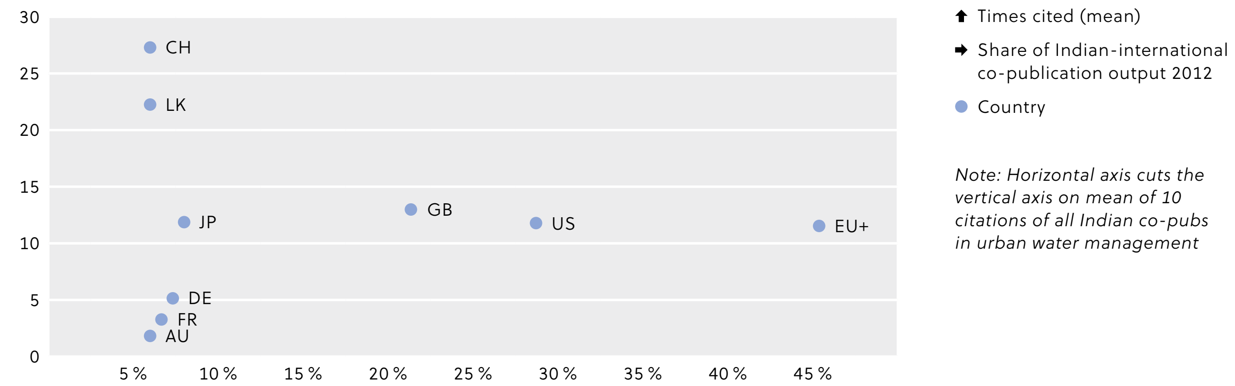

Figure 17: Most significant collaboration partners for India in urban water management, 2003–2012

Looking at the most significant thematic areas in terms of output, *Environmental Engineering* and *Environmental Science* were the most significant. The *Environmental Science* publications were cited 14 times on average, compared to only 3 times for *Environmental Engineering.* The co-publications with Europe were mostly published in *Environmental Engineering* with a mean citation count similar to the average.

3.1.3 Waste water

Waste water was the most active topic in terms of Indian-international co-publications in the field of water, with 430 international co-publications involving Indian authors. Together 176 co-publications or 41 % of these co-publications involved an author from countries associated with the European Research Area.

Figure 18 shows the most frequent publishing partners for India on waste water. The USA was the most frequent co-publishing partner, being involved in 19 % of Indian international co-publications on waste water, followed by Korea with 13 % and the United Kingdom with 11 %. There are three European countries among the five most important co-publishing partners: the United Kingdom, France and Germany. Although the overall number of publications in 2003 was small, figure 22 shows that the collaboration relationship with most of the most frequently collaborating countries was already established in 2003. Despite this, the range of collaborating partners for India has increased and new important collaborations, most notably with Korea and the United Kingdom have developed after 2003.

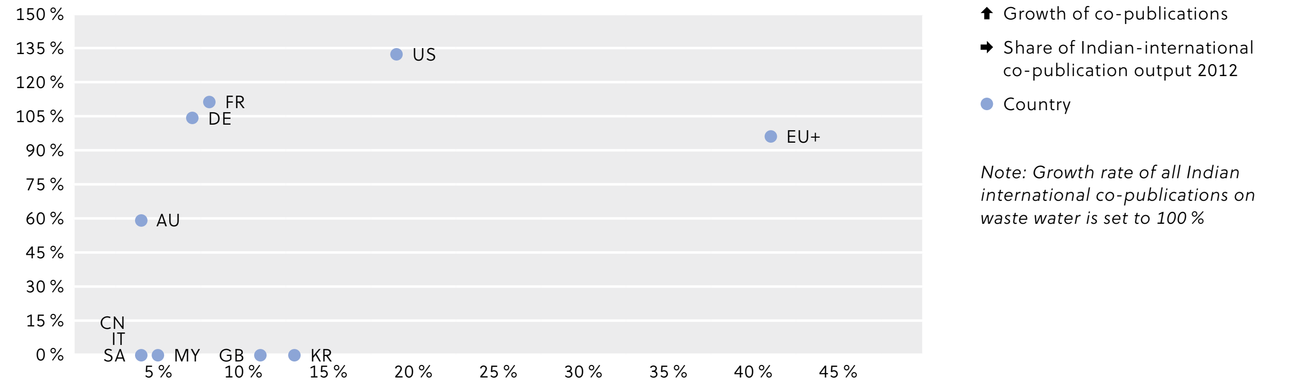

Figure 18: Most frequent collaboration partners for India in waste water, 2003–2012

The India-ERA collaboration proved to be strong, also when given an equal fraction of the publication. This means that India not only collaborated with the ERA-countries frequently, but also the publications had a strong involvement of organisations from ERA-countries. The author network and number of countries involved in each co-publication was similar regardless of whether or not the participating countries were from ERA. On average, there were four authors from two countries involved in each publication. Indeed, the publication networks on waste water seem to be small compared to the other water topics looked at.

Following the overall trend of increasing annual (co-)publication output, the Indian co-publication output grew from 2003 to 2012 in waste water by almost 500 %. The growth of international co-publications on waste water has been rather steady over the last ten years. Although there are no clear breaking points, the growth of collaborating with the USA, the United Kingdom, Germany and Canada slowed down from 2011 to 2012, whereas most notably the growth of collaboration with Korea continued on the same level as previous years (figure 19).

In Europe, organisations most active in collaborating with India were concentrated in the UK, Germany and France. The most active organisations were University of Newcastle (UK), University of Abertay (UK), Technical University Braunschweig (DE), Technical University of Munich (DE) and the French National Institute for Agricultural Research (FR) (figure 20). These organisations represented for around 20 % of the affiliations. The most productive European authors were David Bremmer (University of Abertay) and Victor Popov (Wessex Institute of Technology) with four co-publications involving Indian authors each.

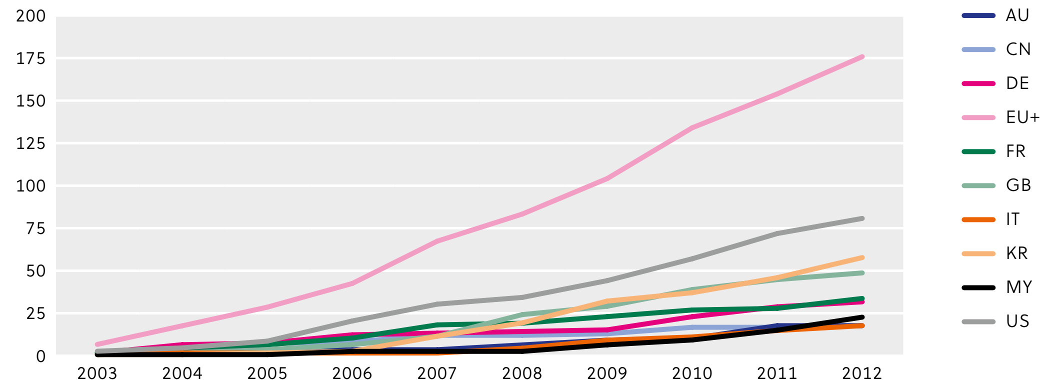

Figure 19: Cumulative annual growth (real) of the output, most frequently collaborating partners in waste water

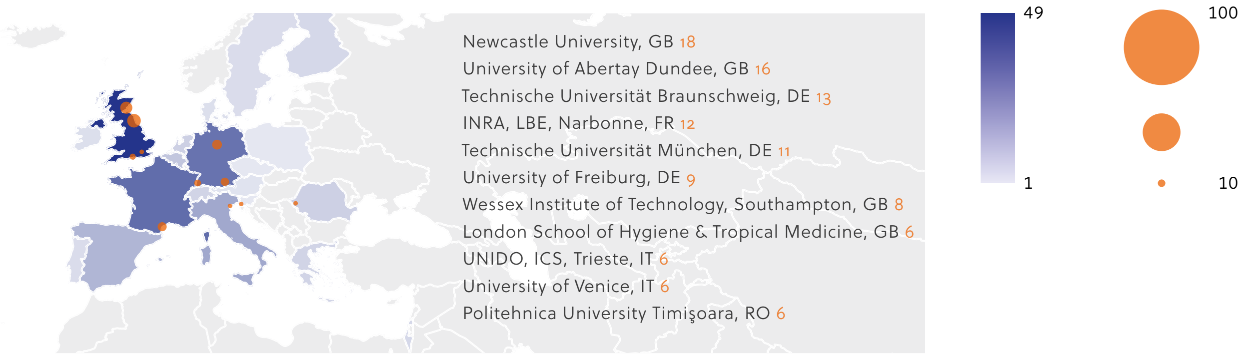

Figure 20: Most active European countries and organisations involved in India-ERA co-publications on waste water

The most active organisation involved in India-international and India-ERA co-publications was the Indian Institute of Technology, in several locations: Roorkee, Kharagpur and Delhi. There were some differences in the most active organisations between Indian-international and India-ERA co-publications. Whereas ERA-based authors collaborated actively with the Bhabha Atomic Research Institute, there was no collaboration with Anna University and Indian Institute of Technology Hyderabad, which were however active in collaborating internationally.

The importance of Indian Institute of Technology in Roorkee is shown by the affiliations of the most active authors. The most internationally active Indian author was Vinod K. Gupta, with 15 publications but the activity in Indian Institute of Technology Roorkee was not solely dependent on him. Other actors collaborating actively internationally were: J. Rajesh Banu (Sungkyunkwan University) and Kaliappan Sudalyandi (Anna University), the latter also publishing with European authors. The two authors having the most intensive publishing collaboration with the EU were Parag R. Gogate (University of Mumbai) and S. Ahmed (Jamia Millia Islamia) each 4–5 publications with European Organisations.

The Indian international co-publications in the field of waste water were highly cited; on average 20 times. When collaborating with the USA, the publications had above average citation impact (see figure 22). This does not change when looking at the fractional count. The citation impact of the three other main collaborating partners: Korea, the United Kingdom and France was average. Although Germany was a significant partner country in terms of publication output, the citation impact was low. Interestingly, when looking at the fractional citation impact, Korea outperforms the ERA-countries together and France and the United Kingdom individually. This can be explained by the fact that most of the publications involving Korean authors with high citations were also centred by Korean organisations.

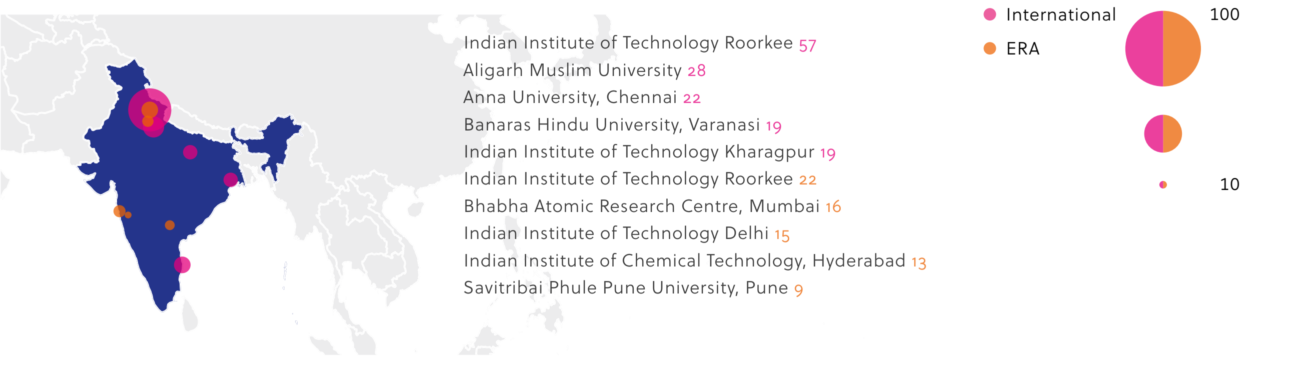

Figure 21: Most active Indian organisations involved in India-International and India-ERA co-publications on waste water

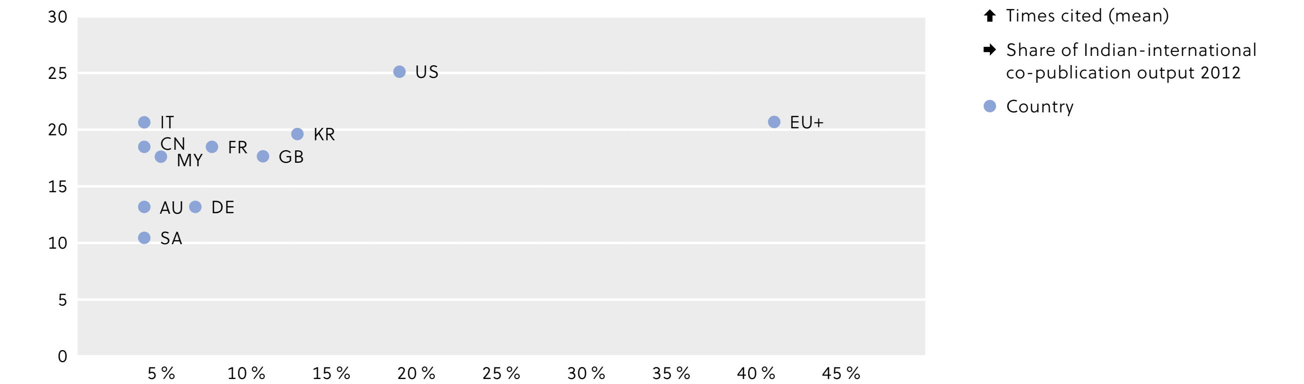

Figure 22: Most significant collaboration partners for India in waste water, 2003–2012

The most significant thematic areas of India-international co-publications on waste water, in terms of the publication output and the citation impact, were *Environmental Sciences* and *Chemical Engineering.* The high citation impact of the USA can be exemplified by its co-publishing with India in the field of *Strategic, Defensive and Security Studies,* in which India-USA co-publications are cited 90 times on average. Interestingly, *Environmental Sciences* was the most significant thematic area for collaboration between India and the ERA-countries; a quarter of the co-publications, cited on average 41 times, were published on this theme.

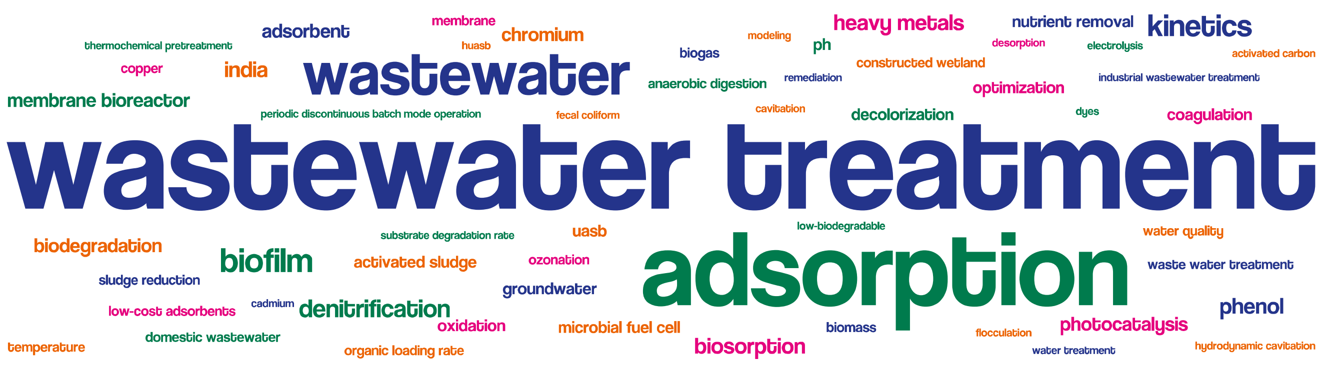

Figure 23: Most prominent author key words in Indian international co-publications on waste water

3.2 Health

- From 2003 to 2012, India was involved in 1,094 international co-publications on affordable health and 2,067 on diabetes. In volume terms, collaboration in health is strong and increasing much faster than on average across the fields. In particular, diabetes research is an active area of international collaboration, with steadily increasing output. The international collaboration output in affordable health grew from year to year in this period, however, the output decreased for the first time in the ten year period from 2011 to 2012.

- India and the USA have had an intensive collaboration relationship in diabetes research. The USA was involved in 45 % of the Indian international co-publications in diabetes whereas ERA-countries in 38 %.

- On affordable health, ERA-countries and the USA were both involved in around half of the publications and demonstrated dominance over the other countries in this respect.

- The United Kingdom was the second most frequent individual collaborating partner country for India after the USA in both fields. Other ERA-countries published less frequently with India, although on affordable health, Switzerland collaborated relatively frequently with India.

- In the health field, most active European organisations were located in the UK and particularly around London. In India, Chennai and Delhi were the capitals of diabetes research and Delhi the capital of research on affordable health. European organisations are generally co-publishing with the internationally active organisations in the field of health.

- On both fields, the publications were highly cited; diabetes publications average of 18 times and affordable health an average of 17 times. The publications involving a large number of collaboration partners had a notably high citation impact.

- Although the co-publications involving ERA-countries were cited more often than on average, they fall behind when looking at fractional publication output and citation impact. From ERA-countries, Switzerland proves to be the most significant collaborating country in terms of citations.

- For diabetes co-publications, *Endocrinology and Metabolism, and General and Internal Medicine* were the most significant thematic areas. Affordable health co-publications show more heterogeneity in terms of discipline, although again *General and Internal Medicine* was the most significant field.

3.2.1 Diabetes

In the period of 2003 to 2012, India was involved in a total of 2,067 international co-publications on diabetes. 783 or 38 % of these international co-publications, involved at least one author from the ERA-countries.

Indian involvement in international co-publications on diabetes grew from 68 publications in 2003 to 408 in 2012. The USA was the most frequent collaborating partner for India over the whole ten-year period. Indeed, the collaboration relationship with the USA but also with the United Kingdom was strong. As figure 24 shows, the collaboration relationship with these and other frequent partners was already established in 2003, and no new important co-publishing relationships developed since. The relationship with the USA and the UK seem well established but not dynamic. On the other hand, some countries publishing with India less frequently, most notably Germany, have significantly intensified the relationship over the ten years. Despite Germany, the other countries showing dynamic growth come outside the European Research Area.

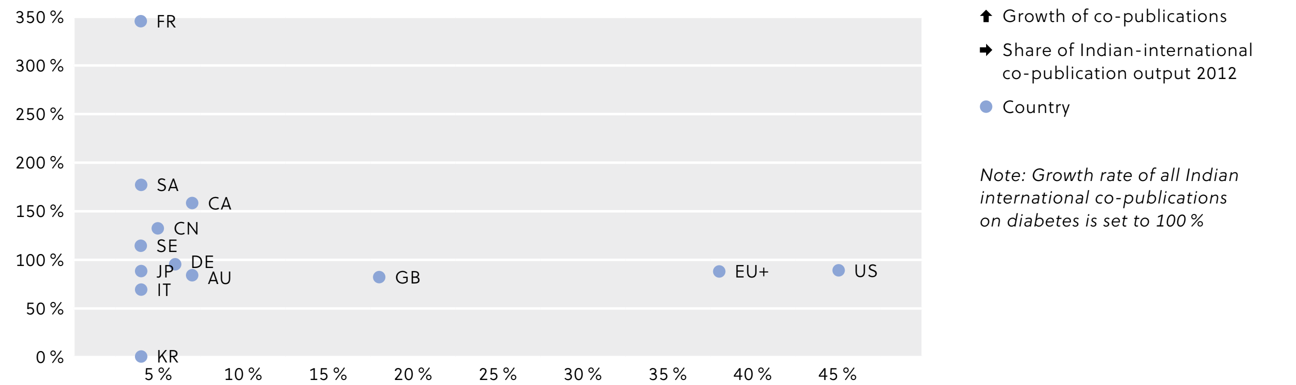

Figure 24: Most frequent collaboration partners for India in diabetes, 2003–2012

The USA does not only collaborate frequently with India on diabetes research but the publications are also USA-centred. This could be turned other way round; when ERA-country based organisations collaborate with India, they have a less prominent role in the publications. This becomes visible when looking at the fractional publication output, where USA stands at 391 (45 %) publications and ERA-countries only at 226 (26 %) publications. It also seems that co-publications involving ERA-country based organisations have generally larger network of authors publishing together; on average the co-publications involving ERA-countries have 11 authors and the publications involving USA-based authors only 9 authors. On average, an Indian-international co-publication on diabetes has 8 authors from 3 countries.

When looking at the cumulative (real) growth of co-publications on diabetes, it can be seen (figure 25) that collaboration with India has increased steadily over the period. Although the number of publications has increased every year, the annual growth rates have slowed down steadily, from around 80 to 90 % in 2003–2004 to around 20 % in the most recent years.

As figure 26 shows, the ERA-country based organisations most frequently collaborating with India are concentrated in United Kingdom. Indeed, despite Karolinska Institutet in Sweden with 97 publications and University of Helsinki in Finland with 55 publications over the 10-year period, all other eight most active organisations were UK-based. The most active organisation was

University of Oxford with 146 publications, followed by Karolinska Institutet and University of Cambridge. Whereas for example in Sweden and Finland the publication activity was heavily concentrated in the above mentioned organisations, in the UK and Germany more organisations collaborated with India. The most productive author, Caroline Fall, with 23 publications, was affiliated to University of Southampton.

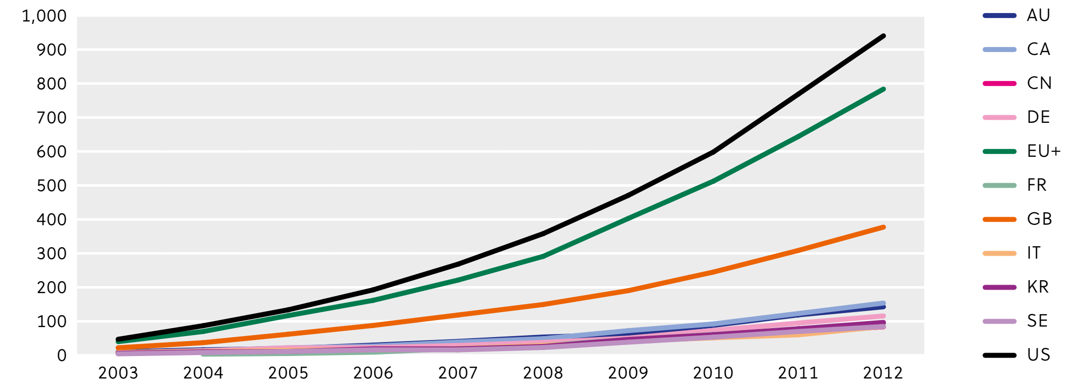

Figure 25: Cumulative annual growth (real) of the output, most frequently collaborating partners in diabetes

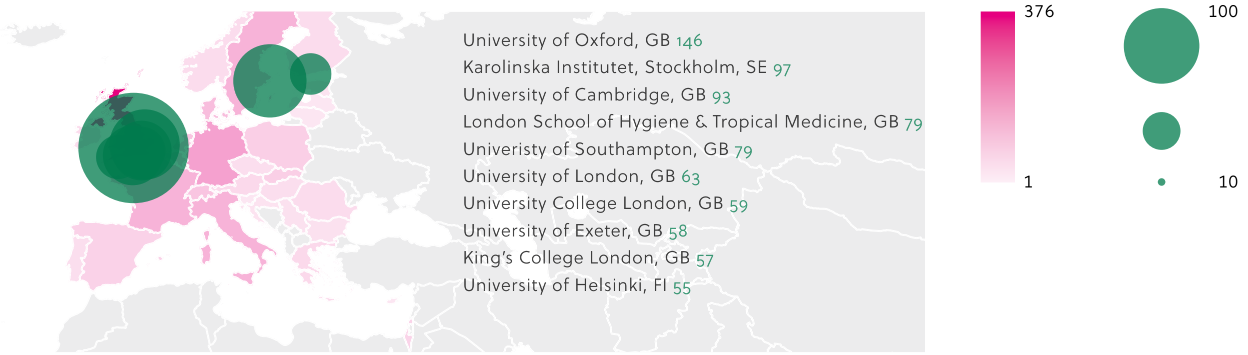

Figure 26: Most active European countries and organisations involved in India-ERA co-publications on diabetes

In India, the organisations collaborating on diabetes research internationally and with ERA-countries were concentrated in Delhi and Chennai and the surrounding states. Madras Diabetes Foundation (Chennai) was the most productive organisation publishing on diabetes, world-wide and with ERA-countries. The most active single author in the organisation was Viswanathan Mohan with 74 publications.

Figure 27: Most active Indian organisations involved in India-International and India-ERA co-publications on diabetes

Indian-international diabetes co-publications are highly cited: 18 times on average. Looking at figure 28, it seems that all countries have an above average citation impact. The reason for this is that the publications which involve a large number of countries (>10) also tend to have an above average citation impact. The fractional citation count provides a more realistic picture of the impact because in fractional count, each participating organisation is allocated an equal share of the citations for the publication. The publications involving the USA had the highest citation impact in terms of fractional count; 8.66. Interestingly, from the important collaboration countries in terms of output, Canada is the most significant in terms of citation impact, followed by the ERA-countries collectively, China and the United Kingdom. Nevertheless, the less significant relationship with Switzerland in terms of co-publication output, bears the second most significant citation impact after the USA.

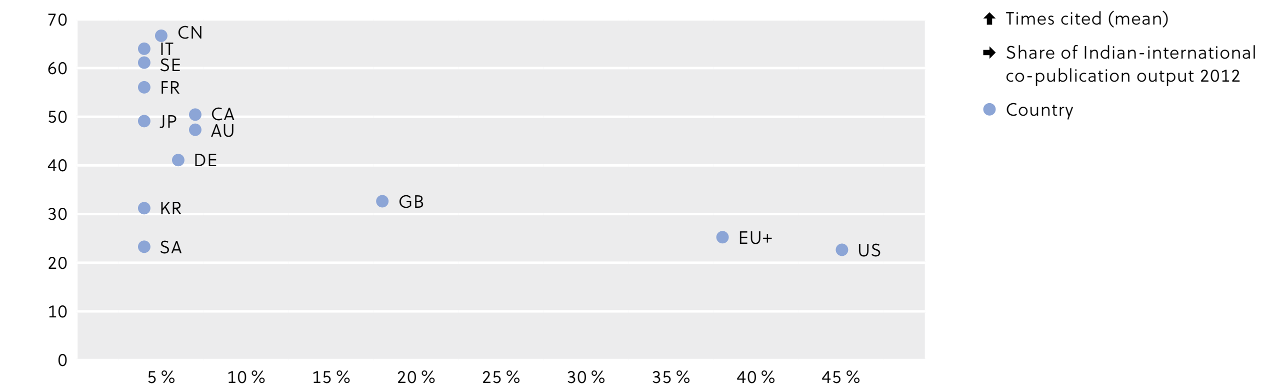

Figure 28: Most significant collaboration partners for India in diabetes, 2003–2012

The most significant collaboration field in terms of output was *Endocrinology and Metabolism* and in terms of citation impact, *General & Internal Medicine*. Both areas were more important than on average when collaborating with ERA-countries. The publications in field of *General & Internal Medicine*, were cited on average more than 100 times compared to the average of 61. Overall, publications on diabetes were published in a wide variety of fields with the most frequent being *Endocrinology and Metabolism*, *Cardiovascular System & Hematology* and *General & Internal Medicine* which totalled around third of the publications. The author keywords can give a hint of the content and scope on the co-publications on diabetes (figure 29), and differences when collaborating with the ERA-countries and with the USA. Co-publications involving the USA have a specific focus

Figure 29: Most prominent author key words in Indian international co-publications on diabetes

on obesity, diabetic retinopathy, metabolic syndrome whereas co-publications involving ERA-countries focus on insulin type 2 diabetes and insulin resistance. Most prominent key words are naturally in all co-publications diabetes and diabetes mellitus (see annex).

3.2.2 Affordable health

Between 2003 and 2012, India was involved in a total of 1,097 co-publications on affordable health. 527 of these publications or 48 % involved at least one author affiliated to an organisation located in the ERA-countries.

Indian involvement in international co-publications on affordable health grew from 46 publications in 2003 to 184 in 2012. The USA was the most frequent collaborating partner, its involvement in co-publications with India increasing at the same pace with Indian co-publishing in the topic (figure 30). The ERA-countries also collaborated frequently with India on affordable health, the India-United Kingdom and India-Switzerland collaboration relationship being the strongest. However, the ERA-India collaboration in the field of affordable health did not intensify over the period. Whereas the most important collaboration relationships were already well established in 2003, the involvement of some less frequent partners demonstrated dynamic growth over the period. Despite Germany, Italy and the Netherlands, the other countries showing dynamic growth come outside the European Research Area.

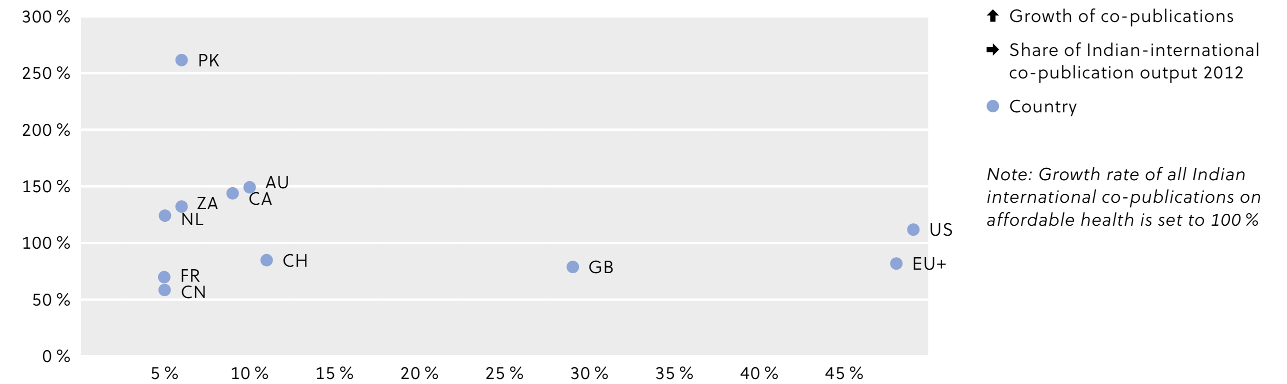

Figure 30: Most frequent collaboration partners for India in affordable health, 2003–2012

Although the USA and ERA-countries are involved in a similar number of publications when looking at the full record counts, the fractional count shows that organisations from the USA took a more central role in the publications than their ERA-countries based colleagues. This becomes visible in the fractional publication count; the USA has 213 publications while the ERA-countries combined only have 143. Moreover, the fractional counting places United Kingdom well behind Canada and Australia, which again means that although United Kingdom was more frequently involved, its role in the publications was more marginal. This difference is not explained by different sized publication networks, which for the USA and ERA-countries was close to the average of seven authors from three different countries but for Canada, Australia and the UK higher, standing at around 11–14 authors from five to seven countries.

Figure 31 shows that co-publications with India on affordable health increased rather steadily over the 10-year period. Although the number of co-publications has grown every year, after 2010 the number of publications started to grow generally faster. The involvement of the USA and the ERA-countries has grown in a similar pace. Despite the increasing real growth of co-publications, the annual growth rates have generally decreased from around 100 % percent to around 20 % by the end of the period.

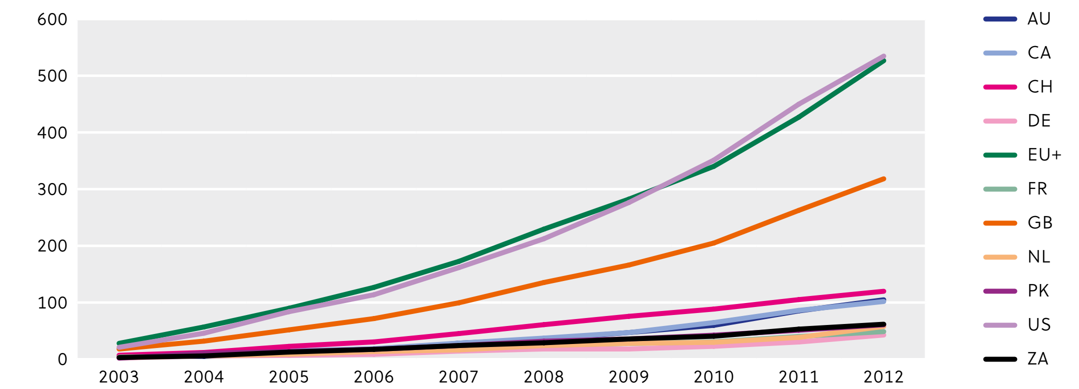

Figure 31: Cumulative annual growth (real) of the output, most frequently collaborating partners in affordable health

As figure 32 shows, in ERA-countries, collaborating with India is concentrated in the UK and particularly in London (30 % of author affiliations). The European institution collaborating most frequently with India was the London School of Hygiene and Tropical Medicine. Thinking of the mandate of the World Health Organization, headquartered in Switzerland, it is logical that it is among the most active institution in Europe publishing on affordable health.

The publication activity was spread over a large number of authors with only few publications. The most active European authors were based in the most active European organisations collaborating with India on affordable health, with around 6 publications. Patel Vikram affiliated to the London School of Tropical Medicine and Goa Medical College topped the others with around 30 publications. Due to the double affiliation he was also the most active Indian author in the field.

Figure 32: Most active European countries and organisations involved in India-ERA co-publications on affordable health

In India, the international co-publication on affordable health is dispersed over a large number of organisations, with the five most active organisations counting only for around 16 % of all affiliations. Nevertheless, the publishing activity was concentrated in Delhi with around a quarter of the publications, followed by Bangalore and Chennai. Despite this, the most active organisation was Christian Medical College and Hospital based in Vellore.

Similarly, the Delhi based organisations were most active in collaborating with ERA-countries. Despite this, the most active organisation was a Goa-based NGO called Sangath, which aims at improving health by empowering existing community resources to provide appropriate physical, psychological and social therapies.[9] Although the organisations collaborating with ERA-countries were also mostly internationally active, Public Health Foundation India and Chota Sion Hospital were partnered more often with ERA-based organisations. On the other hand, although Y. R. Gaitonde Center for AIDS Research and Education and National Institute for Cholera & Enteric diseases collaborated frequently, they did not partner up with organisations based in ERA-countries.

Figure 33: Most active Indian organisations involved in India-International and India-ERA co-publications on affordable health

The Indian-international co-publications on affordable health are highly cited; 17 times on average. As figure 34 shows, all individual countries had above average citation impact. This is because the publications involving a large number of countries (>10) also had above the average citation impact (the publications involving >10 countries were cited on average 49 times). This is also the reason why the countries with a lower number of records seem to have a higher citation impact.

Measured by citation impact and the share of publication output, the USA and the ERA-countries were significant publishing partners for India. Again, counting fractionally, the USA proved to be a more significant co-publication partner for India in affordable health than the ERA-countries, in terms of both output and citation impact. The fractional citation impact stood for the former at 7.1 and for the latter at 5.5. Interestingly, Switzerland is also a significant collaborating partner for India, with the second highest citation rate after the USA.

The most significant thematic area for Indian international co-publications on affordable health was *General & Internal Medicine* both in terms of output and citation impact, the average citations standing at 47 and share of publication output at 12 %. The *General & Internal Medicine* was a more significant field for India-ERA-co-publications, the average citations standing at 63 and share of publication output at 17 %. The more significant field when collaborating with partners from outside the ERA-countries was *Tropical Medicine.* Overall, Indian international co-publications on affordable health were published in several scientific fields, mostly however being focused on *Clinical Medicine, Public Health and Health Services, and Biomedical Research.* Indeed, this heterogeneity is reflected by the most prominent author key words (figure 35).

9 http://www.sangath.com

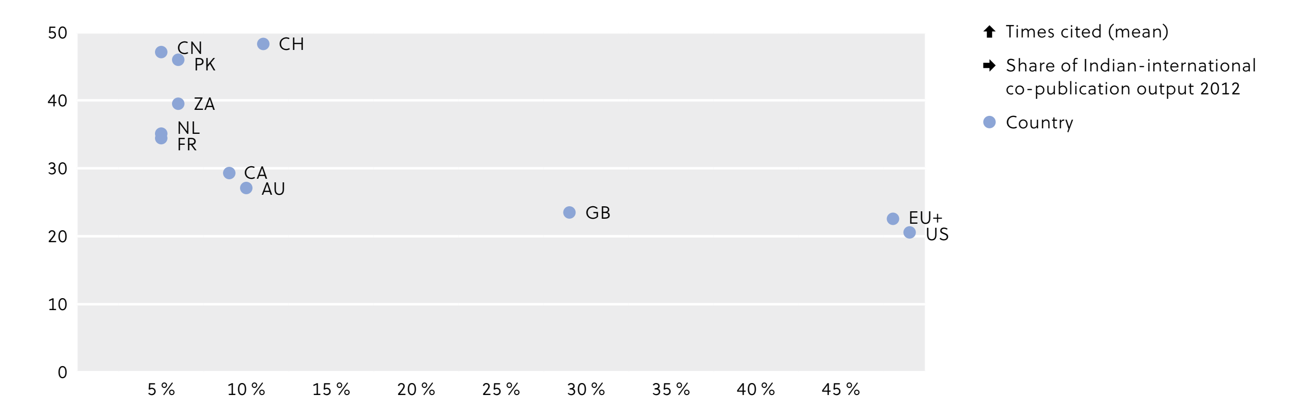

Figure 34: Most significant collaboration partners for India in affordable health, 2003–2012

Figure 35: Most prominent author key words in Indian international co-publications on affordable health

3.3 Energy

- Between 2003 and 2012 India was involved in 1,099 international co-publications on solar energy, 1,093 on biomass, and 116 on smart grids.
- Biomass has become an important field of international collaboration for India in the last 10 years. In 2012, the co-publication output was seven fold compared to 2003. Solar energy is also an important collaboration field, although it showed less dynamic growth than biomass in the 10-year period. The publication output on smart grids research remained small, and it did not appear as an emergent collaboration field.
- ERA-countries collaborated frequently with India in the field of energy. In solar energy and biomass, ERA-countries frequently collaborated with India but despite this, the collaboration relationship did not intensify dramatically over the period.
- Despite the USA being the most frequent collaborating partner for India in all three energy subfields, there were also a number of other countries, such as Korea, Japan and Canada, co-publishing with India actively.
- Compared to the other studied thematic areas, the ERA-India collaboration in the field of energy is not dominated by the United Kingdom. Especially on solar energy, there were a number of countries other than the United Kingdom that collaborated actively with India: France, Greece and Germany.

- The Indian co-publications on solar and bio energy were commonly highly cited. It seems that when publishing on solar and bio energy, ERA-countries were less significant partners for India in terms of citation impact. This might be explained by the fact that, although the collaboration was frequent, ERA-countries did not take a prominent role in the publications. In smart grids on the other hand, the ERA-countries proved to be significant partners in terms of citation impact. However, Indian international co-publications on smart grids did have a low overall citation impact.
- Co-publications on solar and bio energy were spread over a large number of institutions in both Europe and India and a single "key player" in the fields cannot be pointed out. However, the Indian Institute of Technology was active in collaborating on bio energy.
- Not surprisingly, most significant thematic field was *Energy* in all topics. For co-publications on solar energy, also *Applied Physics* was significant and for publications on bio energy, *Biotechnology.*

3.3.1 Solar energy

Between 2003 and 2012, India was involved in total 1,099 international co-publications in the field of solar energy. 432 or 39 % percent of these co-publications involved at least one author affiliated to the ERA-countries.

The involvement of India in international co-publications on solar energy grew from 55 publications in 2003 to 220 in 2012. The most frequent collaboration was with the ERA-countries combined, followed by the USA and Korea (see figure 36). Particularly India-Korea co-publishing had increased over the 10-year period. Although the co-publication relationship with the most frequently collaborating partners had already been established in 2003, during this period, India also started to collaborate with new partners, most notably Greece, Canada and Switzerland.

When looking at the fractional publication output, the order of the most frequent collaboration partners for India on solar energy remains (ERA-countries as whole, USA, Korea, Japan, United Kingdom). Despite this, organisations from ERA-countries seem to have a less significant role in the publications than organisations from the USA and Korea. These differences cannot be explained by the different sized publication networks, as all most frequently collaborating countries had a similar sized publication network, involving on average 5 authors from 2 countries.

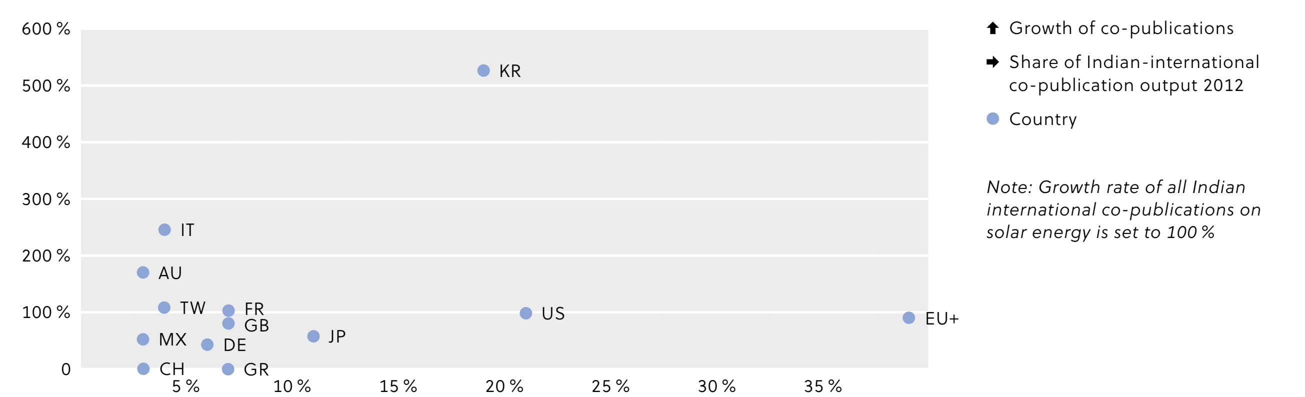

Figure 36: Most frequent collaboration partners for India in solar energy, 2003–2012

Figure 37 shows that whereas the number of publications with ERA-countries started to grow faster after 2007 and with Korea after 2008, the number of publications involving the USA grew steadily over the period. While the number of co-publications grew somewhat steadily for most countries, the publication activity with Greece picked up significantly in 2009. Despite the increasing actual number of publications, the growth rate slowed down significantly from doubling in the start of the period to approximately 20 % annual growth in co-publishing with the main partners, ERA-countries and the USA.

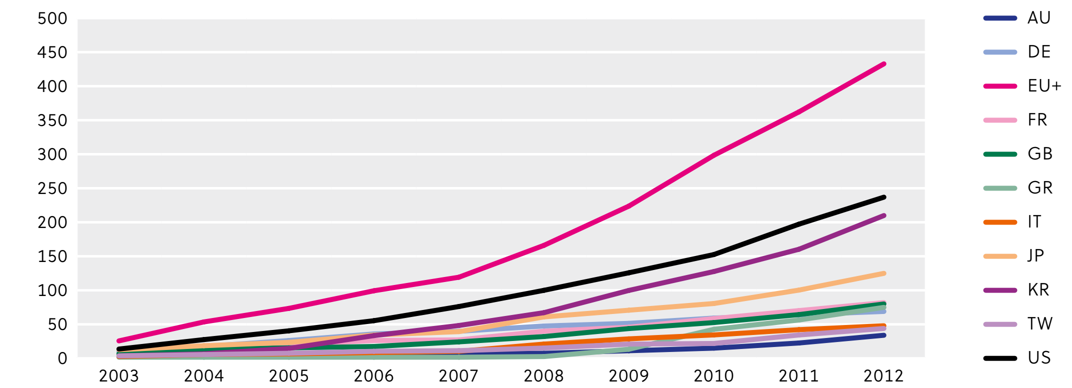

Figure 37: Cumulative annual growth (real) of the output, most frequently collaborating partners in solar energy

In ERA-countries, co-publications with India were dispersed geographically and institutionally (figure 38). Indeed, the five most active ERA-based organisations totalled only for 19 % of the all ERA-based affiliations. The single most active institution was University of Patras (Greece) followed by Ecole Polytech (France). Whereas the vast majority of Greek publications came from the University of Patras, especially in the United Kingdom, there were many organisations collaborating actively with India, each organisation totalling only 10 or less publication. Furthermore, in the University of Patras, the publishing activity was strongly led by one single author.

Figure 38: Most active European countries and organisations involved in India-ERA co-publications on solar energy

In India, international collaboration in solar energy was not clearly concentrated in any particular city. Delhi, Kolkata, Chennai, Bangalore, Jaipur and Mumbai were all active. The most active organisation collaborating on solar energy were Jaipur Engineering College, Jai Narain Vyas University and Shivaji University in Kolhapur. If the different locations were combined, the Indian institute of Technology was the most productive institution.

Figure 39: Most active Indian organisations involved in India-International and India-ERA co-publications on solar energy

The Indian international co-publications on solar energy were cited on average 14 times. Figure 40 shows that the most significant partners in terms of outputs had a similar citation impact but publications involving Japan were cited somewhat more than the others.

In fractional citations, USA sees its significance increasing as compared to ERA-countries. However, Japan and Korea are even more significant collaborating partners in terms of citation impact, the former standing at 9 and the latter at 7, compared to just 6 citations of the USA and 4 of ERA-countries. Indeed, in terms of full and fractional citation count the most significant ERA-countries, Greece, France, Germany and the United Kingdom, all have relatively low citation impact.

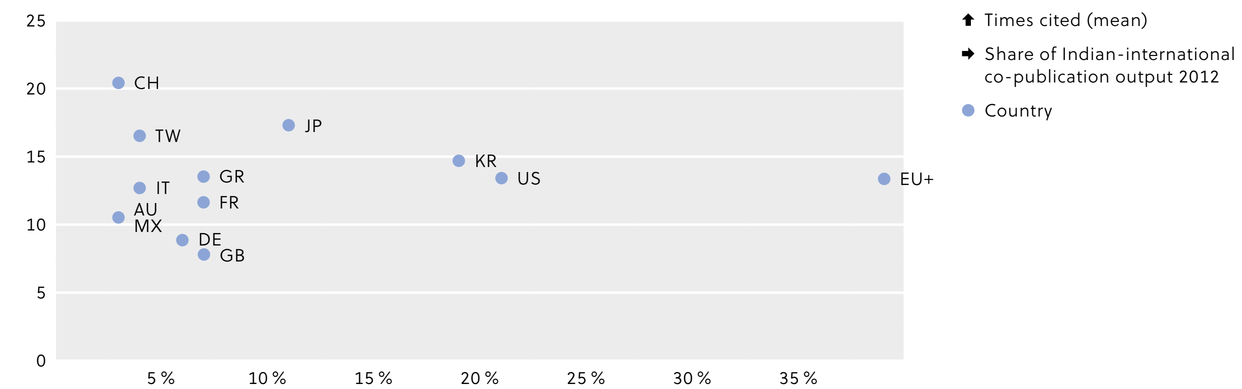

Figure 40: Most significant collaboration partners for India in solar energy, 2003–2012

The most significant fields for Indian international co-publications on solar energy were *Applied Physics* and *Energy*,[10] the former counting for 13 % of the co-publications and the latter 11 %. The Indian international co-publications on solar energy which were published on *Applied Physics* were cited on average 12 times and on *Energy* an average of 19 times. What can explain partly, why ERA-countries have a lower citation impact is that India-ERA co-publications in these fields have below average citation impact. All in all, Indian international co-publications on solar energy focused on solar cells, solar energy, thin film and conversion efficiency (figure 41).

10 Science Metrix classification

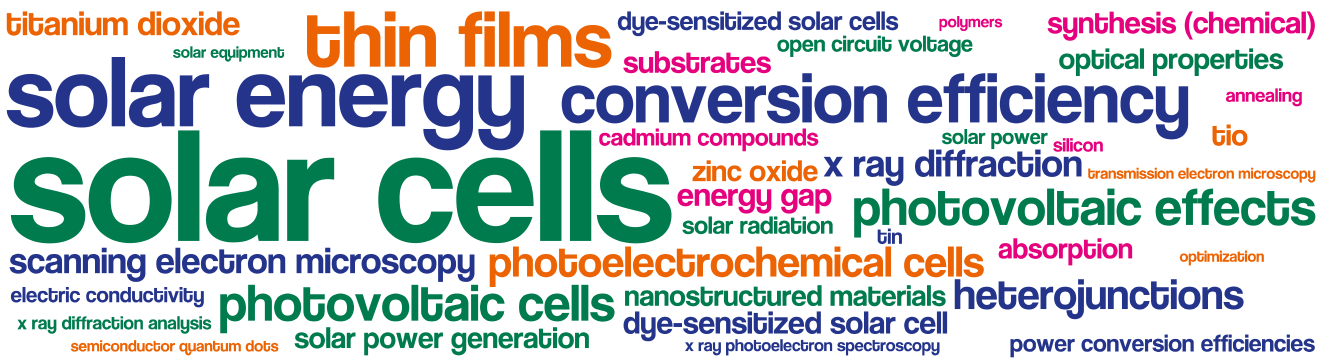

Figure 41: Most prominent author key words in Indian international co-publications on solar energy

3.3.2 Smart cities/grids

From 2003 to 2012, India was involved in a total of only 116 international co-publications on smart grids. Just 32 or 28 % of these publications involved at least one author affiliated to the ERA-countries.

The involvement of India in international co-publications on smart grids grew from 1 publication in 2003 to 25 publications in 2012. As figure 42 shows, in smart grids, India collaborated most frequently with the USA, followed by the UK, South Africa and Canada. From the ERA-countries, alongside the UK, only Sweden collaborated more than once with India in this topic.

Again, when looking at the fractional counts, it can be seen that the organisations affiliated to ERA-countries are not in such prominent positions in the co-publications. This seems to be true particularly for the publications involving UK based organisations.

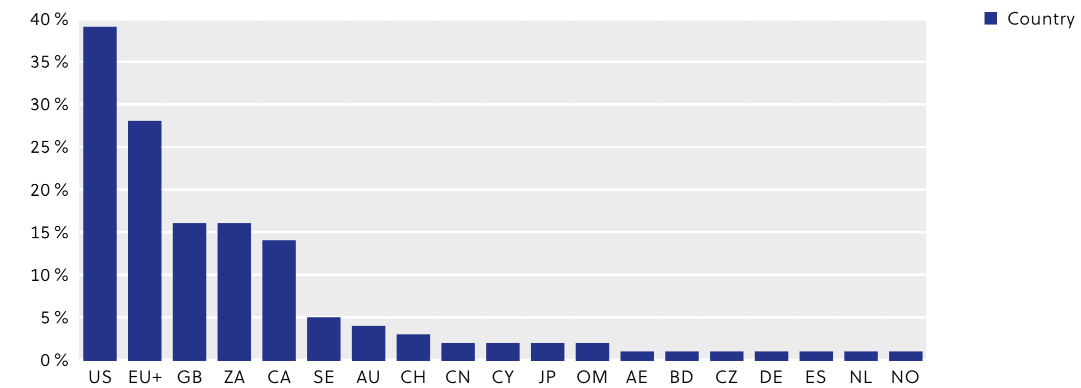

Figure 42: Most frequent collaboration partners for India in smart grids, 2003–2012

As the overall output in smart grids remained low, the growth was also slow. When looking at the cumulative growth of annual output, it can be seen that India established collaboration relationships with many countries only after 2006. In fact, the USA was the only country involved in more than one co-publication before that. Overall, as smart grids is not an established topic for collaboration and there are only very few records, it is no surprise that there are some annual fluctuations in the growth.

On average, Indian international co-publications on smart grids involved 4 authors from 2 countries. As the India-ERA co-publishing was not frequent, even the most active ERA-based organisations were only involved in a few publications. The most active ERA-based organisation was the University

of Manchester, in which also the most productive author P. A. Crossley was affiliated.

In India, the most frequently internationally collaborating organisations on smart grids were concentrated in Kolkata (60 %). The most active organisations were Jadavpur University, Calcutta Institute of Engineering and Management and Women's Polytechnic. On the other hand, Indian Institute of Technology in different locations was also a significant player. Interestingly, there were also active private sector organisations publishing on smart grids: Tata consulting, IBM and ABB Global.

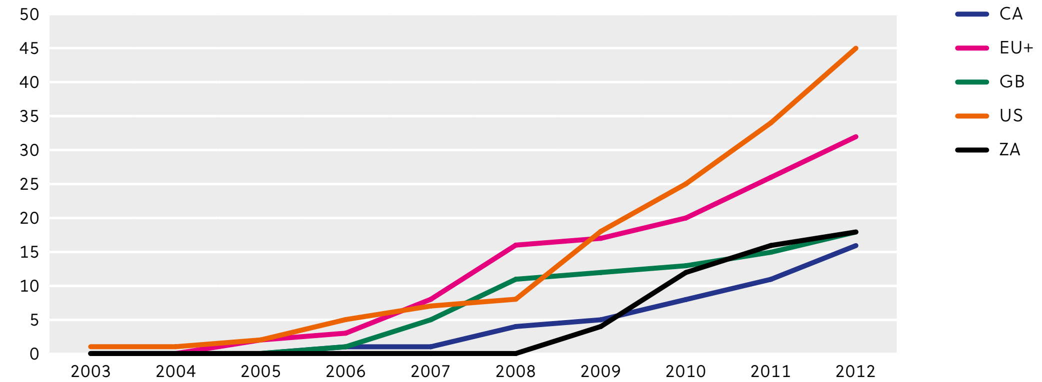

Figure 43: Cumulative annual growth (real) of the output, most frequently collaborating partners in smart grids

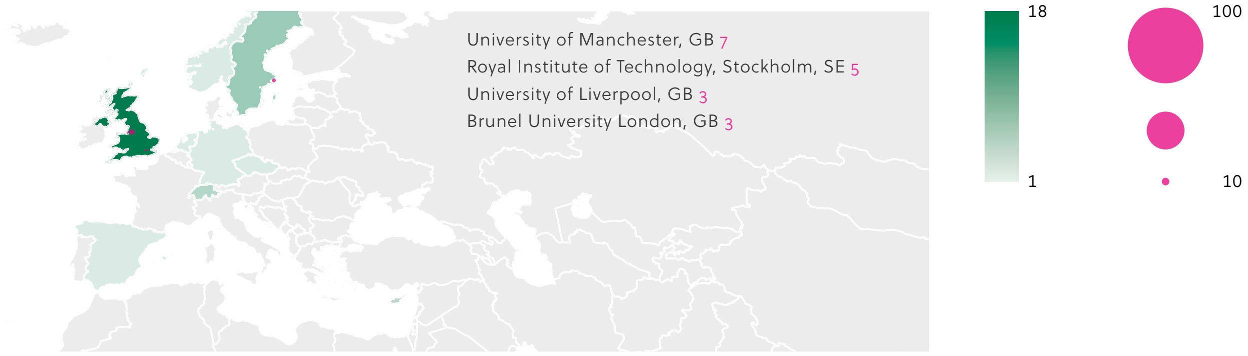

Figure 44: Most active European countries and organisations involved in India-ERA co-publications on smart grids

Indian international co-publications on smart grids were cited on average 6 times. Although the overall number of records was low and can therefore skew the results, it seems that the publications involving ERA-countries have higher citation impact than publications involving the most important partner in terms of the publications output, the USA. Indeed, the fractional citation count supports this. On fractional count, EU totalled to 4.72 citations whereas the USA totalled only 1.16. Although the full counting shows co-publications involving the United Kingdom as having a high citation impact, because the UK based organisations only have a small role in the publications, it totals to 0.43 citations and on the other hand Canada, for the opposite reason, 4.3.

Overall, the Indian international co-publications on smart grids were published in 77 different journals. More than half of these co-publications were published in *Energy* journals. The publications in *Energy* journals were cited on average 4.8 times.

Figure 45: Most active Indian organisations involved in India-International and India-ERA co-publications on smart grids

3.3.3 Bioenergy

From 2003 to 2012, India was involved in a total of 1,093 international co-publications on bioenergy. 359 or 32 % of these co-publications involved at least one author affiliated to ERA-countries.

The involvement of India in international co-publications on bioenergy grew from 33 in 2003 to 220 in 2012. Although the ERA-countries combined were the most frequent collaborating partners for India in bioenergy, the collaboration between India and the USA has intensified more than with ERA-countries from 2003 to 2012. Only the collaboration with the United Kingdom had intensified more than with the USA. Figure 46 also shows that although the collaborating relationship with the most frequent collaborating partners was already established in 2003, India started to co-publish with many new partners in 2003 to 2012. Notably, Canada and Korea had become frequent collaborating partners for India.

Again, the fractional counting shows that although ERA-countries collaborate with India frequently, they do not take the central role in the collaboration. In fractional counting the USA becomes the most frequent collaborating partner with 144 full co-publications followed by ERA-countries (106), Korea (55), Japan (32) and Canada (31).

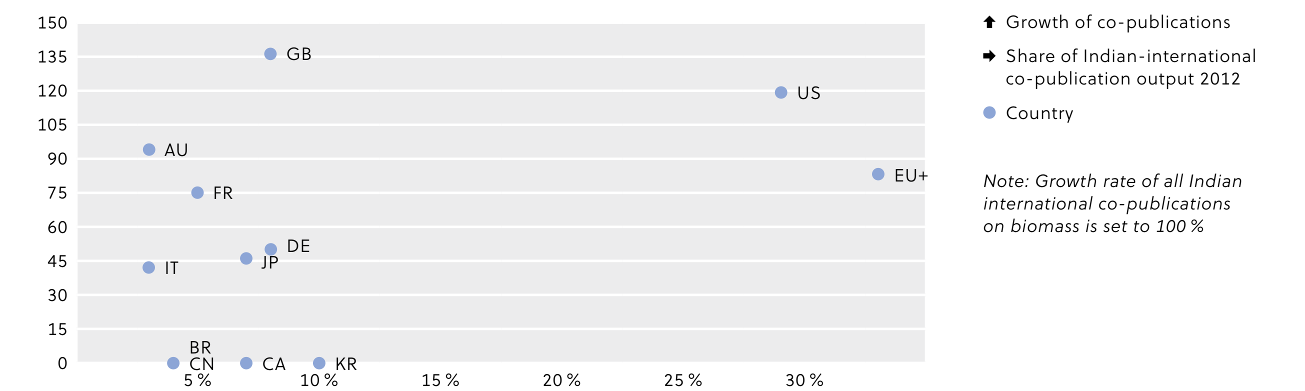

Figure 46: Most frequent collaboration partners for India in biomass, 2003–2012

When looking at the real growth of the Indian international co-publication output on biomass, it can be seen that the number of India-ERA and India-USA co-publications increased every year, although the annual growth rate decreased from around 70 % to around 30 %. Some other countries, such as Brazil, started to co-publish with India only towards the end

of the period and therefore also the annual growth rate grew during the 10-year period (figure 47).

The bioenergy co-publications involved on average five authors from two countries. Although from the ERA-countries, the United Kingdom and Germany were the countries collaborating the most frequently with India, this activity was not particularly concentrated in any single organisation (figure 48). Indeed, the six most active organisations counted only for around 11 % of all affiliations. The most active organisations in collaborating with India were University of Newcastle (UK) and Forschungszentrun Jülich (DE). In Newcastle University, the publishing activity was led by one single author (Keith Scott), who was involved in 19 publications.

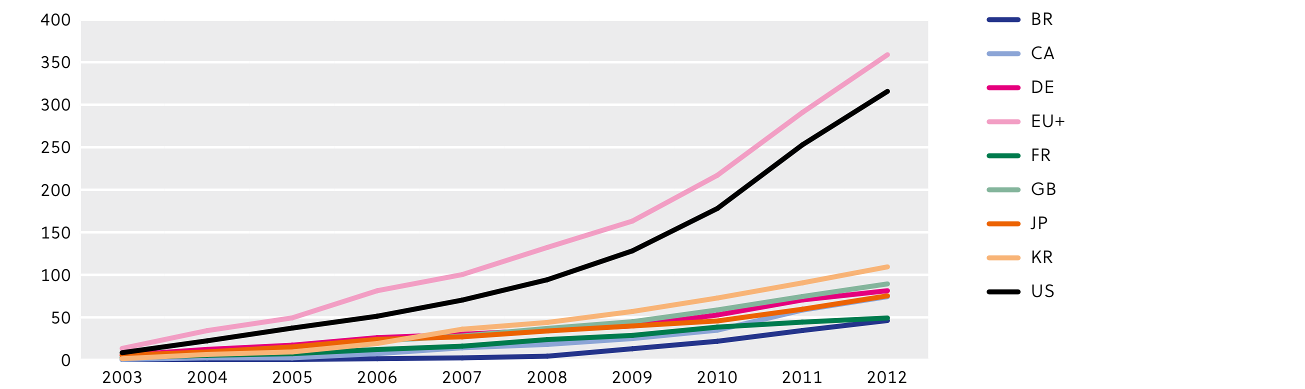

Figure 47: Cumulative annual growth (real) of the output, most frequently collaborating partners in bioenergy

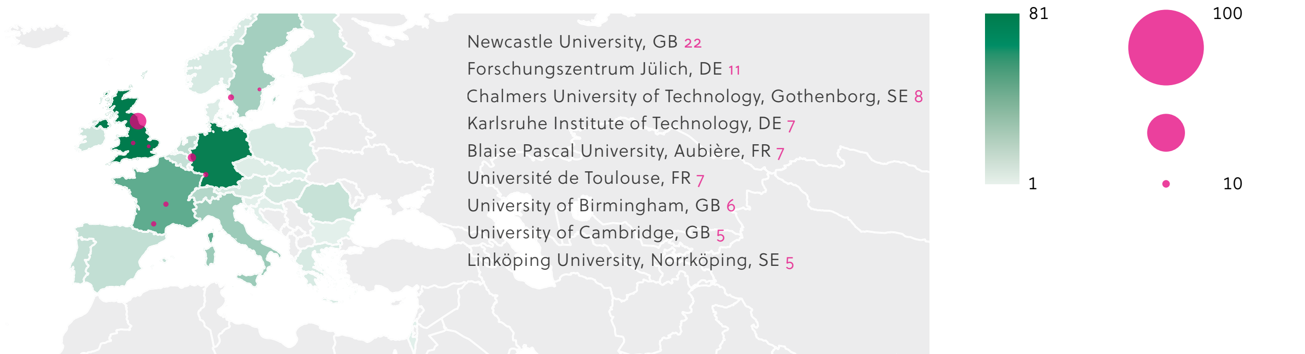

Figure 48: Most active European countries and organisations involved in India-ERA co-publications on biomass

In India, the Indian Institute of Technology, in different locations, was clearly the most active internationally collaborating organisation on biomass (figure 49). In addition to the Indian Institute of Technology, Anna University in Chennai and Banaras Hindu University in Varanasi were also active in collaborating internationally. Interestingly, the most productive authors were not affiliated to the most active organisations but to University of Rajasthan (Rishi Kumar Singhal) and the National Institute for Interdisciplinary Science and Technology (Ashok Pandey), each with 19 publications.

The Indian international co-publications on biomass were highly cited, on average 17 times. As figure 50 shows, although ERA-countries together were the most significant partners in terms of output, the citation impact of India-ERA co-publications was below the average. On the other hand, the citation impact of the India-USA co-publications was well above the average. The countries following in terms of publication output had the citation impact all around the average, the publications involving Japan being the highest from this group. When looking at the fractional citation counts, this picture becomes even clearer as the ERA-countries based organisations are presented in lower numbers in the publications they are involved in.

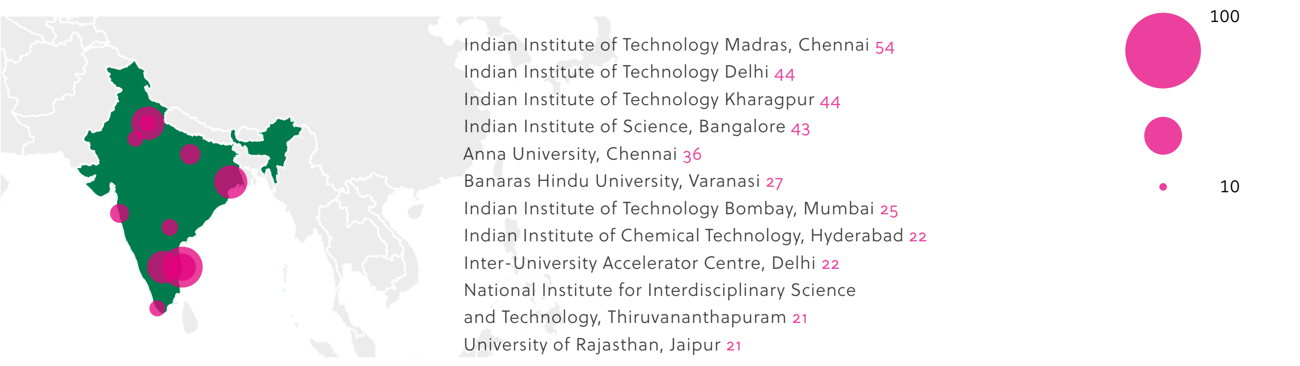

Figure 49: Most active Indian organisations involved in India-International and India-ERA co-publications on biomass

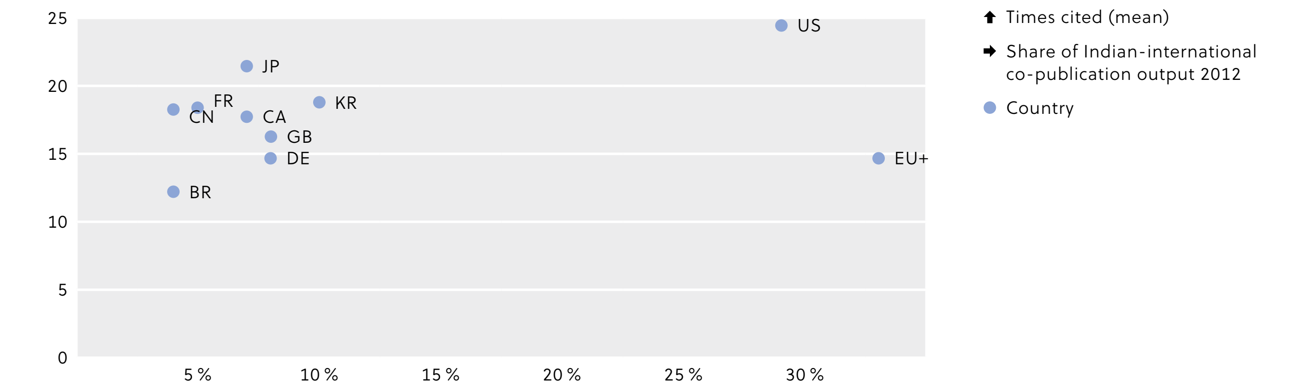

Figure 50: Most significant collaboration partners for India in biomass, 2003–2012

The most significant field for India's international biomass collaboration was *Energy,* totalling a quarter of the co-publication output and being cited on average 22 times. This was followed with *Biotechnology* with similar citation impact but a smaller share of the co-publication output. The India-ERA co-publications in both fields had lower citation impact than on average. Interestingly, India collaborated with the USA significantly in the field of *Biotechology.* As figure 51 shows, the most prominent key words used by authors were fuel cells, fermentation but also hydrolysis and ethanol.

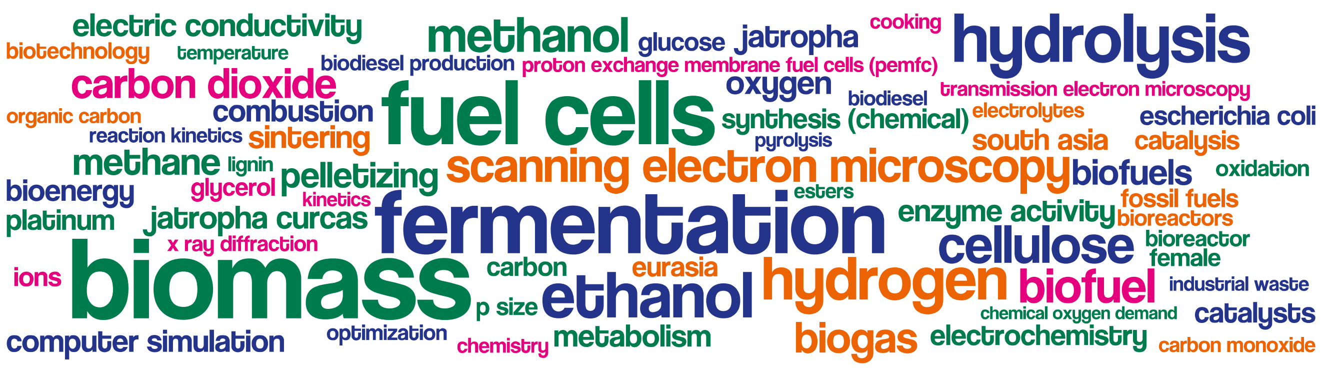

Figure 51: Most prominent author key words in Indian international co-publications on bioenergy

4 Conclusions

The aim of this report was to analyse the patterns of scientific co-publications between India and EU Member States and countries associated to the EU's Seventh Framework Programme for Research (FP7) from 2003 to 2012.

For India, international collaboration is less frequent than for many established economies (see Thomson Reuters 2011). From 2003 to 2012, only 17 % of co-publications involve an additional author from a different country i.e. are international co-publications. However, 42 % of these Indian international co-publications involve at least one author affiliated in one EU or FP7 associated country.

In volume terms, collaborating in all studied fields is growing faster than Indian international collaboration in total; especially bioenergy, diabetes, drinking water and waste water show dynamic growth and are already established collaborating fields. Collaborating in urban water management and smart grids was small scale and they do not seem to be emerging topics either.

The analysis of the three thematic areas water, health and energy shows that ERA-countries collaborated frequently with India. On the other hand, ERA-countries commonly took a less prominent role in the collaboration compared to other partnering countries. Therefore, it could be said that there is potential to build stronger EU-wide research links in collaboration and take a more prominent role when collaborating with India. There were however exceptions: ERA-countries were not only collaborating actively in waste water but also played a prominent role in the publications.

Overall from the ERA-countries, in the field of water and energy, the United Kingdom, Germany and France collaborated actively with India. On the other hand, collaboration on energy field was not dominated by any single country. On health, internationally, the USA and the United Kingdom were the most important partnering countries for India.

Importantly, ERA-countries had been able to link up with most of the internationally active Indian organisations in all fields. However, taken that it seems the content of the co-publications differ between the different partnering countries, it is no surprise that there are some differences in the partnerships between collaborating organisations. However, this could also signal that there are some underutilised opportunities for collaboration.

5 Annex

biomass	solar energy	smart grids	drinking water	urban water management	waste water	affordable health	diabetes
biomass-based	Photovoltaic	Smart grid	Drink water	Access to safe water, city	Waste water, biofuel production	affordability in health care	A1C
Bioenergy	PV	smart grid-enabled	Water treatment technology	Access to safe water, urban	Waste water, power generation	affordable access to healthcare	acanthosis nigricans
Biofuel	PV/T	smarter grid	Water, treatment technology	Aquifer Storage, recovery, city	Waste water, power production	affordable drug	acarbose
Biofuels	PVT	smart microgrid	Water treatment technology	Aquifer Storage, recovery, urban	Waste water, electricity production	affordable essential medicines	acetohexamide
Biogas	PV/battery	Microgrid	Water treatment, new technology	Drainage system, city	waste water, bio-electricity production	affordable health	Albiglutide
Landfill gas	Solar cell	Grid information management	Water purification technology	Drainage system, urban	waste water, electricity generation	affordable health coverage	Aleglitazar
Biodiesel	solar energy	Grid information flows	Water disinfection, technology	Smart water, city	Waste water, energy production	affordable health financing	Alogliptin
Bioethanol	solar-generated electricity	Grid operations	water disinfection technology	Smart water, urban	Sludge, energy recovery	affordable health technology	alpha-glucosidase inhibitor
Biomethane	Solar power	Smart distribution	Solar water disinfection	Urban Flood Prevention	Sludge, bioenergy production	affordable innovation, health	Anagliptin
Bioheat	solar-electric	smart meters	Water filtration, technology	Urban waste water	Sludge, bio-chemicals production	affordable medical	antidiabetic
Bio-oil	solar panel	smart sockets	water treatment, household	Urban wastewater	Sludge, bio-hydrogen production	affordable medicine	anti-diabetic
Biochemical conversion	solar generation	Energy management systems	water treatment, home	Water authorities, city	Sludge, biofuel production	affordable patient treatment	Beta cell
biorefineries	Solar trackers	Intelligent energy network	water purification, household	Water authorities, urban	Sludge, power generation	affordable pharmaceutical	Blood glucose meter
Biorefinery	solar battery chargers	bidirection energy flows	Water purification, home	Water cycle, city	Sludge, power production	affordable vaccine	Blood glucose monitoring
Biorefining	solar-power-charged	bidirectional energy flows	Portable water purification	Water cycle, urban	Sludge, electricity production	Disruptive innovation, health	Blood sugar monitoring
bio-refineries	Solar park	bi-directional electricity	Water treatment, heavy metals	Water demand, city	waste water, resource recovery	equal access to health services	buformin
bio-refinery	Solar farm	Wide Area Measurement System	Water treatment, pesticides	Water demand, urban	waste water, heat recovery	equal access to healthcare	Canagliflozin
Biogasoline	Solar power plant	Wide-area monitoring systems	emerging contaminant, water, removal	Water distribution, city	waste water, recovery technology	equity in health care	Carbutamide
Biobuthanol	Solar solutions	WAMS	Water treatment, reject management	Water distribution, urban	Waste water, Recovery of biogas	Frugal, medical device	chlorpropamide
Biochar	solar array	Phasor measurement unit	Reject water treatment	Water infrastructure, city	Waste water, Recovery of energy	frugal innovation, health	Dapagliflozin
Lignocellulosic	solar modules	PMUs	Reject water management	Water infrastructure, urban	Waste water, Recovery of nutrient	frugal medical device	Diabetes
plant energy	solar concentrators	Power system automation	Water quality monitoring, heavy metals	Water policy, city	waste water, monitoring	health at affordable cost	Diabetic
waste energy	Thermophotovoltaics	self-healing and network	Water quality monitoring, pesticides	Water provision, city	Waste water, sensoring	healthcare, frugal innovation	diabetogenic
BTLs	Floatovoltaics	fault detection and network	Water quality monitoring, emerging contaminants	Water provision, urban	sensor, optimisation, waste water treatment	inexpensive access to healthcare	Diabetologia
dendrothermal energy	photodetector	observability and distribution level	Water quality monitoring, viruses	Water purification, city	Sensor, optimization, waste water treatment	inexpensive drug	Diabetologist
cogeneration plant	photodiode	smart power generation	Water quality monitoring, bacteria	Water purification, urban	waste water, membrane	inexpensive essential medicine	Dulaglutide
Energy crop	Photocurrent	intelligent grid	Water, leak detection	Water recycling, city	sludge, membrane	inexpensive health	Empagliflozin
Energy crops	photo-generated		Water leak detector	Water recycling, urban	grey water, membrane	inexpensive health technology	Exenatide
woodfiring	photoelectric cell		Water reuse	Water restriction, city	water treatment, membrane	inexpensive innovation, health	Exubera
woodfuel	Photoelectrolytic cell		Water re-use	Water restriction, urban	Waste water, membrane distillation	inexpensive medical	Fasiglifam
hogfuel	Photoelectrochemical cell		rain water harvesting	Water reuse, city	Waste water, Membrane electro dialysis	inexpensive medicine	fructosamine test
Green diesel	Photoelectrochemical cells		Water quality, health	Water reuse, urban	Water treatment, Membrane electro dialysis	inexpensive patient treatment	Gemigliptin
wood chip	solar thermal collector		water system, aquifer management	Water service, city	microfiltration, water treatment	inexpensive pharmaceutical	Glibenclamide
Pellets	transduced light energy		water system, aquifer recharge	Water service, urban	microfiltration, waste water	inexpensive vaccine	Gliclazide
Fuel cell	Flexible cells		Management, aquifer recharge	Water supplies, city	ultrafiltration, water treatment	innovation, health, developing country	glimepiride
cellulosic ethanol	Thin film cells		Management, groundwater aquifer	Water supplies, urban	Ultrafiltration, waste water	innovation, health, low income country	glipizide
energy beets	efficient light coupling		groundwater aquifer, data collection	Water supply, city	Water, Microbial fuel cell	innovation, health, low income market	Gliquidone
energy cane			groundwater aquifer, modelling	Water supply, urban	Waste water, capacitive de-ionization	innovation, health, middle income country	Glisoxepide
Energy Sorghum				Water system, city	Waste water, Capacitive deionization	innovation, health, middle income country	Glitazone
hydrothermal upgrading				Water system, urban	Reclaimed water	innovation, health, resource poor country	Glucose tolerance test
co-firing				Water treatment, city	Recycled water	innovation, health, resource poor setting	Glucovance
				Water treatment, urban	Degradation of pollutants, waste water	Jaipur leg	Glyburide
				Management, water, city	Wastewater treatment	Jugaad, health	Glycated hemoglobin test
				Management, water, urban	Wastewater, treatment technology	Jugaad, medicine	Glycopyramide
				Planning, water, city	wastewater, energy production	low-cost access to healthcare	High blood glucose
				Planning, water, urban	wastewater, energy recovery	low-cost drug	High blood sugar
				Sanitation, city	wastewater, bioenergy production	low-cost essential medicines	hyperosmolar hyperglycemic nonketotic
				Sanitation, urban	wastewater, bio-chemicals production	low-cost health	hyperosmolar hyperglycemic non-ketotic
				Sewage, city	wastewater, bio-hydrogen production	low-cost health technology	impaired fasting glucose
				Sewage, urban	Wastewater, biofuel production	low-cost health care	impaired glucose tolerance
				Sewer, city	Wastewater, power generation	low-cost innovation, health	Linagliptin
				Sewer, urban	Wastewater, power production	low-cost medical	Liraglutide
				Urban, water, quality monitoring	Wastewater, electricity production	low-cost medicine	Lixisenatide
				Urban, water, quantity monitoring	wastewater, bio-electricity production	low-cost patient treatment	low blood glucose
				Urban, water, consumption monitoring	wastewater, electricity generation	low-cost pharmaceutical	Low blood sugar
					Wastewater, energy production	low-cost vaccine	Meglitinide
					wastewater, resource recovery	low-tech, health	Metahexamide
					wastewater, heat recovery	medicine, frugal innovation	metformin
					wastewater, recovery technology	resource poor setting, health care	miglitol
					Wastewater, Recovery of biogas	resource poor setting, health technology	Mitiglinide
					Wastewater, Recovery of energy	resource poor setting, medicine	Muraglitazar
					Wastewater, Recovery of nutrient	social innovation, health	nateglinide
					wastewater, monitoring	health, constraint-based innovation	nonketotic hyperosmolar
					Wastewater, sensoring	health, reverse innovation	oral anti-hyperglycemic agent
					sensor, optimisation, wastewater treatment	cheap medical product	oral glucose tolerance test
					Sensor, optimization, wastewater treatment	cost-effective innovation, health	oral hypoglycemic agents
					wastewater, membrane	distributive innovation, health	Phenformin
					Wastewater, membrane distillation	mass production, heath care	pioglitazone
					Wastewater, Membrane electro dialysis	mass screening, heath care	Pramlintide
					microfiltration, wastewater	mechanical heart valve	prediabetes
					Ultrafiltration, wastewater	odon device	pre-diabetes
					Wastewater, capacitive de-ionization	handheld ECG monitor	Remogliflozin
					Wastewater, Capacitive deionization	portable ECG monitor	Repaglinide
					Degradation of pollutants, wastewater	embrace warmer	rosiglitazone
						solar ear	
						open source hearing aid	
						mechanical heart valve	
						inocular lens	
						non-pneumatic anti-shock garment	
						MAC 400	
						economies of scale, health	
						poverty, healthcare	
						poverty, health care	
						low resource setting, health	
						poverty, health	
						low resource setting, health care	
						low resource setting, medicine	
						low resource setting, patient treatment	
						low resource setting, vaccine	

						low resource setting, medical
						resource poor country, health
						resource poor country, health care
						resource poor country, medicine
						resource poor country, vaccine
						resource poor country, medical
						Health Service, cost control
						Health Service, cost sharing
						Health Service, cost reduction
						Health Service, cost effective
						Health Service, affordable cost
						resource poor country, patient treatment
						health care cost
						health care, remote area
						healthcare, remote area
						health service, accessible
						health care, cost control
						health care, cost sharing
						health care, cost reduction
						health care, cost effective
						health care, affordable cost
						healthcare cost
						healthcare, cost control
						healthcare, cost sharing
						healthcare, cost reduction
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						healthcare, affordable cost
						medicine, cost control
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						e-health care, cost control
						medical technology, cost control
						mobile technology, health, cost control
						smart technology, health, cost control
						e-health care, cost sharing
						medical technology, cost sharing
						mobile technology, health, cost sharing
						smart technology, health, cost sharing
						e-health care, cost reduction
						medical technology, cost reduction
						mobile technology, health, cost reduction
						smart technology, health, cost reduction
						cost-effective technology, health
						health expenditure

Table 2: Key-word sets defining the studied subfields