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# Sustainable Environment and Supply of Essential Needs RDI National Priority in Saudi Arabia: Analytical Study

Full Study

Innovation Ecosystem in Focus

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# 1 Introduction

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The Kingdom of Saudi Arabia is undergoing a transformative journey, emphasizing the importance of a knowledge-based economy as a driving force behind *Saudi Vision 2030*. This transformation aims to elevate the research, development, and innovation (RDI) landscape, positioning Saudi Arabia as a global leader within its national priorities:

- Sustainability and Essential Needs
- Health and Wellness
- Energy and Industrials
- Economies of the Future

His Royal Highness Prince Mohammed bin Salman bin Abdulaziz Al Saud has declared Saudi Arabia's goal of becoming a global frontrunner in science, technology, and innovation. The Kingdom targets investing 2.5% of its GDP in RDI by 2040. Establishing the *Research, Development, and Innovation Authority (RDIA)* in 2021 marked a pivotal step in steering RDI initiatives.

RDIA is dedicated to executing and advancing the Kingdom's RDI strategies across these four national priorities. It has led capacity-building initiatives, equipping Saudi leaders and practitioners with the critical skills needed for sustainable innovation. Additionally, RDIA has developed specialized strategies to identify and prioritize key research topics within these national priorities.

The *Sustainability and Essential Needs* priority encompasses a broad range of research and technological advancements, spanning *air quality, virtual cities, and space exploration*. RDIA fosters strategic partnerships between universities, established and emerging companies, and international collaborators to align Saudi Arabia's sustainability efforts with global environmental goals. These partnerships accelerate the local deployment of impactful solutions in *clean energy, circular economy, resource efficiency, and climate adaptation technologies*.

These efforts are central to Saudi Arabia's ambition to achieve global leadership in sustainability, ensuring that research and innovation continue to address the evolving needs of both the Saudi population and the global community. By aligning research output with national priorities, RDIA ensures optimal return on investment, prioritizes high-impact sectors, and positions Saudi Arabia as a leader in sustainable innovation for years to come.

This study builds upon previous analyses conducted under *Saudi Arabia's Enhancing Cooperation and Partnership Program*, which explores the role of academia and industry collaboration in strengthening research capacity and technology readiness:

1. Assessment of Academic-Corporate Partnerships in Saudi Arabia
2. Insights into Saudi Arabia's Research and Innovation Ecosystem
3. Accelerating Technology Transfer from the Lab to the Market in Saudi Arabia

This multi-part study aimed to create a comprehensive overview of the significant aspects of the research ecosystem in Saudi Arabia. This study is intended to provide a baseline dataset of the capabilities of the Saudi research ecosystem. Seven (7) discrete studies were commissioned to establish this baseline, of which this study is one part. The reader is encouraged to read this study in full and explore the other studies to understand how the research ecosystem has developed over the past decade. The deep national priority studies available under this comprehensive review are:

- Sustainability and Essential Needs
- Health and Wellness
- Energy and Industrials
- Economies of the Future

This study focuses on *Sustainability and Essential Needs* and will evaluate the level of academic-corporate partnerships, the research capacity within Saudi Arabia's academic institutions, and the readiness of key technologies in this domain.

To facilitate this program of study, a technical analysis was undertaken to identify key research topics under each National Priority. These research topics then go on to define the datasets of the National Priority Areas themselves. The research topics considered in the area Sustainability and Essential Needs and the number of identified publications and inventions are shown in Figure 1.

The creation of these content sets is based on two primary sources of information:

1. The published documentation by RDIA and other agencies in Saudi Arabia concerning the national priorities themselves.
2. The study's technology analyst team, comprising Science, Technology, Engineering, and Mathematics (STEM) professionals with many years of experience performing innovation and technology research intelligence projects.

Using traditional keyword and technology classification search techniques, one hundred sixty-seven topics were identified and collated across research publications (gathered from the Web of Science) and patented inventions (sourced from the Derwent World Patents Index).

The project technology analyst team reviewed topics to determine their completeness, whether errors were introduced, and whether further definition and extraction were needed. The team's scientific and engineering expertise was used in an iterated review and amendment process.

Once these data extraction strategies were finalized, the records associated with each research topic category were aggregated, name normalized, and ring-fenced into a project-specific data lake, ready for analytical work. The process is illustrated in Figure 2. The finalized data structure for this study is summarized as follows:

- Over 9 million research publications.
- Over 5.5 million patented inventions.
- This data is then structured into 167 research topic categories across both research publications and inventions.
- The 167 research topics themselves then define the 4 National Priority Areas.

The complete list of research topics that define the national priority area of Sustainability and Essential Needs within this study, with global volumes across research publications and inventions, is shown in Figure 1.

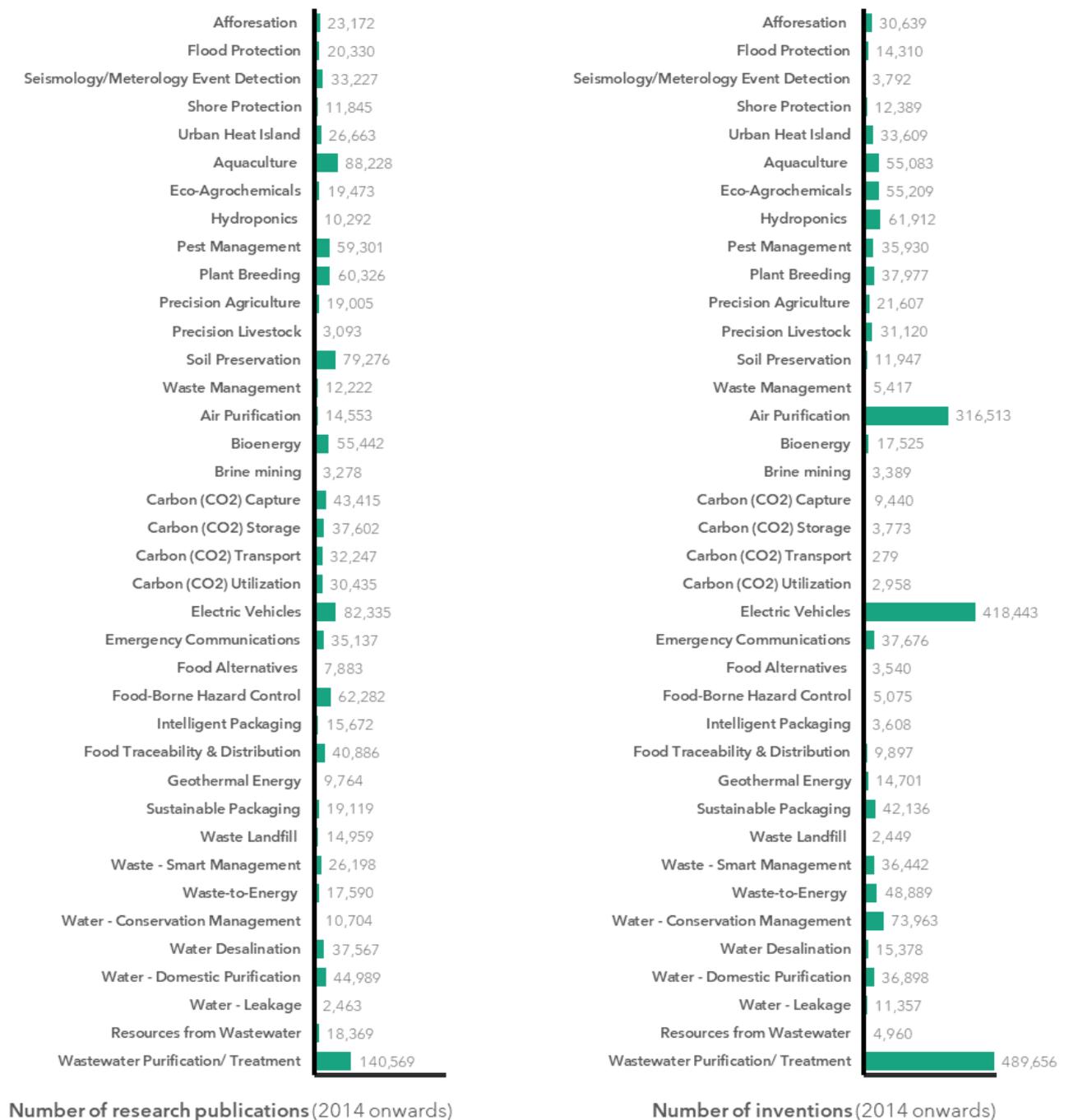


Figure 1: Overview of the number of research publications and inventions within Sustainability and Essential Needs between 2014-2023

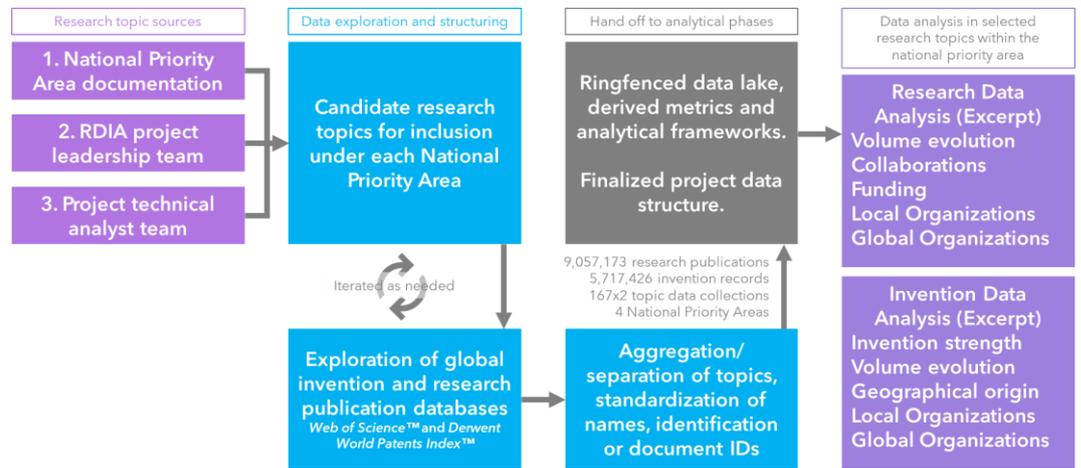


Figure 2: study data curation process

The key RDIA Missions related to Sustainability and Essential Needs are found below, and this study will focus on Missions 2.3, 2.4 and 2.5:

- Mission 2.1 Plant 10 billion trees across Saudi Arabia by 2040
- Mission 2.2 Protect 30% of the Kingdom's land and sea by 2035
- Mission 2.3 Develop technologies in food for sustainable and resilient food systems to achieve more than 50% self-sufficiency by 2040
- Mission 2.4 Achieve net-zero emissions by 2060
- Mission 2.5 Decrease the withdrawal of non-renewable water by 90% and the cost of water production by 50% by 2035
- Mission 2.6 Reduce summer surface temperatures by 4C by 2040
- Mission 2.7 Develop and adopt innovative cooling technologies to reduce cooling electricity consumption by 30% by 2040

The selected deep-dive research topics within Sustainability and Essential Needs are defined as follows:

1. Food Alternatives are Nontraditional and/or synthetically created, such as fungi, microorganism-assisted foods, or substitutes, such as dairy alternatives.
2. Agriculture - Eco-Agrochemicals: Chemicals with reduced environmental impact while increasing agricultural performance by reducing damage from pests, insects, rodents, and competitive plants.
3. Food - Traceability & Distribution: technologies and methods facilitating transparent supply chains of food and ingredients accessible by the end consumer
4. Food-Borne Hazard Control: technologies and methods to effectively monitor and, if necessary, eradicate diseases transmitted via food
5. Carbon (CO<sub>2</sub>) Transport: methods and technologies to capture and transport carbon dioxide (CO<sub>2</sub>)
6. Electric Vehicles: Vehicles powered by electric batteries rather than combustion engines.
7. Waste - Landfill Technologies: methods and technologies to dispose of end-of-life materials underneath a land surface
8. Wastewater Purification: The treatment of waste, black or grey water to remove contaminants.
9. Water Desalination: The process of removing salt from water, commonly seawater.
10. Water - Conservation Management: methods to conserve natural water resources sustainably.

11. Water Leakage: The detection and prevention of water leakage in household and industrial environments.
12. Water - Domestic Purification: methods and technologies to convert wastewater into fresh water that is safe for consumption.

Sustainability and Essential Needs are complex, constantly evolving technology domains. More recent impacts of environmentally sustainable technologies have brought new approaches to traditional processes of providing core needs to an economy and how it produces and supplies daily essentials like food and water. Applying sustainability goals to conventional mechanical and biochemical processes will be essential to continuing to bring efficient new technologies.



# 2 Executive summary

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## 2.1 Overview

The Sustainability and Essential Needs priority area of RDIA represents an opportunity to transform the lives of the local population within Saudi Arabia regarding food and water supply, along with the natural environment, including agriculture, atmosphere, and sustainable transport through electric vehicles.

- King Saud University, King Abdulaziz University, King Fahd University of Petroleum and Minerals, and King Abdullah University of Science and Technology were regularly among the top 5 publishing entities in Saudi Arabia.
- The top three Saudi Arabian universities in terms of the number of papers published with industry collaborations in the area of Sustainability and Essential Needs are KAUST, followed by King Abdulaziz University, which is second, followed by King Saud University, and KFUPM.

Many Sustainability and Essential needs technologies fall into the Technology Readiness Level (TRL) level 5. Only two technologies, Electric Vehicles and Wastewater Purification, sit in the higher TRL levels of 7-9. The overall impact of medium TRL will be a balance of research and invention volumes, while technology has yet to mature enough to satisfy market needs. Subsequently, the time to return on investment may be slower than more mature technologies. Nonetheless, Saudi Arabia's market permission through conducting research at scale in drought- and heat-stressed environments could be the catalyst required to produce future innovations in the field of sustainability.

Saudi Arabia is set up for success by leveraging corporations such as Saudi Aramco with research synergies, particularly across Water and Carbon-related research topics.

## 2.2 Key actions to evaluate for Sustainability and Essential Needs:

- **Prioritize higher-performing and higher-commercial-potential research topics:** Key research topics within Sustainability and Essential Needs have significant commercial potential, specifically Electric Vehicles, Water Desalination, and Water Wastewater Purification. Combined, these three research topics have the potential to generate \$2.33Bn for the Saudi Arabian economy if 7,500 inventions are protected, generating the expected yield of very high-strength inventions, and are subsequently successfully commercialized.
- **Select key academic-corporate partnerships (ACP) for specialized ecosystems.** Focusing on Electric Vehicles, Hyundai, Kia Motors, and Toyota have significant invention portfolios and experience with collaborative commercial research with academia. Therefore, they could be suitable partners to expand and accelerate Saudi technology transfer in local and global markets.
- **Accelerate the creation of Saudi Arabian Sustainability private sector:** To commercialize Sustainability and Essential Needs research topics, Saudi Arabia needs to consider both local and global markets, and therefore, it requires IP protection. The vehicle for IP protection could be start-ups, joint ventures, or existing corporations such as Saudi Aramco, which are synergistic with existing business lines. Electric Vehicles progress includes Lucid Group building Saudi Arabia's first electric vehicle manufacturing site. To fully realize the potential of the EV space, other research topics should be considered, such as battery management. These actions align with RDIA's mission 3.6 Become the 4th largest producer of EVs and EV batteries by 2035, along with fulfilling mission 2.4 Achieve net-zero emissions by 2060, through decreasing transport-related emissions via Electric Vehicles.

- **Continue to fund local academics in key research topics with lower TRL:** Research topics such as Eco-Agrochemicals, Carbon (CO<sub>2</sub>) Transport, Food Alternatives, Food-Borne Hazard Control, and Traceability and Distribution may benefit from additional foundational academic research. In contrast, Water Domestic Purification, Water Wastewater purification, and Water Desalination require more excellent technology transfer and further research funding.
- **Build an ecosystem around Saudi Aramco's Sustainability and Essential Needs diversification:** Saudi Aramco has innovation in the fields of Desalination, Electric Vehicles, Carbon (CO<sub>2</sub>) Transport, Waste - Landfill, Water - Conservation Management, Domestic Purification, Leakage, Wastewater purification. Many of these research topics have planned long-term investments to leverage Saudi Aramco's scale and expertise. Research topics that are not strategically crucial to Saudi Aramco could receive investment into alternative private organizations to work closely with local academia.

Reflecting on the natural resources and challenges underpinning the development of desalination, solar panels, and carbon transport research topics, Saudi Arabia has significant potential to drive and obtain a considerable return on investment in Sustainability and Essential Needs research. Nonetheless, the route to market, time to reap the rewards, and local compared to global market strategy will differ significantly across research topics such as Water, Carbon, and Electric Vehicles.

The insight within this study provides a multi-dimensional evaluation of research topics within the Sustainability and Essential Needs priority area to provide key actions and options to consider and benchmarks against global leadership. Subsequently, the tailored insight, metrics, and findings can enhance both the foundational research within academia and commercially applied innovation to achieve the national missions and aspirations of Saudi Arabia.

# 3 Overview of research publication and patent performance in Sustainability and Essential Needs



This section provides an overview of Saudi Arabia's research publication and patent performance within the Sustainability and Essential Needs National Priority. This study is part of a wider program of analysis across research output, the research ecosystem and technology commercialization, and therefore the analysis presented here includes extracted data from several studies across these wider studies, now focused within this national priority area.

### 3.1 Overview of Performance in Research

In this section we evaluate the research performance of Saudi Arabia in the national priority area Sustainability and Essential Needs in the period 2014-2023. The aim is to examine the evolution and current status regarding research volume and impact. For this, we examine the evolution of the number of papers in the priority area over this period and benchmark it with the global baseline and other countries/regions. Afterwards, we examine the citation impact. For this we will use the Category Normalized Citation Impact (CNCI). CNCI is a valuable and unbiased indicator of impact irrespective of age, subject focus, or document type. Therefore, it allows comparisons between entities of different sizes and different subject mixes. A CNCI value of 1 represents performance at par with global average when considering the same document type, year and subject. A value above 1 reflects a performance higher than the worldwide average while a value below 1 reflects a performance below the global average (for more information see Metrics). To further understand the research dynamics in the national priority area we also look at top 20 countries in terms of number of papers collaborating with Saudi Arabia and top 20 funding organizations in terms of the number of papers in each priority area. Looking at the top 20 funders will allow identifying key organizations funding Saudi Arabia research in the national priority area.

We also investigate the research performance of Saudi Arabia in this national priority areas with a specific focus on research performed within an industry collaboration. A paper with industry collaboration is a paper that contain two or more Organizations with at least one organization listing its organization type as corporate or global corporate (see Metrics). This gives us insights on the academic-corporate partnership status currently in Saudi Arabia within this national priority area. It is important here to differentiate that a paper published as an output of research performed through a collaboration between academic affiliated researchers and corporate does not necessarily underpin a long-term or a strategic partnership. Nevertheless, investigating papers with an industry collaboration gives insights about the academic-corporate activity. To provide an overview of the academic-corporate activity in Saudi Arabia we investigate several domains: the evolution of the percentage and number of papers with industry collaboration, funding of papers with industry collaboration, corporates collaborating with Saudi affiliated researchers and top Saudi academic institutions in terms of number of papers with industry collaboration.

Finally, we analyse the research out and impact of the priority area on a more granular level by performing a SWOT analysis of the categories constituting the national priority area. The research topics constituting the priority area are described in Program of Work. This allows for an overview of research performance in the research topics constituting this area, before investigating in more detail chosen priority research topics in the following sections. This allows classifying the underlying categories into strengths, weaknesses, opportunities, and threats. Accordingly, all of the above analysis will create a relatively detailed overview of Saudi Arabia research performance in the priority area.

#### 3.1.1 Main Findings:

- Saudi Arabia's research output increased rapidly in the national priority area Sustainability and Essential Needs, with an average annual growth rate (25%) higher than that of the comparator countries/regions.

- The citation impact of Saudi Arabian papers in this area is 57% higher than the global average and higher than that of all considered countries/regions
- We do not observe a central funding entity when considering Saudi Arabia's top 20 funding organizations in Sustainability and Essential Needs. More centralised funding could help ensure alignment with national priorities and goals across all research institutions. With the establishment of RDIA in 2021, one of its mandates is providing funding. This could be achieved in the future and reflected in the data.
- Although the number of Saudi Arabian papers with industry collaborations in Sustainability and Essential Needs increased between 2014 and 2023, the percentage decreased. One possible explanation for this dynamic is that efforts to increase research output did not simultaneously focus on increasing academic-corporate collaborations.
- Only 29% of Saudi Arabian papers with industry collaborations are performed with a local corporate. This has the advantage of gaining international visibility and expertise from global corporations. On the other hand, having more local corporations collaborate with Saudi-affiliated researchers would further enhance local knowledge transfer and build local expertise.
- The top three Saudi Arabian universities in terms of number of papers published with an industry collaboration in the area Sustainability and Essential Needs are King Abdullah University of Science & Technology followed by King Abdulaziz University sharing the second place with King Saud University and King Fahd University of Petroleum & Minerals.
- When investigating Saudi Arabia's performance in the research topics in the national priority area Sustainability and Essential Needs, we noticed that out of the 38 research topics, there are 23 strength research topics, 14 opportunity research topics, and one threat area: Water Leakage. Saudi Arabia has a high productivity relative to global productivity but a low CNCI (0.89). One should focus on increasing the research output in the opportunity areas and improving the research quality in the identified threat area.

### **3.1.2 Research volume analysis**

The number of Saudi Arabian papers published in the national priority area of Sustainability and Essential Needs grew continuously from 569 papers in 2014 to 4007 papers in 2023, as shown in Figure 3.

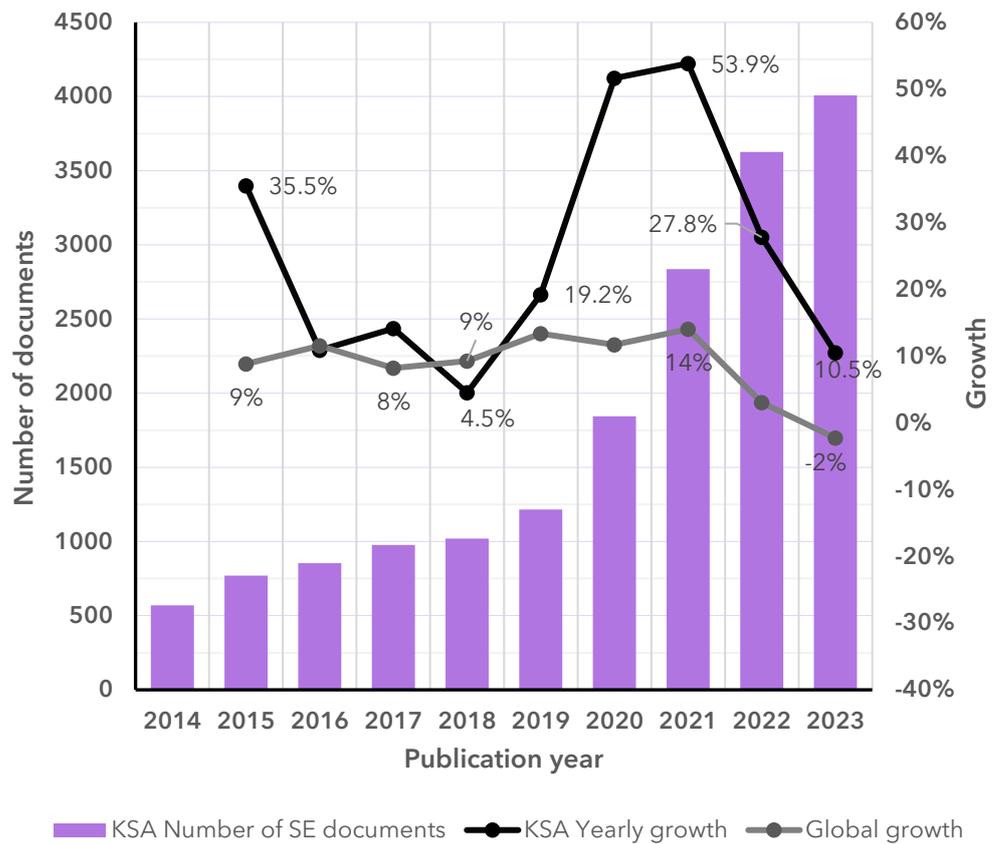


Figure 3: Saudi Arabia's number of papers and growth in the national priority area of Sustainability and Essential Needs

This reflects double-digit growth for all years; for some years, the growth rate was above 50%, and there was a much higher growth rate than the global rate in the same area. It is worth highlighting that although globally there was a negative growth rate between 2022 and 2023, we still observe a double-digit growth rate of 10.5% in Saudi Arabia.

In the considered period, Saudi Arabia had a yearly average growth rate not only three times the average global rate but also higher than all of the other considered benchmark countries/regions, as shown in Figure 4.

It is worth mentioning that this growth rate is not only higher than countries with more almost saturated research output, such as Japan, Germany and the USA, but also higher than that of countries/regions with growing research output, such as Mainland China and the GCC, excluding KSA. All of the above indicates that the focus is on increasing research activity in this national priority area.

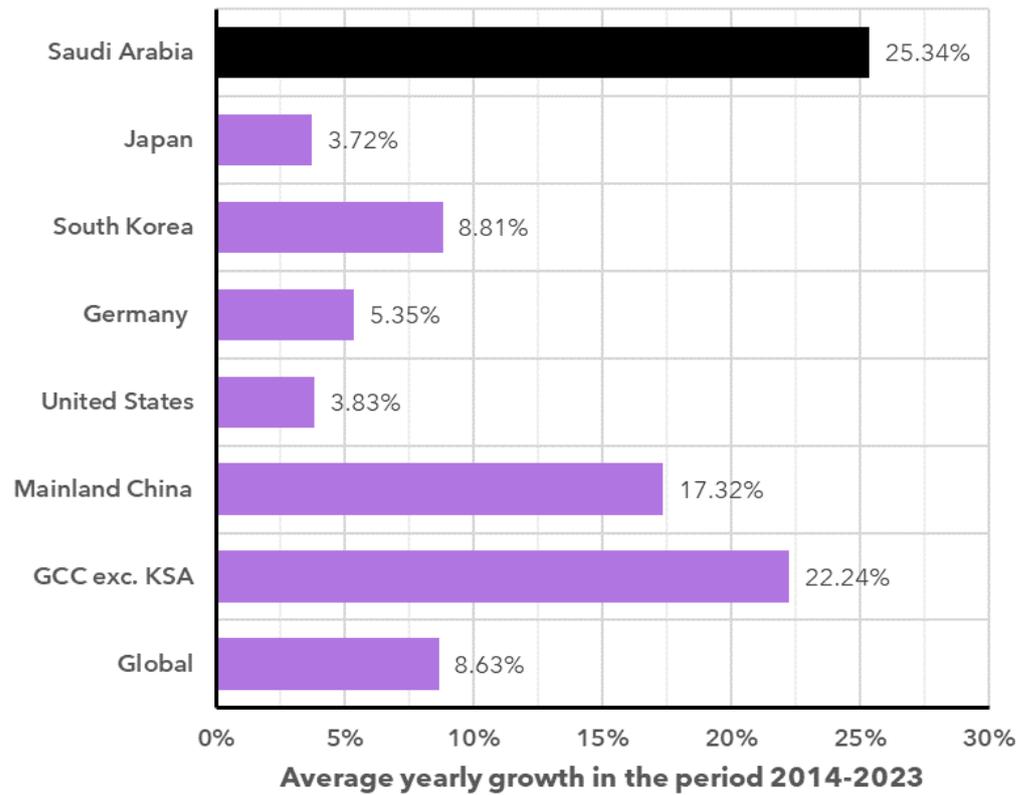


Figure 4: average yearly growth of the number of papers in the area of Sustainability and Essential Needs in the period 2014-2023

### 3.1.3 Citation impact analysis

The category normalized citation impact (CNCI) of Saudi Arabia from 2014-2023 was consistently above 1.4, indicating a citation impact performance at least 40% higher than the global average, as shown in Figure 5. The CNCI fluctuated slightly in this period between 1.4 and 1.67.

Saudi Arabia also achieved a CNCI in this period and in this area higher than that of all the considered benchmark countries/regions, as shown in Figure 6. This indicates a very high citation impact performance. It is also worth noting that the high citation impact footprint was maintained during a high research output growth period.

Usually, we notice citation impact decreases in periods with high volume growth, because in such periods the knowledge and expertise are accumulated by the expanded researcher's base.

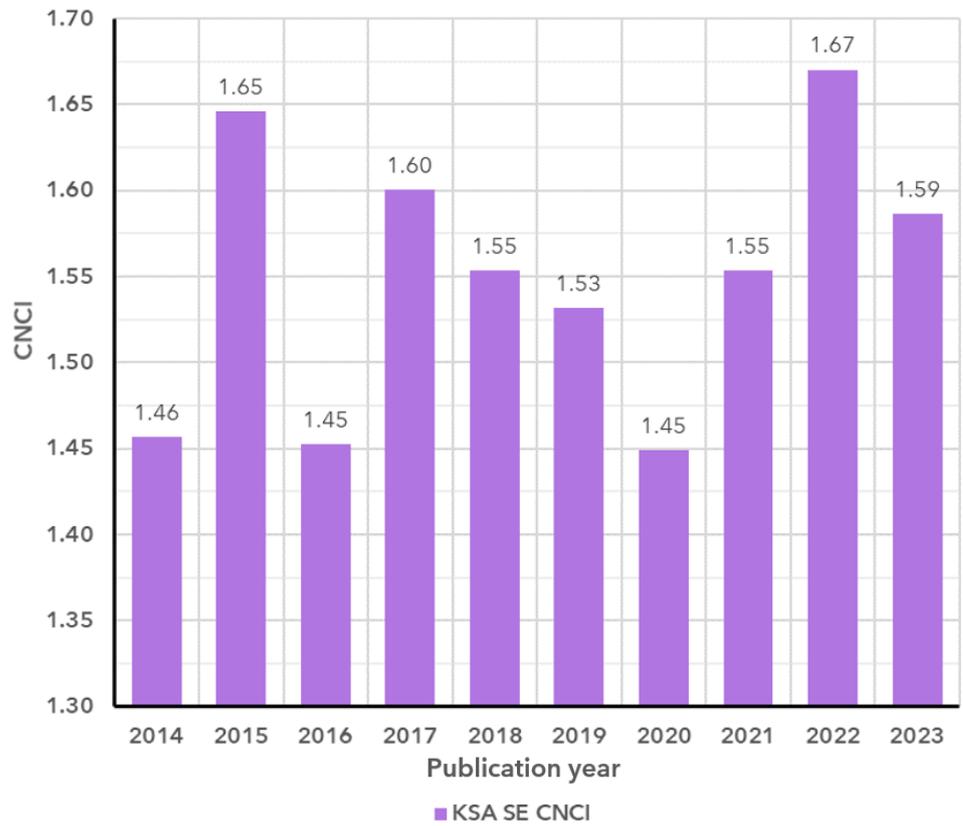


Figure 5: Saudi Arabia's yearly category normalized citation impact in the area of Sustainability and Essential Needs

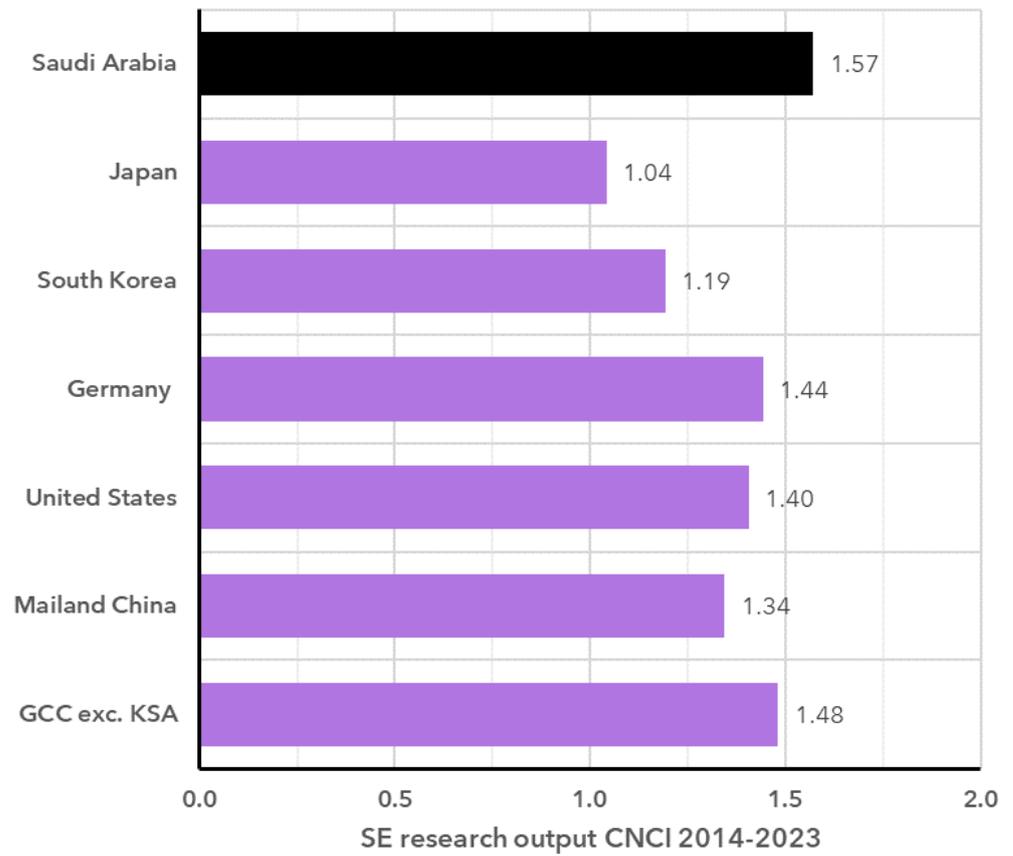


Figure 6: Sustainability and Essential Needs research output CNCI in the period 2014-2023

### 3.1.4 Funding dynamics analysis

The top three funding organizations mentioned in the Saudi Arabia funding papers related to Sustainability and Essential Needs from 2014 to 2023 are King Saud University, the National Natural Science Foundation of China (NSFC), and King Abdullah University of Science & Technology, with 2,408, 823, and 681 papers respectively, as shown in Figure 6.

Research funded by the Japan Society for the Promotion of Science in collaboration with Saudi Arabia in the field of SE achieved the highest citation impact based on CNCI, followed by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) and UK Research & Innovation (UKRI), with CNCI scores of 4.8, 4.4, and 4.1 respectively. The lowest CNCI is noted in papers funded by King Saud University, although it is still 50% higher than the global average; it is also important to consider the high volume of funded papers compared to the other organizations.

We see that three funding organizations based in Saudi Arabia rank among the top 20, reflecting the capacity of Saudi-affiliated researchers to attract international funding. However, we do not see a central entity funding research in this national priority area. Furthermore, all three organizations are universities rather than central funding institutions. A central entity could allocate funding in alignment with national priorities and goals across all research institutions.

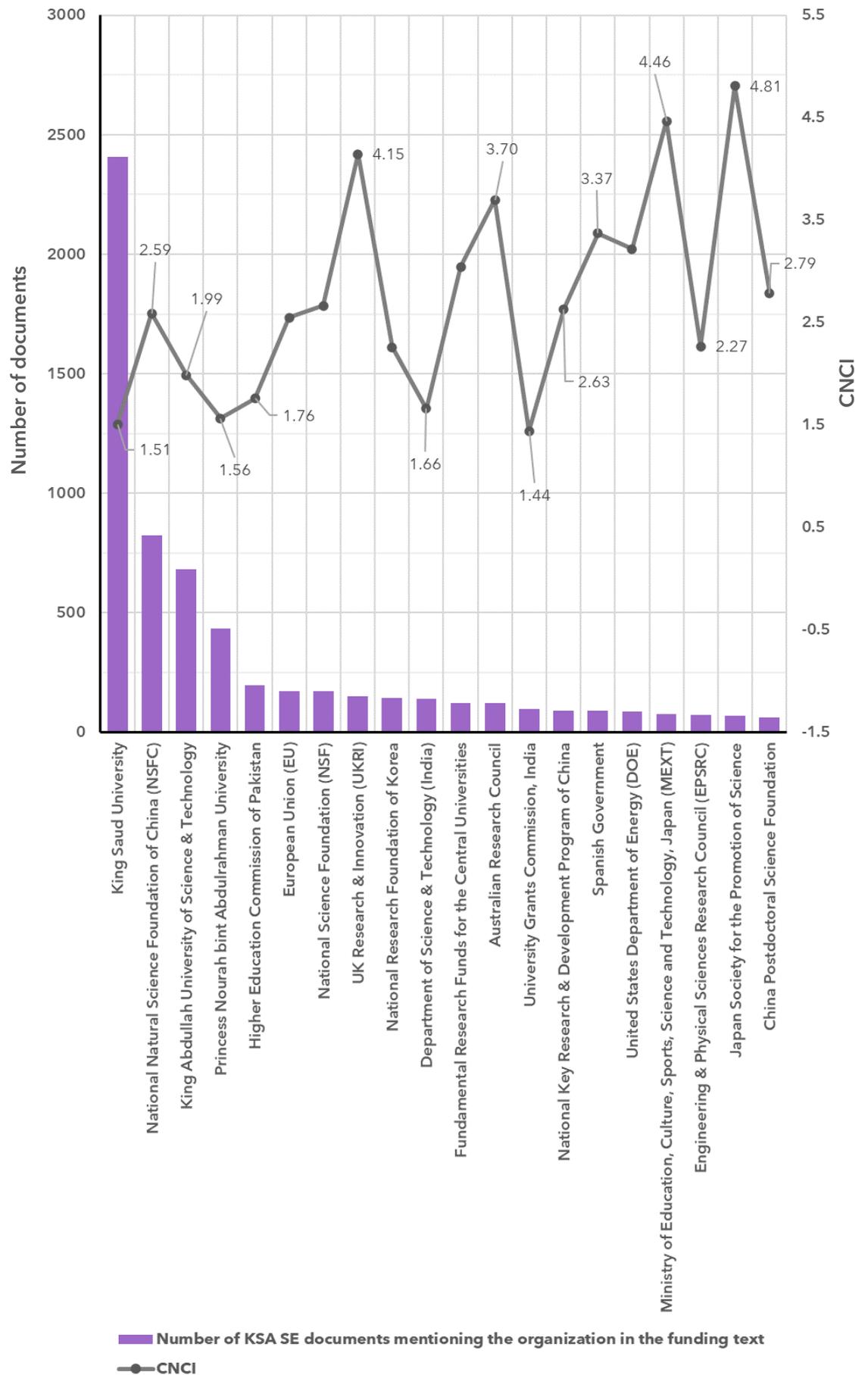


Figure 7: Top 20 funding organizations mentioned in the funding text of Saudi Arabia Sustainability and Essential Needs papers in the period 2014-2023

### 3.1.5 Collaboration dynamics analysis

Egypt, followed by India and Pakistan, had the highest number of publications in collaboration with Saudi Arabia-affiliated researchers in the national priority area Sustainability and Essential Needs from 2014-2023 with 4051, 2882 and 2549 publications, respectively, as shown in Figure 8.

Regarding citation impact measured by the category normalized citation impact, papers in collaboration with Japan followed by Spain and Germany with a CNCI of 3.37, 2.86 and 2.60 respectively. Nevertheless, research with all the top 20 collaborating countries with Saudi Arabia in this area resulted in a CNCI higher than the global average performance of ~1.

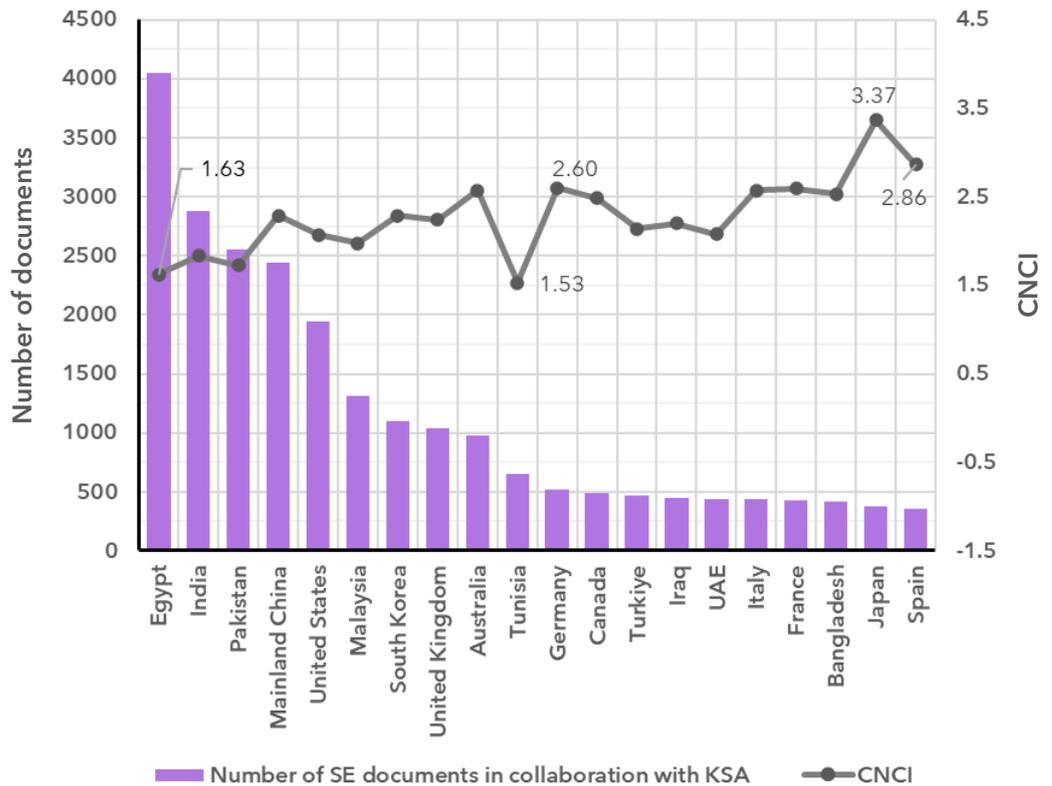


Figure 8: Top 20 collaborating countries with Saudi Arabia in the area of Sustainability and Essential Needs in the period 2014-2023

### 3.1.6 Academic-corporate collaboration in Saudi Arabia identified from research publications in the area of Sustainability and Essential Needs

The number of Saudi Arabian papers with industry collaboration in the area of Sustainability and Essential Needs remained almost constant in the years 2014-2020, with small fluctuations to then increase continuously till 2023, as shown in Figure 9. At the same time, the percentage of Saudi Arabia papers from overall Saudi Arabia research output in Sustainability and Essential Needs decreased from 2014 to 2020 and then increased continuously till 2023.

This indicates that starting from 2020, Saudi Arabia's research output in SE also began to grow with a higher growth rate than papers with industry collaboration.

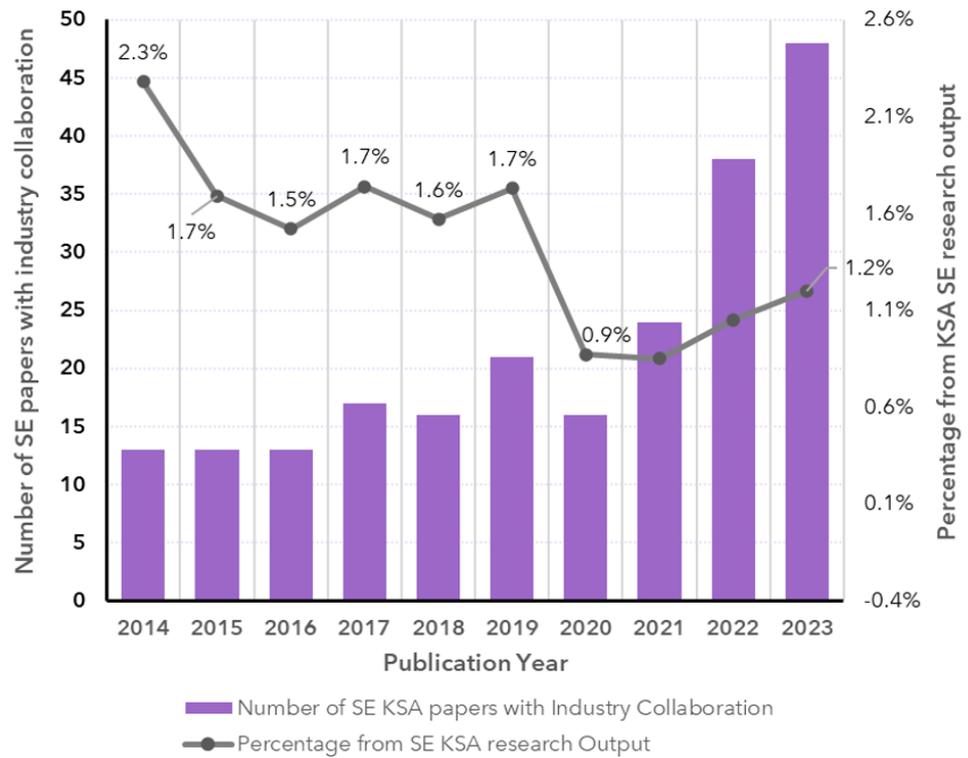


Figure 9: Number and percentage of Saudi Arabian publications that have been performed with an industry collaboration in the national priority area of Sustainability and Essential Needs

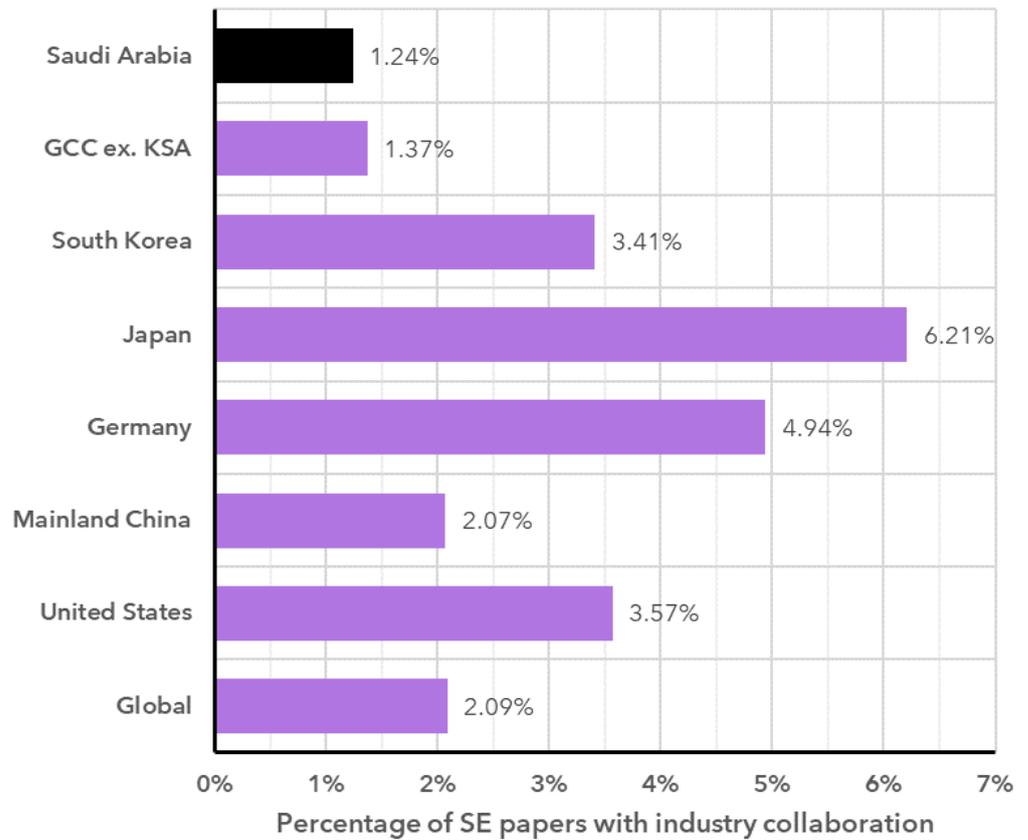


Figure 10: Percentage of papers that have been performed with an industry collaboration in the national priority area Sustainability and Essential Needs

When comparing the percentage of Saudi Arabia's Sustainability and Essential Needs papers with industry collaboration to the considered benchmark countries/regions, we notice that Saudi Arabia has the lowest rate with ~1.24%, which is also lower than the global baseline of ~2% as shown in Figure 10.

The highest percentage of papers with industry collaboration in the area Sustainability and Essential Needs is achieved by Japan with ~6.2% followed by Germany with ~4.9% and by USA with 3.57%.

In Figure 11 shows the top 20 funding organizations of Saudi Arabia publications with industry collaborations in the area Sustainability and Essential Needs ranked by number of funded collaborations is shown. The top three funding organizations are King Abdullah University of Science & Technology, followed by the Australian Research Council and King Saud University, with 16, 13 and 10 publications, respectively. Among the top 20 funding organizations, there are only two Saudi organizations that are among the top three. Among the top 20 funding organizations, there are no corporations as funding organizations.

There is a high prevalence of international funding organizations among the top 20. This shows the ability of Saudi-affiliated researchers to attract international funding and/or collaborate with corporates in an international context.

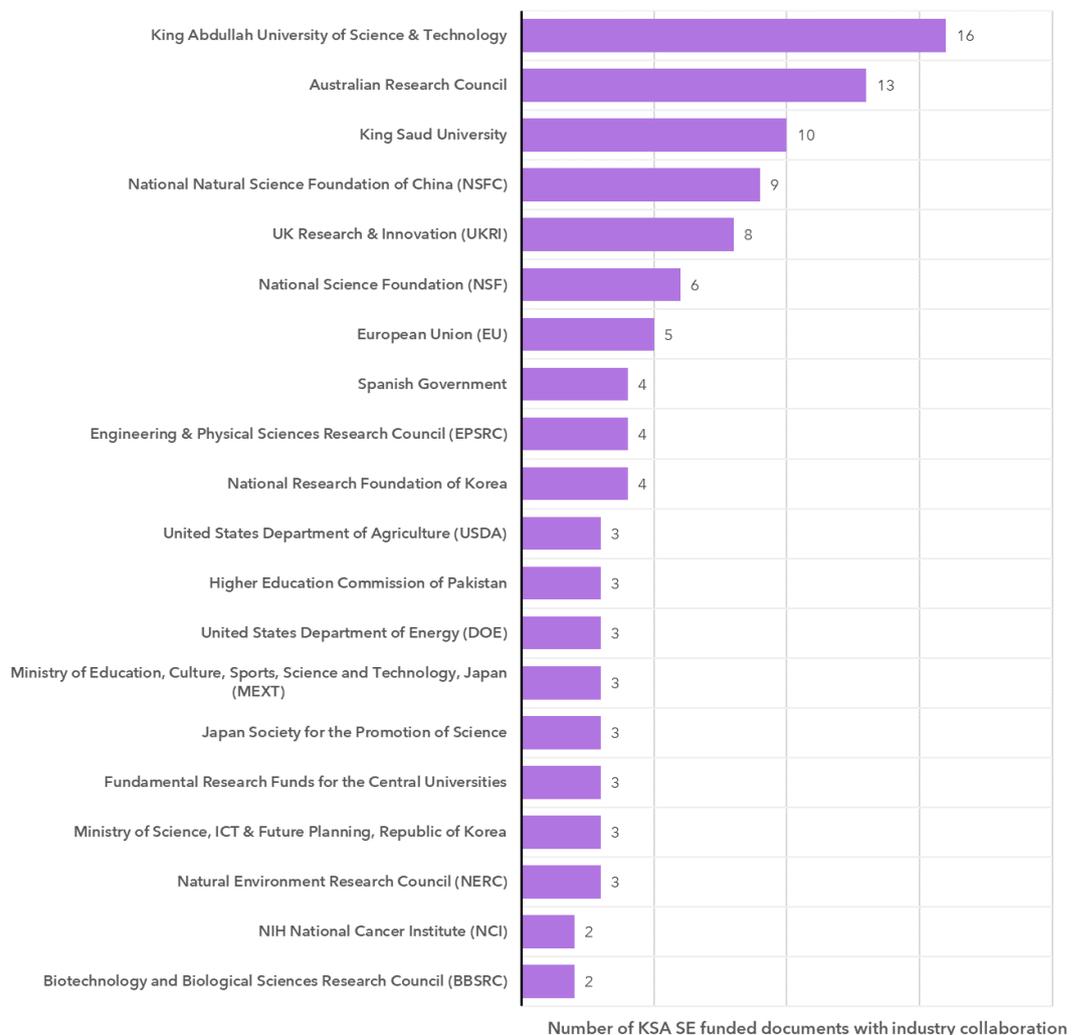


Figure 11: Saudi Arabia's top 20 funding organizations of research with industry collaboration in the national priority area Sustainability and Essential Needs in terms of the number of publications and in the period 2014-2023

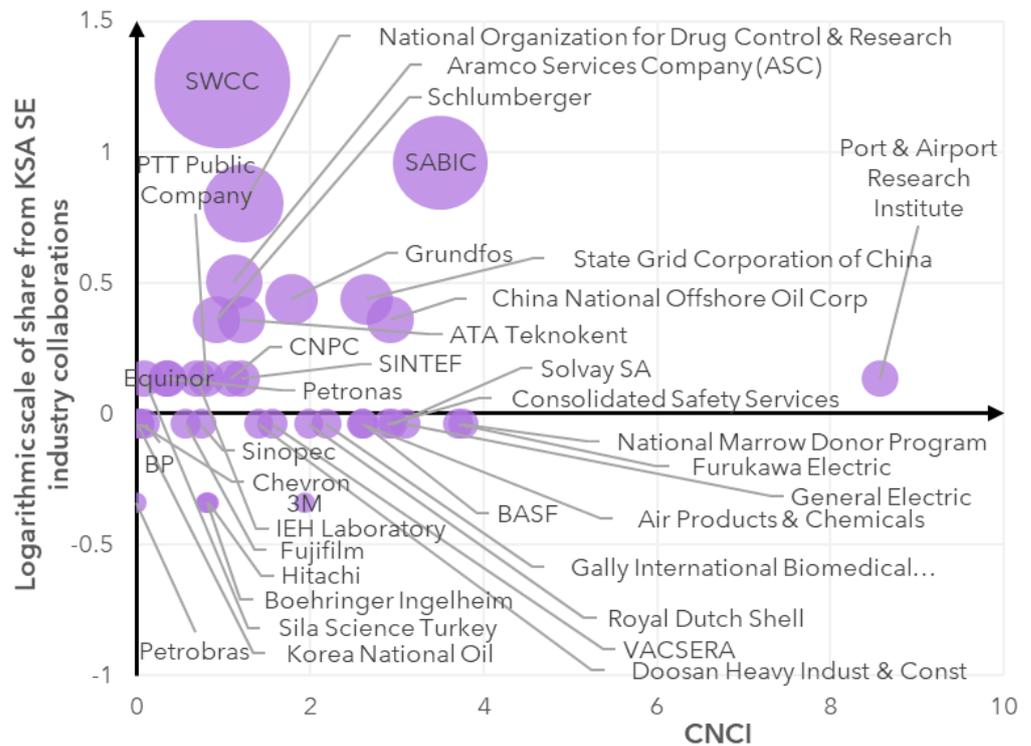


Figure 12: Top 40 corporates that have paper collaborations with Saudi-affiliated researchers regarding the number of papers in the period 2014-2023 in the area SE. The figure plots the share of papers with industry collaboration in the area of Sustainability and Essential Needs on a logarithmic scale, which an organization has versus the CNCI.

In Figure 12, we investigate the top 40 corporates collaborating with Saudi Arabia-affiliated researchers in terms of the number of publications in the area of Sustainability and Essential Needs. Specifically, the share of a specific corporation from the overall Saudi Arabia publications in Sustainability and Essential Needs with industry collaborations is plotted on the y-axis. A logarithmic scale is used because of the significant difference between the top three and the rest of the corporates.

On the x-axis, the CNCI of those publications is plotted. Corporates that have a share above 1% of the overall Saudi Arabian papers with industry collaborations lie above the null on the y-axis. Corporates that have a CNCI above 1 lie right to the dotted line, marking a citation impact higher than the global average when considering the same document type, year of publication and subject area. Accordingly, all corporates lying in the upper quadrante are corporates that have more than 1% share of Saudi Arabian papers with industry collaborations and an impact performance higher than the global average measured by the CNCI.

These corporates lie in the upper quadrante, and their output is listed in Table 1. As these corporates are having relatively high share from Saudi Arabia overall publications with industry collaborations and their impact is higher than the global average, further developing these collaborations to partnerships could be considered. Here it is important as well to consider other criteria such as alignment with national priorities, goals of the partnerships, etc. Such criteria can be derived from the analysis illustrated in the section Academic Corporate Partnership Models.

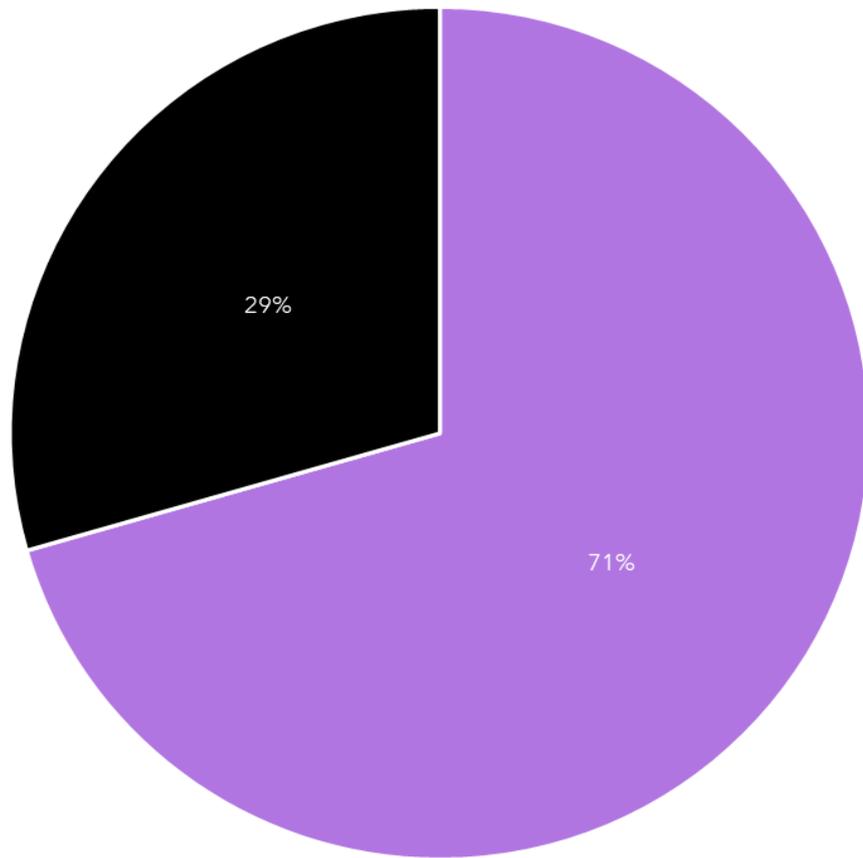
The top three corporates collaborating with Saudi affiliated researchers from 2014-2023 in Sustainability and Essential Needs are Saline Water Conversion Corporation (SWCC) followed by Saudi Basic Industries Corporation (SABIC) and National Organization for Drug Control & Research (NODCAR) with ~18.7%, ~9.1% and ~6.4% from the overall Saudi Arabian publications with industry collaborations in SE.

Among the top three, there are two national corporates, and one regional NODCAR is based in Egypt. Having two local corporations among the top three is important to ensure local knowledge transfer. Among the top 40, there are only three local

corporations, and the others are international ones. 71% of Saudi Arabia's Sustainability and Essential Needs papers, in collaboration with industry, are conducted by an international corporation, as seen in Figure 13. Having more local corporations that collaborate with Saudi-affiliated researchers would further enhance local knowledge transfer and build local expertise in this national priority area.

Table 1: Corporates having at least 1% share from Saudi papers with industry collaboration in the area of Sustainability and Essential Needs and have at least an impact on par with the global average (CNCI 1 or above)

Corporate	Number of papers	Share	CNCI
SABIC	20	9.1%	3.50
National Organization for Drug Control & Research	14	6.4%	1.23
Aramco Services Company (ASC)	7	3.2%	1.12
State Grid Corporation of China	6	2.7%	2.65
Grundfos	6	2.7%	1.78
China National Offshore Oil Corp	5	2.3%	2.92
ATA Teknokent	5	2.3%	1.21
Stiftelsen for Industriell og Teknisk Forskning (SINTEF)	3	1.4%	1.20
China National Petroleum Corporation (CNPC)	3	1.4%	1.08
Port & Airport Research Institute	3	1.4%	8.58
IBM	3	1.4%	17.70



- KSA percentage of SE papers within an international corporate collaboration from overall KSA SE papers with an industry collaboration
- KSA percentage of SE papers within a national corporate collaboration from overall KSA Se papers with an industry collaboration

Figure 13: Percentage of Saudi Arabia's Sustainability and Essential Needs papers with an industry collaboration with national versus international corporates from overall papers with an industry collaboration

The top three Saudi Arabian universities in terms of the number of papers with an industry collaboration in the area of Sustainability and Essential Needs from 2014-2023 are King Abdullah University of Science & Technology followed by King Abdulaziz University sharing the second place with King Saud University and King Fahd University of Petroleum & Minerals with 64, 27 and 18 publications as shown in Figure 14.

When looking at the percentage of Sustainability and Essential Needs papers with an industry collaboration from the overall Sustainability and Essential Needs papers, King Abdullah University of Science & Technology has the highest rate, followed by King Abdulaziz City for Science & Technology and Al Baha University with 3.49%, 2.46% and 2.13% respectively.

It is worth noting that King Abdullah University of Science & Technology (KAUST) has the highest volume and percentage of Sustainability and Essential Needs papers with an industry collaboration. This indicates that KAUST is a central academic institution in Saudi Arabia for performing academic-corporate collaborations in this area.

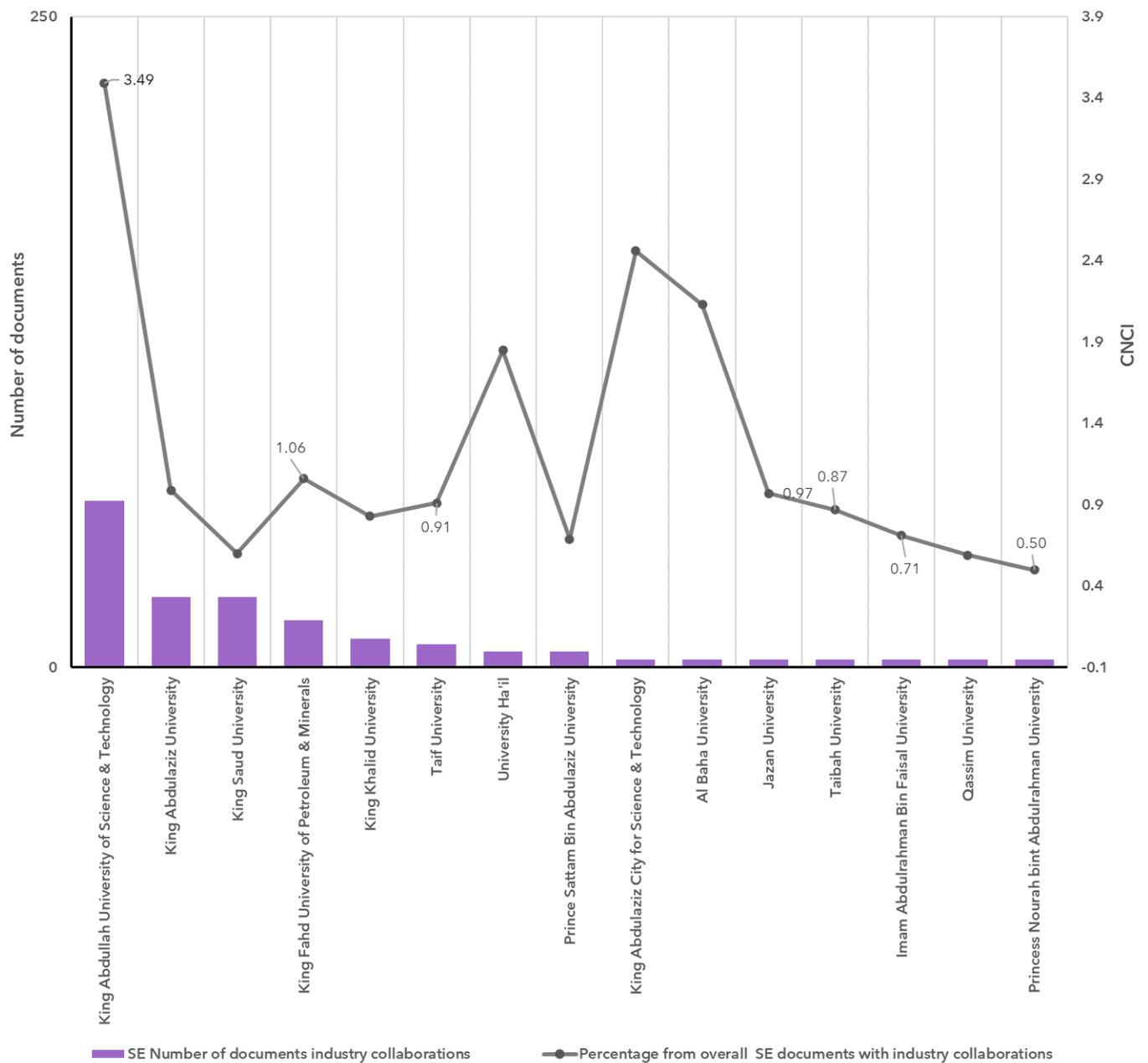


Figure 14: Number and percentage of publications with an industry collaboration in the area of Sustainability and Essential Needs in the period 2014-2023 of the top 20 Saudi academic institutions in terms of the number of papers with an industry collaboration with at least three Sustainability and Essential Needs industry collaboration papers

### 3.1.7 SWOT Analysis of Underlying Research Topics in the Area Sustainability and Essential Needs

In this part, we have a more granular look by analyzing the research performance of Saudi Arabia in the underlying categories that constitute the national priority area of Sustainability and Essential Needs. The research topics constituting the area and the selection of those research topics are described in the Dataset Description. To perform this, we perform a Strength, Weakness, Opportunity and Threat (SWOT) analysis.

The analysis is based on two primary metrics: productivity relative to the global productivity and impact measured by the category normalized citation impact. The productivity relative to global productivity is measured by the number of Saudi Arabian papers in a specific research topic divided by the number of global publications in the same research topic and period. This is then normalized by the

share of Saudi Arabia's overall research from the global research in the same period. Thus, a value in this indicator above 1 indicates that Saudi Arabia has a share of the global research in this research topic higher than the share of Saudi Arabia from the global research in the same period. Similarly, a CNCI above 1 indicates a citation impact footprint in the research topic higher than that of the global average. Accordingly, we can classify the research topics into four regions:

- Strength: Productivity relative to global productivity is above 1, and the CNCI is above 1
- Threat: Productivity relative to the global productivity is above 1 and CNCI less than one
- Opportunity: Productivity relative to global productivity is less than 1, but CNCI is above 1
- Weakness: both the productivity relative to the global productivity and CNCI are less than 1

**SWOT Analysis**  
plot of CNCI versus productivity relative to the world

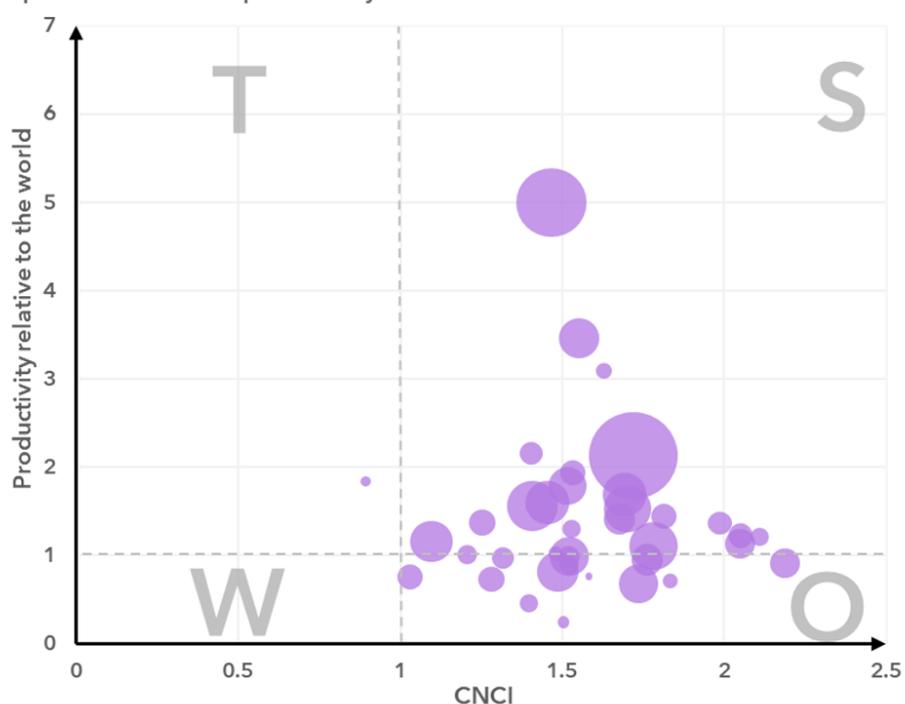


Figure 15: SWOT analysis of the national priority area Sustainability and Essentials. The y-axis shows the productivity relative to the world (share of Saudi Arabia from the global productivity in the research topic normalized by Saudi Arabia's share of global productivity when considering overall research). The x-axis shows the impact relative to the world.

When investigating Saudi Arabia's performance in the research topics in the national priority area Sustainability and Essential Needs, we noticed out of the 38 research topics; there are 23 strength research topics listed in Table 2, 14 opportunity research topics listed in Table 3 and one threat area, Water Leakage, with high productivity relative to the global productivity (1.83) and low CNCI (0.89), as also shown in Figure 15.

As all of these research topics are of national priority, one should try to conserve the high performance in the strength research topics, increase the productivity in the opportunity areas by leveraging on the gained expertise that is evident with the CNCI being higher than 1 and improve the quality and accordingly the citation impact in the research topic Water Leakage.

Table 2: Saudi Arabia's strength research topics in the national priority area of Sustainability and Essentials

Research topic	CNCI	Productivity relative to global productivity
Water - Wastewater Purification	1.7	2.1
Electric Vehicles	1.8	1.1
Food - Food-Borne Hazard Control	1.4	1.6
Agriculture - Pest Management	1.1	1.2
Bioenergy	1.7	1.5
Water - Domestic Purification	1.5	1.6
Carbon (CO2) Capture	1.7	1.7
Water Desalination	1.5	5.0
Carbon (CO2) Transport	2.0	1.1
Carbon (CO2) Utilization	1.5	1.8
Waste - Smart Mgt	1.7	1.4
Eco-Agrochemicals	1.3	1.4
Agriculture - Precision Agriculture	2.0	1.2
Water - Resources from Wastewater	1.6	3.5
Waste - Waste-to-Energy	1.8	1.4
Food - Intelligent Packaging	2.0	1.4
Air Purification	1.2	1.0
Agriculture - Waste Management	1.5	1.9
Water - Conservation Management	2.1	1.2
Agriculture - Hydroponics	1.5	1.3
Geothermal Energy	1.4	2.2

Food - Alternatives	1.5	1.0
Brine mining	1.6	3.1

Table 3: Saudi Arabia's opportunity technologies in the national priority area of Sustainability and Essentials

Research topic	CNCI	Productivity relative to global productivity
Agriculture - Aquaculture	1.7	0.7
Agriculture - Soil Preservation	1.5	0.8
Agriculture - Plant Breeding	1.5	1.0
Food Traceability & Distribution	1.8	0.9
Carbon (CO2) Storage	2.2	0.9
Emergency Communications	1.3	0.7
Adaptations - Seismology/Meteorology Event Detection	1.0	0.8
Adaptations - Urban Heat Island	1.4	0.5
Adaptations - Afforestation	1.5	0.2
Adaptations - Flood Protection	1.3	1.0
Sustainable Packaging	1.5	1.0
Waste Landfill	1.5	0.9
Adaptations - Shore Protection	1.8	0.7
Agriculture - Precision Livestock	1.6	0.8

### 3.2 Overview of Performance in Patents

This section summarizes and reviews information collated during the study: Assessment of Academic-Corporate Partnerships in Saudi Arabia) of the program, which is specific to the Sustainability and Essential Needs National Priority.

This section concerns benchmarking invention volumes, strength, and academic-corporate partnerships in Saudi Arabia against globally relevant benchmarks.

#### 3.2.1 Percentage of academic-corporate invention activity

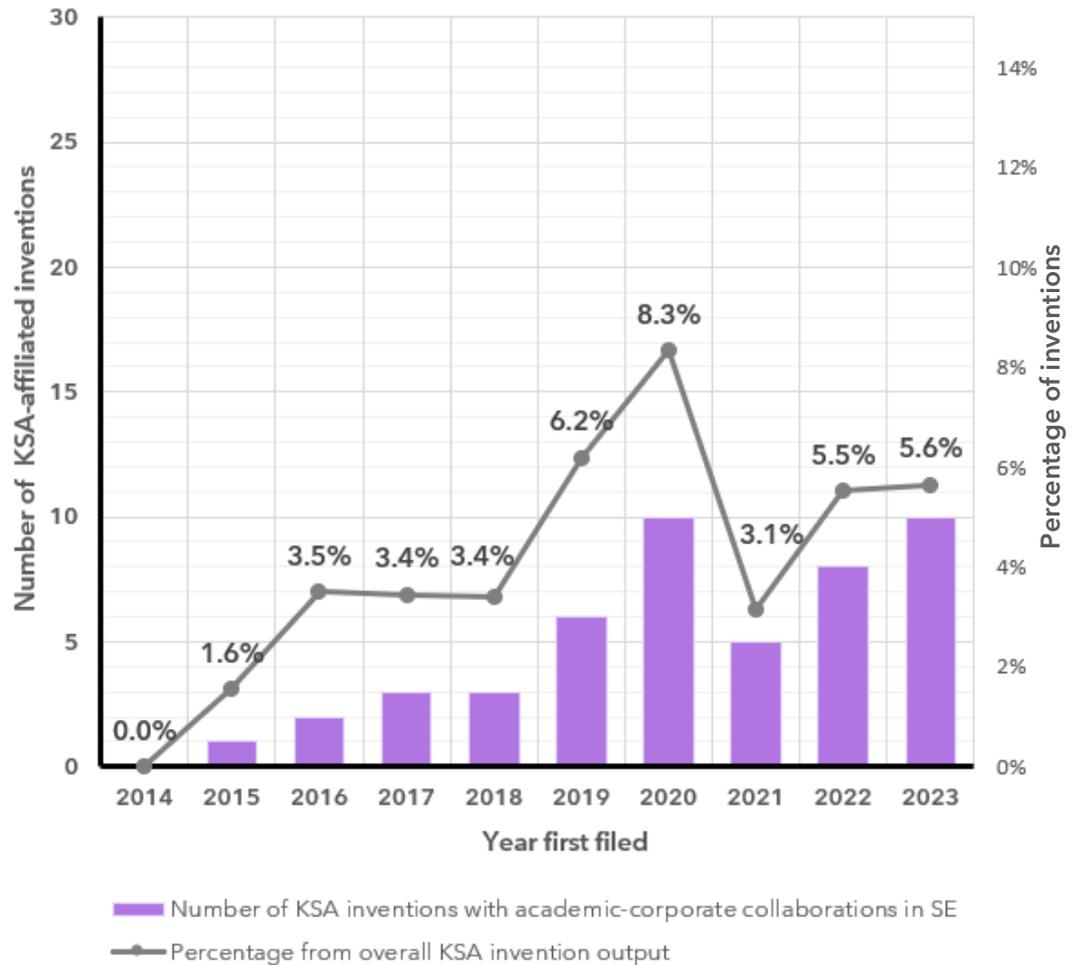


Figure 16: Timeline and trend of Saudi Arabia-affiliated inventions with industry collaboration in Sustainability and Essential Needs, 2014-2023

In Figure 16 Saudi Arabia has shown considerable diversification and focus on Sustainability and Essential Needs but with room for development. The sector has experienced 5x growth in invention output. Nonetheless, absolute volumes are comparatively low. By comparison, academic-corporate partnerships developed much later than in other areas (with no partnerships recorded in 2014).

The proportion of partnerships peaked at 8.3% in 2020 but has since dropped to 5.6% in 2023, indicating a modest but slightly inconsistent partnership trend. Late-onset could suggest that academic engagement is not fully embedded in sustainability-related developments. Given the interdisciplinary nature of environmental challenges, there is significant potential to leverage cross-sector partnerships to accelerate innovation.

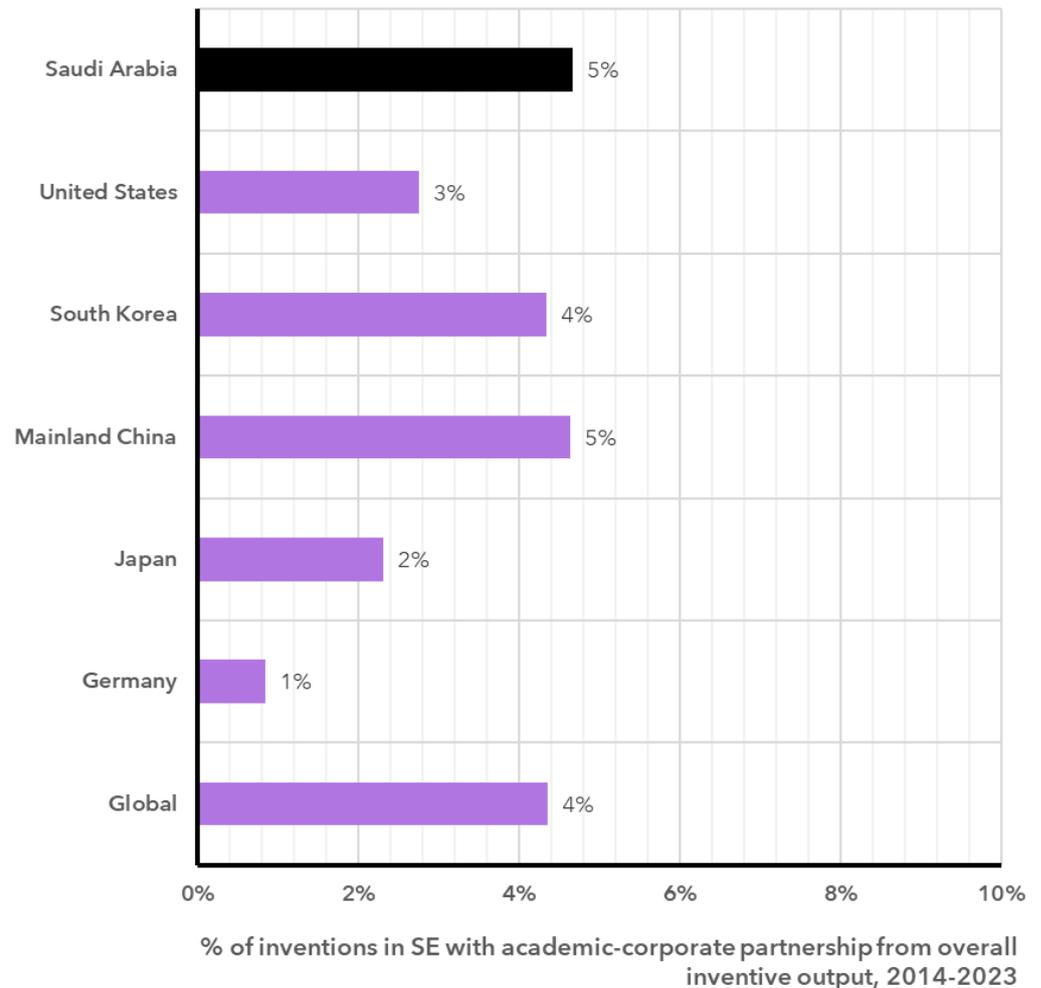


Figure 17: Academic and industry collaboration in inventions in Sustainability and Essential Needs by significant countries, compared to global baseline, 2014-2023

Saudi Arabia’s partnership rate in Sustainability and Essential Needs stands at ~5%, aligning well with Mainland China (~5%) and surpassing the global average of ~4% (Figure 17). This suggests that Saudi Arabia’s industry engagement in the sustainability sector aligns with international standards. South Korea also demonstrates similar levels of partnerships, while Japan (~2%) and Germany (~1%) exhibit significantly lower levels of collaboration. For Saudi Arabia, these figures emphasize the importance of continuing to expand partnerships, particularly in sustainability, where global trends point toward greater collaboration between academia and industry to address environmental challenges.

Sustainability and Essential Needs innovation in Saudi Arabia overall has increased, reflecting the country’s growing focus on environmental challenges. The volume of inventions remains low, however, compared to other priority areas. Academic-corporate partnerships in Sustainability and Essential Needs emerged later than in different sectors, with no partnerships recorded in 2014. The proportion of partnerships peaked at 8.3% in 2020 but has since dropped to 5.6% in 2023, highlighting some inconsistency. This late start may indicate that academic engagement in sustainability is not yet fully integrated. Still, the sector presents substantial opportunities for cross-sector partnerships and the possibility to leverage the global impetus to solve environmental challenges. Globally, Saudi Arabia’s partnership rate of ~5% in Sustainability and Essential Needs aligns with Mainland China and exceeds the global average of ~4%. South Korea shows similar levels,

whereas Japan (~2%) and Germany (~1%) lag in terms of collaboration. These figures suggest that Saudi Arabia is well-positioned but should focus on expanding academic-corporate partnerships to keep pace with global trends and fully leverage the potential of sustainability innovation.

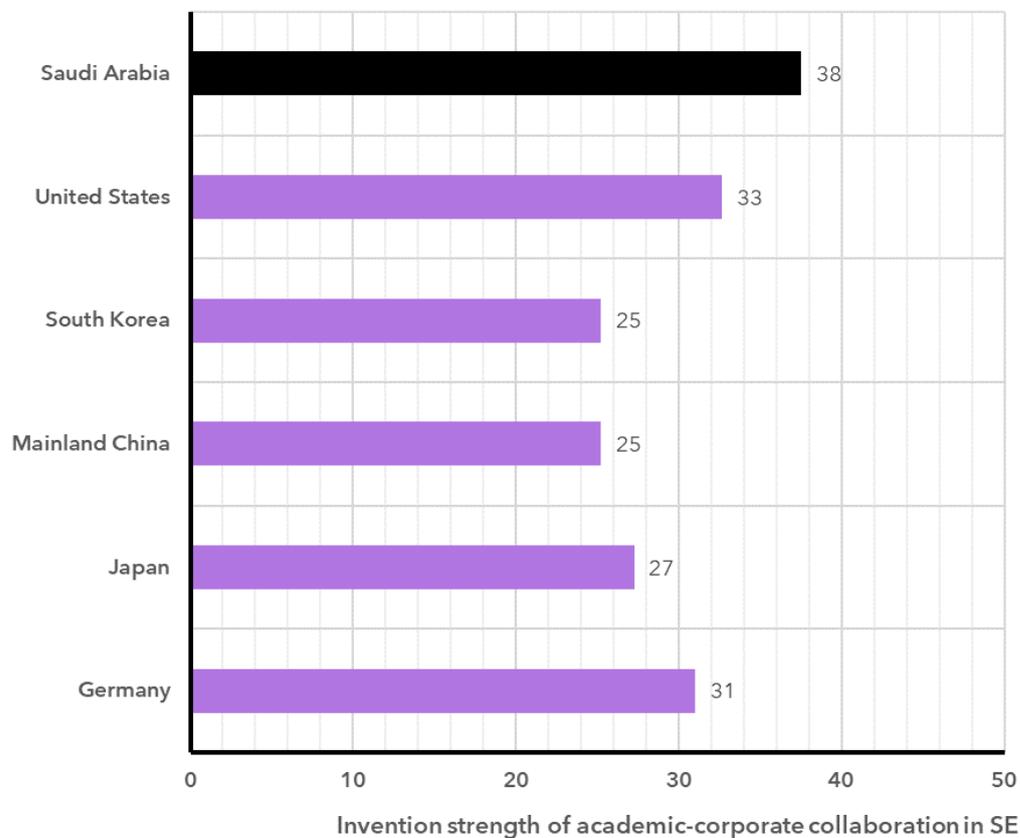


Figure 18: Strength of academic and industry collaboration inventions in Sustainability and Essential Needs by major countries, 2014-2023

In Figure 18 SE, Saudi Arabia has the highest invention strength score of 38, surpassing the benchmark for partnership strength compared to other regions like the United States (33) and Germany (31). By comparison, Japan (27), Mainland China (25), and South Korea (25) trail significantly in terms of invention strength. Despite possibly larger volumes of activity, Saudi Arabia’s partnerships score well on strength parameters. Leveraging existing capabilities in EI could offer a viable pathway to scaling partnerships that further enhance the position of Saudi vis-à-vis SE.

### 3.2.2 Invention impact analysis

In Sustainability and Essential Needs, Saudi Arabia outperforms global peers like the United States and Germany in invention strength despite having a smaller volume of patent activity (Figure 19). Leveraging established capabilities from Energy and Industrials could further scale these partnerships, enhancing Saudi Arabia’s position in sustainability-focused innovation.

By aligning with global trends in sustainability, such as the Sustainable Development Goals (SDGs), Saudi Arabia can benefit from policy frameworks that incentivize cross-sector partnerships. This approach would not only support national priorities but also contribute significantly to global efforts to address sustainability challenges.

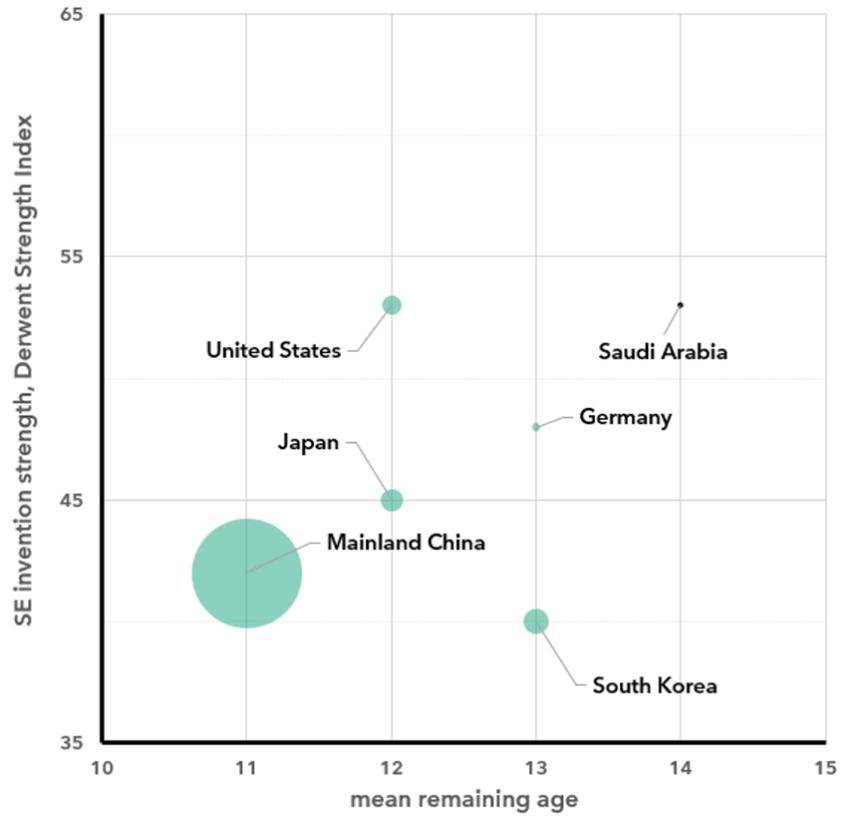


Figure 19: Invention strength dynamics of academic and industry collaboration in Sustainability and Essential Needs by significant countries and Saudi Arabia, 2014-2023

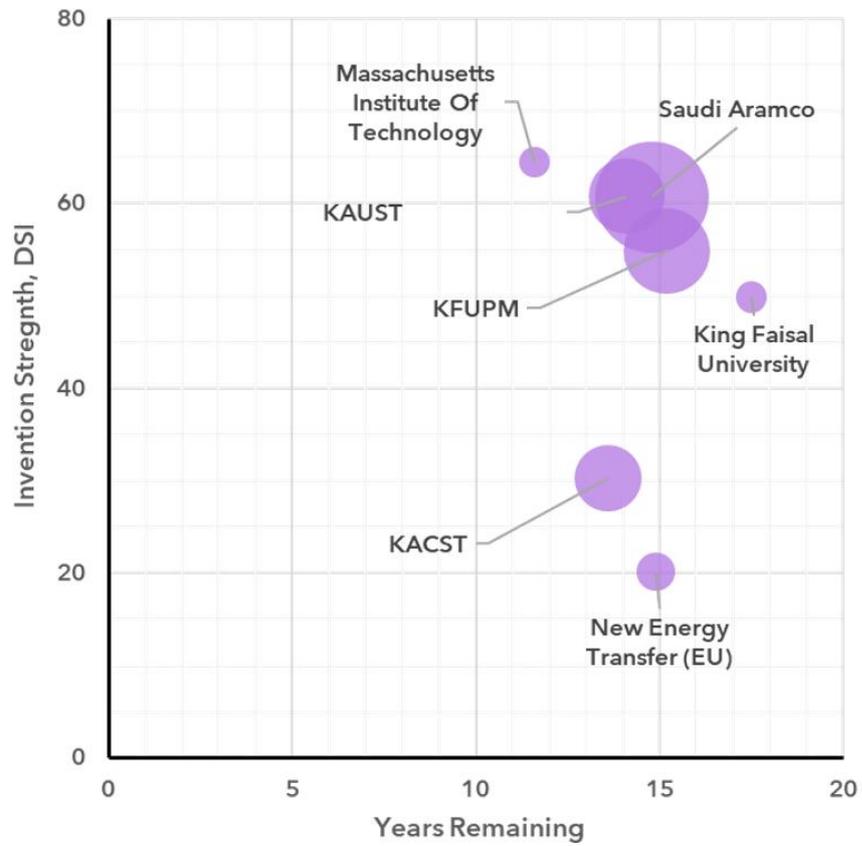


Figure 20: Invention strength dynamic of top collaborating entities in Saudi Arabia in Sustainability and Essential Needs, 2014-2023

In Sustainability and Essential Needs, we see the presence of the same local entities, with Saudi Aramco leading in both volume and invention strength (Figure 20). Aramco's 26 partnerships and a strong DSI of 60.7 reflect its increasing contribution (and partnership) to sustainability. Academic institutions, particularly KAUST and KFUPM, are also major contributors, boasting high DSI scores (~60) and a combined 27 collaborations.

These collaborations are predominantly local, emphasizing a domestic focus. However, this model highlights the importance of select international partnerships. For example, MIT has collaborated with researchers from King Abdulaziz City for Science and Technology's Center for Complex Engineering Systems researchers in climate modeling under high-emissions conditions. This partnership highlights the need for advanced research to inform local and regional climate adaptation strategies, a critical component for designing actionable sustainability plans in Saudi Arabia's distinct ecosystems. Despite the high strength of these collaborations (e.g., MIT with a DSI of 64.5), the limited number of international engagements presents an opportunity for Saudi Arabia to further deepen global partnerships, thereby expanding the diversity and impact of its sustainability innovations.

1. One of the largest topics in the study for invention activity is wastewater treatment; this is also the largest topic in the National Priority Area for research publications - though with a notable variation in overall volume: this is primarily an applied research area represented by invention activity.
2. There is agreement between basic and applied research focus on Electric Vehicle technology in terms of proportion of focus, though as for wastewater treatment, a significant volumetric emphasis on invention activity levels with almost 5x the number of patented inventions. Again, this split in level of output indicates the commercial and applied nature of the innovation activity in the segment.
3. Aquaculture is a topic of research publication focus (and similarly to a degree in invention levels). It is the highest-volume research publication topic across agriculture as a whole. In invention focus, it ranks third out of nine agriculture topics (behind Hydroponics and Eco-Agrochemicals). Therefore, it stands out as a topic of interest in the field potentially awaiting heavier commercialization of current research fronts.
4. Lowest levels of research represent disagreement between research publications and inventions: water leakage research, precision livestock agriculture and brine mining are the bottom three topics of academic interest globally in the National Priority; within global inventions, this change to CO2 transport and utilization alongside landfill technologies.
5. Also notable as a delta in focus in the Sustainability and essential needs priority area is the strong research focus on soil preservation, with almost 80,000 papers but just 12,000 inventions in the last decade.

### 3.3 Overview from Technology maturity, readiness and commercialization

This section summarizes and reviews information collated during Study - Accelerating Technology Transfer from the Lab to the Market in Saudi Arabia of the program that is specific to the Sustainability and Essential Needs National Priority.

This analysis focuses on the invention levels globally and in Saudi Arabia due to the strong link between research and commercial activity inherent to the patent process, as well as the role of patent protection in the ownership and usage of technology in commercial contracts and processes.

Inherent to this analysis is a review of several key measures:

1. The evaluation of the overall technical maturity of research (on a scale of basic theory through to full market commercialization) within a specific research topic.
2. Evaluation of Saudi Arabian research commercialization activity within the National Priority, particularly compared to global levels. This also includes assessing the depth and strength of invention levels within the Saudi research and innovation ecosystem.
3. The future commercial potential of individual research topics within the National Priority Area

Using these criteria, we can describe the dynamics of research within a Sustainability and Essential Needs, how it meets commercial application, where Saudi Arabia makes a contribution today, and how future research funding policy in the National Priority can be tailored to these dynamics.

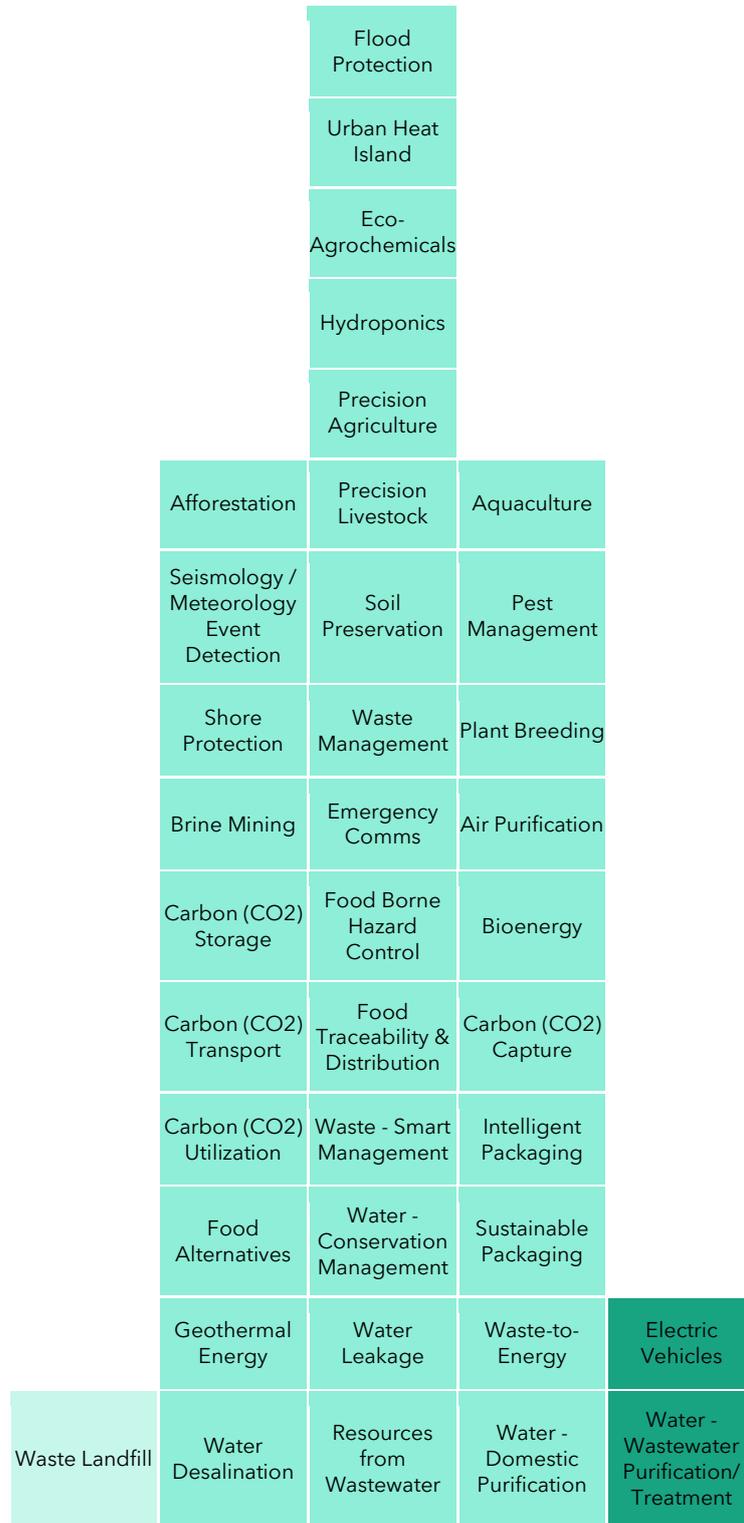
At a global level, in Figure 21, Sustainability and Essential Needs research topics trend as second-most immature compared to the other National Priorities. For example, no research topic within the priority area was evaluated at TRL levels 1-2.

The priority also shows no research topics at TRL 8 or 9 and is, therefore, the RDI national priority with the narrowest TRL spread. Fifteen separate research topics within the priority area sit at TRL 5, in the middle of the technology maturity range across all analyses performed. It is therefore evaluated as a relatively constrained theme in research, with less diversity of maturity and readiness of the topics, segments and applications of technology.

The maturity and readiness analysis shows only two research topics in the most mature TRL levels of 7-9: Electric Vehicles and Wastewater Purification and Treatment - no other concepts in the priority area are beyond these in maturity. The least mature topics contain a cluster of climate adaption technologies, such as those dealing with the effects of changing climatic conditions (i.e. shore protection, meteorological event detection, flood protection, urban heat island and afforestation).

Also relatively immature are topics surrounding the treatment and management of CO<sub>2</sub> (primarily within TRL 4), except for carbon capture technologies (TRL 6). This produces a paradox and opportunity, where carbon sequestration technologies lack downstream commercial processing technologies, leading to a lack of commercialization in carbon capture itself.

Water management is particularly interesting due to Saudi Arabia's expertise in producing municipal water almost 100% from seawater and its experience with water supply in arid environments. Given the global climate change, both topics will likely see increased demand.



1 2 3 4 5 6 7 8 9

**Technology Maturity Index** (scaled as Technology Readiness Level)

Figure 21 - Technology Maturity Index result for research topics within the within Sustainability and Essential Needs National Priority Area; vertical axis represents count of categories in each tier

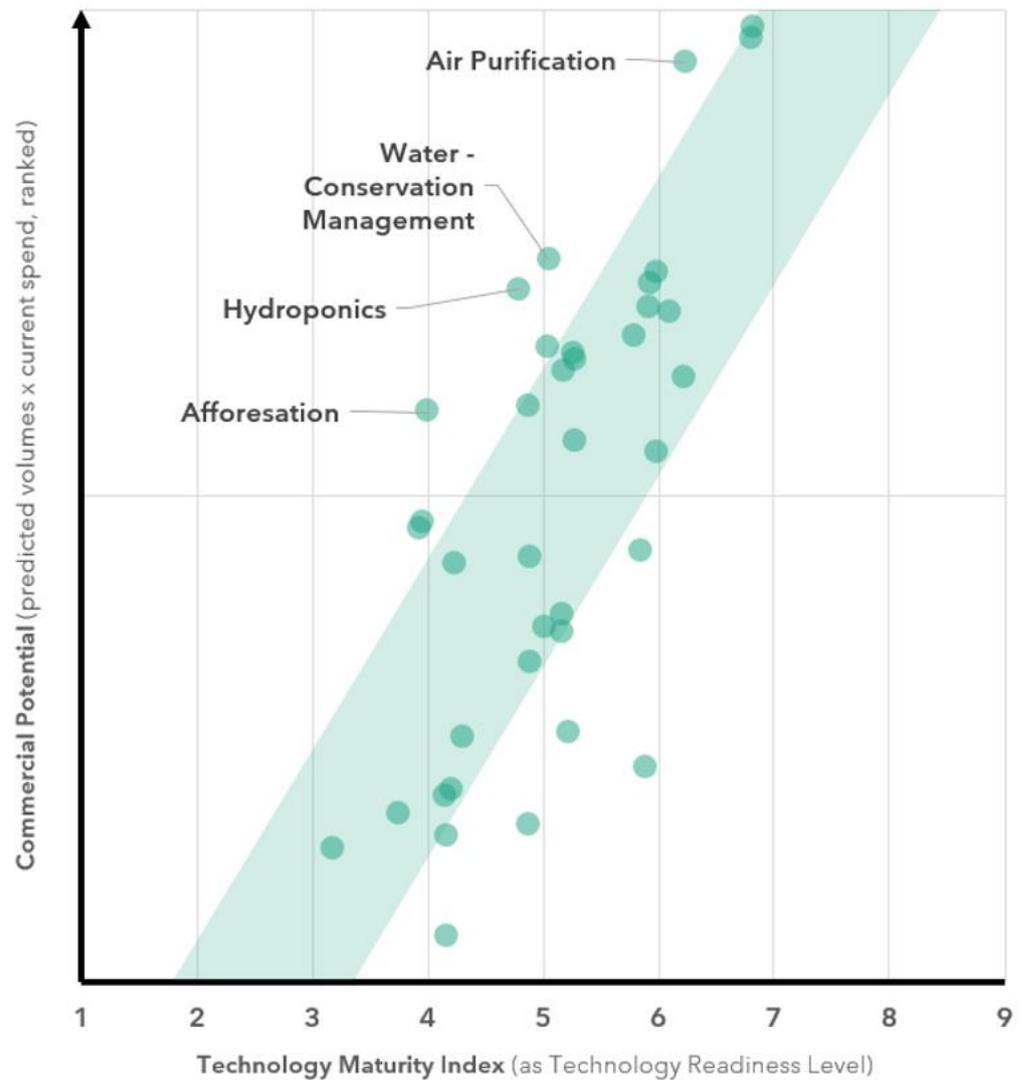


Figure 22 - scatterplot of Technology Maturity Index for each research topic (represented on a technology readiness scale) and commercial potential (a ranked axis based on the future predicted invention volumes in each topic, multiplied by the current relative level of investment in Intellectual property protection)

Wastewater treatment is the second largest invention topic in the National Priorities (only the semiconductor field has more patents). It is notably comparable to desalination in that global wastewater treatment is evaluated at TRL 7, versus TRL 4 for desalination. This factor is of interest as Saudi Arabia has a five-time higher share of global invention activity in desalination than its baseline invention share, identifying it as an area of applied research strength.

On average, essential need topics (water, agriculture, food) are more mature than adaption, carbon or waste management topics.

Also shown in the analysis and a profile that is exhibited in all four National Priorities, there is a strong relationship between the future commercial potential of the research topics and their evaluated TRL maturity (Figure 22). This is, to a degree, inherent in modeling technology maturity itself and, therefore, an expected result.

Within the Sustainability and Essential Needs space, this trend is constrained by the narrow spread of technical maturity of the research topics themselves. Still, generally, the most mature have the highest commercial potential, and the least mature have the lowest currently evaluated commercial potential. Few topics, or arguably any, break from this distribution - indicating a relatively low space for further intervention for applied research to directly tap into commercial markets via the rapid maturation of existing technologies. Instead, the distribution suggests a more substantial need for earlier, more foundational research to create the conditions for market interest. An alternative suggested finding is that several technologies are not envisioned as major

commercial topics. Within this National Priority, the analysis suggests applied research intervention would occur at TRLs 4-5 to balance the risk of research being performed with lower commercial return.

Moving to Saudi Arabian applied research within the Sustainability and Essential Needs sector, a review of predicted commercial potential versus the depth of Saudi invention levels shows a weak correlation: the Saudi research and innovation ecosystem has a slight tendency to focus on research topics that are also more likely to be in demand in future years, but it also significantly focuses on technologies that do not yet show high commercial potential.

The very highest commercial potential fields in Sustainability and Essential Needs surround only three topics - Electric Vehicles, Air Purification and Wastewater Purification.

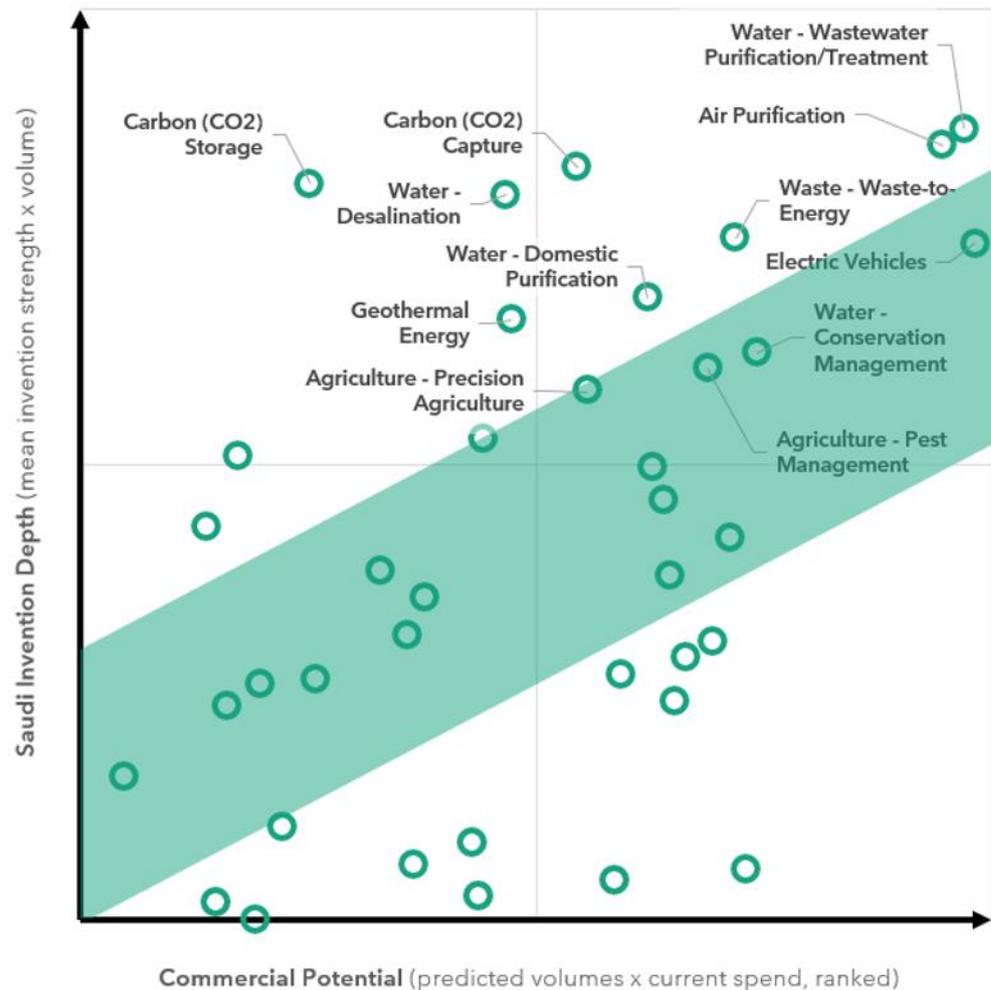


Figure 23 - views Sustainability and Essential Needs research topics arrayed by the level of Saudi Arabian research strength and depth vs the commercial potential of the research topic; high potential/high invention depth topics are labeled

The highest area of Saudi Arabian invention depth (measured as a combined measure of both the volume of inventions and their relative strength) occurs in wastewater treatment and air purification (which are, therefore, aligned with global needs), followed by Carbon Capture, Carbon Storage, and Water Desalination (Figure 23).

This analysis suggests Saudi Arabia can play an important role in Carbon and Water management as these technologies mature. Also hypothesized in this view is a potential mismatch between the global maturity of desalination technologies and the desalination reliance (and therefore deployment maturity) of Saudi Arabia that provides an opportunity for rapid maturation of the technology may be available.

Further summarizing the commercialization directions potentially available to the Saudi research ecosystem was performed using the Technology Maturity/Technology Readiness spectrum against a hybrid metric that distills the desirability of research itself for Saudi Arabia.

Performed as a topic recommendation score, this metric combines the predicted commercial potential measured across the topics, the depth of Saudi Arabian research today, the level of academic-corporate partnership exhibited to date from Saudi Arabian activity and finally, a check of expert opinion across the research topics.

Arraying the topic recommendation against TRL levels provides a good decision matrix surrounding modes of research intervention.

For example, areas of low-level recommendation for Saudi Arabia, regardless of TRL level, can be de-prioritized for either ad hoc academic research selection or, if already highly mature, for the private sector to choose to intervene.

Where research topics already exhibit a track record of applied research intensity in Saudi Arabia, the TRL spread can be used to recommend either the prioritization of further academic research (for more immature topics, where research is needed to transition to more maturity) or where they are occurring in more mature fields, the transfer of Saudi academic research to the private sector should be strengthened.

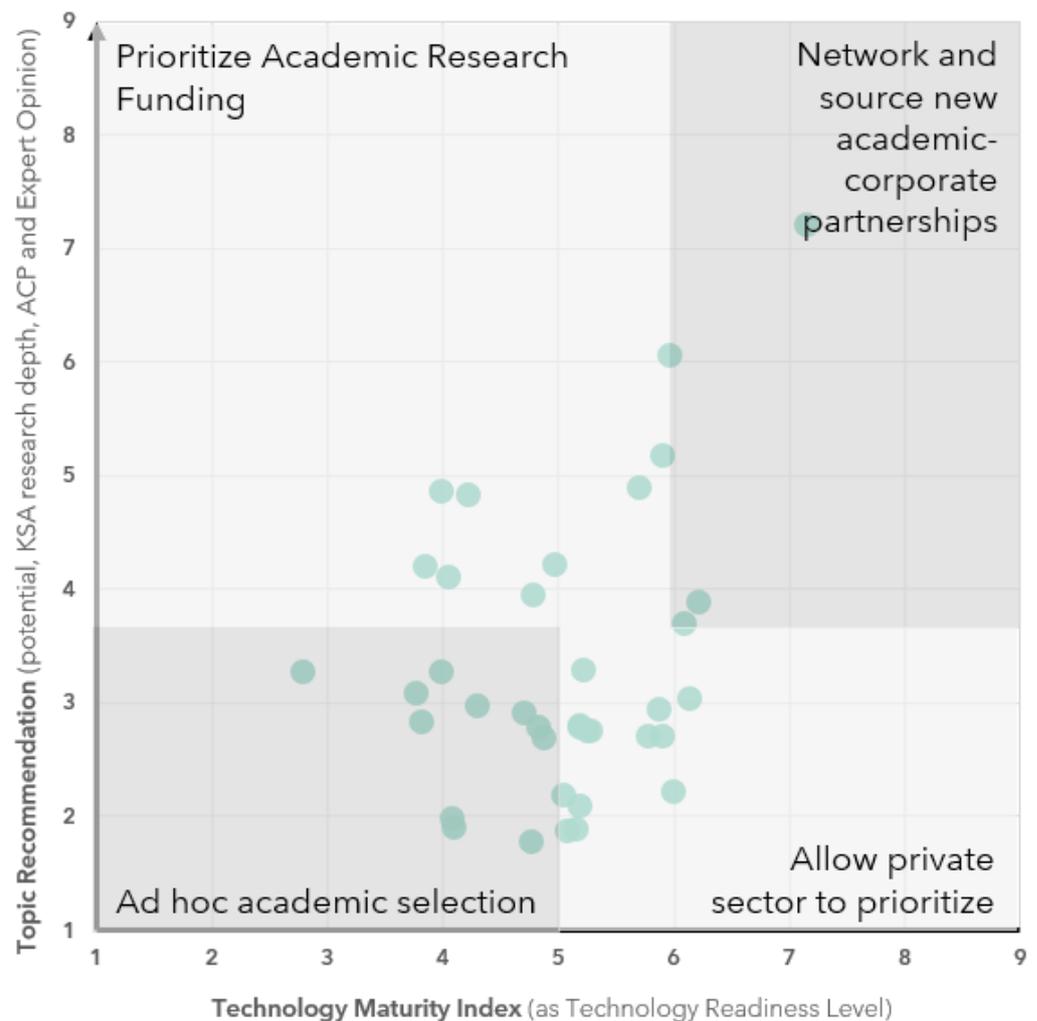


Figure 24 - summary scatterplot view of the study: Accelerating Technology Transfer from the Lab to the Market in Saudi Arabia recommendations of research topics based on the commercial potential measure, the depth of research within Saudi Arabia, the level of academic/corporate potential, and the views of RDIA experts for interest/impact; all arrayed on the Technology Maturity Index spectrum; limited to the Sustainability and Essential Needs National Priority

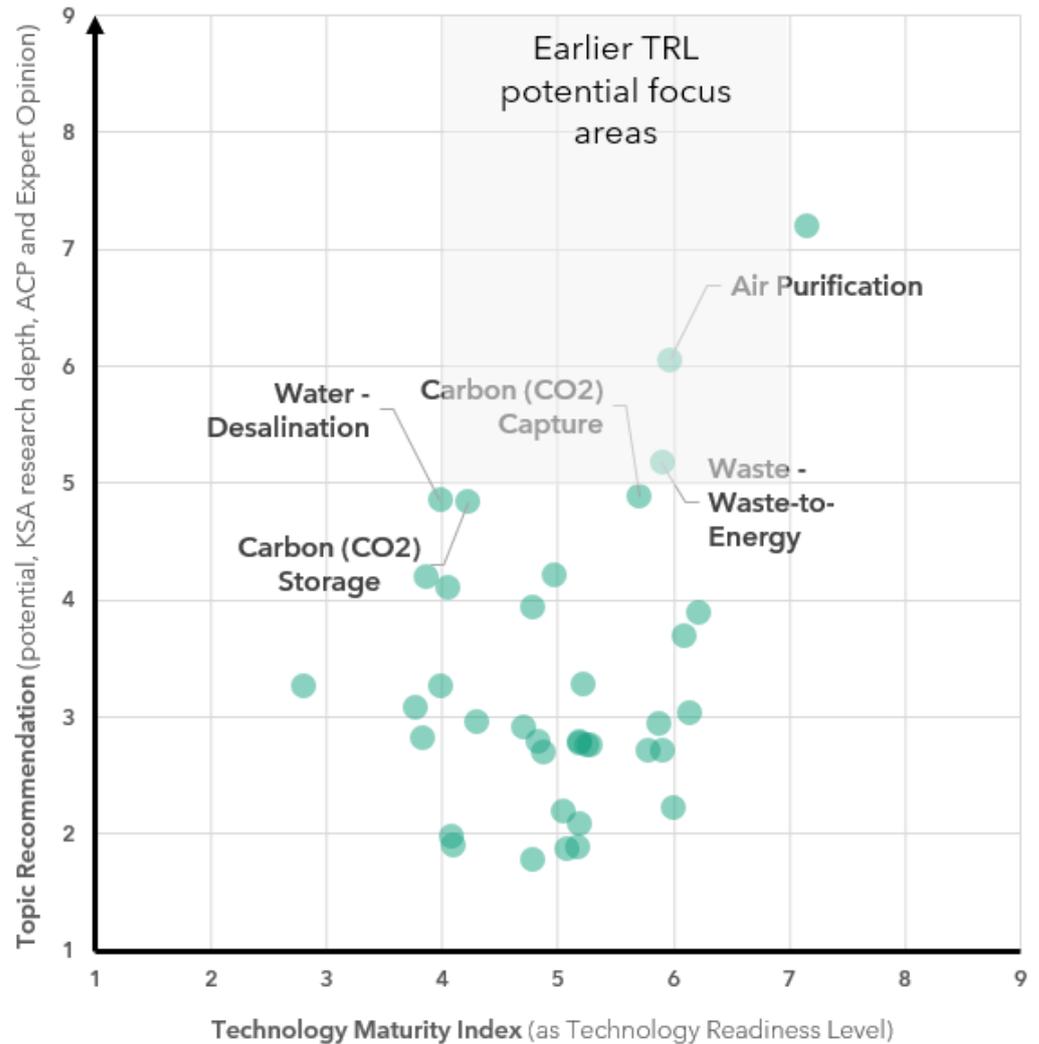


Figure 25 - scatterplot of Technical Maturity Index versus Topic Recommendation in the Sustainability and Essential Needs National Priority, annotation for research topics categories of >5 in recommendation and sitting in TRLs 4 - 7.

The view in Figure 24 is summarized here (Figure 25 and Figure 26) for the Sustainability and Essential Needs national priority and highlights:

1. Within earlier TRLs (Figure 25), a focus on applied research in water desalination, carbon capture and storage, air purification and waste-to-energy technologies.
2. Within higher TRL areas (Figure 26), where the commercialization of existing research pathways could be prioritized through further partnership by Saudi Arabian academic researchers with private enterprises, only one segment is revealed: Electric Vehicles.

This finding implies that the Saudi Arabian research & innovation policy within this National Priority may be best served in pursuing academic-first or academic-only applied research development for the short term as the broader commercial market for Sustainability technologies develops.

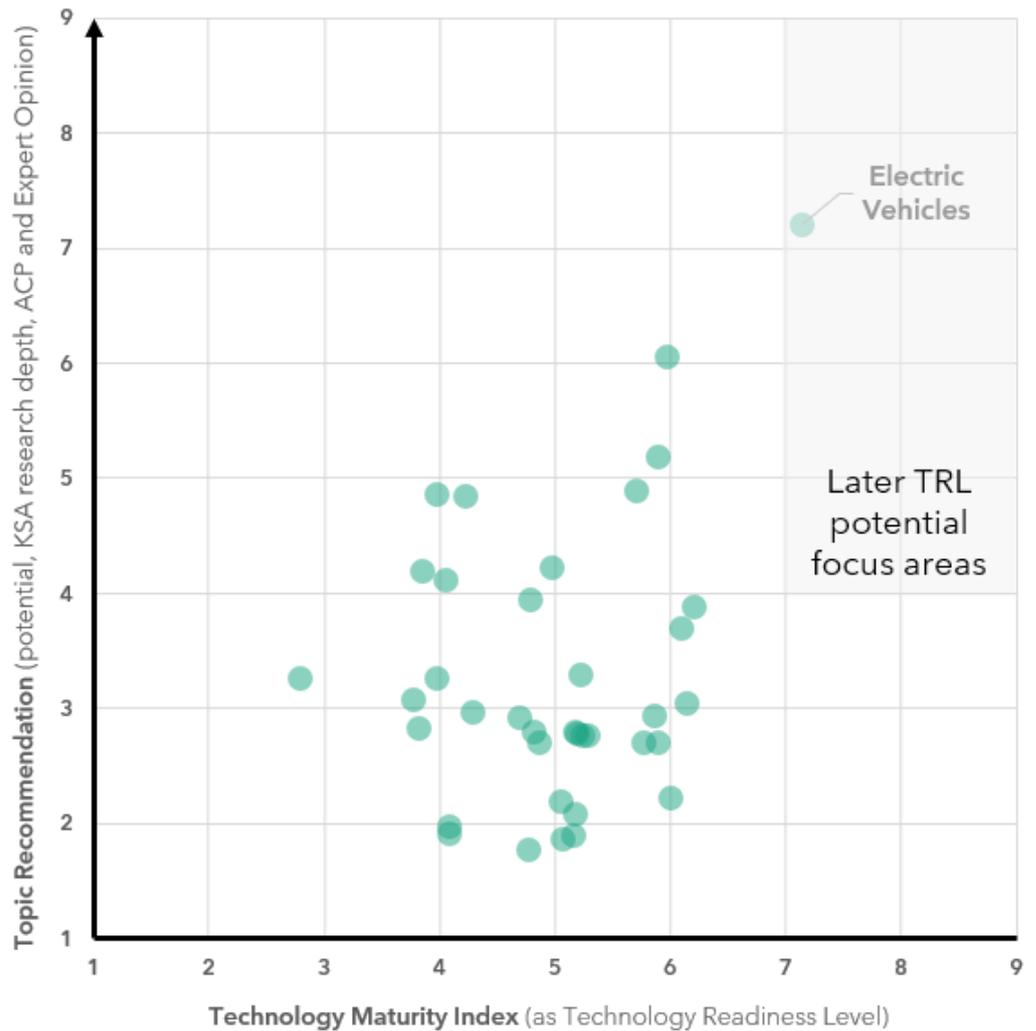


Figure 26 - scatterplot of Technical Maturity Index versus Topic Recommendation in the within Sustainability and Essential Needs National Priority, annotation for research topics categories of >5 in recommendation and sitting in TRLs 8 - 9.

Finally, this section shows the relative ranking and mode of research topics within the Sustainability and Essential Needs National Priority. Based on the evaluated TRL level, topics are ranked by the confluence of topic recommendation factors and by the action/recommendation quadrant they fall within (Table 4).

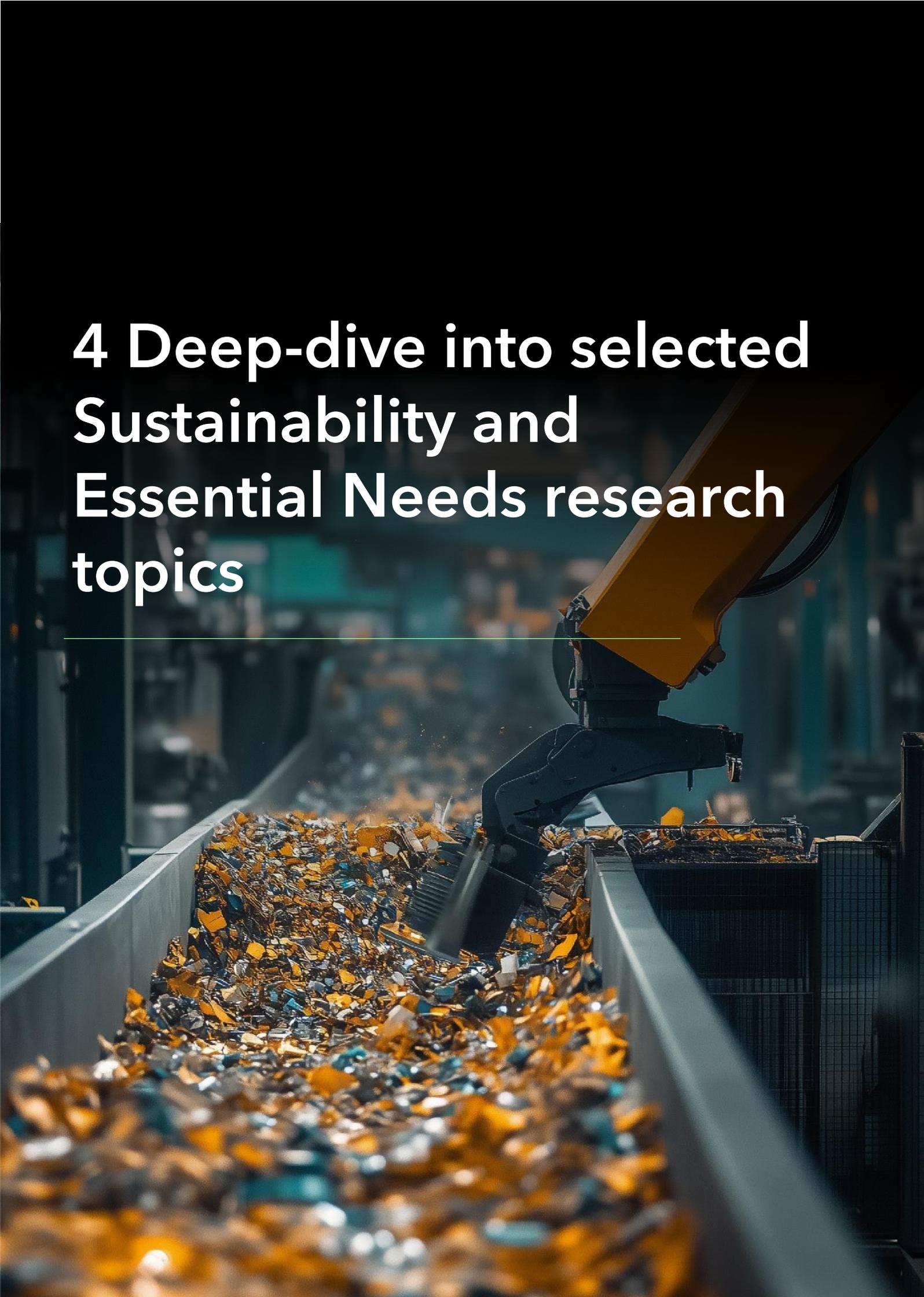
This list can assess the specificity of research topics in the Saudi Arabian research ecosystem, alongside the assessed technology maturity index of global research within that same topic. This will identify areas where Saudi Arabia can contribute further innovation that produces competitive, commercial technologies.

Table 4 - outcome scorecard for Sustainability and Essential Needs research topic categories, ranked by recommendation level; includes Technology Maturity Index/TRL score. Circle fill denotes a metric from highest quartile evidenced (full) to lowest quartile (single quarter).

Category	TMI as TRL	Commercial Potential	Saudi Arabia Research Depth	Level of Partnership	Expert Opinion	Recommended mode
Wastewater Purification/Treatment	7	●	●	●	●	Prioritize tech transfer
Electric Vehicles	7	●	●	○	●	Prioritize tech transfer
Air Purification	6	○	●	○	●	Prioritize tech transfer
Waste - Waste-to-Energy	6	○	●	○	●	Prioritize tech transfer
Water Desalination	4	○	●	○	●	Prioritize academic funding
Carbon (CO2) Capture	6	○	●	○	●	Prioritize tech transfer
Carbon (CO2) Storage	4	○	●	○	●	Prioritize academic funding
Water - Conservation Management	5	○	○	○	●	Prioritize academic funding
Water - Domestic Purification	6	○	○	○	●	Prioritize tech transfer
Geothermal Energy	4	○	○	○	●	Prioritize academic funding
Bioenergy	6	○	○	○	●	Prioritize tech transfer
Brine mining	4	○	○	○	●	Prioritize academic funding
Waste - Smart Mgt	5	○	○	○	●	Prioritize academic funding
Agriculture - Precision Agriculture	5	○	○	○	○	Ad hoc academic activity
Agriculture - Hydroponics	5	○	○	○	●	Ad hoc academic activity
Emergency Communications	5	○	○	○	●	Ad hoc academic activity
Sustainable Packaging	6	○	○	○	●	Private sector led
Carbon (CO2) Utilization	4	○	○	○	●	Ad hoc academic activity
Waste Landfill	3	○	○	○	●	Ad hoc academic activity
Water - Resources from Wastewater	5	○	○	○	●	Ad hoc academic activity
Agriculture - Pest Management	6	○	○	○	○	Private sector led
Agriculture - Precision Livestock	5	○	○	○	○	Ad hoc academic activity
Food Traceability & Distribution	5	○	○	○	○	Ad hoc academic activity
Adaptations - Afforestation	4	○	○	○	●	Ad hoc academic activity
Agriculture - Aquaculture	6	○	○	○	●	Private sector led
Eco-Agrochemicals	5	○	○	○	●	Ad hoc academic activity
Agriculture - Waste Management	5	○	○	○	●	Ad hoc academic activity
Carbon (CO2) Transport	4	○	○	○	●	Ad hoc academic activity
Food Alternatives	4	○	○	○	●	Ad hoc academic activity
Food - Intelligent Packaging	6	○	○	○	●	Private sector led
Adaptations - Flood Protection	5	○	○	○	○	Ad hoc academic activity
Adaptations - Seismology/Meteorology Event Detection	4	○	○	○	○	Ad hoc academic activity
Adaptations - Shore Protection	4	○	○	○	○	Ad hoc academic activity
Adaptations - Urban Heat Island	5	○	○	○	○	Ad hoc academic activity
Agriculture - Plant Breeding	6	○	○	○	○	Private sector led
Agriculture - Soil Preservation	5	○	○	○	○	Ad hoc academic activity
Food-Borne Hazard Control	5	○	○	○	○	Ad hoc academic activity
Water Leakage	5	○	○	○	na	Ad hoc academic activity

# 4 Deep-dive into selected Sustainability and Essential Needs research topics

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Within this section, the following research topics, as they map to specific RDIA missions, will be explored in detail:

National Priority	Topic	2.3 Develop technologies in food for sustainable and resilient food systems to achieve more than 50% self-sufficiency by 2040	2.4 Achieve net-zero emissions by 2050	2.5 Decrease the withdrawal of non-renewable water by 90% and the cost of water production by 50% by 2035
Sustainability and Essential Needs	Food Alternatives	✓		
	Eco-friendly agrochemicals	✓		
	Food traceability & distribution	✓		
	Food-borne hazard control	✓		
	Electric Vehicles		✓	
	Landfill technologies		✓	
	Carbon (CO2) Transport		✓	
	Industrial Emissions		✓	
	Waste-water Purification			✓
	Water Desalination			✓
	Water Conservation Management			✓
	Water Leakage			✓
	Water - Domestic Purification			✓

#### 4.1 Research Performance in the Selected Priority Research Topics

In this section, we investigate the research output performance of selected priority research topics in Saudi Arabia and globally. Program of Work section describes the overall dataset structure and the chosen priority research topics.

The research output performance for Saudi Arabia is investigated, for each selected research topic. First, the share of Saudi Arabian publications from global publications published on the research topic is investigated. Investigating the share of publications shows the evolution of the number of Saudi Arabian publications relative to the

global share. If the share increases, this means that the number of Saudi Arabian publications on the research topic is expanding at a rate higher than the global one and vice versa. We also investigate the citation impact of Saudi publications in the research topic by looking at the Category Normalized Citation Impact (CNCI). The metric provides information on the citation impact relative to the global average citation impact for publications of the same type, year of publication and subject area (For more details, see 6.6 Metrics). A CNCI above 1.0 would generally reflect a citation impact performance above the global average.

Second, we investigate the top 10 countries collaborating with Saudi Arabia on the research topic, the top 20 funding organizations, the top 20 publishing organizations in Saudi Arabia, and the top 20 researchers regarding the number of publications on the research topic. This will provide insights about the research ecosystem in Saudi Arabia around this specific research topic. Identifying key players from this ecosystem will support deriving targeted initiatives to enhance research performance in those research topics. Also, all the indicators used are described in Metrics.

Third, we also investigate the top 10 global publishing countries, top 20 global publishing entities, top 20 global funding organizations, and top 20 global researchers regarding the number of papers published on the research topic. This will provide insights into the global research ecosystem around this specific research topic. Identifying key global players in the research ecosystem of a particular research topic will also help enhance Saudi Arabia's research performance by aiming to collaborate with those key players.

Finally, we identify emerging topics globally and within Saudi Arabia research output in a specific research topic. This is determined by selecting the top topics regarding growth in number of papers from 2014 to 2023. Although, the Saudi Arabia research output within a research topic should focus on local and regional needs and priorities, it should be aware of international trends that could become important in the future. Thus we compare the emerging trends within Saudi Arabia to the global ones. The international trends provide insights to Saudi affiliated researchers on topics that one should monitor and/or could be also of local importance.

### **Main Findings**

- The share of Saudi Arabian publications in several of the research topics from the global papers in the research topic increased almost continuously in 2019-2023. This shows that for the majority of the research topics the growth in Saudi Arabian papers was higher than the global average.
- In Waste Landfill, Food-Borne Hazard Control and Water - Domestic Purification, we observe a similar trend but a slight decrease in the share in 2023.
- In the research topic Water Leakage we observe fluctuations in the share with a decreasing share in 2023, whereas in Food Alternatives we observe an increase in the share in 2021-2023
- As the research topics investigated are national priorities, research output should continuously increase while preserving sound quality. One way to do this is to collaborate with key publishing organizations, researchers, and top funding organizations identified in those research topics.
- In all the investigated research topics, except for Eco-Agrochemicals and Water - Conservation Management, at least five of the top 10 collaborators with Saudi Arabia in terms of number of publications, were also among the top 10 globally in terms of number of papers. This shows that Saudi Arabia collaborates with key global players on those research topics.
- In almost all research topics, at least seven of Saudi Arabia's Top 20 funders in terms of the number of papers are also among the top funders globally. This again shows that Saudi-affiliated researchers collaborate with key global players on research topics and can attract funding from key global funders.

- Only in the research topics Food Alternatives and Water Leakage do we observe that among the top 20 funders in Saudi Arabia, three and four organizations are also among the top 20 global funders.
- In several research topics, we observe King Saud University, King Abdulaziz University, King Fahd University of Petroleum & Minerals, and King Abdullah University of Science & Technology among the top five publishing entities in Saudi Arabia.
- Emerging global trends could become more important, so one should monitor identified trends and assess their relevance to local priorities.

## 4.1.1 Food Alternatives

### 4.1.1.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabian publications from global publications in the research topic increased continuously from 2014 till 2019, then decreased continuously till 2021, and afterward increased till 2023, as shown in Figure 27. This indicates that Saudi Arabia in the period 2014-2019 and 2022-2023 was not only able to increase the number of publications on this research topic but also had a growth higher than the global growth rate. This is evident as the share of Saudi Arabian publications in the research topic is growing.

The CNCI of Saudi Arabian publications in this research topic were several years higher than 1, indicating a citation impact performance higher than the global average. On the other hand, the CNCI decreased from 1.71 in 2015 to 0.5 in 2019, then recovered to 1.52 in 2022 and 1.14 in 2023. It is usually observed that the citation impact decreases in high publication period, as also observed in this case.

Overall, Saudi Arabian publications increased with a higher growth rate than the global average in this research topic and had a relatively good citation impact, as measured by the CNCI. Nevertheless, after this high growth rate in terms of publications, one should focus on increasing/preserving the impact of citations.

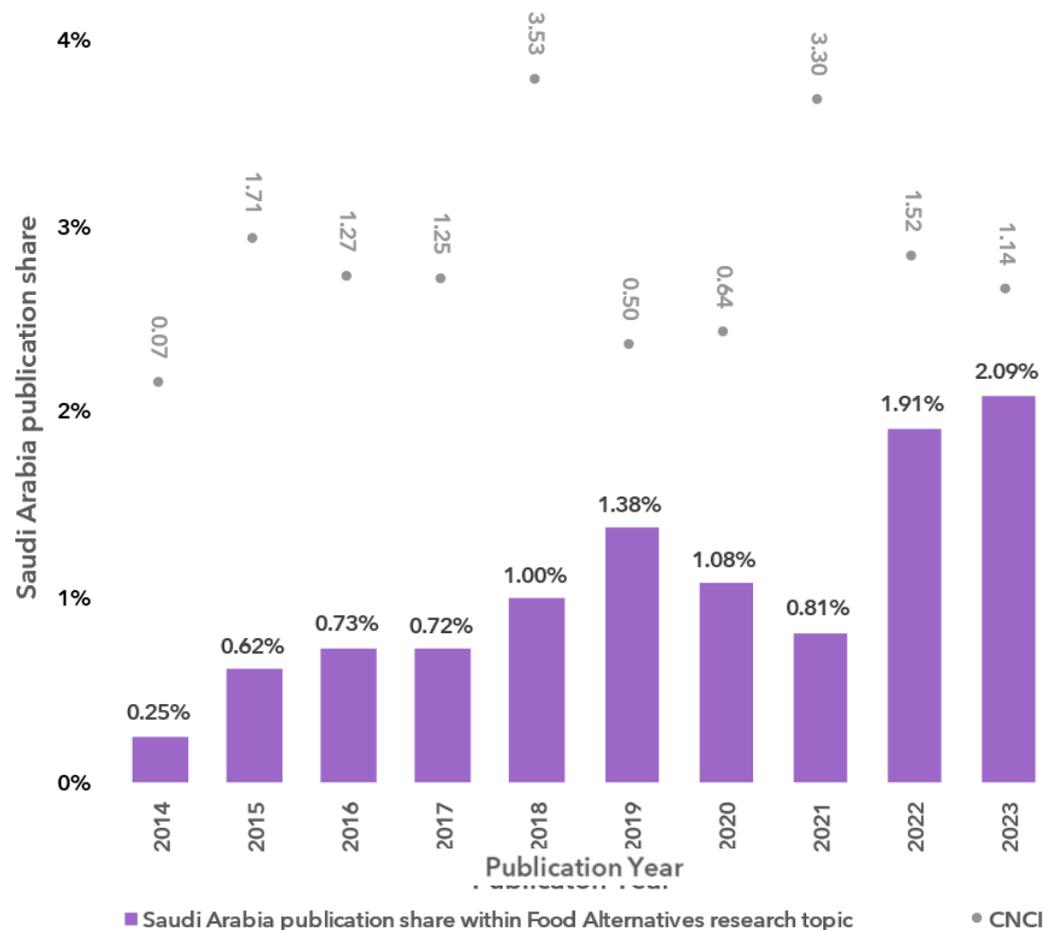


Figure 27: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabian publications in the research topic Food Alternatives in the period 2014-2023

### 4.1.1.2 Top 10 countries collaborating with Saudi Arabia

Egypt is the top collaborating country with Saudi Arabia in this research topic in the period 2014-2023, followed by India and Pakistan with 28, 19 and 11 publications, respectively, as shown in Figure 28. Regarding citation impact, as measured by the CNCI publications published in collaboration with Mainland China, Egypt and

Malaysia had the highest CNCI with 2.45, 1.59 and 1.34, respectively. Publications with only five out of the top 10 collaborating countries had a CNCI higher than 1, reflecting a performance higher than the global average.

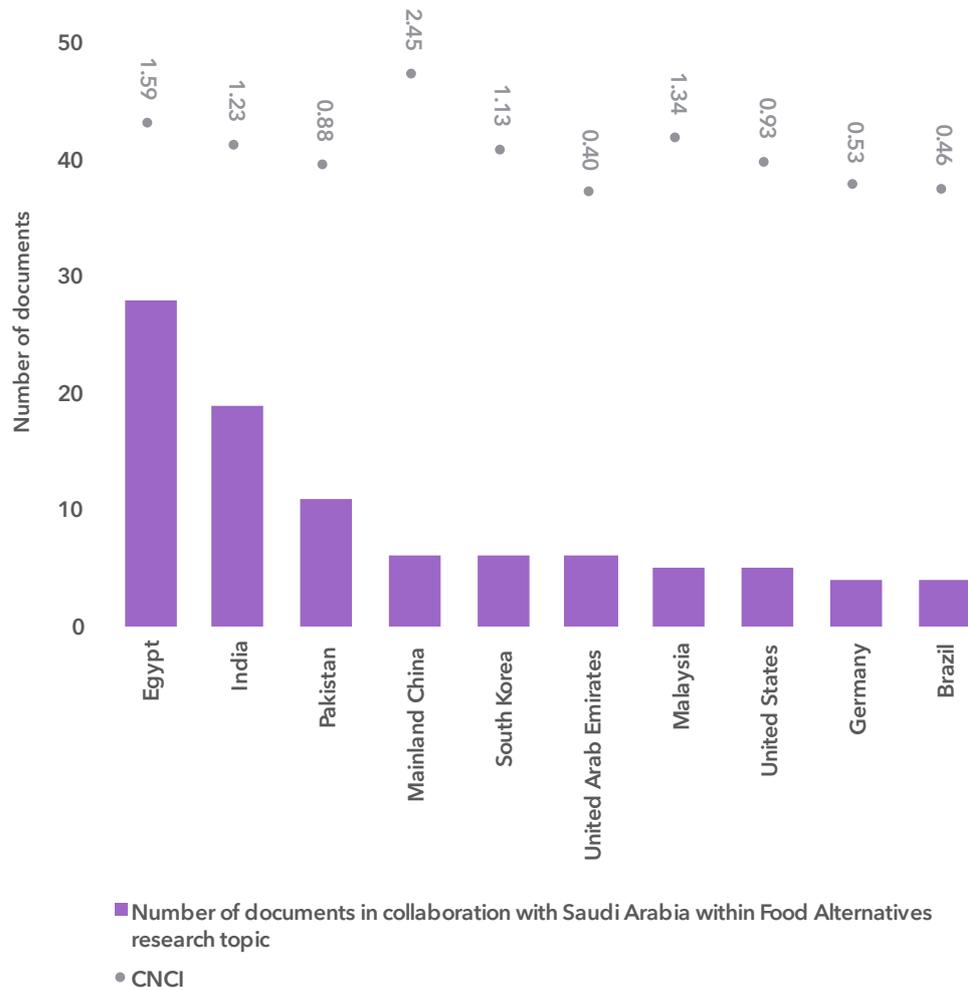


Figure 28: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications in the research topic Food Alternatives in the period 2014-2023

#### 4.1.1.3 Top 20 funders of Saudi publications by number of publications

There are only two organizations that have funded more than one Saudi Arabian publication on this research topic, and these are King Saud University, with 14 publications, and Princess Nourah bint Abdulrahman University as shown in Figure 29.

The CNCI of these publications was also higher than 1, reflecting a performance higher than the global average.

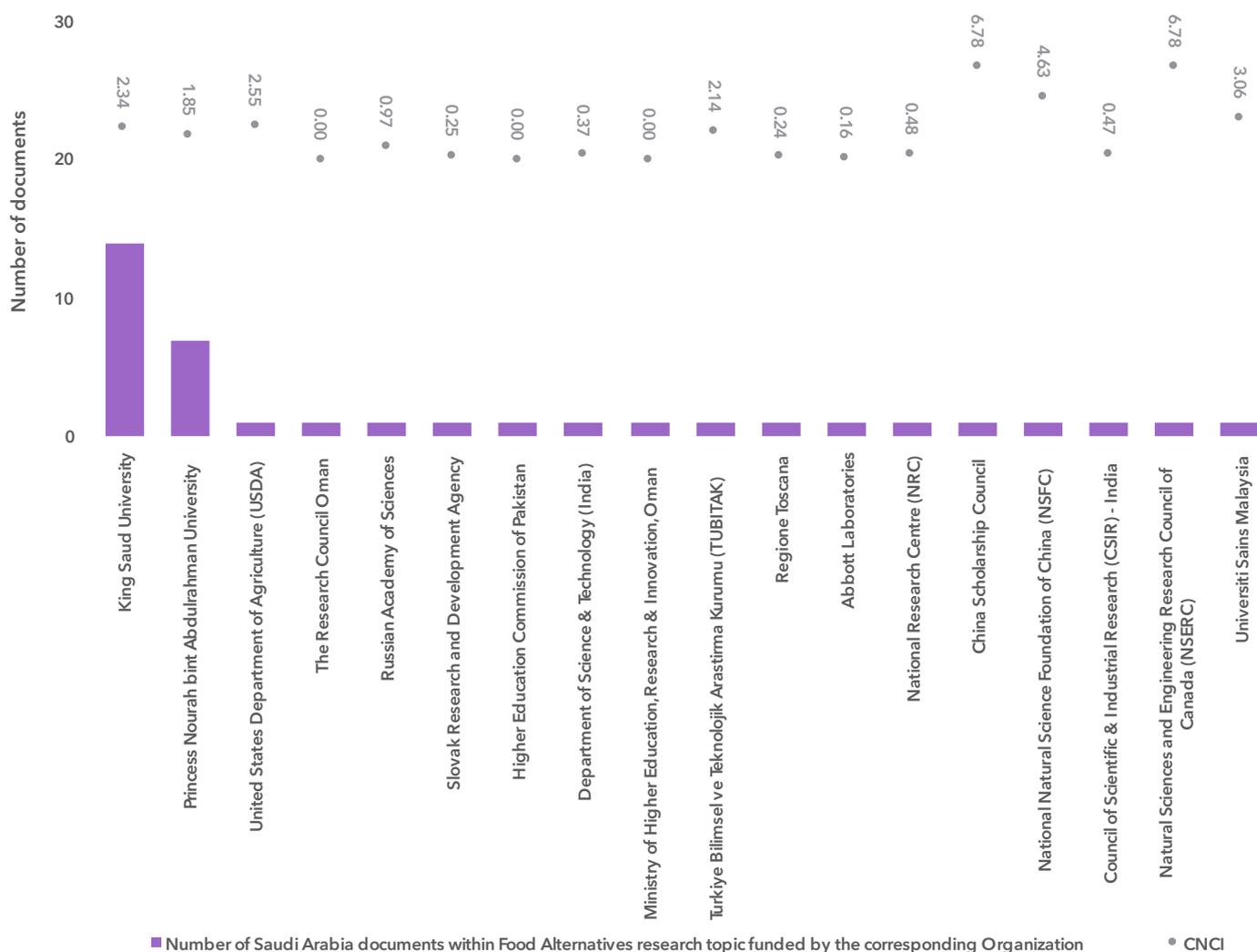


Figure 29: Top 20 funding organizations of Saudi Arabian publications in the research topic Food Alternatives in terms of number of publications in the period 2014-2023

#### 4.1.1.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top three organizations in terms of publications published on this research topic from 2014-2023 are King Saud University, followed by King Abdulaziz University and Umm Al Qura University, sharing the same number of publications with Taif University with 29, 23 and 8 publications respectively as shown in Figure 30.

Regarding citation impact as measured by the CNCI, all top 20 organizations except Al Baha University, Taif University, King Faisal University, King Khalid University, University of Tabuk, Al Jouf University and King Faisal Specialist Hospital & Research Center had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

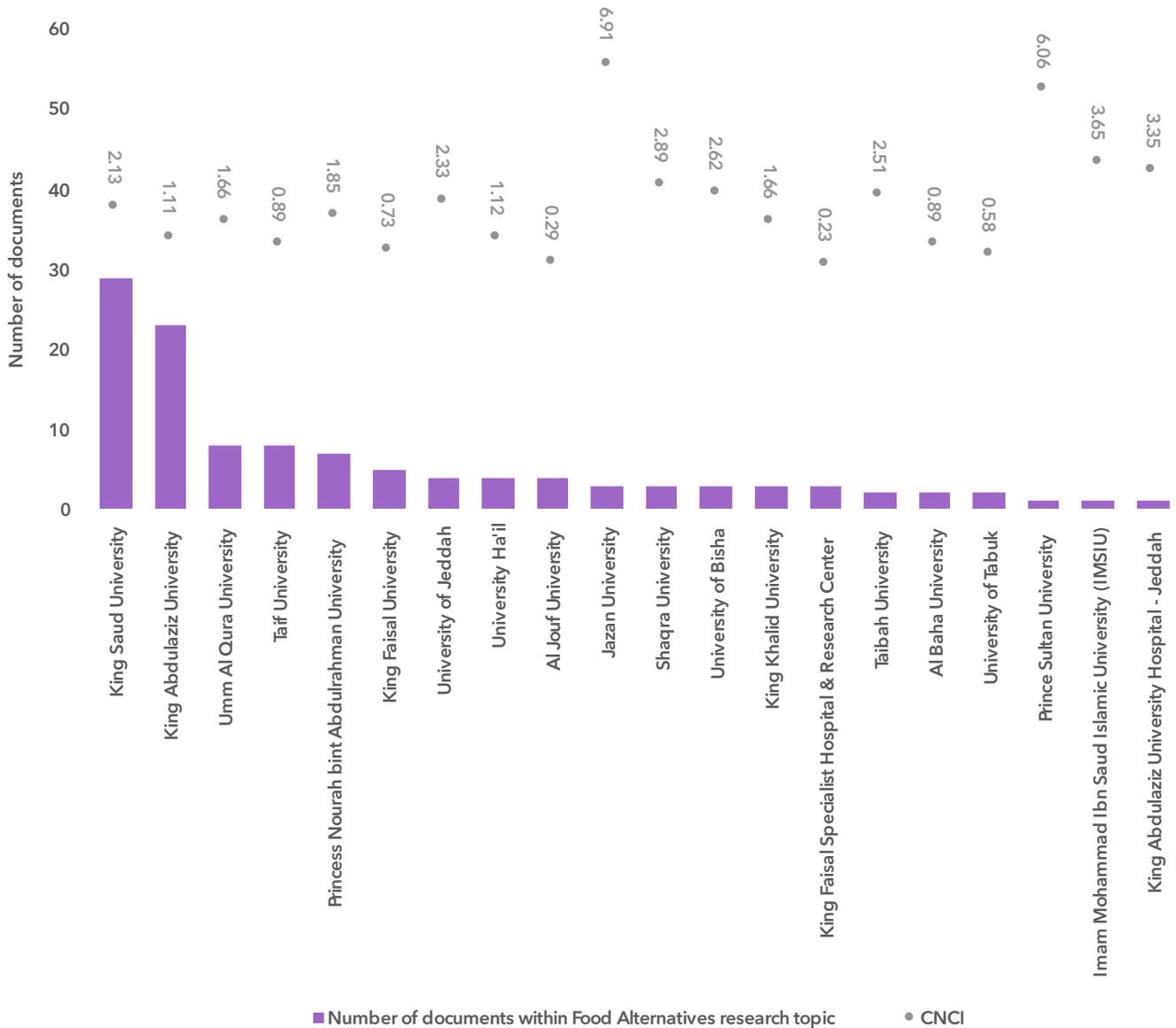


Figure 30: Top 20 Saudi organizations in terms of publications published in the research topic Food Alternatives in the period 2014-2023 and their corresponding CNCI

#### 4.1.1.5 The top 20 researchers are affiliated with Saudi organizations in terms of the number of publications they publish

The highest number of publications are published by Amal Bakr Shori, affiliated with King Abdulaziz University, with three publications, followed by several other researchers with two publications as shown in Table 5. Four researchers have the same CNCI and the highest CNCI of 18.24 and all have published only one document in the research topic. It is likely these researchers are co-authors on the same publications. This publication is apparently a Top 1% document.

There is only one researcher having more than 1 Top 10% document and this is Shaaban H. Moussa affiliated with Shaqra University, with two Top 10% publications.

Table 5: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published on the research topic Food Alternatives in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%
<b>Shori, Amal Bakr</b>	King Abdulaziz University	3	1.74	0	1
<b>Almaary, Khalid S.</b>	King Saud University	2	9.59	1	1
<b>Dawoud, Turki M.</b>	King Saud University	2	9.12	1	1
<b>Moussa, Shaaban H.</b>	Shaqra University	2	3.50	0	2
<b>Shami, Ashwag</b>	Princess Nourah bint Abdulrahman University	2	2.55	0	1
<b>Arasu, Mariadhas Valan</b>	King Saud University	2	0.44	0	0
<b>Kamran, Muhammad</b>	King Saud University	2	0.23	0	0
<b>Al-Askar, Abdulaziz A.</b>	King Saud University	1	18.24	1	1
<b>Bakri, Marwah M.</b>	Jazan University	1	18.24	1	1
<b>Mostafa, Ashraf A.</b>	King Saud University	1	18.24	1	1
<b>Sholkamy, Essam N.</b>	King Saud University	1	18.24	1	1
<b>Aldawoud, Turki M. S.</b>	King Saud University	1	18.10	1	1
<b>Yagoub, Abu ElGasim Ahmed</b>	King Saud University	1	6.78	1	1
<b>Abdeljawad, Thabet</b>	Prince Sultan University	1	6.06	0	1
<b>Alqudah, Manar A.</b>	Princess Nourah bint Abdulrahman University	1	6.06	0	1
<b>Al-Radadi, Najlaa S.</b>	Taibah University	1	4.77	0	1
<b>Alshareef, Sahar A.</b>	University of Jeddah	1	4.63	0	1
<b>Jalal, Rewaa S.</b>	University of Jeddah	1	4.63	0	1
<b>Sameeh, Manal Y.</b>	Umm Al Qura University	1	4.63	0	1
<b>Tashkandi, Manal Abdulbari</b>	University of Jeddah	1	4.63	0	1

#### 4.1.1.6 Top 10 countries in terms of publications

The highest number of publications published on this research topic is attributed to the United States (1,240 publications), followed by Brazil (842 publications) and Mainland China (542 publications), as illustrated in *Figure 31*.

The greatest citation impact measured by the CNCI is achieved by publications published by Canada, United Kingdom and Italy with a CNCI of 1.62, 1.60 and 1.53 respectively. Five of the top 10 countries in terms of number of publications published in the research topic are also among the top 10 collaborators with Saudi Arabia. These are the United States, Mainland China, Germany, India and Brazil.

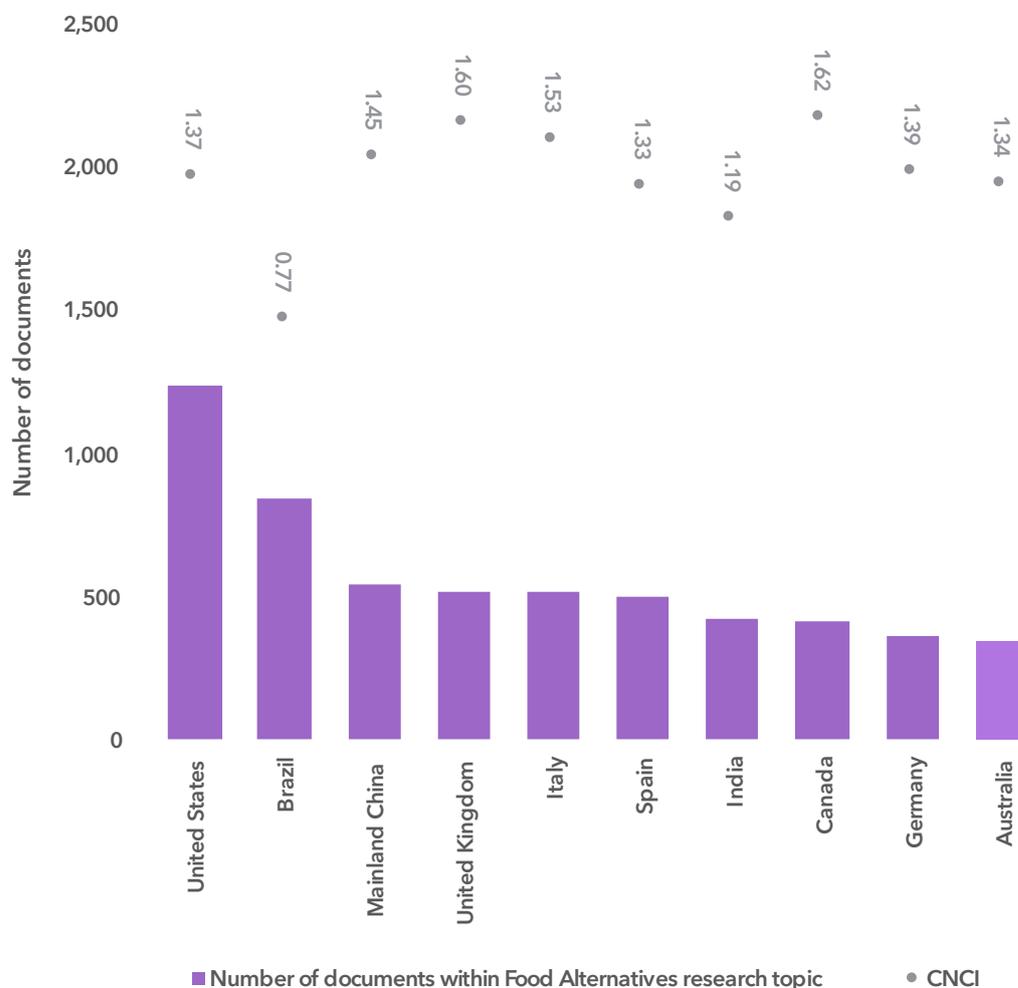


Figure 31: Top 10 countries in terms of the number of publications in the Food Alternatives in the period 2014-2023 and their corresponding CNCI

#### 4.1.1.7 Top 20 organizations globally in terms of number of publications

The top three organizations in terms of the number of publications published on this research topic from 2014-2023 are Wageningen University & Research (114 publications), followed by INRAE (111 publications) and Consejo Superior de Investigaciones Cientificas (CSIC) (100 publications) as shown in Figure 32.

Regarding citation impact measured by the CNCI, University College Cork followed jointly by University of Alberta and Wageningen University & Research and the University of California Davis, had the highest CNCI with 2.62, 1.97 and 1.85 respectively.

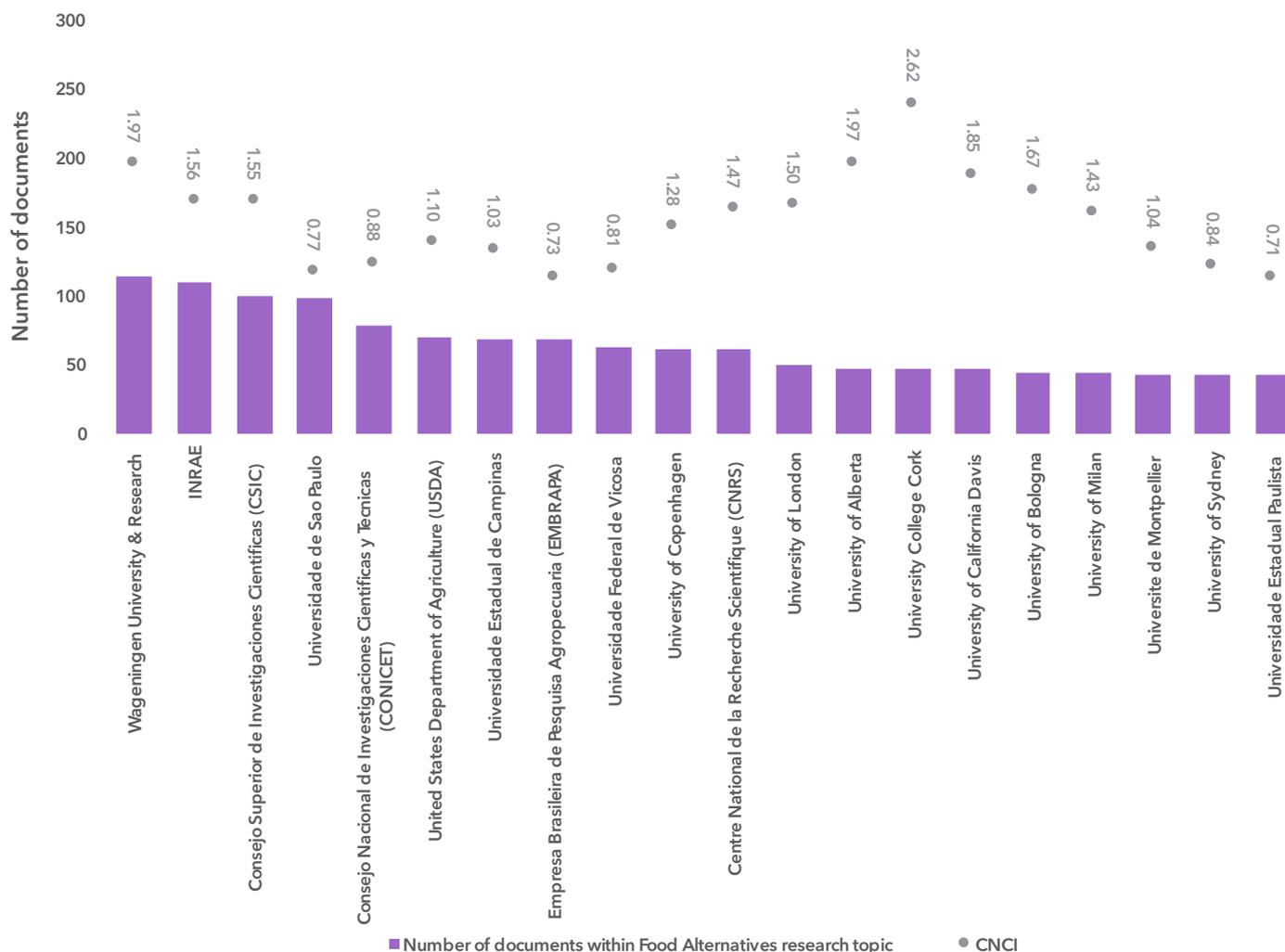


Figure 32: Top 20 organizations globally in terms of the number of publications published in the research topic Food Alternatives in the period 2014-2023 and their corresponding CNCI

#### 4.1.1.8 Top 20 researchers globally in terms of number of publications

The top three researchers globally in terms of the number of publications in this research topic are Yaghoub Fathipour, affiliated with Tarbiat Modares University, with 24 publications, followed by Emanuele Zannini, affiliated with University College Cork, with 17 publications, and Elke K. Arendt, affiliated with University College Cork having the same number of publications of 16 publications with Lillian Barros affiliated with Instituto Politecnico de Braganca as shown in Table 6.

The highest CNCI is achieved by M. A. Drake affiliated with North Carolina State University with 3.33. The highest number of Top 1% is achieved by Emanuele Zannini with 4 publications. The highest number of Top 10% is achieved by Yaghoub Fathipour with 12 publications.

Table 6: Top 20 researchers globally in terms of the number of publications published on the research topic Food Alternatives in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%	Country
<b>Fathipour, Yaghoub</b>	Tarbiat Modares University	24	2.27	0	12	Iran
<b>Zannini, Emanuele</b>	University College Cork	17	2.85	4	9	Ireland
<b>Arendt, Elke K.</b>	University College Cork	16	2.57	3	8	Ireland
<b>Barros, Lillian</b>	Instituto Politecnico de Braganca	16	1.73	1	3	Portugal
<b>Riahi, Elham</b>	Tarbiat Modares University	14	1.87	0	6	Iran
<b>McClements, David Julian</b>	University of Massachusetts Amherst	13	2.44	1	8	United States
<b>Ferreira, Isabel C. F. R.</b>	Instituto Politecnico de Braganca	13	1.88	1	3	Portugal
<b>Migliore, Giuseppina</b>	University of Palermo	10	2.02	0	3	Italy
<b>Janssen, Arne</b>	University of Amsterdam	10	1.50	0	3	Netherlands
<b>Schifani, Giorgio</b>	University of Palermo	9	2.44	0	4	Italy
<b>Bang-Berthelsen, Claus Heiner</b>	Technical University of Denmark	9	1.24	0	1	Denmark
<b>Pallini, Angelo</b>	Universidade Federal de Vicosa	9	1.17	0	1	Brazil
<b>Vatanparast, Hassan</b>	University of Saskatchewan	9	0.90	0	0	Canada
<b>Yazdanpanah, Shima</b>	Tarbiat Modares University	8	2.25	0	3	Iran
<b>Riddick, Eric W.</b>	United States Department of Agriculture (USDA)	8	1.17	0	2	United States
<b>Rangan, Anna</b>	University of Sydney	8	0.57	0	0	Australia
<b>Nunes, Ricardo Vianna</b>	Universidade Estadual do Oeste do Parana	8	0.31	0	0	Brazil
<b>Drake, M. A.</b>	North Carolina State University	7	3.33	2	3	United States
<b>Jehlicka, Petr</b>	Masaryk University Brno	7	3.14	0	4	Czech Republic
<b>Scott, Steffanie</b>	University of Waterloo	7	2.82	1	2	Canada

#### 4.1.1.9 Top 20 global funders globally in terms of number of publications

The top three organizations in terms of funded publications in this research topic are Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPQ) with 355 publications, followed by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) with 333 publications and European Union (EU) with 246 publications as shown in Figure 33.

The highest citation impact measured by the CNCI is observed in publications funded by Natural Sciences and Engineering Research Council of Canada (NSERC), National Science Foundation (NSF) and National Institutes of Health (NIH) - USA with 1.68, 1.64 and 1.58 respectively.

Among the top 20 global funding organizations, only three are also among the top 20 funding organizations of Saudi publications in this research topic.

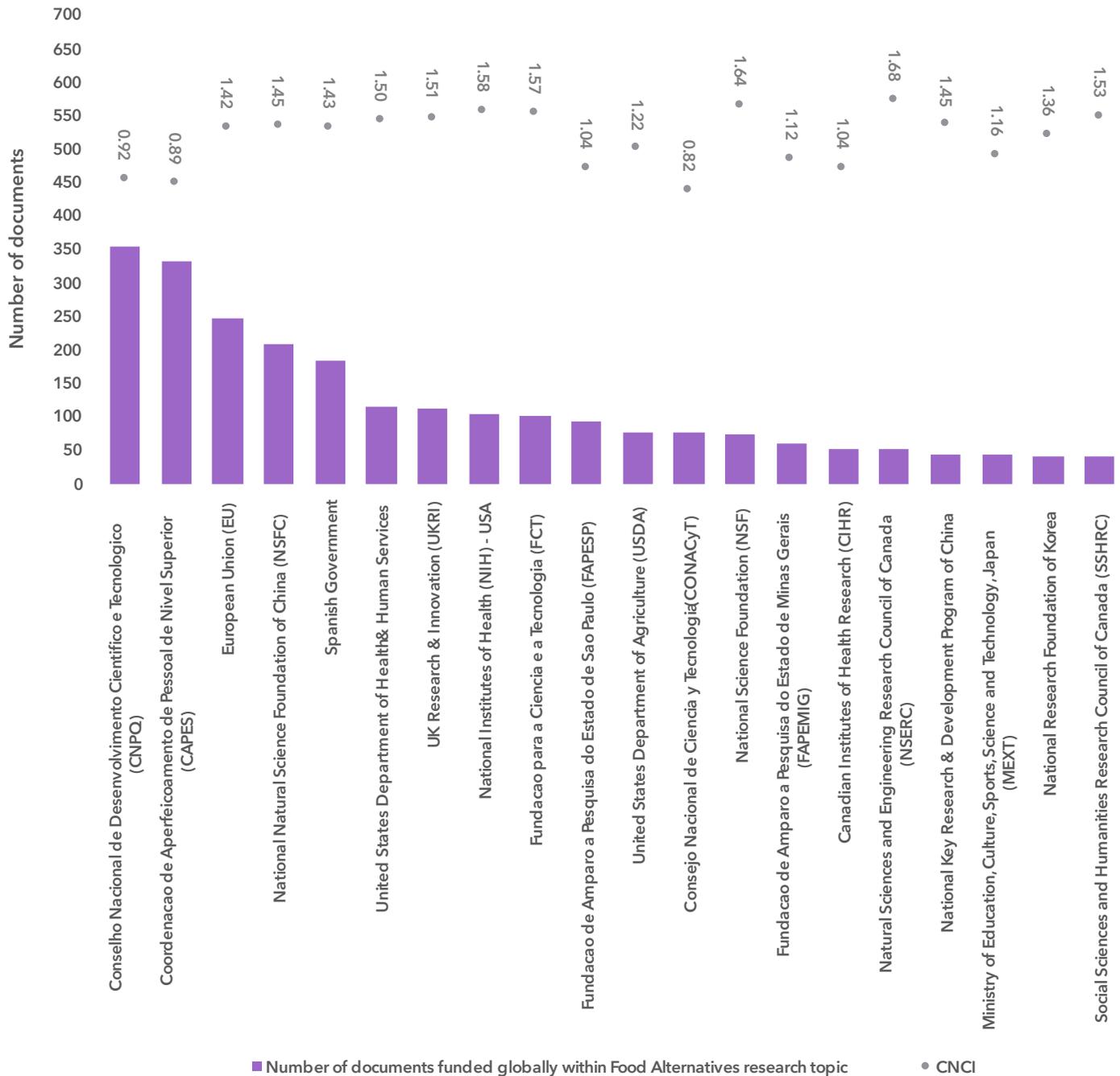


Figure 33: Top 20 funding organizations globally publications in the research topic Food Alternatives in terms of number of publications in the period 2014-2023

#### 4.1.1.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section we investigate the emerging trends globally and in Saudi Arabia within this research topic Food Alternatives. For more information on the methodology used to identify emerging trends, please see the section Emerging Trends.

The top three emerging micro-topics globally in this research topic are Agricultural Policy: Edible Insects followed by Food Science & Technology: Chitosan and Inflammatory Bowel Diseases & Infections: Lactic Acid Bacteria as shown in Figure 34.



Figure 34: Top 20 emerging micro-topics globally in the research topic Food Alternatives in the period 2014-2023

Table 7 shows the identified top 10 micro-topics in Saudi Arabia's research output on this research topic. Saudi Arabia has publications in the following identified global emerging topics: Inflammatory Bowel Diseases & Infections: Lactic Acid Bacteria, Nanoparticles: Silver Nanoparticles, Agricultural Policy: Edible Insects and Dairy & Animal Sciences: Meat Characteristics.

Table 7: Micro-topics identified in Saudi Arabia research output in the research topic Food Alternatives in the period 2014-2023

Topic	Number of Saudi Arabian publications 2014-2023
Food Alternatives research topic	95
Inflammatory Bowel Diseases & Infections: Lactic Acid Bacteria	8
Lipids: Virgin Olive Oil	5
Nanoparticles: Silver Nanoparticles	3
Allergy: Food Allergy	3
Agricultural Policy: Edible Insects	3
Obstetrics & Gynecology: Breastfeeding	2
Crop Science: Firmness	2
Numerical Methods: Global Stability	2
Phytochemicals: Aristolochic Acid	1
Manufacturing: Tool Wear	1

## 4.1.2 Eco-Agrochemicals

### 4.1.2.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabian publications from global publications on the research topic has increased almost continuously from 2014 to 2023, as shown in Figure 35.

This indicates that Saudi Arabia not only managed to boost the number of publications in this area but also experienced growth that surpassed the global growth rate. This is evident since the share of Saudi Arabian papers in this research topic is increasing. The CNCI of Saudi Arabian publications in this research topic were in almost all years higher than 1, indicating a citation impact performance higher than the global average. On the other hand, the CNCI decreased from 3.00 in 2014 to 0.87 in 2019, then recovered to 1.23 in 2023.

Overall, Saudi Arabian papers have increased at a faster growth rate than the global average in this research area and exhibited a relatively strong citation impact as indicated by the CNCI. Nevertheless, following this rapid growth in publications, there may be a need to focus on enhancing or maintaining citation impact metrics.

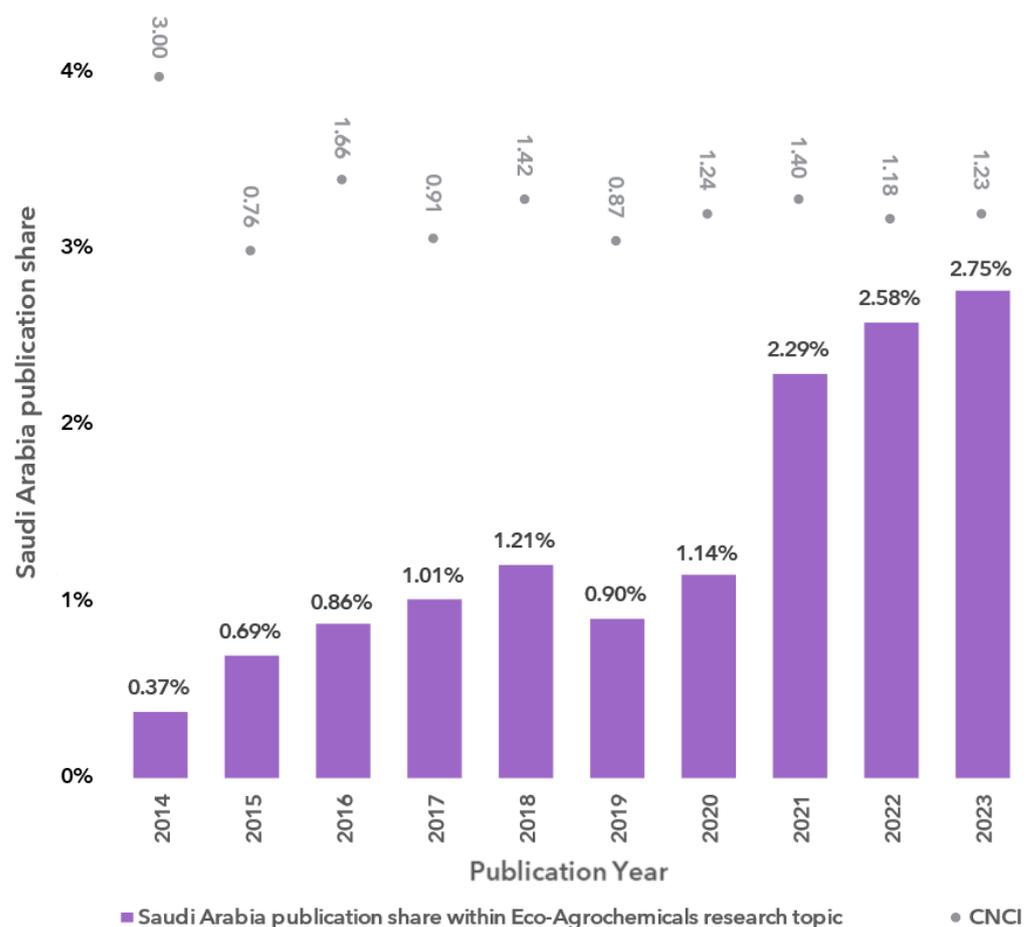


Figure 35: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabian publications in the research topic

### 4.1.2.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating country with Saudi Arabia in this research topic from 2014-2023 is Egypt, followed by Pakistan and India with 114, 70 and 65 publications, respectively, as shown in Figure 36.

Regarding citation impact measured by the CNCI, publications published in collaboration with South Korea followed by the United States and Pakistan had the highest CNCI with 1.94, 1.65 and 1.54 respectively. Nevertheless, all publications with

the top 10 collaborating countries had a CNCI higher than 1, except for collaborations with Turkiye, reflecting a performance higher than the global average.

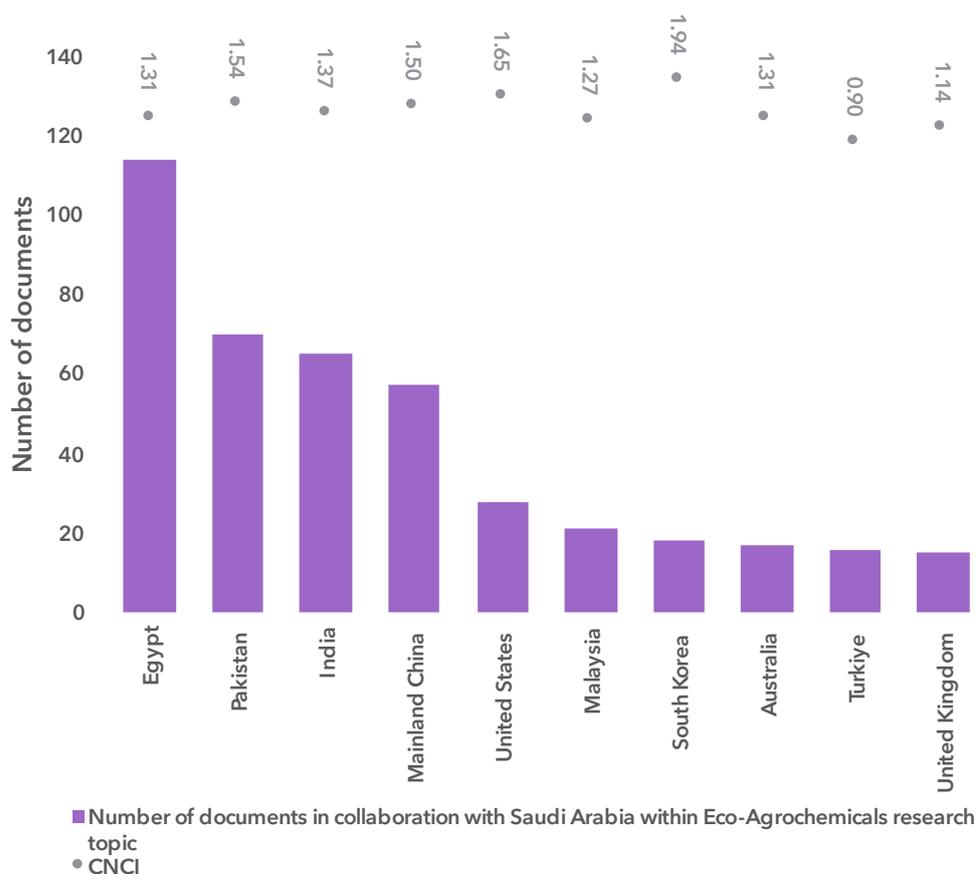


Figure 36: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications in the research topic Eco-Agrochemicals in the period 2014-2023

#### 4.1.2.3 Top 20 funders of Saudi publications by number of publications

The top three funding organizations of Saudi Arabia publications in this research topic in terms of the number of publications mentioning the organization in the funding text from 2014-2023 are King Saud University followed by the National Natural Science Foundation of China (NSFC) and Princess Nourah bint Abdulrahman University with 74, 14 and 9 publications respectively as shown in Figure 37.

Publications funded by the Mainland China Scholarship Council, Natural Science Foundation of Hunan Province and Ministry of Science & ICT (MSIT), Republic of Korea, had the highest citation impact measured by the CNCI with 3.89, 3.89 and 3.72, respectively.

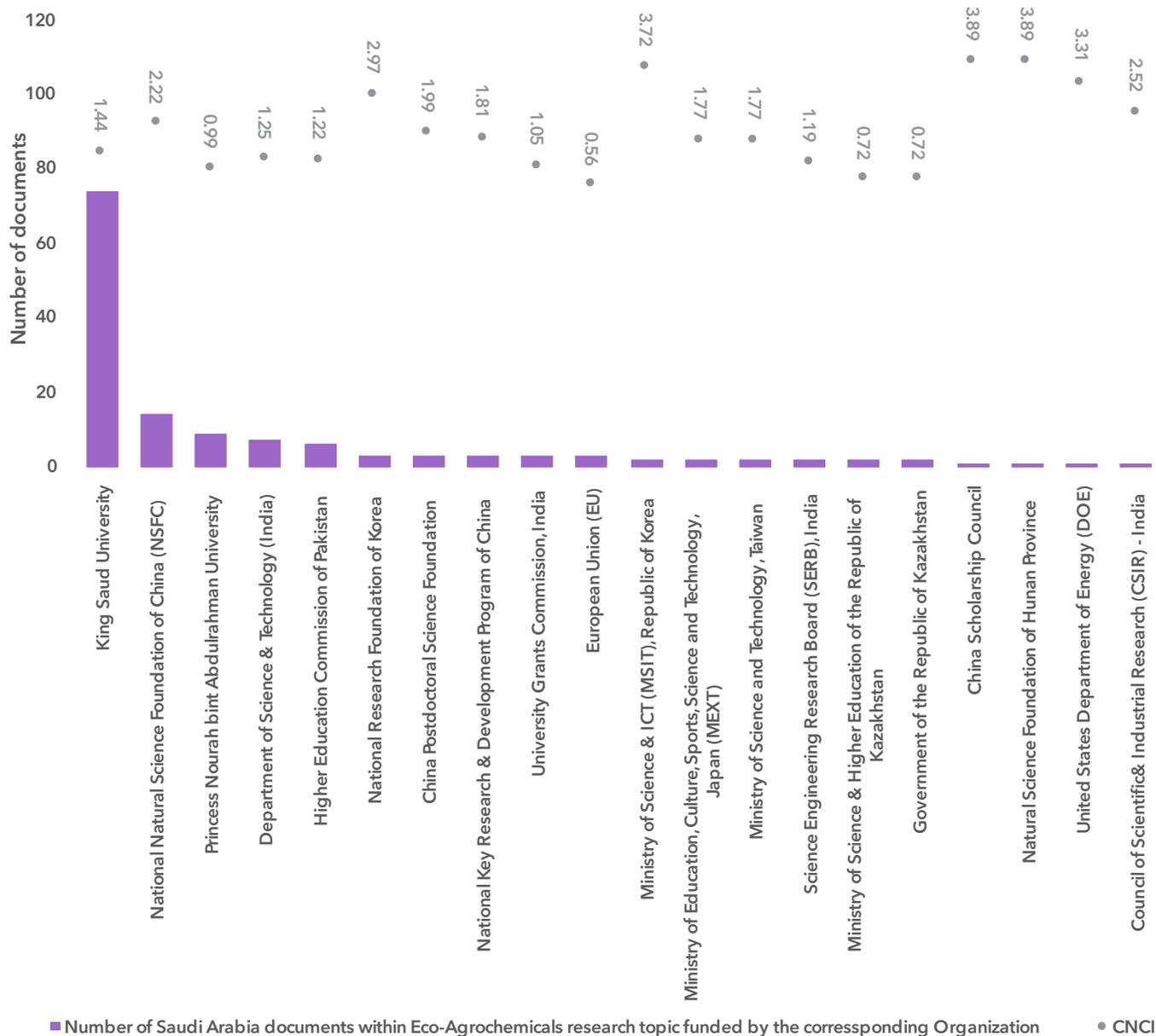


Figure 37: Top 20 funding organizations of Saudi Arabia publications in the research topic Eco-Agrochemicals in terms of number of publications in the period 2014-2023

#### 4.1.2.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top three organizations in terms of publications published on this research topic from 2014-2023 are King Saud University, followed by King Abdulaziz University and Taif University with 128, 48 and 38 publications, respectively, as shown in Figure 38.

Regarding citation impact as measured by the CNCI, Prince Sattam Bin Abdulaziz University, followed by University Ha'il and Majmaah University, had the highest CNCI with 3.11, 2.23 and 1.80, respectively.

Thirteen institutions from the top 20 organizations had a CNCI higher than 1, reflecting a citation impact performance higher than the global average. Within the group of institutions with CNCI below 1, two out of the seven had an impact very close to the global average, Umm Al Qura University and Qassim University, with 0.95 and 0.93, respectively.

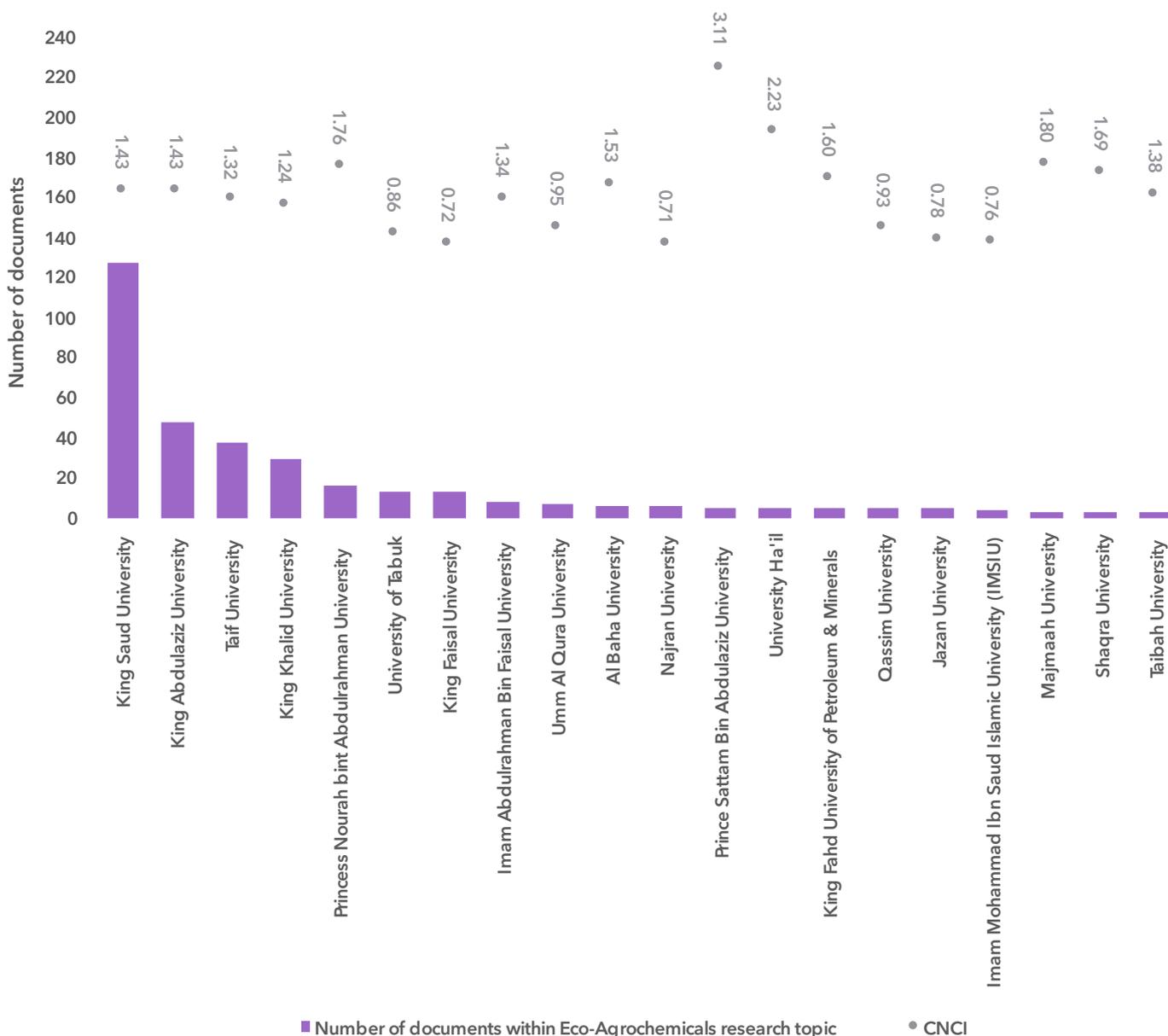


Figure 38: Top 20 Saudi organizations in terms of publications published in the research topic Eco-Agrochemicals in the period 2014-2023 and their corresponding CNCI

#### 4.1.2.5 The top 20 researchers are affiliated with Saudi organizations in terms of the number of publications they publish

The highest number of publications are published by Esmat F. Ali, affiliated with Taif University, followed by Manzer H. Siddiqui, affiliated with King Saud University, and Muhammad Imtiaz Rashid, affiliated with King Abdulaziz University, with 12, 10 and 5 publications, respectively as shown in Table 8.

The highest CNCI is achieved by publications published by Khalid F. Almutairi affiliated with King Saud University with a CNCI of 4.76. Esmat F. Ali affiliated with Taif University has the highest number of Top 10% with four publications. Only four researchers among the top 20 have one Top 1% document.

Table 8: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published in the research topic Eco-Agrochemicals in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%
Ali, Esmat F.	Taif University	12	1.56	0	4
Siddiqui, Manzer H.	King Saud University	10	2.46	1	3
Rashid, Muhammad Imtiaz	King Abdulaziz University	5	4.06	1	2
Alarfaj, Abdullah A.	King Saud University	5	1.46	0	1
Eid, Ebrahim M.	King Khalid University	5	1.27	0	0
Alrumman, Sulaiman A.	King Khalid University	5	1.14	0	0
Majrashi, Ali	Taif University	5	0.99	0	0
Elgorban, Abdallah M.	King Saud University	5	0.48	0	0
Syed, Asad	King Saud University	4	2.01	0	1
Gaber, Ahmed	Taif University	4	1.60	0	1
AL-Huqail, Arwa Abdulkreem	Princess Nourah bint Abdulrahman University	4	1.20	0	1
Almadiy, Abdulrhman A.	Najran University	4	0.89	0	0
Alamri, Saud	King Saud University	4	0.78	0	0
Alamri, Saad	King Khalid University	4	0.41	0	0
Almutairi, Khalid F.	King Saud University	3	4.76	1	1
Al-Wabel, Mohammad I.	King Saud University	3	2.94	1	1
Alharbi, Naiyf S.	King Saud University	3	1.90	0	1
Hassan, Mohamed M.	Taif University	3	1.88	0	1
Ali, Hayssam M.	King Saud University	3	1.59	0	1
Taher, Mostafa A.	King Khalid University	3	1.42	0	0

#### 4.1.2.6 Top 10 countries in terms of publications

The highest number of publications published on this research topic is published by Mainland China (5,531 publications), followed by the United States (2,005 publications) and India (1,562 publications), as shown in Figure 39.

The highest citation impact measured by the CNCI is achieved by publications published by United Kingdom, Australia and Germany with a CNCI of 1.74, 1.63 and 1.57 respectively.

Three of the top 10 countries in terms of number of publications published in the research topic are also among the top 10 collaborators with Saudi Arabia. These are the United Kingdom, Australia, Mainland China, the United States and India.

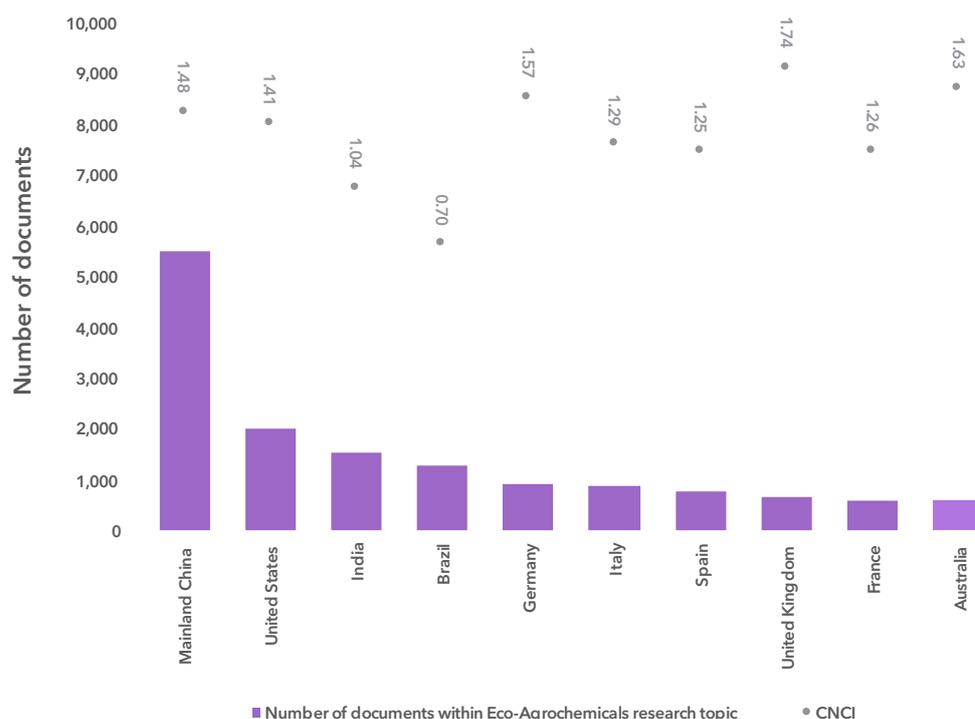


Figure 39: Top 10 countries in terms of the number of publications in the Eco-Agrochemicals in the period 2014-2023 and their corresponding CNCI

#### 4.1.2.7 Top 20 organizations globally in terms of number of publications

The top three organizations in terms of the number of publications published in this research topic from 2014-2023 are the Chinese Academy of Sciences (1143 publications) followed by the Ministry of Agriculture & Rural Affairs - Mainland China (733 publications) and the Chinese Academy of Agricultural Sciences (670 publications) as shown in Figure 40.

Regarding citation impact measured by the CNCI, Wageningen University & Research, Nanjing Agricultural University and Institute of Agricultural Resources & Regional Planning, CAAS had the highest CNCI with 2.38, 2.12 and 2.04, respectively.

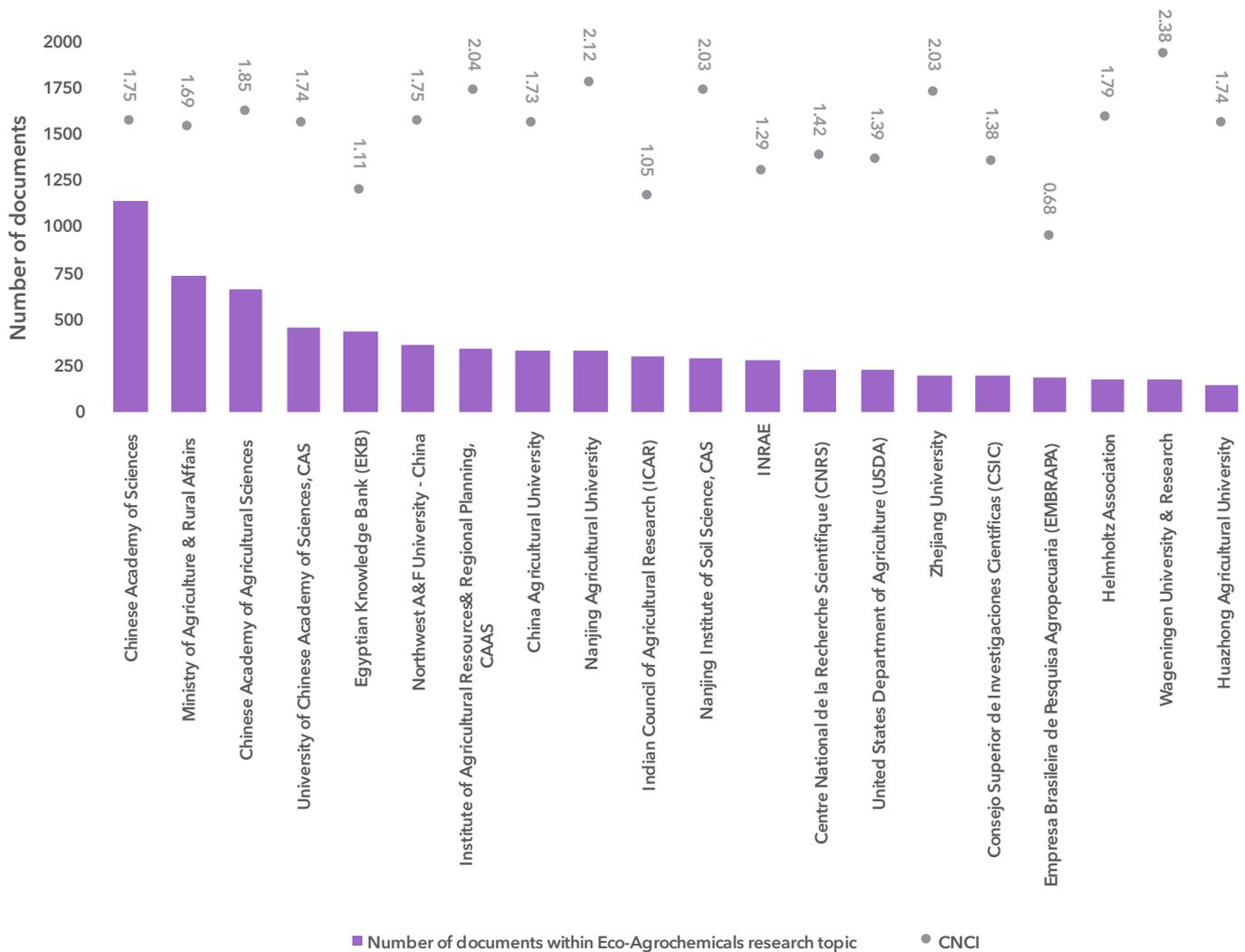


Figure 40: Top 20 organizations globally in terms of the number of publications published in the research topic Eco-Agrochemicals in the period 2014-2023 and their corresponding CNCI

#### 4.1.2.8 Top 20 researchers globally in terms of number of publications

The top three researchers globally in terms of the number of publications on this research topic are Qirong Shen, affiliated with Nanjing Agricultural University, with 94 publications, followed by Minggang Xu, affiliated with the Chinese Academy of Agricultural Sciences, with 56 publications, and Giovanni Benelli, affiliated with the University of Pisa, with 47 publications as shown in Table 9.

The highest CNCI is achieved by Yakov Kuzyakov, affiliated with the University of Gottingen, with 3.96.

The highest number of Top 1% and Top 10% publications is achieved by the researcher Qirong Shen, affiliated with Nanjing Agricultural University, who has the highest number of publications on this research topic, as mentioned before.

Table 9: Top 20 researchers globally in terms of the number of publications published in the research topic Eco-Agrochemicals in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%	Country
<b>Shen, Qirong</b>	Nanjing Agricultural University	94	2.79	8	49	Mainland China
<b>Xu, Minggang</b>	Chinese Academy of Agricultural Sciences	56	1.97	1	16	Mainland China
<b>Benelli, Giovanni</b>	University of Pisa	47	2.39	2	21	Italy
<b>Maggi, Filippo</b>	University of Camerino	43	2.21	0	20	Italy
<b>Kuzyakov, Yakov</b>	University of Gottingen	37	3.96	6	23	Germany
<b>Zhou, Wei</b>	Chinese Academy of Agricultural Sciences	36	2.45	2	14	Mainland China
<b>Xu, Hui</b>	Northwest A&F University - Mainland China	36	1.00	0	3	Mainland China
<b>Zhu, Ping</b>	Jilin Academy of Agricultural Sciences	35	2.19	2	12	Mainland China
<b>Zhu, Yong-Guan</b>	Chinese Academy of Sciences	33	2.97	4	13	Mainland China
<b>He, Ping</b>	Chinese Academy of Agricultural Sciences	32	2.26	1	12	Mainland China
<b>Zhang, Jiabao</b>	Nanjing Institute of Soil Science, CAS	32	2.09	3	8	Mainland China
<b>Li, Rong</b>	Nanjing Agricultural University	30	3.57	5	15	Mainland China
<b>Zhu, Bo</b>	Chinese Academy of Sciences	30	1.91	2	8	Mainland China
<b>Wang, Boren</b>	Chinese Academy of Agricultural Sciences	29	2.01	1	11	Mainland China
<b>Ling, Ning</b>	Nanjing Agricultural University	27	2.56	1	14	Mainland China
<b>Huang, Qiaoyun</b>	Huazhong Agricultural University	27	1.81	1	7	Mainland China
<b>Ran, Wei</b>	Nanjing Agricultural University	27	1.78	0	10	Mainland China
<b>Pavela, Roman</b>	Czech Crop Research Institute (CRI)	26	2.83	2	14	Czech Republic
<b>Yang, Xueyun</b>	Northwest A&F University - Mainland China	26	1.64	0	7	Mainland China
<b>Naveed, Muhammad</b>	University of Agriculture Faisalabad	24	1.89	1	9	Pakistan

#### 4.1.2.9 Top 20 global funders globally in terms of number of publications

The top three organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC) with 3011 publications, followed by the National Key Research & Development Program of China with 894 publications, and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPQ) with 521 publications as shown in Figure 41.

The highest citation impact measured by the CNCI is observed in publications funded by the National Basic Research Program of China, the Chinese Academy of Sciences and the National Science Foundation (NSF), with 2.08, 1.98 and 1.95, respectively.

Among the top 20 global funding organizations, seven are also among the top 20 funding organizations of Saudi publications in this research topic.

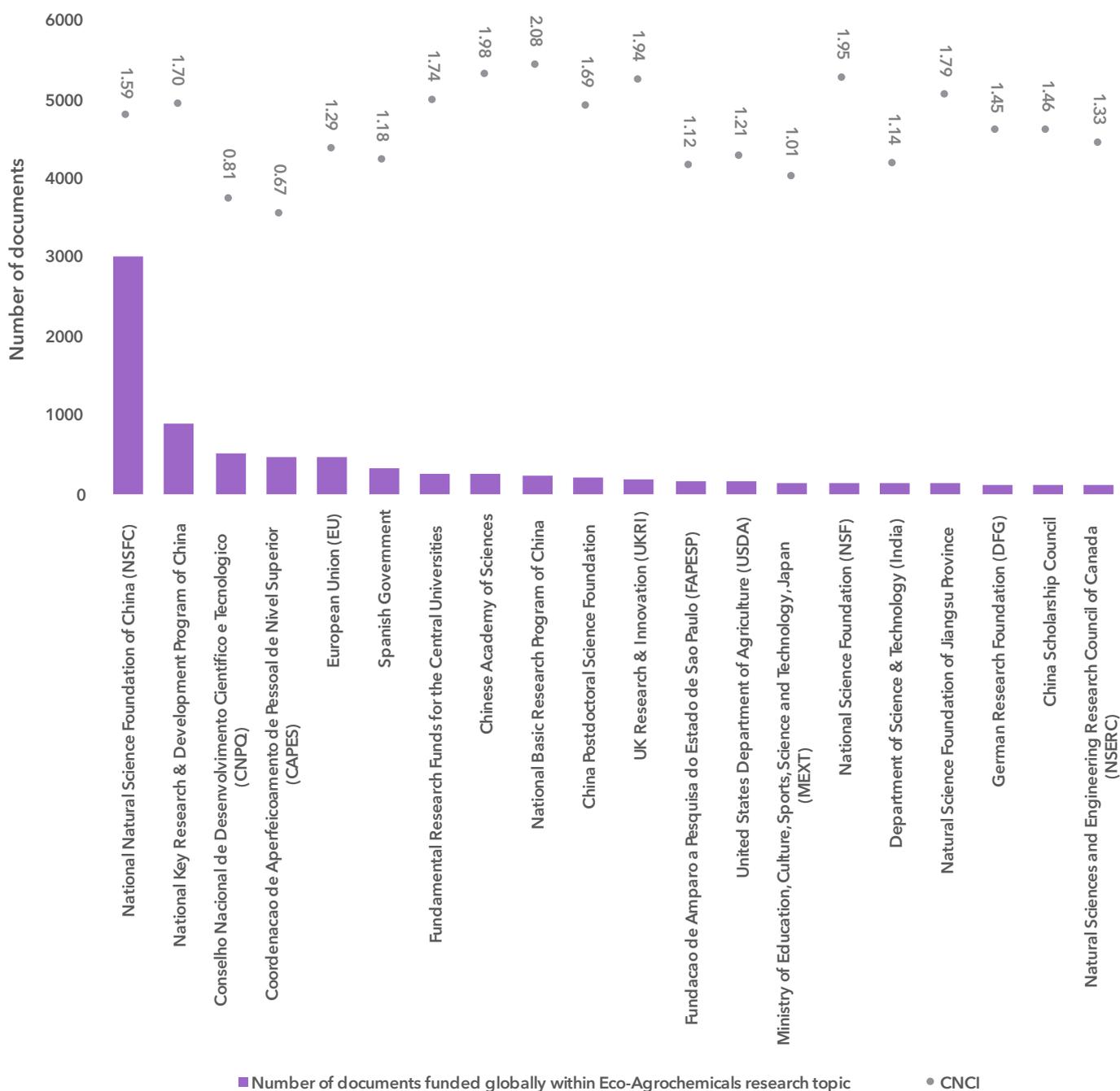


Figure 41: Top 20 funding organizations globally publications in the research topic Eco-Agrochemicals in terms of number of publications in the period 2014-2023

#### 4.1.2.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section we investigate the emerging trends globally and in Saudi Arabia in the research topic Eco-Agrochemicals. For more information on the methodology used to identify emerging trends, please see the section Emerging Trends.

The top three emerging micro-topics globally in this research topic are Soil Science: Biochar followed by Synthesis: Cross-Coupling and Herbicides, Pesticides & Ground Poisoning: Microplastics, as shown in Figure 42.

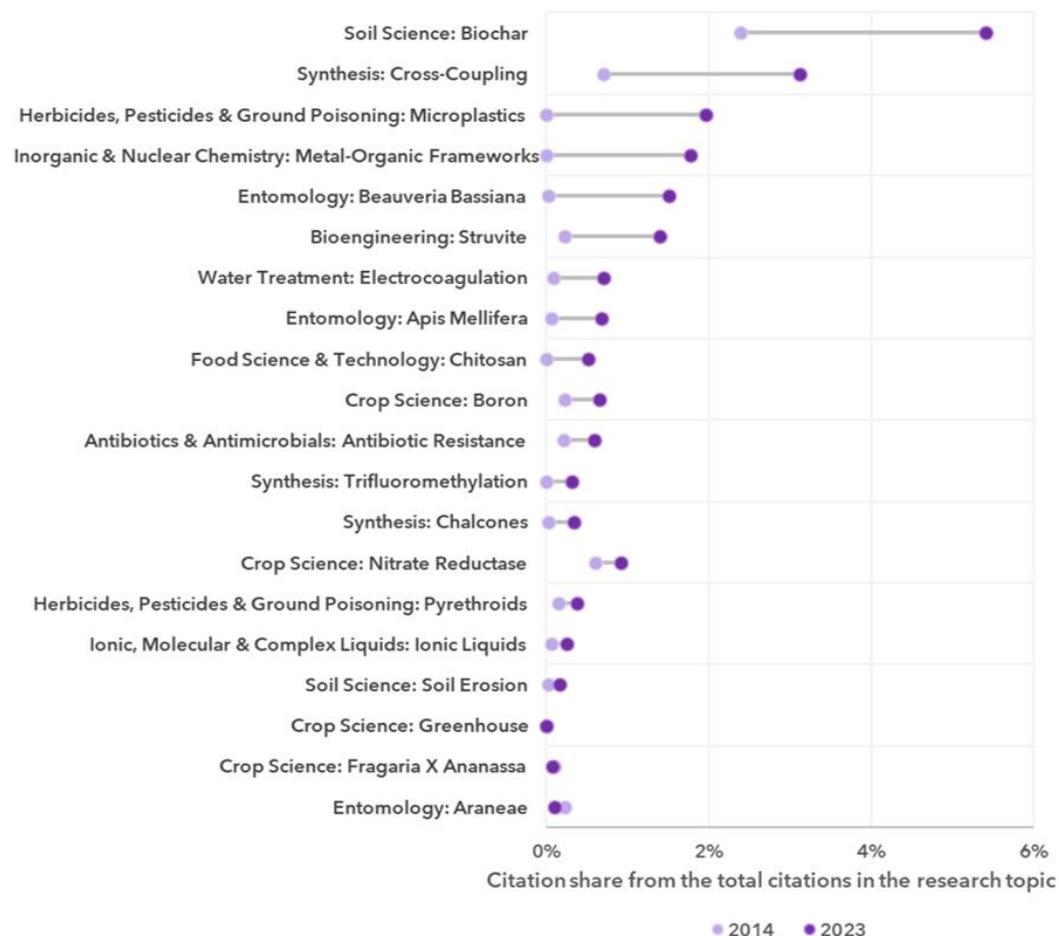


Figure 42: Top 20 emerging micro-topics globally in the research topic Eco-Agrochemicals in the period 2014-2023

Table 10 shows the identified top 10 micro-topics in Saudi Arabia research output in this research topic. Saudi Arabia has publications in the following identified emerging global topics: Soil Science - Biochar.

Table 10: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Eco-Agrochemicals in the period 2014-2023

Topic	Number of Saudi Arabian publications in the period 2014-2023
Eco-Agrochemicals research topic	319
Entomology: Limonoids	34
Nanoparticles: Silver Nanoparticles	25
Soil Science: Biochar	23
Plant Pathology: PGPR	23
Soil Science: Microbial Biomass	18
Soil Science: Composting	10
Photocatalysts: Photocatalysis	10
Herbicides, Pesticides & Ground Poisoning: Atrazine	9
Phytochemicals: Essential Oil	8
Soil Science: Nitrous Oxide	7

### 4.1.3 Food Traceability & Distribution

#### 4.1.3.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabian publications from global publications in the research topic had an oscillating growth trend between 2014 and 2019, but the period between 2020 and 2023 is showing accelerated growth, as seen in Figure 43. This shows that Saudi Arabia was able to increase the number of publications on this research topic and also to have a growth higher than the global growth rate. This is evident as the share of Saudi Arabian publications in the research topic is growing.

The CNCI of Saudi Arabian publications on this research topic were below 1 in 2014 and 2015 and higher than 1 from 2016 to 2023, indicating a citation impact performance higher than the global average. It is important to mention that the CNCI growth is seen in a period of productivity growth. This means that the new publications are not diluting the impact but rather adding or consolidating it. The CNCI oscillations are normal in publication high growth periods, as observed here.

Nevertheless, in 2023, the year with the highest share, the CNCI was still high, showing 69% higher citation impact performance than the global average. Overall, Saudi Arabia's publications increased with a higher growth rate than the worldwide average in this research topic and had a high citation impact as measured by the CNCI.

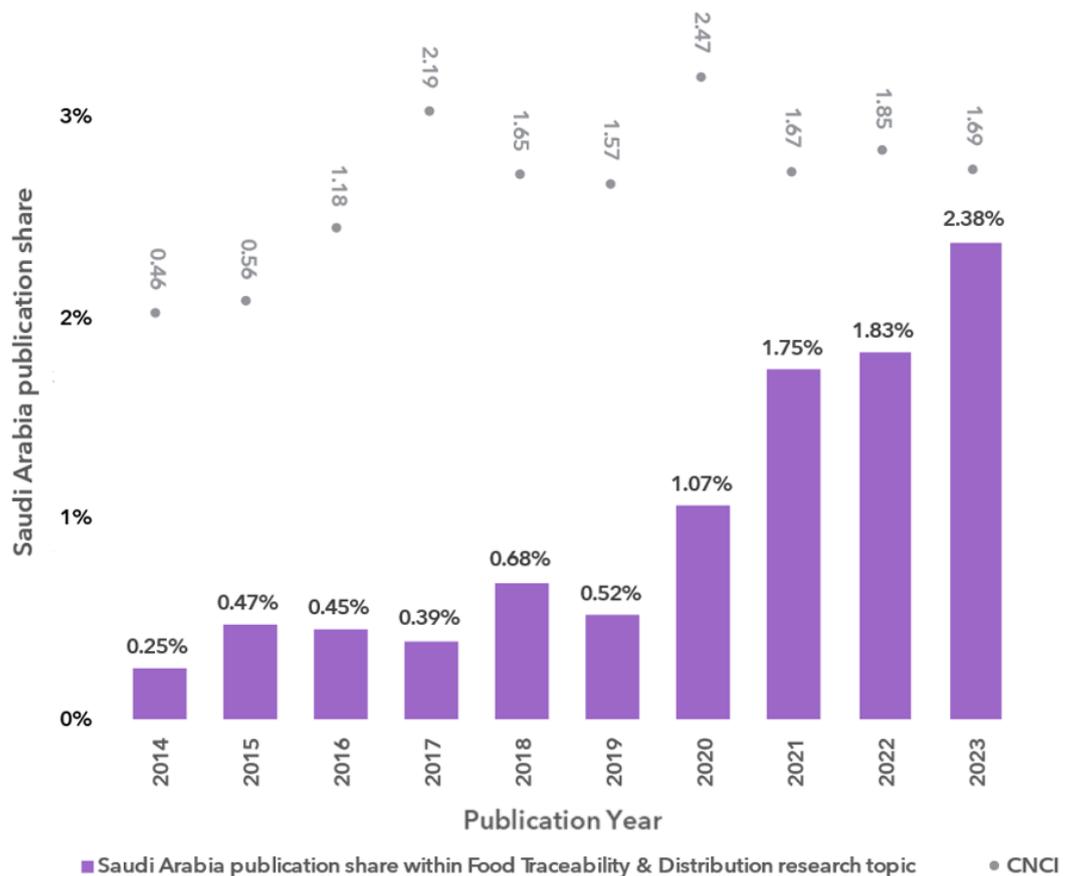


Figure 43: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabian publications in the research topic

#### 4.1.3.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating country with Saudi Arabia in this research topic from 2014-2023 is Egypt, followed by India and Pakistan with 124, 96 and 69 publications, respectively, as shown in Figure 44.

Regarding citation impact measured by the CNCI publications published in collaboration with Mainland China, Malaysia and Pakistan had the highest CNCI with 2.55, 2.51 and 2.33, respectively. Nevertheless, all publications with the top 10 collaborating countries had a CNCI higher than 1, ranging from 1.37 to 2.55, reflecting a performance starting at 37% higher than the global average.

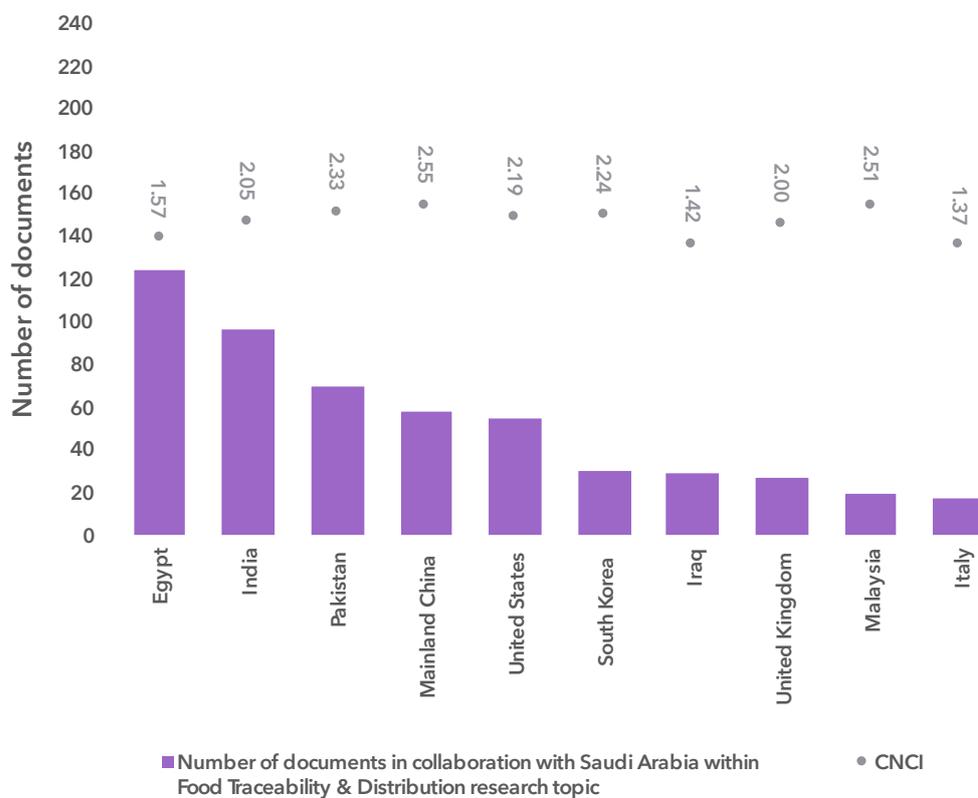


Figure 44: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications in the research topic Food Traceability & Distribution in the period 2014-2023

#### 4.1.3.3 Top 20 funders of Saudi publications by number of publications

The top three funding organizations of Saudi Arabia publications in this research topic in terms of the number of publications mentioning the organization in the funding text in the period 2014-2023 are King Saud University followed by the National Natural Science Foundation of China (NSFC) and Princess Nourah bint Abdulrahman University with 65, 22 and 18 publications respectively as shown in Figure 45.

Publications funded by Ministry of Education, Malaysia, National Key Research & Development Program of China and Genome Canada had the highest citation impact measured by the CNCI with 5.83, 4.47 and 4.25 respectively.

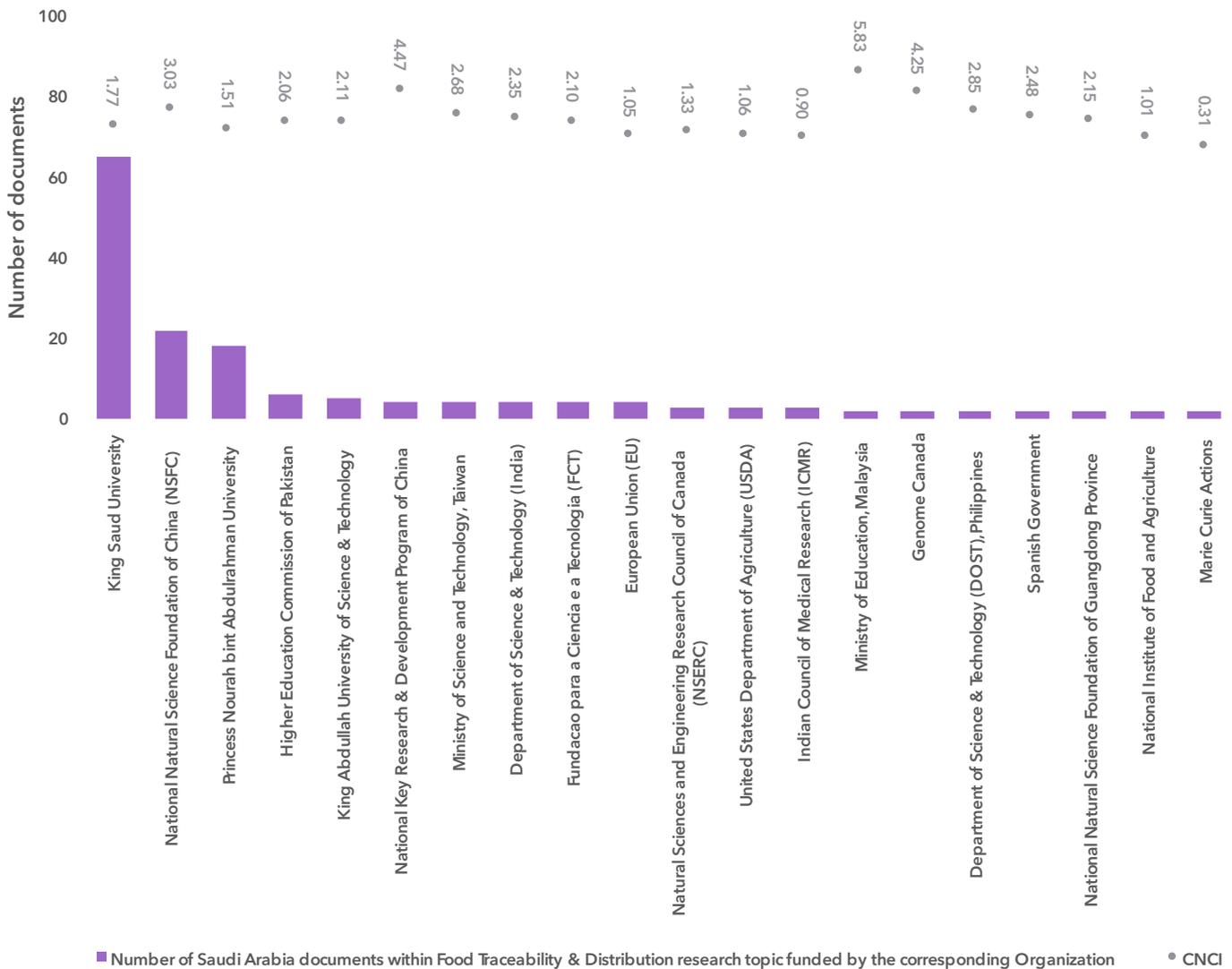


Figure 45: Top 20 funding organizations of Saudi Arabian publications in the research topic Food Traceability & Distribution in terms of number of publications in the period 2014-2023

#### 4.1.3.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top three organizations in terms of publications published in this research topic and the period 2014-2023 are King Saud University, followed by King Abdulaziz University and King Khalid University with 119, 70 and 38 publications, respectively, as shown in Figure 46.

Regarding citation impact as measured by the CNCI, King Saud University, followed by King Abdullah University of Science & Technology, and King Khalid University had the highest CNCI with 2.54, 2.46 and 2.25, respectively. Nevertheless, all top 20 organizations, except Imam Abdulrahman Bin Faisal University, had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

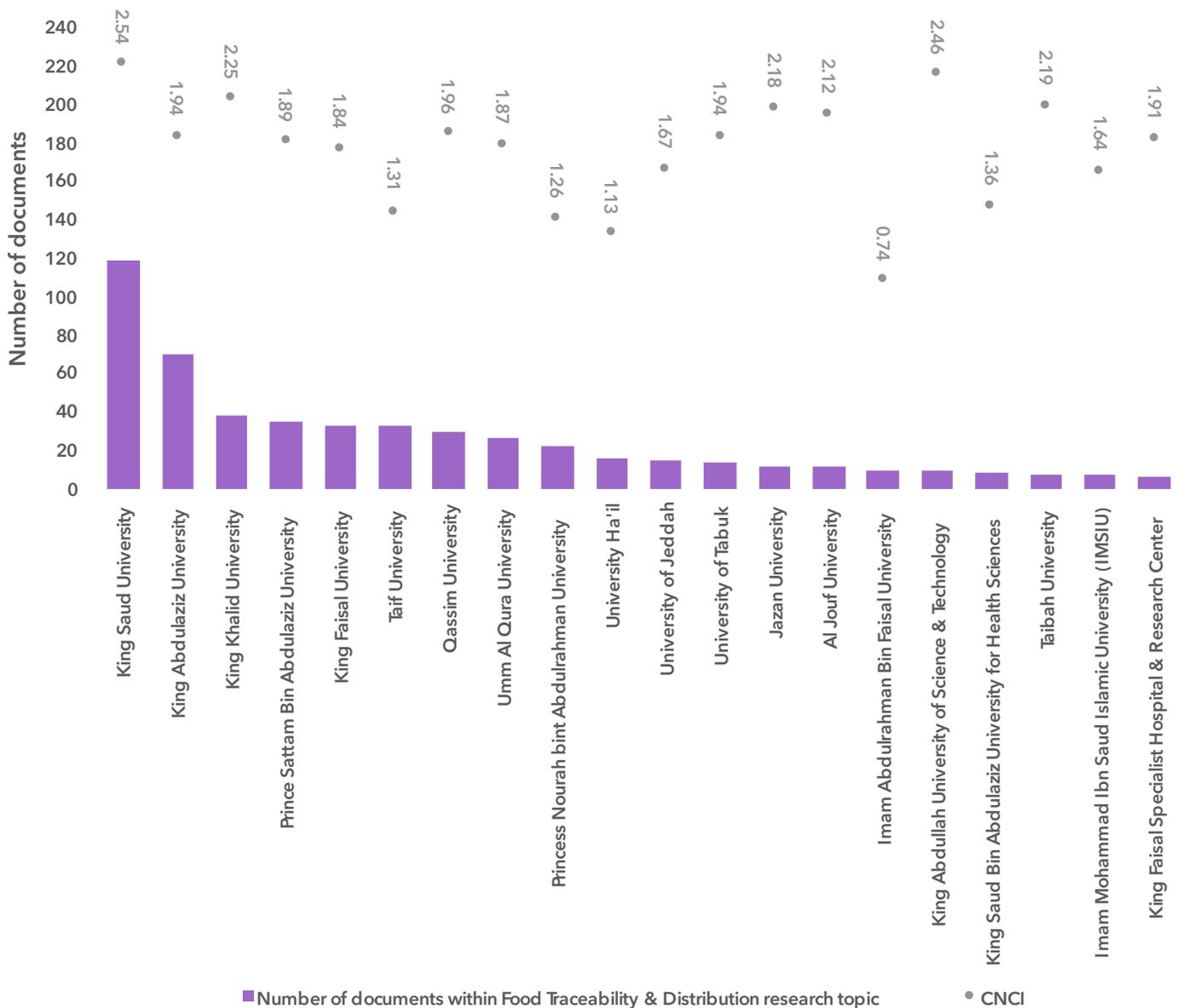


Figure 46: Top 20 Saudi organizations in terms of publications published in the research topic Food Traceability & Distribution in the period 2014-2023 and their corresponding CNCI

#### 4.1.3.5 The top 20 researchers are affiliated with Saudi organizations in terms of the number of publications they publish

The highest number of publications are published by N.N., Misra affiliated with Taif University, followed by Fohad M. Husain, affiliated with King Saud University and Walid Kamal, affiliated with Prince Sattam Bin Abdulaziz University, with 12, 11 and 8 publications, respectively as shown in Table 11.

The highest CNCI is achieved by publications published by N.N. Misra, affiliated with Taif University, with a CNCI of 5.53.

The latter researcher also has the highest number of Top 10% publications, with seven publications.

Table 11: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published in the research topic Food Traceability & Distribution in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%
Misra, N.N.	Taif University	11	5.53	1	7
Husain, Fohad M	King Saud University	11	1.67	0	2
Kamal, Walid	Prince Sattam Bin Abdulaziz University	8	2.40	1	3
Khan, Javed Masood	King Saud University	8	1.39	0	1
AlShabib, Nasser	King Saud University	8	2.00	0	2
Khan, Mohammad Rizwan	King Saud University	7	2.59	1	5
Mani, Veerappan	King Abdullah University of Science & Technology	7	2.72	0	4
Alshejari, A. A.	Princess Nourah bint Abdulrahman University	7	0.40	0	0
El-Seedi, Hesham R.	Islamic University of Al Madinah	6	1.58	0	3
Aljasir, Sulaiman	Qassim University	6	0.55	0	0
Khan, Shahbaz	University of Tabuk	5	1.86	0	2
Mir, Shabir Ahmad	Govt Coll Women	5	2.35	0	2
Alsayeqh, Abdullah F.	Qassim University	5	1.12	0	1
Alves, Ricardo N.	King Abdullah University of Science & Technology	4	1.43	0	1
Shehata, Adel B.	Saudi Standards, Quality & Metrology Organization (SASO)	4	1.53	0	1
Khan, Rais Ahmad	King Saud University	4	2.21	0	1
Alam, Syed Shah	Prince Sultan University	4	1.15	0	0
Sameeh, Manal Y.	Umm Al Qura University	4	1.89	0	2
Althomali, Raed H.	Prince Sattam Bin Abdulaziz University	4	0.47	0	0

#### 4.1.3.6 Top 10 countries in terms of publications

The highest number of publications published on this research topic is published by Mainland China (10,849 publications), followed by the United States (6,475 publications) and Italy (3,153 publications), as shown in Figure 47.

The highest citation impact measured by the CNCI is achieved by publications published by Mainland China, Canada and India with a CNCI of 1.42, 1.40 and 1.36 respectively.

Six of the top 10 countries in terms of number of publications published in the research topic are also among the top 10 collaborators with Saudi Arabia. These are Mainland China, the United States, Italy, the United Kingdom, India and South Korea.

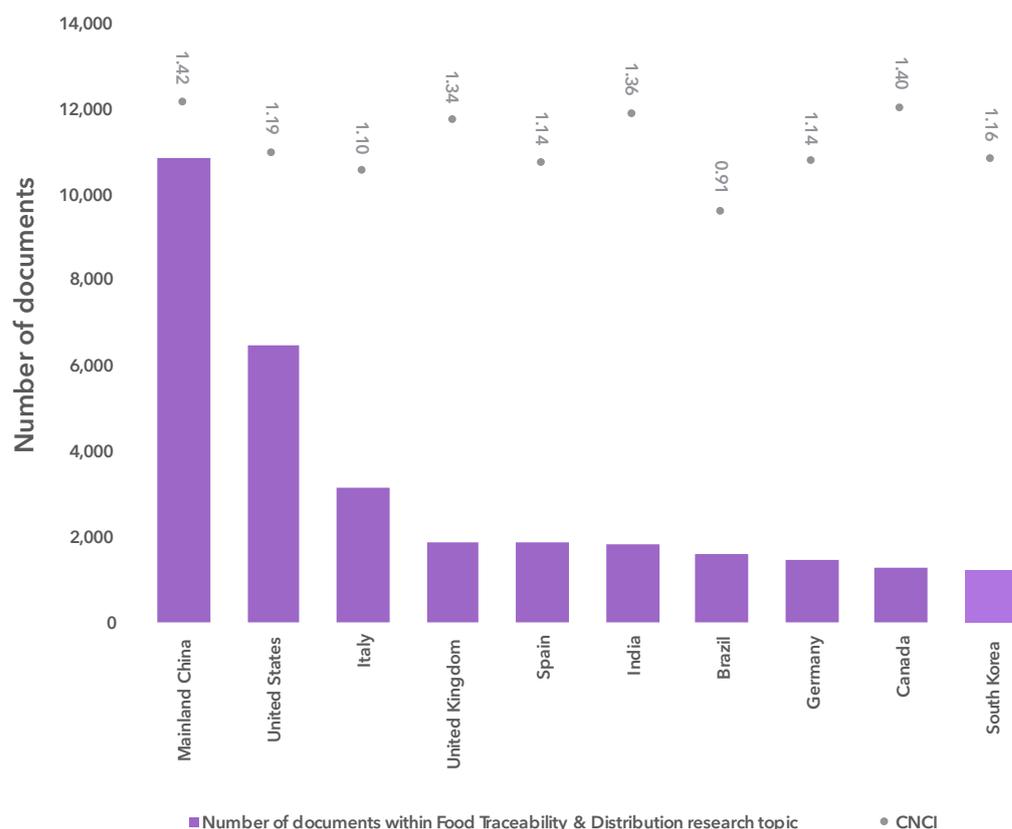


Figure 47: Top 10 countries in terms of the number of publications in the Food Traceability & Distribution in the period 2014-2023 and their corresponding CNCI

#### 4.1.3.7 Top 20 organizations globally in terms of number of publications

The top three organizations in terms of the number of publications published on this research topic from 2014-2023 are the United States Department of Agriculture (USDA) (858 publications), followed by the Chinese Academy of Sciences (821 publications) and the European Food Safety Authority (805 publications) as shown in Figure 48.

Regarding citation impact measured by the CNCI, Nanjing Agricultural University followed by the Chinese Academy of Agricultural Sciences and Jiangsu University had the highest CNCI with 1.77, 1.67 and 1.66 respectively.

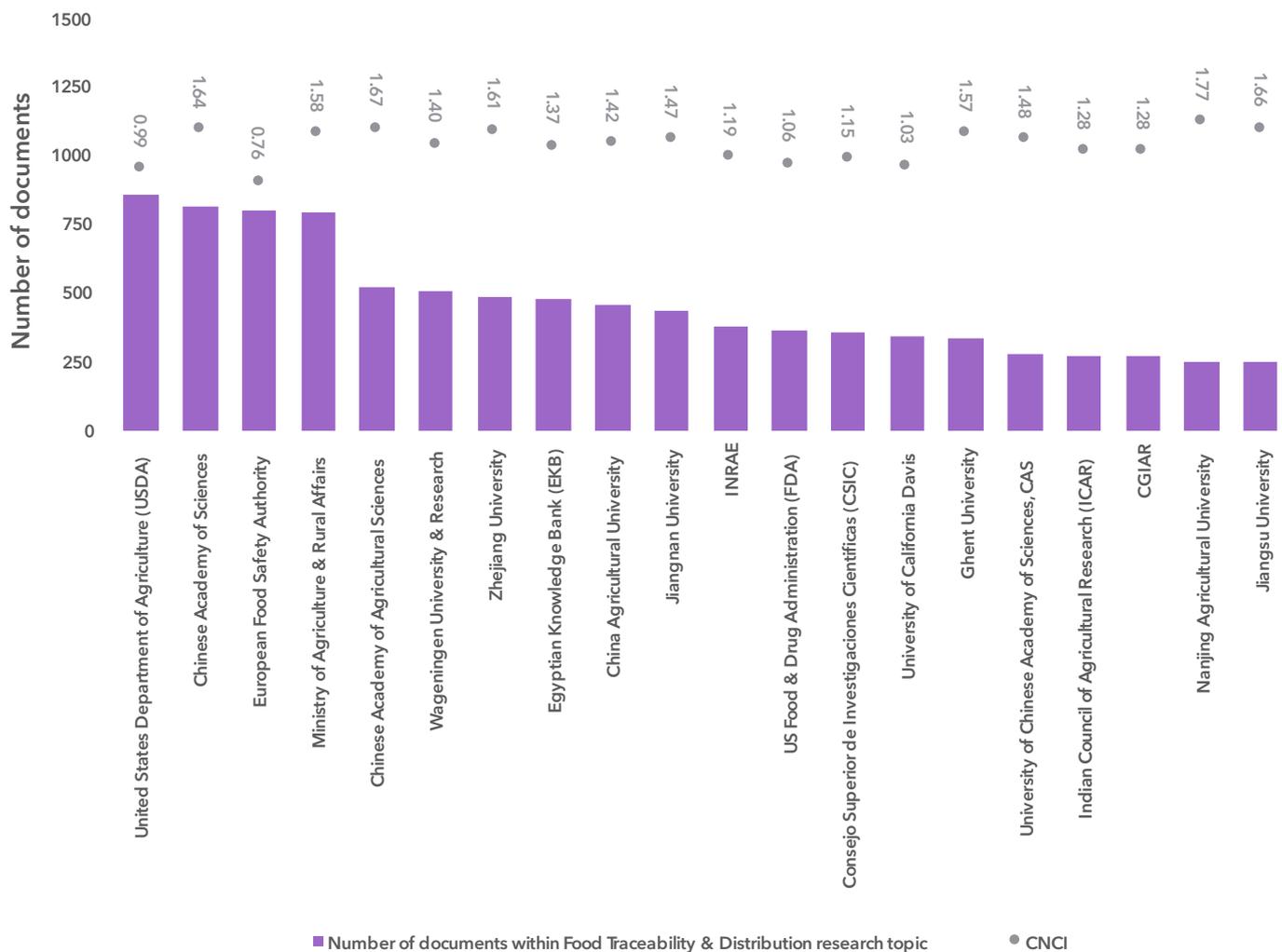


Figure 48: Top 20 organizations globally in terms of the number of publications published in the research topic Food Traceability & Distribution in the period 2014-2023 and their corresponding CNCI

#### 4.1.3.8 Top 20 researchers globally in terms of number of publications

The top three researchers globally in terms of the number of publications in this research topic are Vasileios A. Bampidis, affiliated with International Hellenic University, with 655 publications, followed by Secundino López affiliated with Universidad de Leon, with 644 publications, and Baltasar Mayo, affiliated with Consejo Superior de Investigaciones Científicas (CSIC) with 626 publications as shown in Table 12.

The highest CNCI is achieved by van Henk Loveren, affiliated with Maastricht University, with 0.64. The highest number of Top 1% is achieved by Vasileios A. Bampidis, affiliated with International Hellenic University, with 14 publications, and the Top 10% publications are achieved by Yolanda Sanz, affiliated with Instituto de Agroquímica y Tecnología de los Alimentos (IATA) with 27 publications.

Table 12: Top 20 researchers globally in terms of the number of publications published in the research topic Food Traceability & Distribution in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%	Country
<b>Bampidis, Vasileios A.</b>	International Hellenic University	655	0.47	14	21	Greece
<b>López, Secundino</b>	Universidad de Leon	644	0.32	6	8	Spain
<b>Mayo, Baltasar</b>	Consejo Superior de Investigaciones Científicas (CSIC)	626	0.32	6	8	Spain
<b>Ramos, Fernando</b>	Universidade de Coimbra	590	0.35	7	10	Portugal
<b>de Lourdes Bastos, Maria</b>	Universidade do Porto	573	0.32	5	7	Portugal
<b>Chesson, Andrew</b>	EFSA Food Contact Mat	571	0.37	8	9	USA
<b>COCCONCELLI, Pier Sandro</b>	Catholic University of the Sacred Heart	560	0.46	11	16	Italy
<b>Sanz, Yolanda</b>	Instituto de Agroquímica y Tecnología de los Alimentos (IATA)	512	0.44	7	27	Spain
<b>Bolognesi, Claudia</b>	Osped Policlin San Martino	511	0.24	4	8	Italy
<b>Azimonti, Giovanna</b>	European Food Safety Authority	476	0.38	6	7	Italy
<b>Dusemund, Birgit</b>	Bergstr 114	451	0.34	2	9	Germany
<b>Tlustos, Christina</b>	EFSA Food Contact Mat	446	0.24	3	7	Italy
<b>Grob, Konrad</b>	EFSA Food Contact Mat	443	0.24	3	7	Italy
<b>Zorn, Holger</b>	Justus Liebig University Giessen	439	0.24	3	6	Germany
<b>van Loveren, Henk</b>	Maastricht University	430	0.64	11	24	Netherlands
<b>Mortensen, Alicja</b>	National Research Centre for the Working Environment	426	0.56	10	20	Denmark
<b>Crebelli, Riccardo</b>	EFSA Panel Food Contact Mat	410	0.42	5	12	Italy
<b>Saarela, Maria</b>	VTT Technical Research Center Finland	383	0.39	5	6	Finland
<b>Marcon, Francesca</b>	Istituto Superiore di Sanita (ISS)	378	0.22	2	4	Italy
<b>Jarrah, Samira</b>	European Food Safety Authority	378	0.19	1	1	Italy

#### 4.1.3.9 Top 20 global funders globally in terms of number of publications

The top three organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC) with 5,546 publications, followed by the European Union (EU) with 1,023 publications, and the National Key Research & Development Program of China with 1,017 publications as shown in Figure 49.

The highest citation impact measured by the CNCI is observed in publications funded by the China Postdoctoral Science Foundation and National Science Foundation (NSF), with 1.75 and 1.74, respectively, followed by Fundamental Research Funds for the Central Universities and UK Research & Innovation (UKRI) achieving the same CNCI of 1.72. Among the top 20 global funding organizations, seven are also among the top 20 funding organizations of Saudi publications in this research topic.

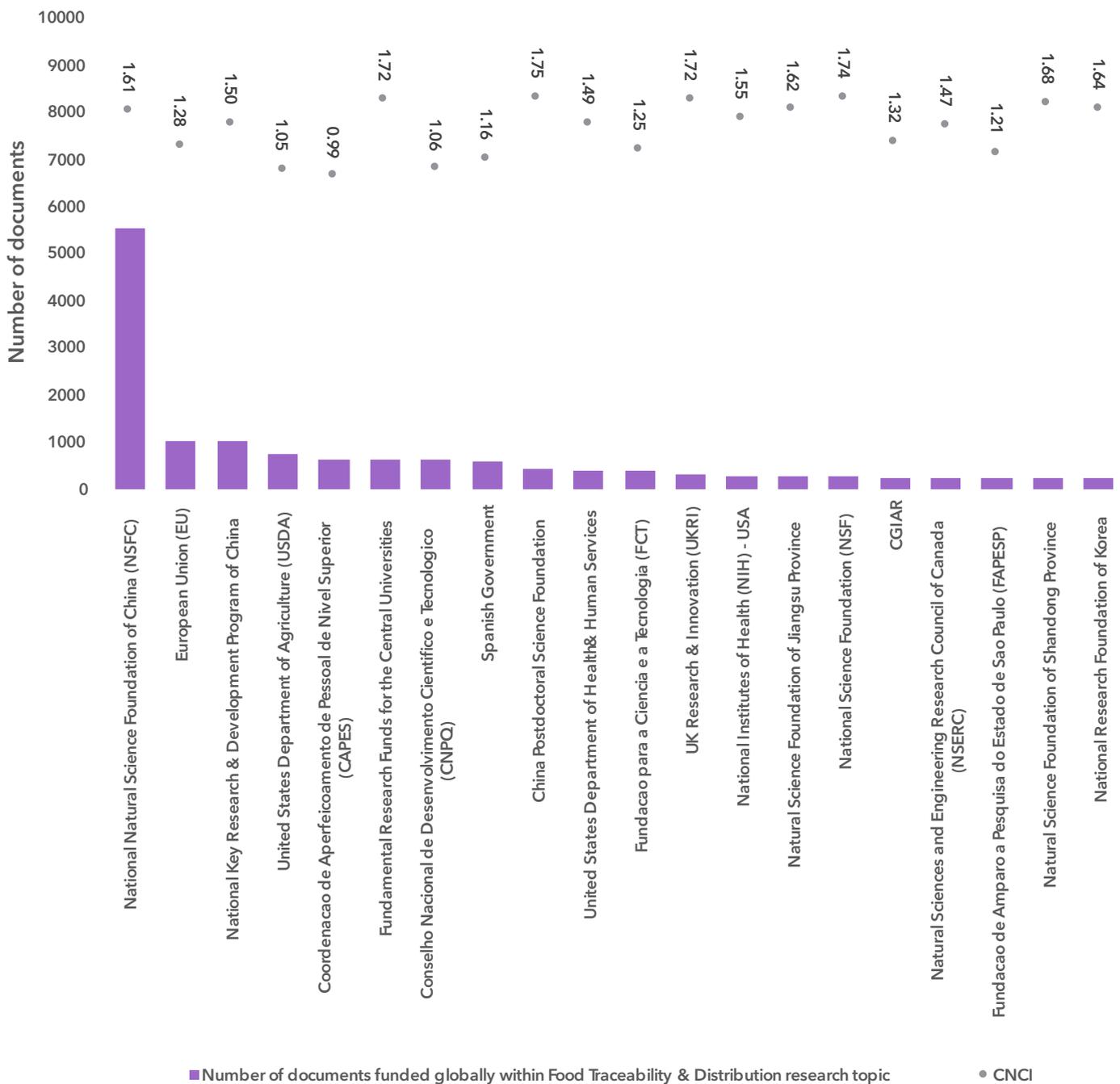


Figure 49: Top 20 funding organizations globally publications in the research topic Food Traceability & Distribution in terms of number of publications in the period 2014-2023

#### 4.1.3.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section, we investigate the emerging trends globally and in Saudi Arabia on the research topic of Food Traceability & Distribution. For more information on the methodology used to identify emerging trends, please see the section Emerging Trends.

The top three emerging micro-topics globally in this research topic are Nanoparticles: Carbon Dots, Security Systems: Blockchain and Molecular & Cell Biology - Genetics: Genome Editing, as shown in Figure 50.

Table 13 shows the identified top 10 micro-topics in Saudi Arabia research output in this research topic.

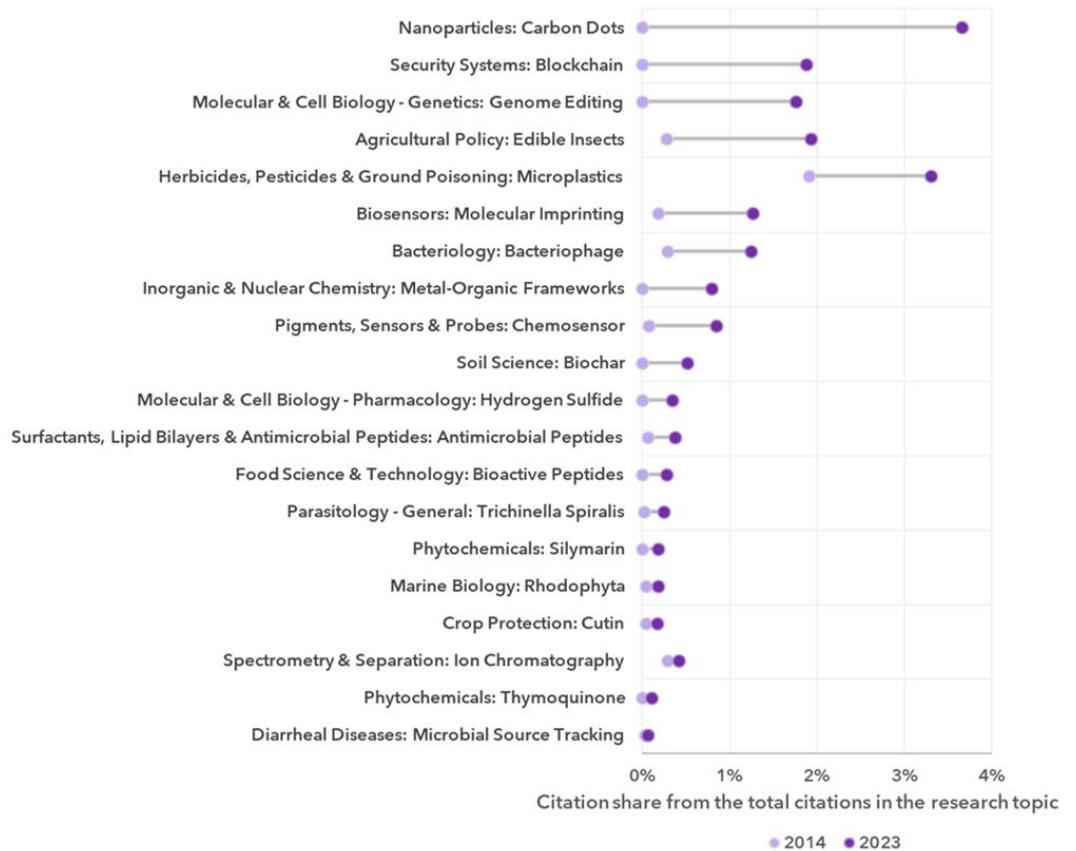


Figure 50: Top 20 emerging micro-topics globally in the research topic Food Traceability & Distribution in the period 2014-2023

Table 13: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Food Traceability & Distribution in the period 2014-2023

Topic	Number of Saudi Arabian publications in the period 2014-2023
Food Traceability & Distribution research topic	461
Bacteriology: Listeria Monocytogenes	37
Contamination & Phytoremediation: Heavy Metals	31
Biosensors: Aptamer	29
Nanoparticles: Silver Nanoparticles	16
Biosensors: Glucose Oxidase	15
Bacteriology: Salmonella	12
Inflammatory Bowel Diseases & Infections: Lactic Acid Bacteria	10
Food Science & Technology: Chitosan	9
Dairy & Animal Sciences: Meat Characteristics	8
Herbicides, Pesticides & Ground Poisoning: Solid-Phase Microextraction	8

## 4.1.4 Food-Borne Hazard Control

### 4.1.4.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabian publications from global publications on the research topic increased continuously from 1.05 % in 2014 to 3.42% in 2023, as shown in Figure 51. The highest share was achieved in 2022, with 3.69%. This shows that Saudi Arabia was not only able to increase the number of publications on this research topic but also had a growth higher than the global growth rate. This is evident as the share of Saudi Arabian publications in the research topic is growing.

The CNCI of Saudi Arabian publications on this research topic were in all years higher than 1, except for 2014, indicating a citation impact performance higher than the global average. During this period, the CNCI increased from 0.87 in 2014 to 1.64 in 2023, and the highest value was achieved in 2015 with 1.72. In a high-growth publication period, it is usually observed that the citation impact oscillates, as also observed in this case.

Overall, Saudi Arabia's publications increased with a higher growth rate than the global average in this research topic and had a citation impact well above the global average as measured by the CNCI. Nevertheless, after this high growth rate in terms of publications, one should focus on maintaining the impact of citations.

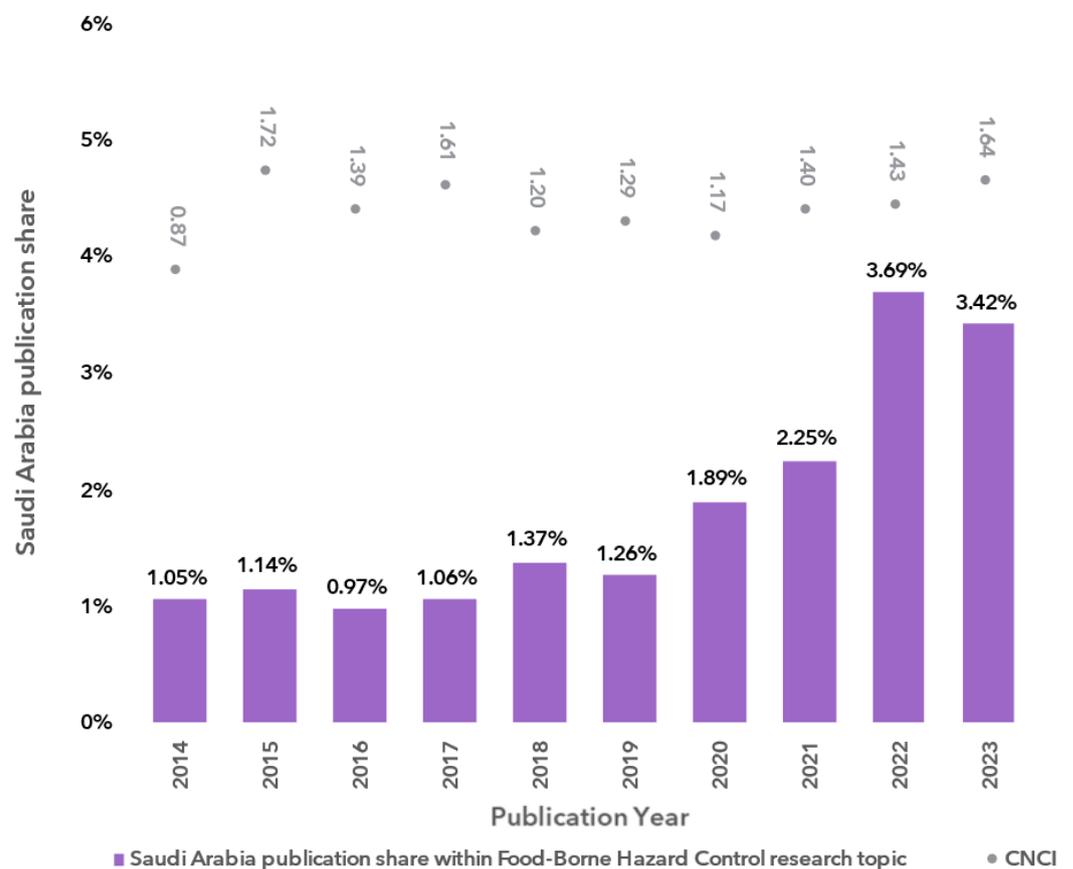


Figure 51: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabian publications in the research topic

### 4.1.4.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating countries with Saudi Arabia in this research topic from 2014-2023 is Egypt, followed by India and Pakistan with 395, 190 and 138 publications, respectively, as shown in Figure 52.

Regarding citation impact measured by the CNCI publications published in collaboration with Italy followed by Malaysia and United Kingdom had the highest

CNCI with 3.63, 3.43 and 3.34 respectively. Nevertheless, all publications with the top 10 collaborating countries had a CNCI higher than 1, ranging from 1.78 to 3.63, reflecting a performance higher than the global average of at least 78%.

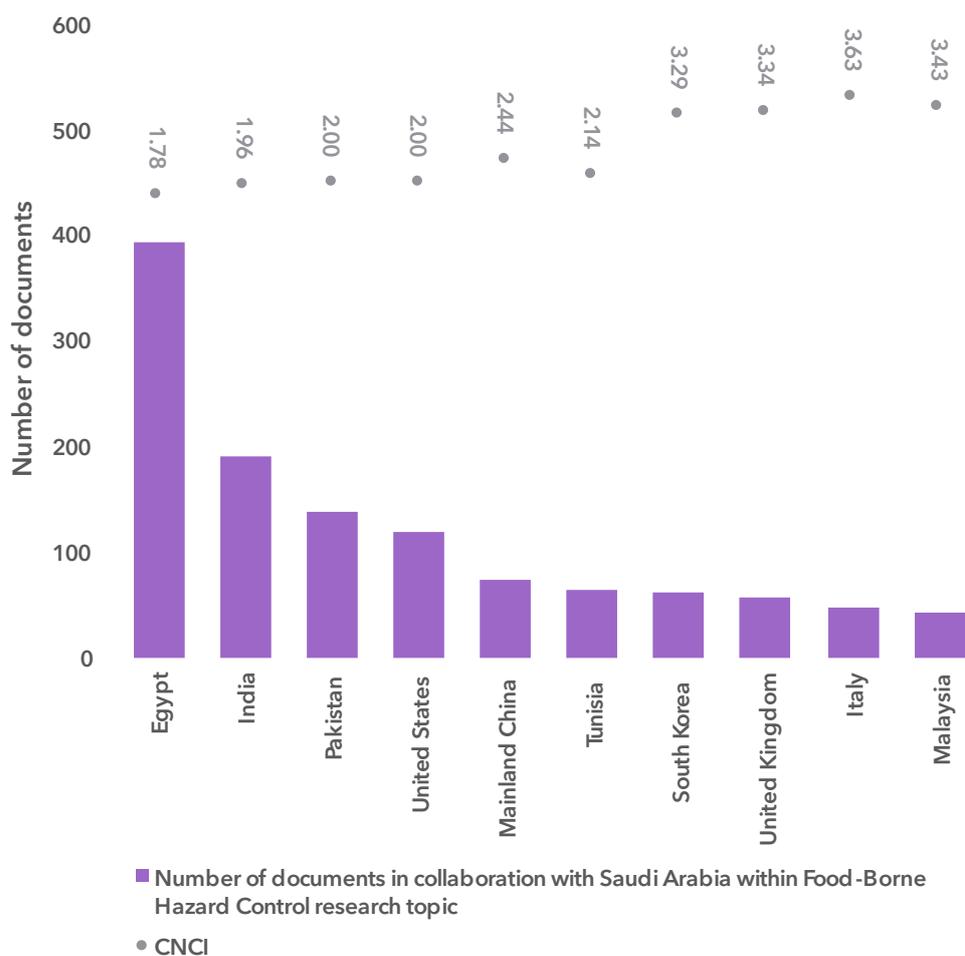


Figure 52: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications in the research topic Food-Borne Hazard Control in the period 2014-2023

#### 4.1.4.3 Top 20 funders of Saudi publications by number of publications

The top three funding organizations of Saudi Arabian publications in this research topic in terms of the number of publications mentioning the organization in the funding text from 2014-2023 are King Saud University followed by Princess Nourah bint Abdulrahman University and National Natural Science Foundation of China (NSFC) with 228, 45 and 18 publications respectively as shown in Figure 53.

Publications funded by Wellcome Trust, CGIAR and UK Research & Innovation (UKRI) had the highest citation impact measured by the CNCI with 12.63, 11.08 and 8.28, respectively.

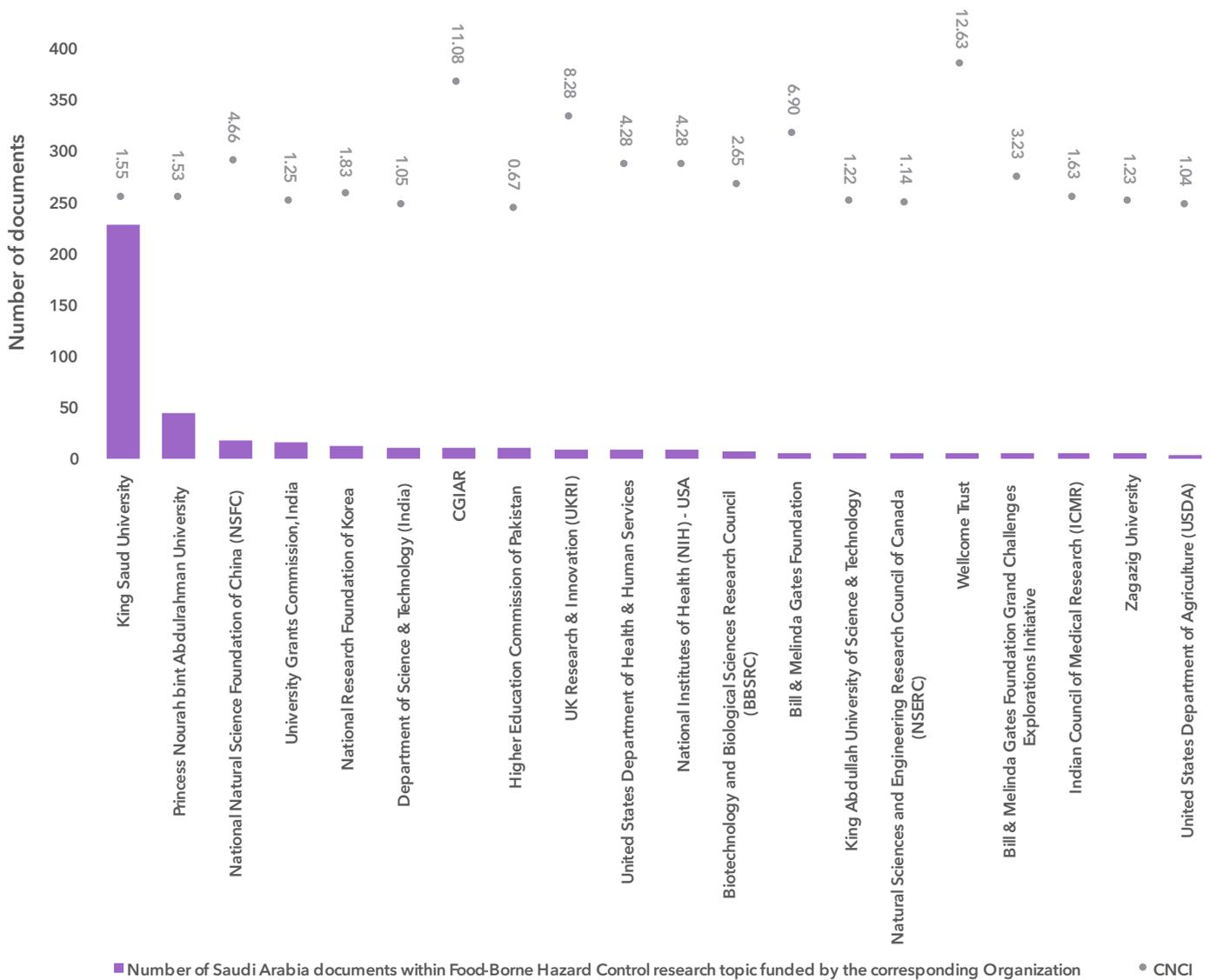


Figure 53: Top 20 funding organizations of Saudi Arabian publications in the research topic Food-Borne Hazard Control in terms of number of publications in the period 2014-2023

#### 4.1.4.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top three organizations in terms of publications published in this research topic from 2014-2023 are King Saud University followed by King Abdulaziz University and Taif University with 392, 155 and 92 publications, respectively, as shown in Figure 54.

Regarding citation impact as measured by the CNCI, Jazan University, King Faisal Specialist Hospital & Research Center, and King Khalid University had the highest CNCI with 3.28, 2.10 and 2.00, respectively. Nevertheless, almost all top 20 organizations, except Al Jouf University and Majmaah University, had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

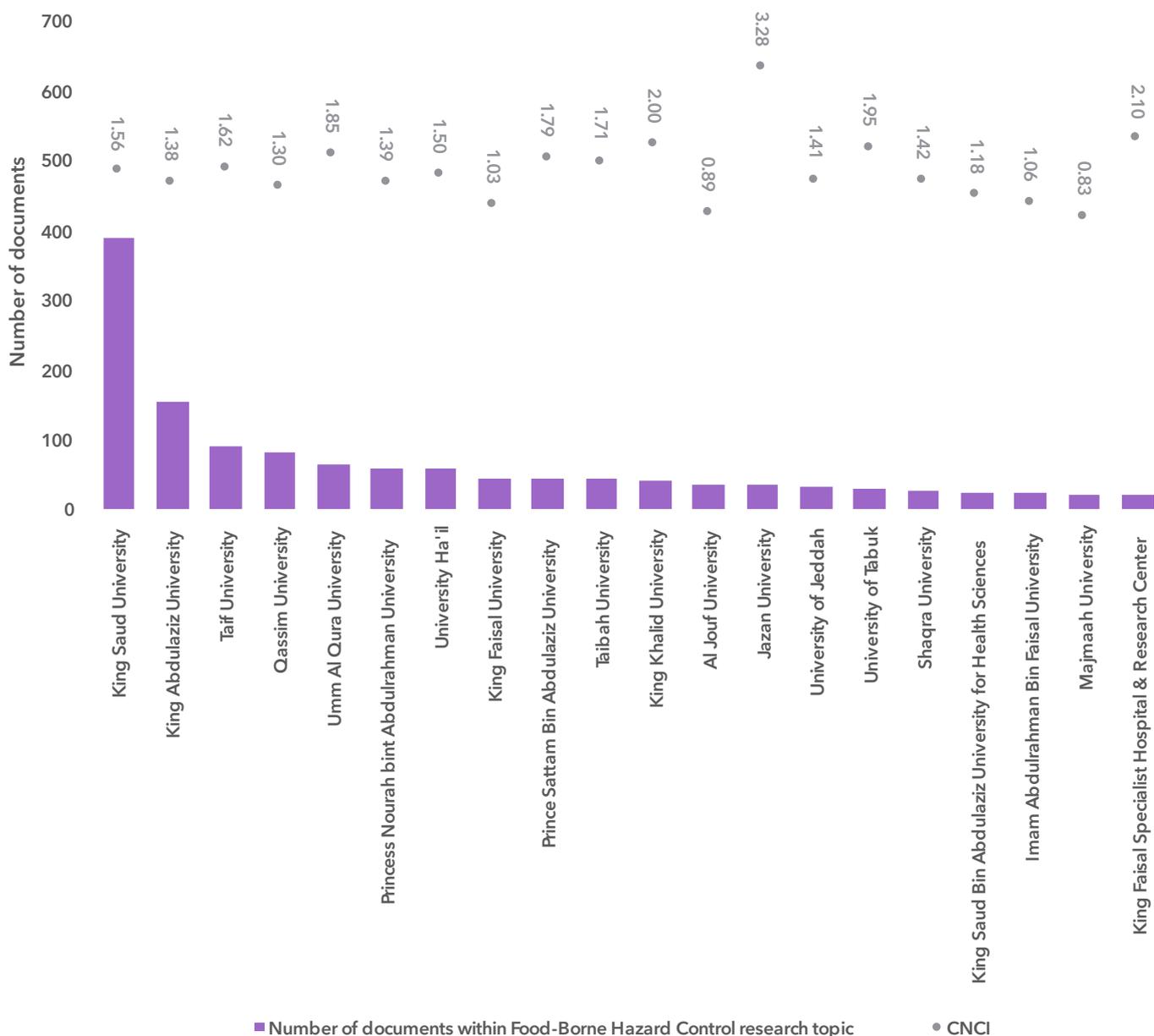


Figure 54: Top 20 Saudi organizations in terms of publications published in the research topic Food-Borne Hazard Control in the period 2014-2023 and their corresponding CNCI

#### 4.1.4.5 The top 20 researchers are affiliated with Saudi organizations in terms of the number of publications they publish

The highest number of publications are published by researchers affiliated with King Saud University: Fohad Mabood Husain followed by Alaeldein M. Abudabos and Hany M. Yehia, with 16, 15 and 11 publications, respectively, as shown in Table 14. The highest CNCI is achieved by publications published by Ayman A. Swelum affiliated with King Saud University with a CNCI of 7.04.

The latter researcher has also the highest number of Top 1% with 3 publications while Fohad Mabood Husain affiliated with King Saud University has the highest number of Top 10% publications with 5 publications, mentioned above as the researcher with the highest overall number of publications. Only six researchers among the top 20 have one Top 1% document.

Table 14: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published in the research topic Food-Borne Hazard Control in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%
Husain, Fohad Mabood	King Saud University	16	1.97	0	6
Abudabos, Alaeldein M.	King Saud University	15	2.31	2	5
Yehia, Hany M.	King Saud University	11	0.56	0	0
Al-Hindi, Rashad R.	King Abdulaziz University	10	2.25	1	3
Selim, Samy	Al Jouf University	10	1.00	0	1
Swelum, Ayman A.	King Saud University	10	7.04	3	5
Al-Dhabi, Naif Abdullah	King Saud University	9	1.61	0	3
Alharbi, Mona G.	King Abdulaziz University	9	1.63	0	2
Devanesan, Sandhanasamy	King Saud University	9	2.12	1	4
Mnif, Wissem	University of Bisha	9	1.95	1	3
Moussa, Shaaban H.	Shaqra University	9	1.37	0	2
Sami, Rokayya	Taif University	9	1.05	0	1
Adnan, Mohd	University Ha'il	8	2.51	0	5
Al-Shabib, Nasser A.	King Saud University	8	1.58	0	2
Elbanna, Khaled	Umm Al Qura University	8	1.91	0	2
Elbehiry, Ayman	Qassim University	8	1.10	0	1
Hemeg, Hassan A.	Taibah University	8	1.05	0	1
Khan, Javed Masood	King Saud University	8	2.06	0	3
Banawas, Saeed	Majmaah University	7	0.50	0	0
Dawoud, Turki M.	King Saud University	7	3.65	1	2

#### 4.1.4.6 Top 10 countries in terms of publications

The highest number of publications published on this research topic is published by the United States (14,419 publications), followed by Mainland China (9,318 publications) and India (4,336 publications), as shown in Figure 55. The highest citation impact measured by the CNCI is achieved by publications published by United Kingdom, Germany and Italy with a CNCI of 1.40, 1.35 and 1.30 respectively.

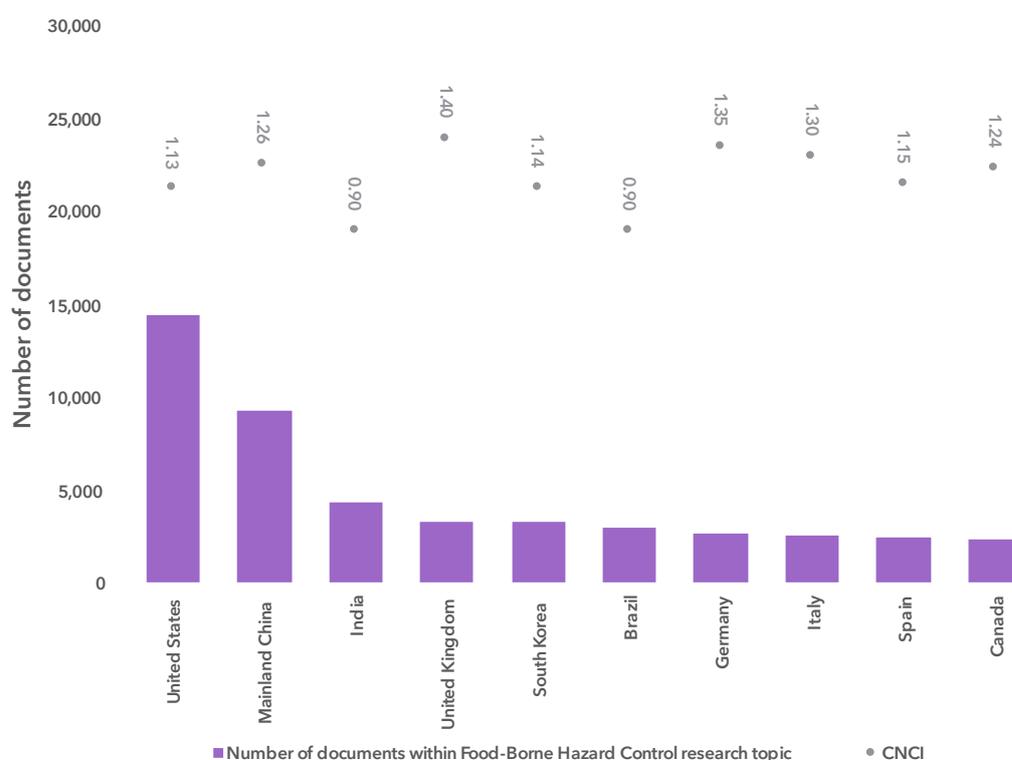


Figure 55: Top 10 countries in terms of the number of publications in the Food-Borne Hazard Control in the period 2014-2023 and their corresponding CNCI

Seven of the top 10 countries in terms of number of publications published in the research topic are also among the top 10 collaborators with Saudi Arabia. These are the United States, Mainland China, India, the United Kingdom, South Korea and Italy.

#### 4.1.4.7 Top 20 organizations globally in terms of number of publications

The top three organizations in terms of number of publications published in this research topic from 2014-2023 are the United States Department of Agriculture (USDA) (1726 publications) followed by the US Food & Drug Administration (FDA) (824 publications) and the University of Georgia (803 publications) as shown in Figure 56.

Regarding citation impact measured by the CNCI, Centers for Disease Control & Prevention - USA, Peter Doherty Institute and the University of Oxford had the highest CNCI with 2.48, 1.78, and 1.65, respectively.

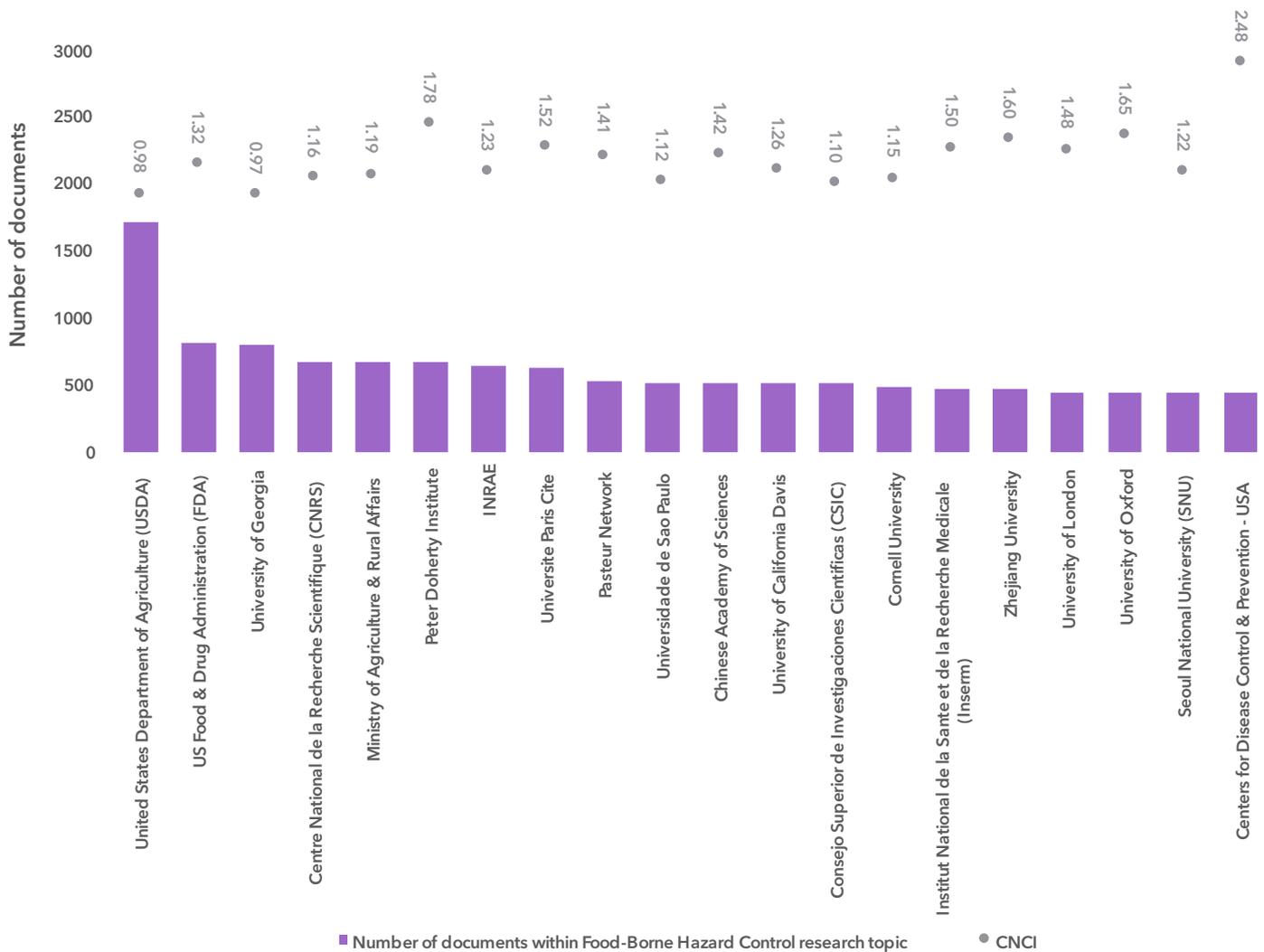


Figure 56: Top 20 organizations globally in terms of the number of publications published in the research topic Food-Borne Hazard Control in the period 2014-2023 and their corresponding CNCI

#### 4.1.4.8 Top 20 researchers globally in terms of number of publications

The top three researchers globally in terms of the number of publications in this research topic are Martin Wiedmann, affiliated with Cornell University, with 136 publications, followed by Xinan Jiao, affiliated with Yangzhou University, with 126 publications, and Dong-Hyun Kang, affiliated with Seoul National University (SNU), with 115 publications as shown in Table 15.

The highest CNCI is achieved by Jianhan Lin affiliated with China Agricultural University with 1.95.

The latter is also the researcher with the highest number of Top 10% publications with 25 publications. In comparison, Baker, Stephen, affiliated with University of Oxford, achieved the highest number of Top 1% papers. affiliated with

Table 15: Top 20 researchers globally in terms of the number of publications published on the research topic Food-Borne Hazard Control in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%	Country
<b>Wiedmann, Martin</b>	Cornell University	136	1.25	2	18	United States
<b>Jiao, Xinan</b>	Yangzhou University	126	0.83	0	3	Mainland China
<b>Kang, Dong-Hyun</b>	Seoul National University (SNU)	115	1.13	0	10	South Korea
<b>Lee, John Hwa</b>	Jeonbuk National University	112	0.65	0	3	South Korea
<b>Hoffman, Robert M.</b>	University of California San Diego	108	0.98	0	15	United States
<b>Wu, Qingping</b>	Guangdong Academy of Sciences	108	1.42	1	24	Mainland China
<b>Ricke, Steven C.</b>	University of Arkansas Fayetteville	97	0.95	3	10	United States
<b>Pan, Zhiming</b>	Yangzhou University	90	0.85	0	3	Mainland China
<b>Zhang, Jumei</b>	Guangdong Academy of Sciences	90	1.54	1	24	Mainland China
<b>Ha, Sang-Do</b>	Chung Ang University	89	1.63	3	19	South Korea
<b>Stephan, Roger</b>	University of Zurich	88	1.03	1	16	Switzerland
<b>Baker, Stephen</b>	University of Oxford	78	1.85	3	22	England
<b>Xu, Hengyi</b>	Nanchang University	75	1.50	0	18	Mainland China
<b>Ryu, Sangryeol</b>	Seoul National University (SNU)	73	1.05	0	7	South Korea
<b>Xu, Xuebin</b>	Shanghai Center for Disease Control & Prevention	73	1.35	1	13	Mainland China
<b>Tang, Juming</b>	Washington State University	71	1.32	0	11	United States
<b>Pollard, Andrew J.</b>	University of Oxford	70	1.25	0	14	England
<b>Hensel, Michael</b>	University Osnabruck	68	0.81	0	5	Germany
<b>Fanning, Seamus</b>	University College Dublin	67	1.08	0	12	Ireland
<b>Lin, Jianhan</b>	China Agricultural University	67	1.95	2	25	Mainland China

#### 4.1.4.9 Top 20 global funders globally in terms of number of publications

The top three organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC) with 4838 publications, followed by the United States Department of Health & Human Services with 3590 publications, and the National Institutes of Health (NIH) - USA with 3299 publications as shown in Figure 57.

The highest citation impact measured by the CNCI is observed in publications funded by Bristol-Myers Squibb, AstraZeneca & Medical Research Council UK (MRC), achieving the same CNCI and NIH National Cancer Institute (NCI) with Wellcome Trust, UK Research & Innovation (UKRI) and United States Department of Health & Human Services respectively. Among the top 20 global funding organizations, nine are also among the top 20 funding organizations of Saudi publications in this research topic.

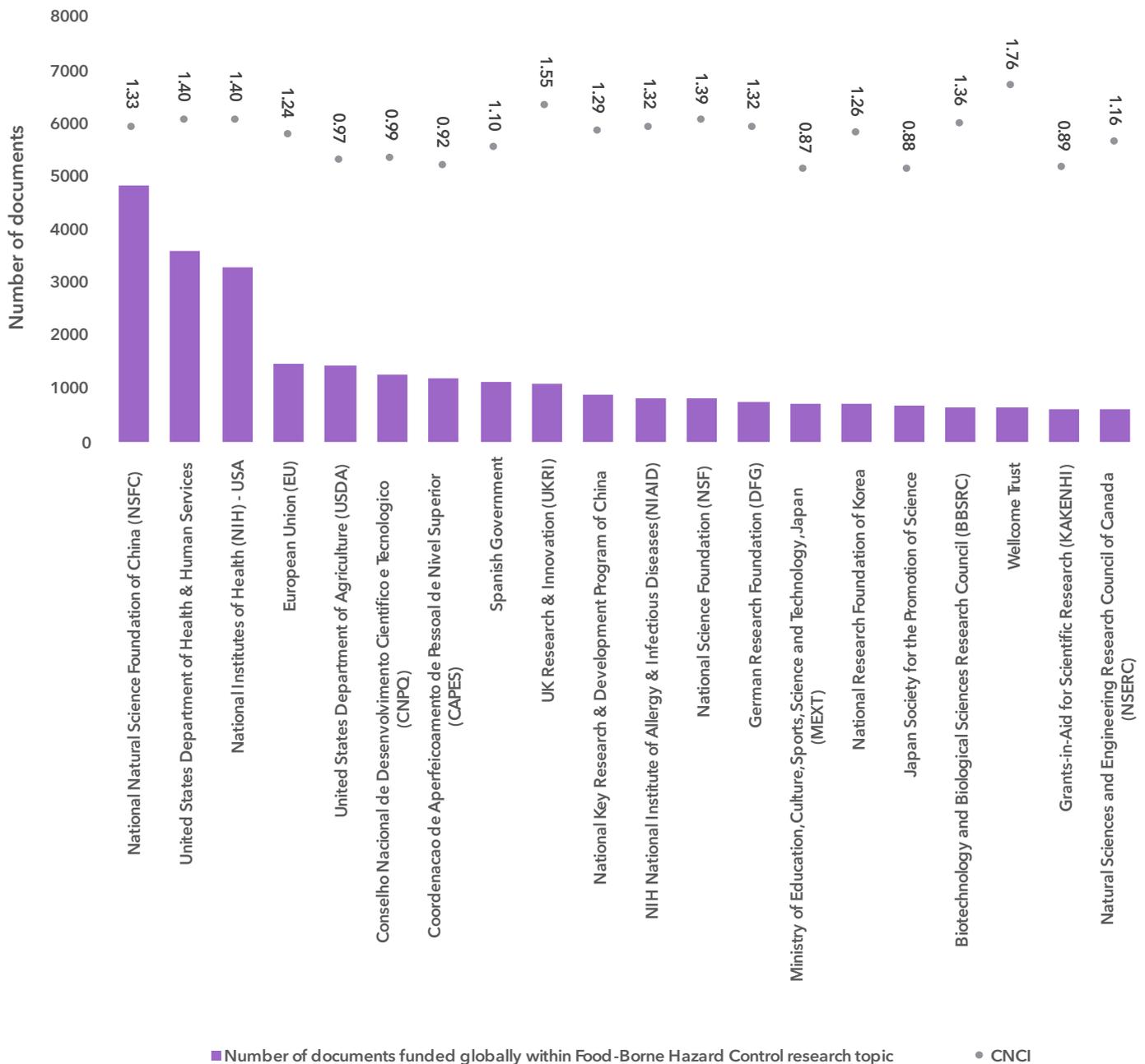


Figure 57: Top 20 funding organizations globally publications in the research topic Food-Borne Hazard Control in terms of number of publications in the period 2014-2023

#### 4.1.4.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section, we investigate the emerging trends globally and in Saudi Arabia on the research topic of Food-Borne Hazard Control. For more information on the methodology used to identify emerging trends, please see the section Emerging Trends.

The top three emerging micro-topics globally in this research topic are Molecular & Cell Biology - Genetics: Genome Editing, Nanoparticles: Carbon Dots and Protein Structure, Folding & Modelling: Carbonic Anhydrase as shown in Figure 58.

Table 16 shows the identified top 10 micro-topics in Saudi Arabia research output in this research topic.



Figure 58: Top 20 emerging micro-topics globally in the research topic Food-Borne Hazard Control in the period 2014-2023

Table 16: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Food-Borne Hazard Control in the period 2014-2023

Topic	Number of Saudi Arabian publications in the period 2014-2023
Food-Borne Hazard Control research topic	1161
Nanoparticles: Silver Nanoparticles	143
Phytochemicals: Essential Oil	115
Bacteriology: Salmonella	88
Bacteriology: Listeria Monocytogenes	43
Inflammatory Bowel Diseases & Infections: Lactic Acid Bacteria	42
Antibiotics & Antimicrobials: Antibiotic Resistance	34
Bacteriology: Quorum Sensing	33
Dairy & Animal Sciences: Poultry	32
Phytochemicals: Antioxidant Activity	31
Food Science & Technology: Chitosan	21

## 4.1.5 Carbon (CO2) Transport

### 4.1.5.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabian publications from global publications in the research topic showed an oscillating growth between 2014 and 2019 followed by a steep increase between 2020 and 2023, when it reached the highest share of 2.36%, as shown in Figure 59. This shows that Saudi Arabia was not only able to increase the number of publications on this research topic but also had a growth higher than the global growth rate.

This is evident as the share of Saudi Arabian publications in the research topic is growing. The CNCI of Saudi Arabian publications in this research topic were in all years higher than 1, ranging from 1.04 to 2.55, indicating a citation impact performance higher than the global average. It is worth mentioning that the increase in impact has happened in a period with high growth in publications. This means the newer papers positively contributed to the impact as measured by CNCI.

Overall, Saudi Arabia's publications increased with a higher growth rate than the global average in this research topic and had a very good citation impact as measured by the CNCI. Nevertheless, after this high growth rate in terms of publications, one should focus on increasing the impact of citations and productivity pace.

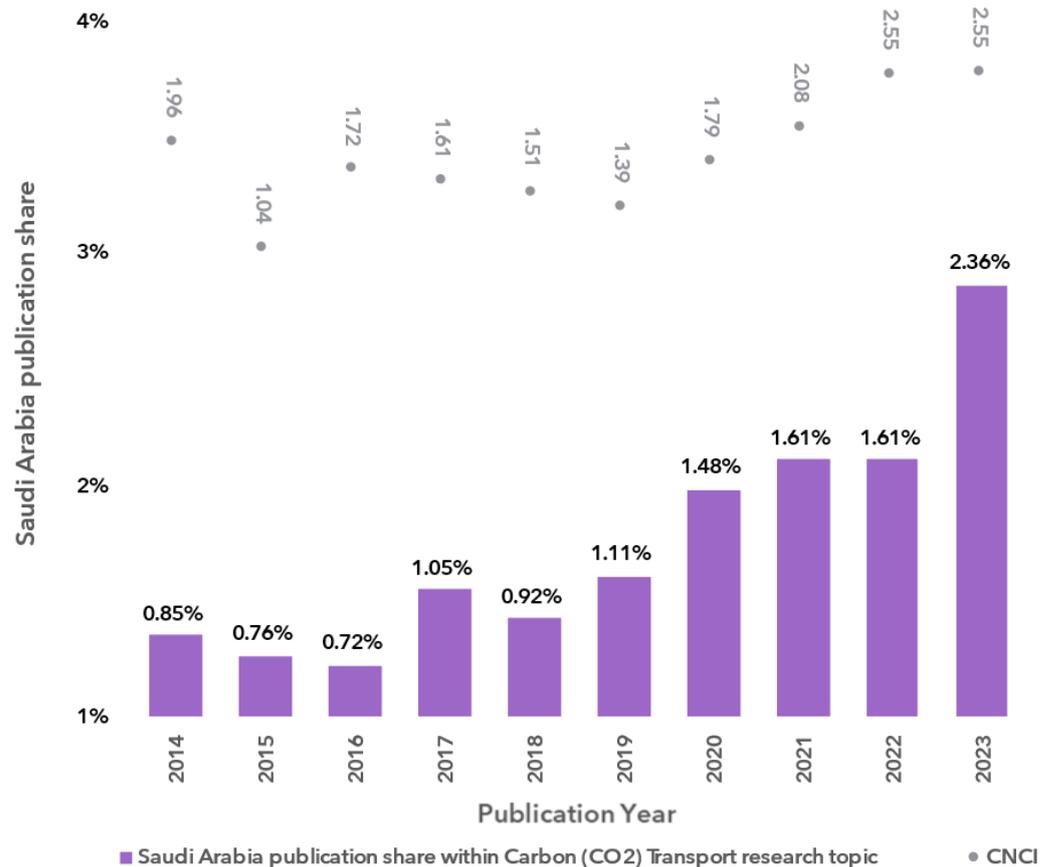


Figure 59: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabian publications in the research topic

### 4.1.5.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating countries with Saudi Arabia in this research topic from 2014-2023 are Mainland China, with 93 publications, followed by Egypt and Pakistan, with 60 publications, as shown in Figure 60.

Regarding citation impact measured by the CNCI publications published in collaboration with South Korea, Tunisia and India had the highest CNCI with 4.13, 3.52 and 2.85, respectively.

Nevertheless, all publications with the top 10 collaborating countries had a CNCI higher than 1, ranging from 1.55 to 4.13, reflecting a performance at least 55% higher than the global average.

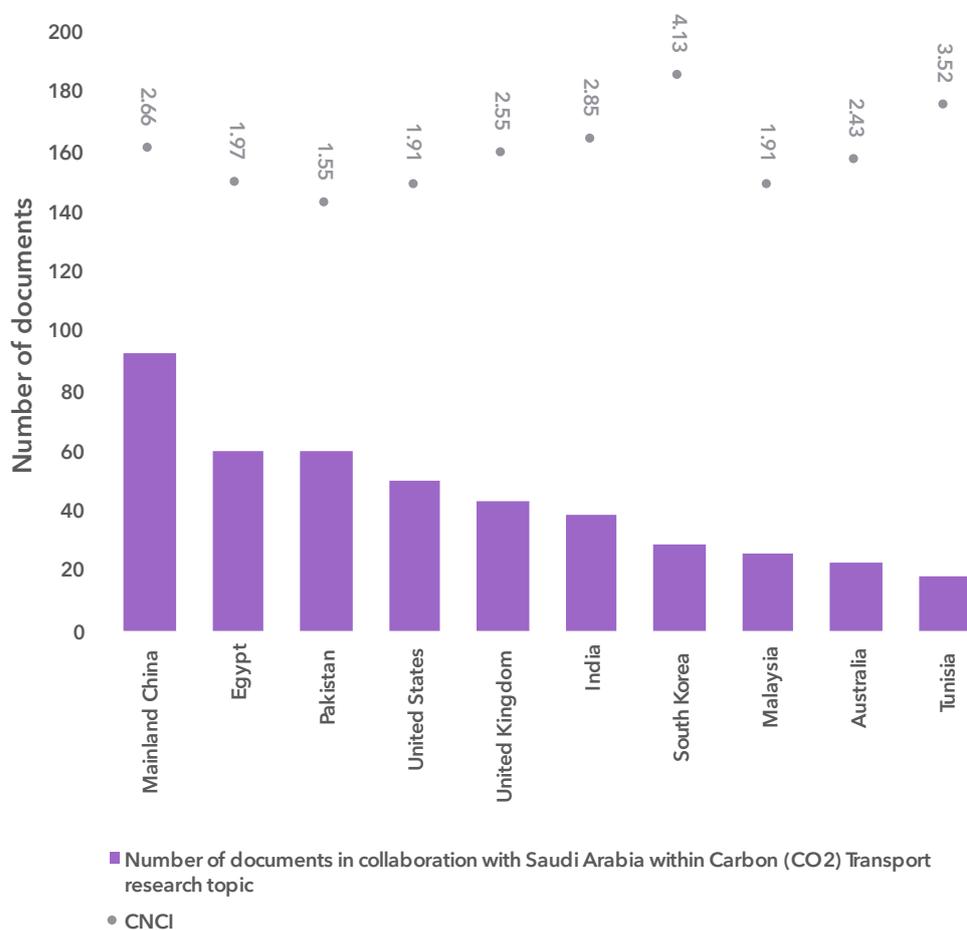


Figure 60: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications in the research topic Carbon (CO<sub>2</sub>) Transport in the period 2014-2023

#### 4.1.5.3 Top 20 funders of Saudi publications by number of publications

The top three funding organizations of Saudi Arabia publications in this research topic in terms of the number of publications mentioning the organization in the funding text from 2014-2023 are King Saud University followed by the National Natural Science Foundation of China (NSFC) and King Abdullah University of Science & Technology with 48, 37 and 31 publications respectively as shown in Figure 61.

Publications funded by National Key Research & Development Program of China, Australian Research Council and National Natural Science Foundation of China (NSFC) had the highest citation impact measured by the CNCI with 4.82, 3.73, and 3.54 respectively.

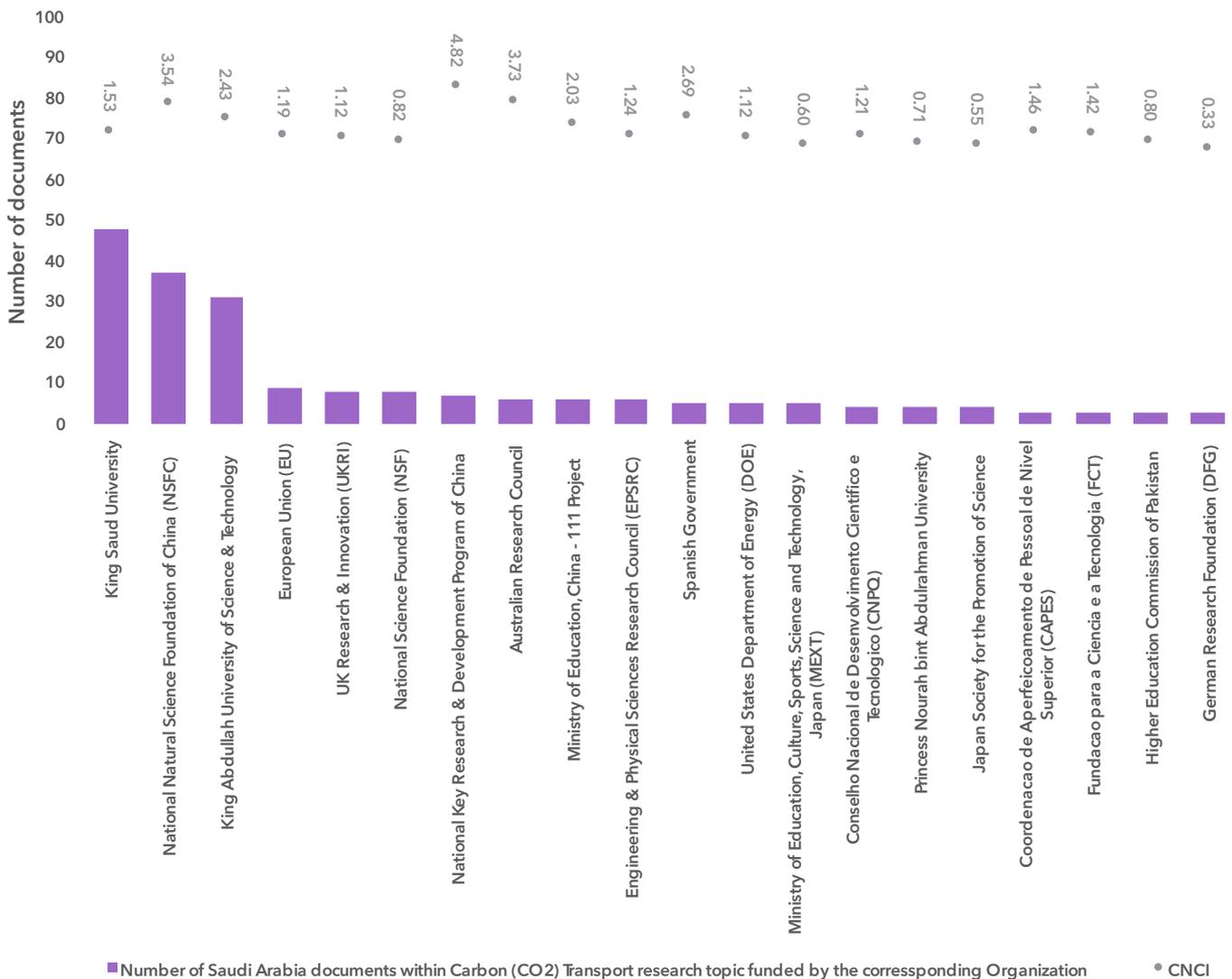


Figure 61: Top 20 funding organizations of Saudi Arabian publications in the research topic Carbon (CO<sub>2</sub>) Transport in terms of number of publications in the period 2014-2023

#### 4.1.5.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top three organizations in terms of publications published on this research topic from 2014-2023 are King Saud University, followed by King Abdullah University of Science & Technology and King Fahd University of Petroleum & Minerals, with 87, 82 and 67 publications, respectively as shown in Figure 62.

Regarding citation impact as measured by the CNCI, Najran University, University of Tabuk, and Al Jouf University had the highest CNCI with 5.29, 4.02 and 3.52, respectively.

Nevertheless, the majority of the top 20 organizations, except for Taif University, Qassim University, Saudi Aramco, Princess Nourah bint Abdulrahman University and the Islamic University of Al Madinah, had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

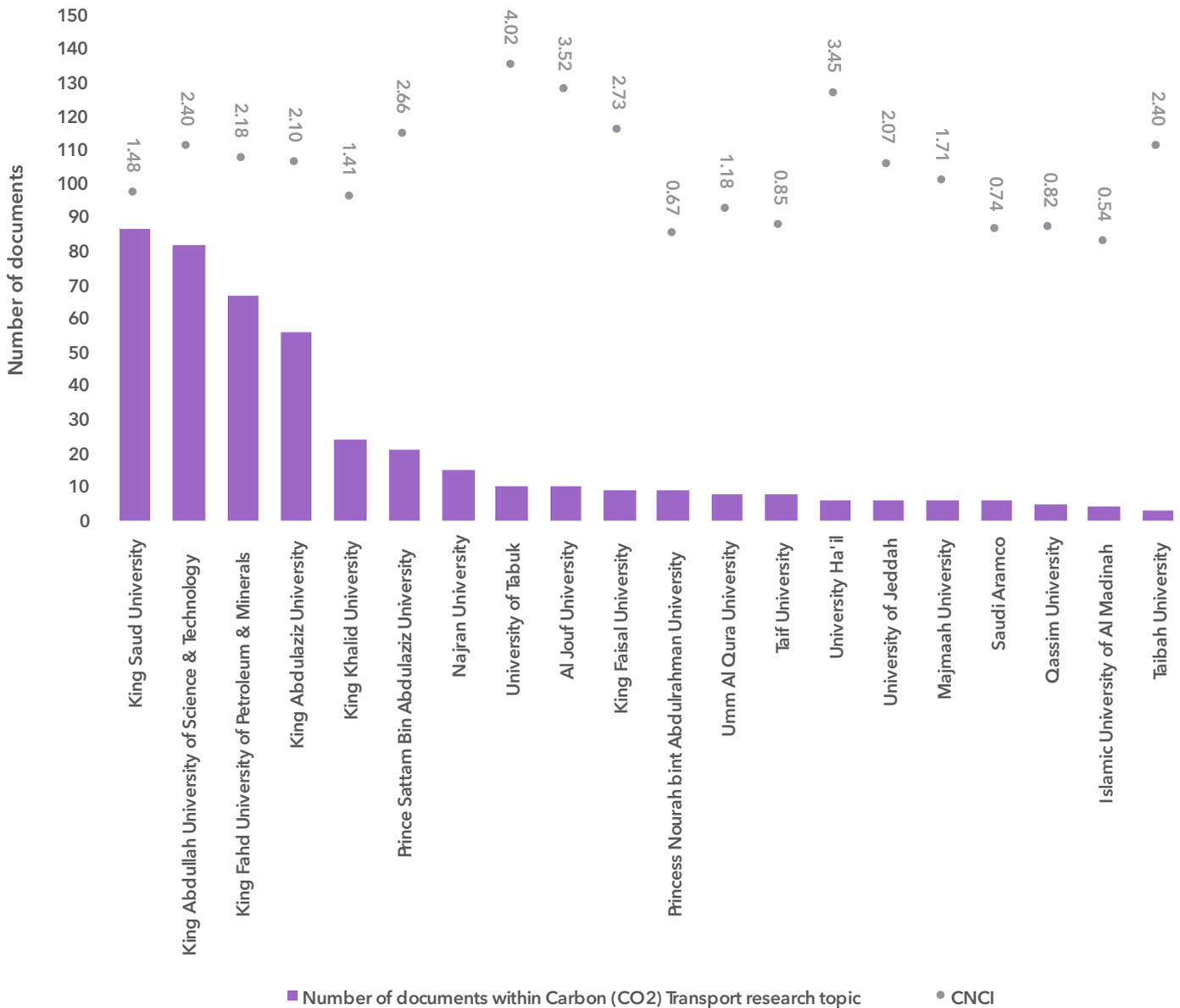


Figure 62: Top 20 Saudi organizations in terms of publications published in the research topic Carbon (CO<sub>2</sub>) Transport in the period 2014-2023 and their corresponding CNCI

#### 4.1.5.5 The top 20 researchers are affiliated with Saudi organizations in terms of the number of publications they publish

The highest number of publications are published by Abdelmohsen A. Nassani, affiliated with King Saud University, followed by Muhammad Moinuddin Qazi Abro, affiliated with King Saud University, and Ebrahim M. Eid, affiliated with King Khalid University with 8, 7 and 6 publications respectively as shown in Table 17. The highest CNCI is achieved by publications published by Hassan Algadi affiliated with Najran University with a CNCI of 16.09.

The latter researcher has also the highest number of Top 10% with 3 publications while Carlos M. Duarte affiliated with King Abdullah University of Science & Technology has the highest number of Top 10% publications with 4 publications. Eighteen out of Top 20 researchers affiliated with Saudi organizations have a CNCI above 1, reflecting a citation impact performance higher than the global average.

Table 17: Top 20 researchers affiliated with Saudi organizations in terms of number of publications published in the research topic Carbon (CO2) Transport in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in top 10%
<b>Nassani, Abdelmohsen A.</b>	King Saud University	8	1.79	0	2
<b>Abro, Muhammad Moinuddin Qazi</b>	King Saud University	7	1.91	0	2
<b>Eid, Ebrahim M.</b>	King Khalid University	6	2.06	1	1
<b>Gascon, Jorge</b>	King Abdullah University of Science & Technology	6	1.98	1	2
<b>Harrison, Roy M.</b>	King Abdulaziz University	6	1.07	0	0
<b>Hayat, Tasawar</b>	King Abdulaziz University	6	2.44	0	3
<b>Hoteit, Hussein</b>	King Abdullah University of Science & Technology	6	1.91	1	1
<b>Alsaedi, Ahmed</b>	King Abdulaziz University	5	2.57	0	3
<b>Duarte, Carlos M.</b>	King Abdullah University of Science & Technology	5	3.05	0	4
<b>Sarathy, S. Mani</b>	King Abdullah University of Science & Technology	5	2.08	1	1
<b>Mahmoud, Mohamed</b>	King Fahd University of Petroleum & Minerals	4	1.56	0	1
<b>Sun, Shuyu</b>	King Abdullah University of Science & Technology	4	1.15	0	1
<b>Abdullah-Al-Wadud, M.</b>	King Saud University	3	1.39	0	1
<b>Ahamad, Tansir</b>	King Saud University	3	0.10	0	0
<b>Algadi, Hassan</b>	Najran University	3	16.09	2	3
<b>Alshehri, Saad M.</b>	King Saud University	3	0.26	0	0
<b>Arshad, Muhammad</b>	King Khalid University	3	1.10	0	0
<b>Asiri, Abdullah M.</b>	King Abdulaziz University	3	1.47	0	1
<b>Bedia, E. A. Adda</b>	King Fahd University of Petroleum & Minerals	3	5.73	1	3
<b>Eddaoudi, Mohamed</b>	King Abdullah University of Science & Technology	3	5.12	1	1

#### 4.1.5.6 Top 10 countries in terms of publications

The highest number of publications published in this research topic are published by the United States (12,068 publications) followed by Mainland China (5,685 publications) and United Kingdom (2,364 publications) as shown in Figure 63. The highest citation impact measured by the CNCI is achieved by publications published by Australia, United Kingdom and Mainland China with a CNCI of 1.59, 1.58 and 1.426 respectively.

Six of the top 10 countries in terms of number of publications published in the research topic are also among the top 10 collaborators with Saudi Arabia. These are the United States, Mainland China, the United Kingdom, India, South Korea and Australia.

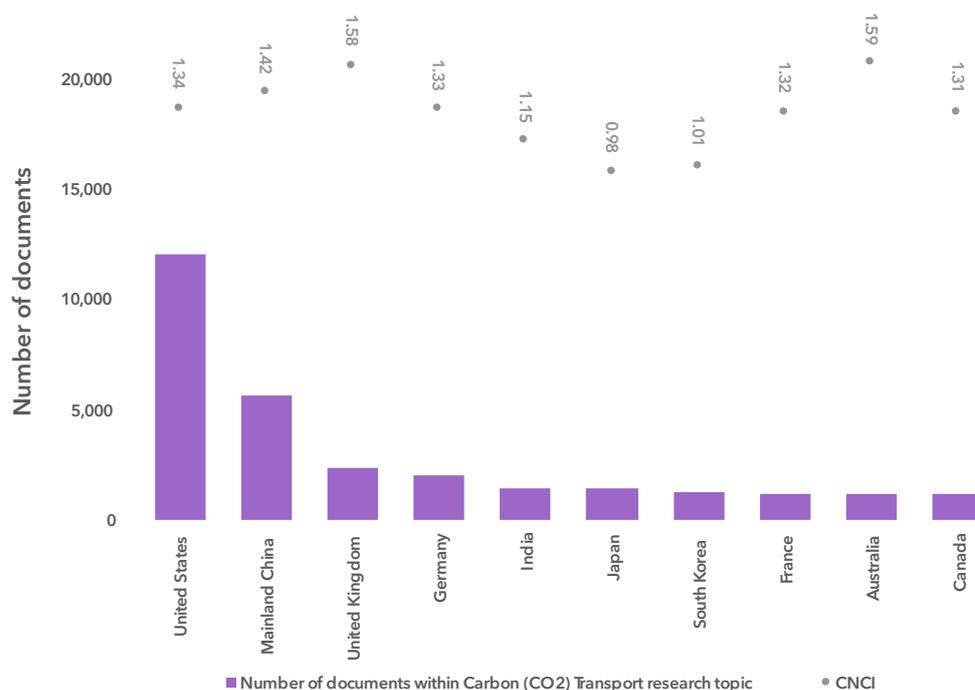


Figure 63: Top 10 countries in terms of number of publications in the Carbon (CO<sub>2</sub>) Transport in the period 2014-2023 and their corresponding CNCI

#### 4.1.5.7 Top 20 organizations globally in terms of number of publications

The top three organizations in terms of number of publications published in this research topic from 2014-2023 are the Chinese Academy of Sciences (1843 publications) followed by United States Department of Energy (DOE) (762 publications) and Centre National de la Recherche Scientifique (CNRS) (725 publications) as shown in Figure 64.

Regarding citation impact measured by the CNCI, Max Planck Society, Swiss Federal Institutes of Technology Domain and Tsinghua University had the highest CNCI with 2.15, 2.14, and 1.89 respectively.

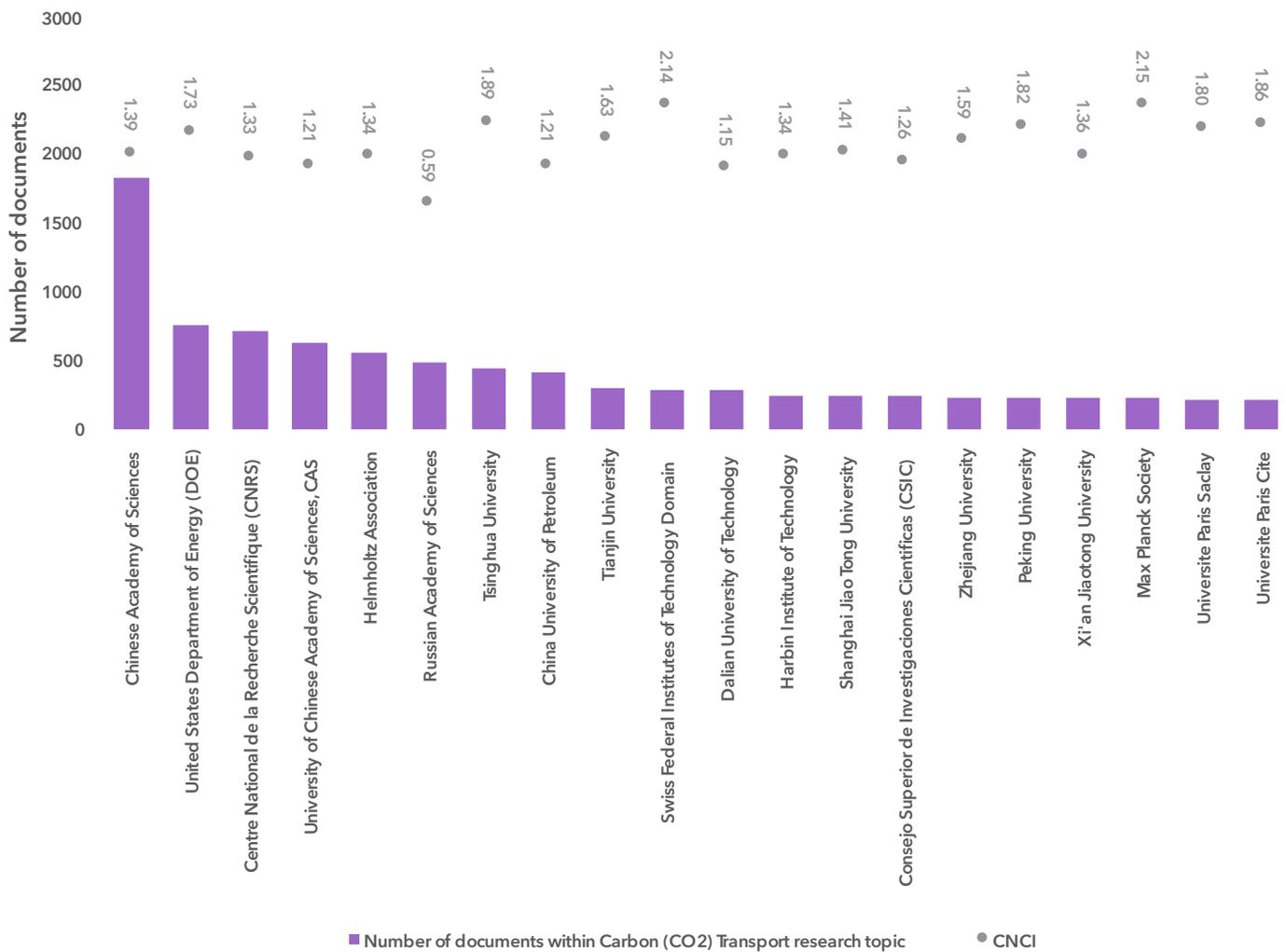


Figure 64: Top 20 organizations globally in terms of number of publications published in the research topic Carbon (CO<sub>2</sub>) Transport in the period 2014-2023 and their corresponding CNCI

#### 4.1.5.8 Top 20 researchers globally in terms of number of publications

The top three researchers globally in terms of number of publications in this research topic are Hong Wu affiliated with Tianjin University with 35 publications, followed by Philippe Ciais, affiliated with Universite Paris Saclay, Kenneth J. Davis, affiliated with Pennsylvania State University and Yongchen Song, affiliated with Dalian University of Technology with 34 publications as shown in Table 18.

The highest CNCI is achieved by Philippe Ciais affiliated with Universite Paris Saclay with 3.46.

The latter researcher achieved the highest number of Top 1% with 2 on pair with Hong Wu affiliated with Tianjin University which also achieved the highest number of Top 10% with 16 publications.

Table 18: Top 20 researchers globally in terms of number of publications published in the research topic Carbon (CO2) Transport in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in top 10%	Country
<b>Wu, Hong</b>	Tianjin University	35	2.31	2	16	Mainland China
<b>Ciais, Philippe</b>	Universite Paris Saclay	34	3.48	2	9	France
<b>Davis, Kenneth J.</b>	Pennsylvania State University	34	0.98	0	2	United States
<b>Song, Yongchen</b>	Dalian University of Technology	34	1.02	1	2	Mainland China
<b>Ho, W. S. Winston</b>	Ohio State University	31	1.65	0	11	United States
<b>Rochelle, Gary T.</b>	University of Texas Austin	29	1.25	0	5	United States
<b>Deng, Liyuan</b>	Norwegian University of Science & Technology (NTNU)	28	1.69	1	6	Norway
<b>Kang, Sang Wook</b>	Sangmyung University	25	0.48	0	0	South Korea
<b>Fontaras, Georgios</b>	European Commission Joint Research Centre	24	1.43	0	6	Belgium
<b>Mahgerefteh, Haroun</b>	University College London	24	1.13	0	4	England
<b>Steppe, Kathy</b>	Ghent University	21	1.35	0	3	Belgium
<b>Liu, Yu</b>	Dalian University of Technology	20	0.91	1	1	Mainland China
<b>Wang, Zhi</b>	Tianjin University	20	1.86	0	6	Mainland China
<b>Jiang, Lanlan</b>	Dalian University of Technology	19	0.59	0	0	Mainland China
<b>Martynov, Sergey</b>	University College London	19	1.29	0	4	England
<b>Feng, Sha</b>	Pennsylvania State University	18	0.93	0	1	United States
<b>He, Gaohong</b>	Dalian University of Technology	18	1.44	0	5	Mainland China
<b>Lu, Cheng</b>	University of Wollongong	18	0.74	0	1	Australia
<b>Xing, Yihan</b>	Universitetet i Stavanger	18	2.00	0	6	Norway
<b>Xue, Ziqiu</b>	Research Institute of Innovative Technology for the Earth	18	0.74	0	1	Japan

#### 4.1.5.9 Top 20 global funders globally in terms of number of publications

The top three organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC) with 7,477 publications, followed by the National Science Foundation (NSF) with 1214 publications, and Fundamental Research Funds for the Central Universities with 1,113 publications as shown in Figure 65.

The highest citation impact measured by the CNCI is observed in publications funded by the Australian Research Council and the United States Department of Energy (DOE), with both having a CNCI of 1.72, followed by the China Scholarship Council and National Science Foundation (NSF) with both having the CNCI of 1.71. Among the top 20 global funding organizations, 13 are also among the top 20 funding organizations of Saudi publications in this research topic.

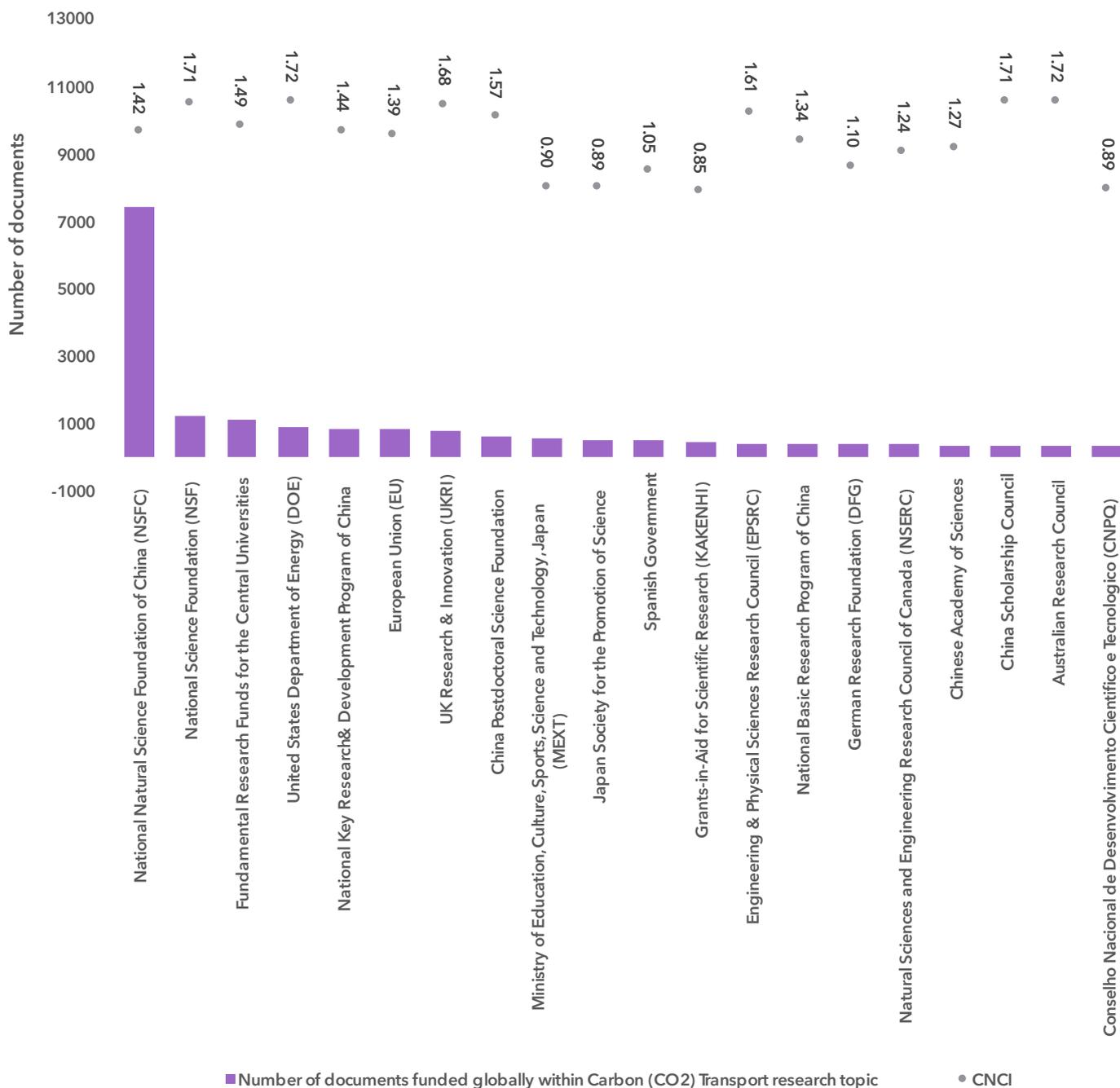


Figure 65: Top 20 funding organizations globally publications in the research topic Carbon (CO2) Transport in terms of number of publications in the period 2014-2023

#### 4.1.5.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section, we investigate the emerging trends globally and in Saudi Arabia on the research topic of Carbon (CO<sub>2</sub>) Transport. For more information on the methodology used to identify emerging trends, please see the section Emerging Trends.

The top three emerging micro-topics globally in this research topic are Electrochemistry, CO<sub>2</sub> Reduction, followed by Power Systems & Electric Vehicles, Distributed Generation, and Perovskite Solar Cells Perovskite Solar Cells as shown in Figure 66.

Table 19 shows the identified top 10 micro-topics in Saudi Arabia's research output on this research topic. Among those are Perovskite Solar Cells, which are among the top 20 global emerging micro-topics.

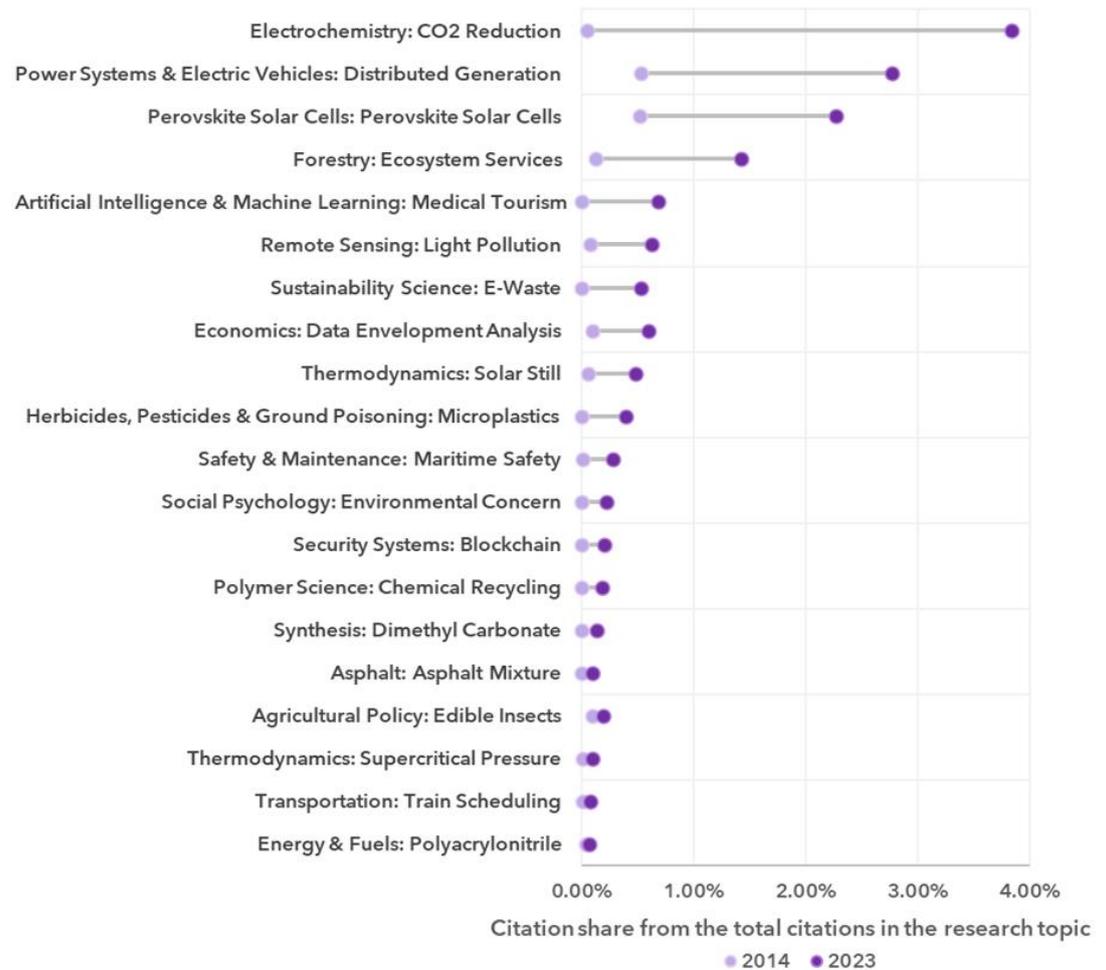


Figure 66: Top 20 emerging micro-topics globally in the research topic Carbon (CO<sub>2</sub>) Transport in the period 2014-2023

Table 19: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Carbon (CO2) Transport in the period 2014-2023

Topic	Number of Saudi Arabian publications in the period 2014-2023
Carbon CO2 Transport research topic	435
Sustainability Science: Environmental Kuznets Curve	28
Water Resources: Enhanced Oil Recovery	22
Corrosion & Deposition Chemistry: Corrosion	21
Thermodynamics: Nanofluid	19
Membrane Science: Pervaporation	17
Electrochemistry: Supercapacitor	16
Mechanics: Free Vibration	15
Perovskite Solar Cells: Perovskite Solar Cells	11
2D Materials: Carbon Nanotubes	10
Combustion: Biodiesel	9

## 4.1.6 Electric Vehicles

### 4.1.6.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabian publications from global publications on the research topic increased vigorously from 0.32% in 2014 to the peak of 2.59% in 2023, as shown in Figure 67. This shows that Saudi Arabia was not only able to increase the number of publications on this research topic but also had a growth higher than the global growth rate. This is evident as the share of Saudi Arabian publications in the research topic is growing.

The CNCI of Saudi Arabian publications in this research topic were in all years higher than 1, ranging from 1.39 to 2.35, indicating a citation impact performance higher than the global average. It is important to mention that the impact of steady progress has happened in a period with high growth in publications.

This means the newer papers had a positive contribution to the impact as measured by CNCI rather than diluting it, as is expected in similar cases of high publication growth.

Overall, Saudi Arabia's publications increased with a higher growth rate than the global average in this research topic and had a relatively good citation impact, as measured by the CNCI. Nevertheless, after this high growth rate in terms of publications, one should focus on increasing the impact of citations.

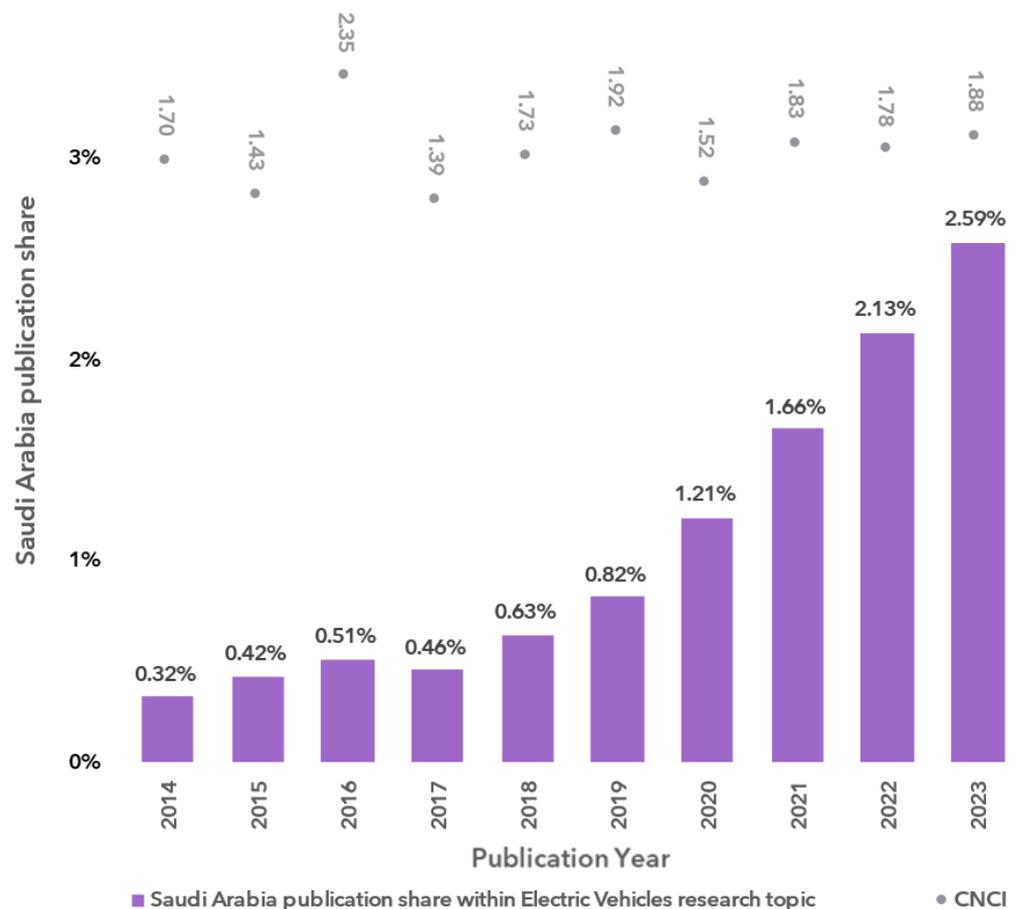


Figure 67: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabian publications in the research topic

### 4.1.6.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating countries with Saudi Arabia in this research topic from 2014-2023 are Egypt, followed by India and the United States with 213, 212 and 190 publications, respectively, as shown in Figure 68. Regarding citation impact measured

by the CNCI publications published in collaboration with the United Kingdom, Mainland China and Canada had the highest CNCI with 2.67, 2.64 and 2.46, respectively. Nevertheless, all publications with the top 10 collaborating countries had a CNCI higher than 1, ranging from 1.52 to 2.67, reflecting a performance at least 52% higher than the global average.

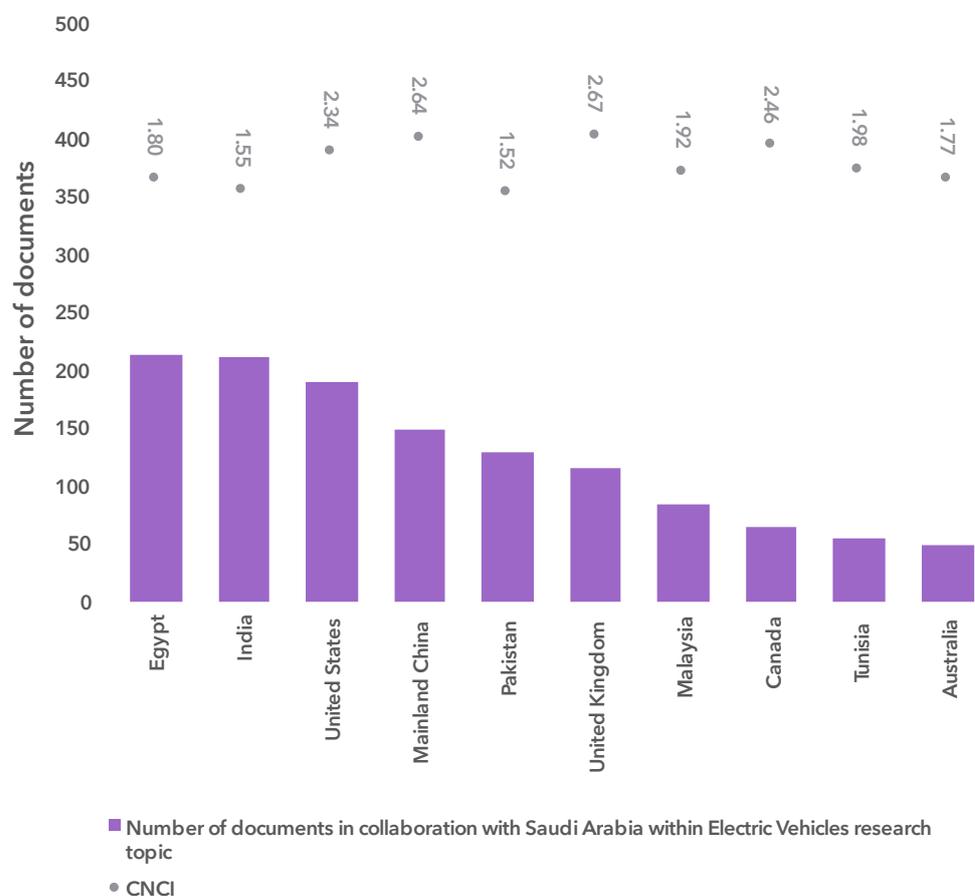


Figure 68: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications in the research topic Electric Vehicles in the period 2014-2023

#### 4.1.6.3 Top 20 funders of Saudi publications by number of publications

The top three funding organizations of Saudi Arabia publications in this research topic in terms of the number of publications mentioning the organization in the funding text from 2014-2023 are King Saud University followed by the National Natural Science Foundation of China (NSFC) and the UK Research & Innovation (UKRI) with 60, 57 and 23 publications respectively as shown in Figure 69.

Publications funded by Ministry of Education, Malaysia, Fundamental Research Funds for the Central Universities and UK Research & Innovation (UKRI) had the highest citation impact measured by the CNCI with 5.85, 5.39 and 4.06 respectively.

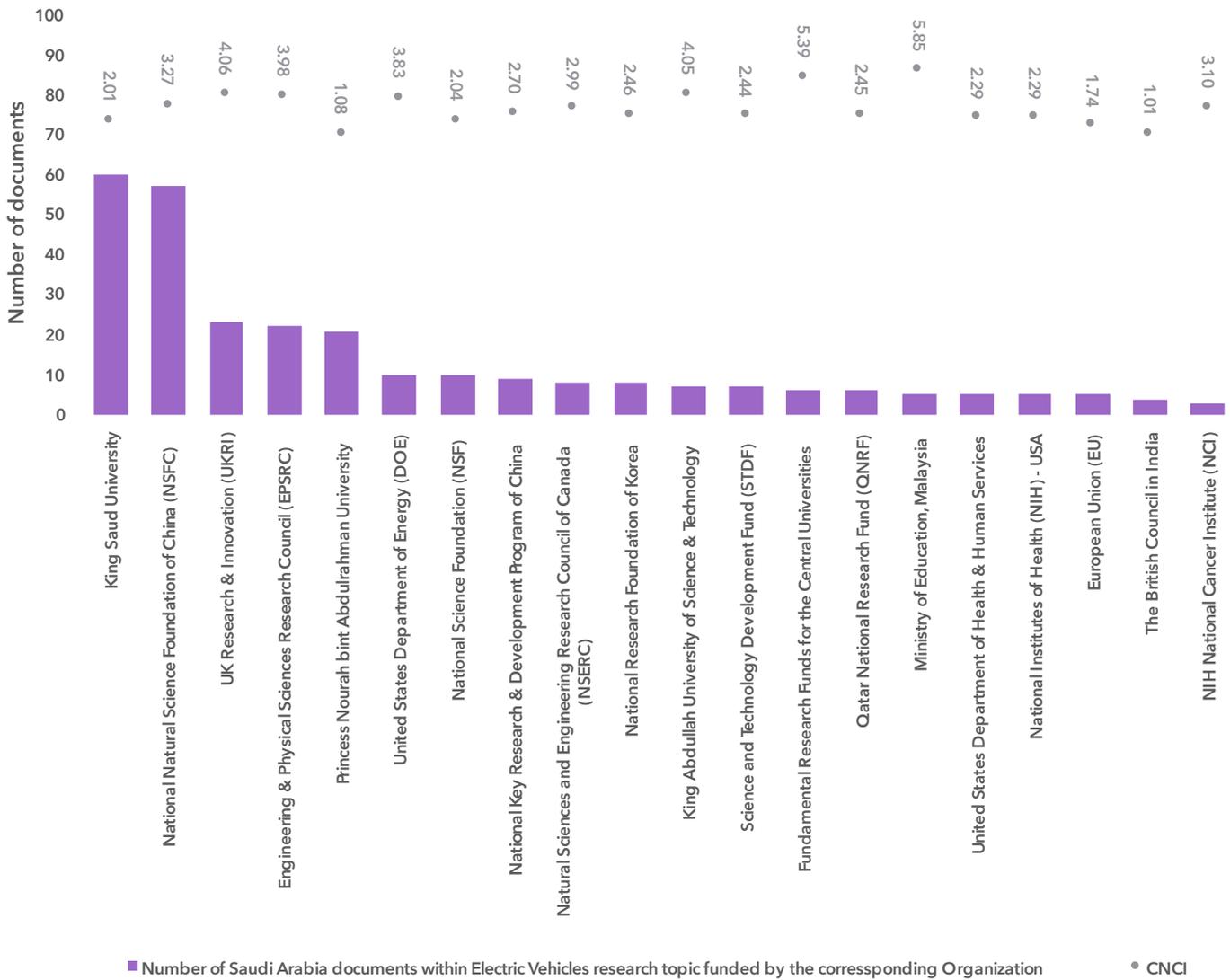


Figure 69: Top 20 funding organizations of Saudi Arabian publications in the research topic Electric Vehicles in terms of number of publications in the period 2014-2023

#### 4.1.6.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top three organizations in terms of publications published in this research topic between 2014-2023 are King Abdulaziz University, followed by King Saud University and King Fahd University of Petroleum & Minerals, with 183, 126 and 107 publications, respectively, as shown in Figure 70.

Regarding citation impact as measured by the CNCI, King Faisal Specialist Hospital & Research Center, followed by Imam Abdulrahman Bin Faisal University and Al Jouf University, had the highest CNCI with 3.57, 3.01 and 2.52, respectively.

Nevertheless, all top 20 organizations had a CNCI higher than 1, ranging from 1.05 to 3.57, reflecting a citation impact performance starting at 5% higher than the global average.

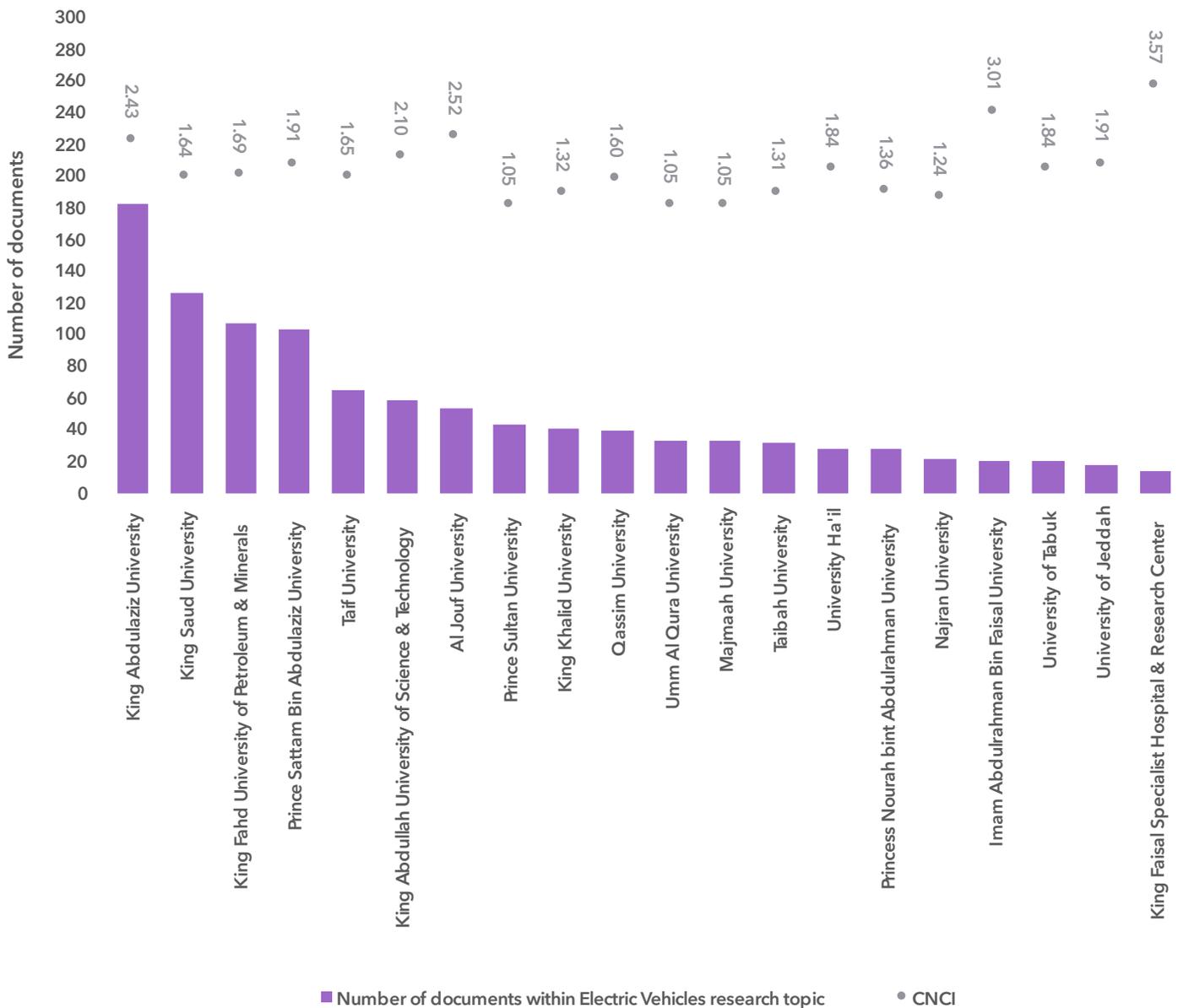


Figure 70: Top 20 Saudi organizations in terms of publications published in the research topic Electric Vehicles in the period 2014-2023 and their corresponding CNCI

#### 4.1.6.5 The top 20 researchers are affiliated with Saudi organizations in terms of the number of publications they publish

The highest number of publications are published by Hegazy. Rezk is affiliated with Prince Sattam Bin Abdulaziz University, followed by Ali T. Al-Awami, affiliated with King Fahd University of Petroleum & Minerals, and Emad M. Ahmed, affiliated with Al Jouf University, with 19, 18 and 16 publications, respectively, as shown in Table 20.

The highest CNCI is achieved by publications published by Abdullah Abusorrah, affiliated with King Abdulaziz University, with a CNCI of 4.57. The latter researcher also has the highest number of Top 1% with three publications, while Sherif S. M. Ghoneim, affiliated with Taif University, has the highest number of Top 10% publications with nine publications. Nevertheless, eighteen researchers from the Top 20 affiliated with Saudi organizations had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

Table 20: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published on the research topic of Electric Vehicles in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%
<b>Rezk, Hegazy</b>	Prince Sattam Bin Abdulaziz University	19	1.86	1	6
<b>Al-Awami, Ali T.</b>	King Fahd University of Petroleum & Minerals	18	0.98	0	4
<b>Ahmed, Emad M.</b>	Al Jouf University	16	2.38	0	6
<b>Khalid, Muhammad</b>	King Fahd University of Petroleum & Minerals	16	2.40	1	8
<b>Ahmed, Shehab</b>	King Abdullah University of Science & Technology	15	1.16	0	2
<b>Subramaniam, Umashankar</b>	Prince Sultan University	13	1.39	0	3
<b>Almutairi, Abdulaziz</b>	Majmaah University	12	1.08	0	1
<b>Ghoneim, Sherif S. M.</b>	Taif University	12	2.70	0	9
<b>Abusorrah, Abdullah</b>	King Abdulaziz University	10	4.57	3	7
<b>Alamri, Basem</b>	Taif University	10	2.27	0	4
<b>Almakhles, Dhafer</b>	Prince Sultan University	10	0.95	0	1
<b>Shariff, Samir M.</b>	Taibah University	10	1.87	0	5
<b>Akram, Umer</b>	King Fahd University of Petroleum & Minerals	9	1.68	0	4
<b>Aljafari, Belqasem</b>	Najran University	9	1.20	0	0
<b>Fathy, Ahmed</b>	Al Jouf University	9	2.91	1	3
<b>Shafiq, Saifullah</b>	King Fahd University of Petroleum & Minerals	8	1.24	0	2
<b>Abdullah-Al-Wadud, M.</b>	King Saud University	7	1.32	0	2
<b>Al-Shetwi, Ali Q.</b>	Fahad Bin Sultan University	7	2.42	1	2
<b>Albogamy, Fahad R.</b>	Taif University	7	1.51	0	2
<b>Ali, Hafiz Muhammad</b>	King Fahd University of Petroleum & Minerals	7	3.94	1	3

#### 4.1.6.6 Top 10 countries in terms of publications

The highest number of publications published on this research topic is published by Mainland China (24,862 publications), followed by the United States (15,551 publications) and Germany (5,729 publications), as shown in Figure 71. The highest citation impact measured by the CNCI is achieved by publications published in the United States, Canada and the United Kingdom with a CNCI of 2.21, 2.09 and 1.90, respectively.

Five of the top 10 countries, in terms of the number of publications published on the research topic, are also among the top 10 collaborators with Saudi Arabia. These are Mainland China, the United States, India, the United Kingdom and Canada

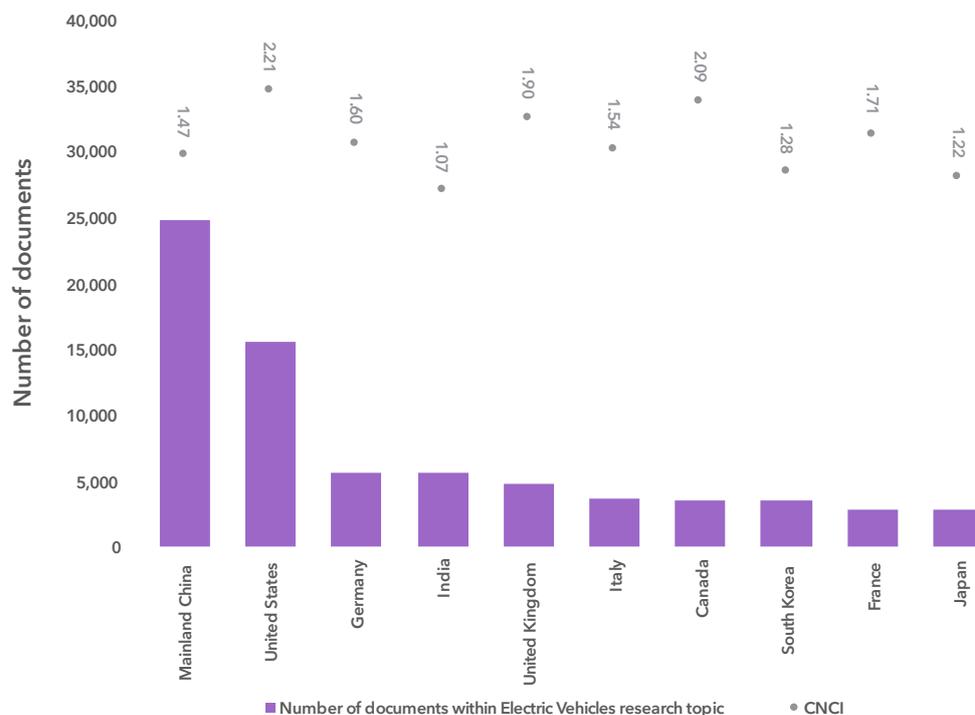


Figure 71: Top 10 countries in terms of number of publications in the Electric Vehicles in the period 2014-2023 and their corresponding CNCI

#### 4.1.6.7 Top 20 organizations globally in terms of number of publications

The top three organizations in terms of number of publications published in this research topic from 2014-2023 are Tsinghua University (1652 publications) followed by Beijing Institute of Technology (1545 publications) and the Chinese Academy of Sciences (1409 publications) as shown in Figure 72.

Regarding citation impact measured by the CNCI, the University of Pennsylvania, Harvard University, and University of Michigan had the highest CNCI with 5.36, 4.44 and 2.77, respectively.

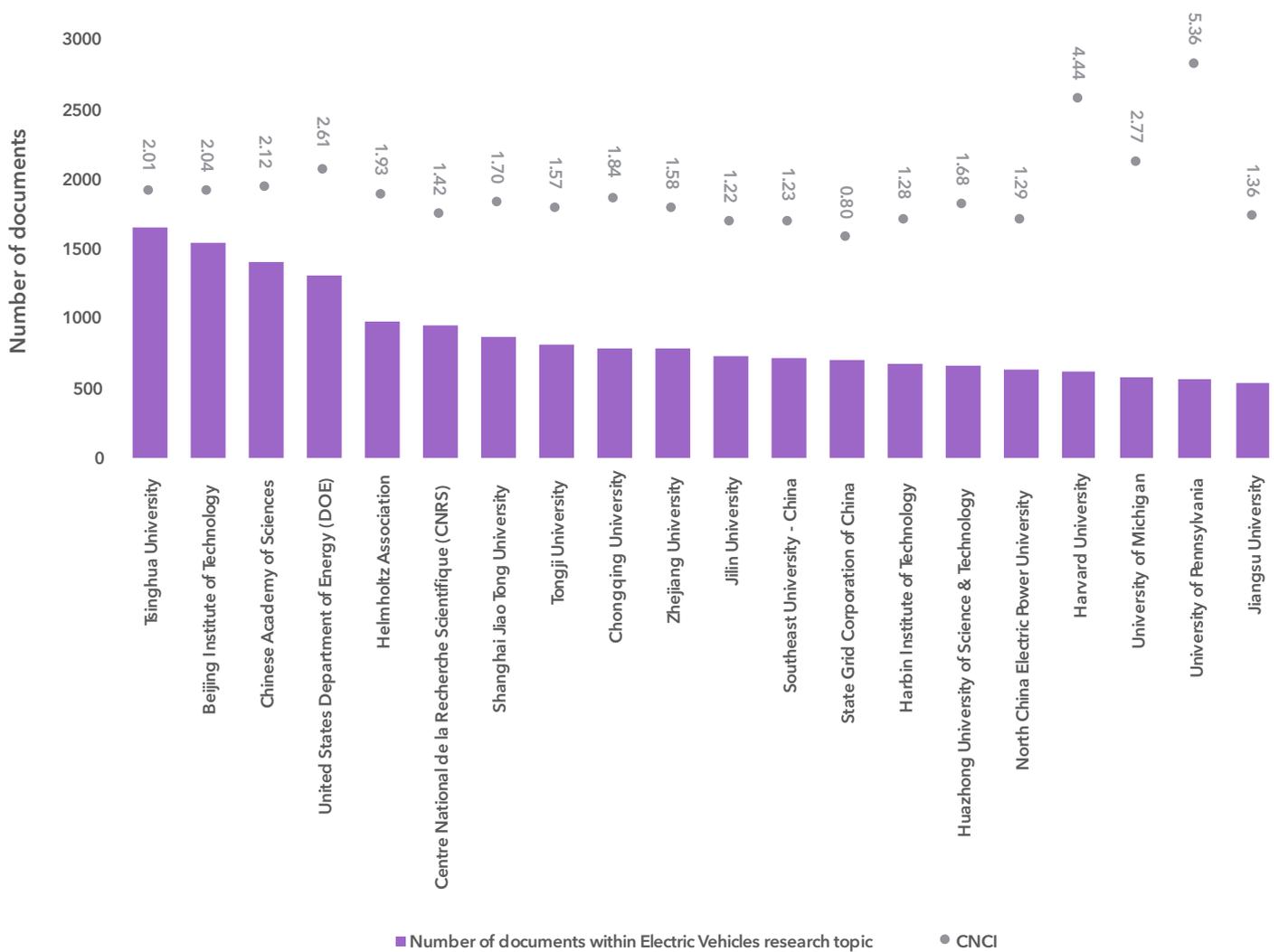


Figure 72: Top 20 organizations globally in terms of number of publications published in the research topic Electric Vehicles in the period 2014-2023 and their corresponding CNCI

#### 4.1.6.8 Top 20 researchers globally in terms of number of publications

The top three researchers globally in terms of the number of publications on this research topic are Minggao Ouyang, affiliated with Tsinghua University, with 228 publications, followed by Bhim Singh, affiliated with the Indian Institute of Technology System, with 157 publications, and Hongwen He affiliated with Beijing Institute of Technology with 150 publications as shown in Table 21.

The highest CNCI is achieved by Carl H. June affiliated with University of Pennsylvania with 10.08.

The latter researcher achieved the highest number of Top 1% while the highest number of Top 10% publications is achieved by Minggao Ouyang affiliated with Tsinghua University.

Table 21: Top 20 researchers globally in terms of the number of publications published on the research topic Electric Vehicles in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%	Country
<b>Ouyang, Minggao</b>	Tsinghua University	228	3.02	30	107	Mainland China
<b>Singh, Bhim</b>	Indian Institute of Technology System (IIT System)	157	1.10	1	19	India
<b>He, Hongwen</b>	Beijing Institute of Technology	150	2.58	13	58	Mainland China
<b>Wang, Zhenpo</b>	Beijing Institute of Technology	148	3.12	16	68	Mainland China
<b>Xiong, Rui</b>	Beijing Institute of Technology	146	3.54	25	80	Mainland China
<b>Emadi, Ali</b>	McMaster University	140	3.01	7	50	Canada
<b>June, Carl H.</b>	University of Pennsylvania	120	10.08	48	103	United States
<b>Hu, Xiaosong</b>	Chongqing University	116	4.69	25	89	Mainland China
<b>Catalao, Joao P. S.</b>	Universidade do Porto	109	1.59	0	29	Portugal
<b>Lienkamp, Markus</b>	Technical University of Munich	109	1.07	1	13	Germany
<b>Lu, Languang</b>	Tsinghua University	104	3.09	13	51	Mainland China
<b>Han, Xuebing</b>	Tsinghua University	102	3.10	12	60	Mainland China
<b>Van Mierlo, Joeri</b>	Vrije Universiteit Brussel	97	2.09	7	35	Belgium
<b>Zhang, Chenghui</b>	Shandong University	96	1.81	1	29	Mainland China
<b>Chen, Hong</b>	Jilin University	93	2.30	5	29	Mainland China
<b>Fujimoto, Hiroshi</b>	University of Tokyo	93	1.13	1	14	Japan
<b>Li, Jianqiu</b>	Tsinghua University	93	2.87	15	44	Mainland China
<b>Bauer, Pavol</b>	Delft University of Technology	90	1.88	1	24	Netherlands
<b>Feng, Xuning</b>	Tsinghua University	89	4.17	18	56	Mainland China
<b>Sun, Fengchun</b>	Beijing Institute of Technology	86	3.50	16	42	Mainland China

#### 4.1.6.9 Top 20 global funders globally in terms of number of publications

The top three organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC) with 12,258 publications, followed by the European Union (EU) with 2,047 publications, and United States Department of Health & Human Services with 2,034 publications as shown in Figure 73.

The highest citation impact measured by the CNCI is observed in publications funded by NIH National Cancer Institute (NCI), National Institutes of Health (NIH) - USA and United States Department of Health & Human Services with 4.42, 3.67 and 3.64 respectively. Among the top 20 global funding organizations, 13 are also among the top 20 funding organizations of Saudi publications in this research topic.

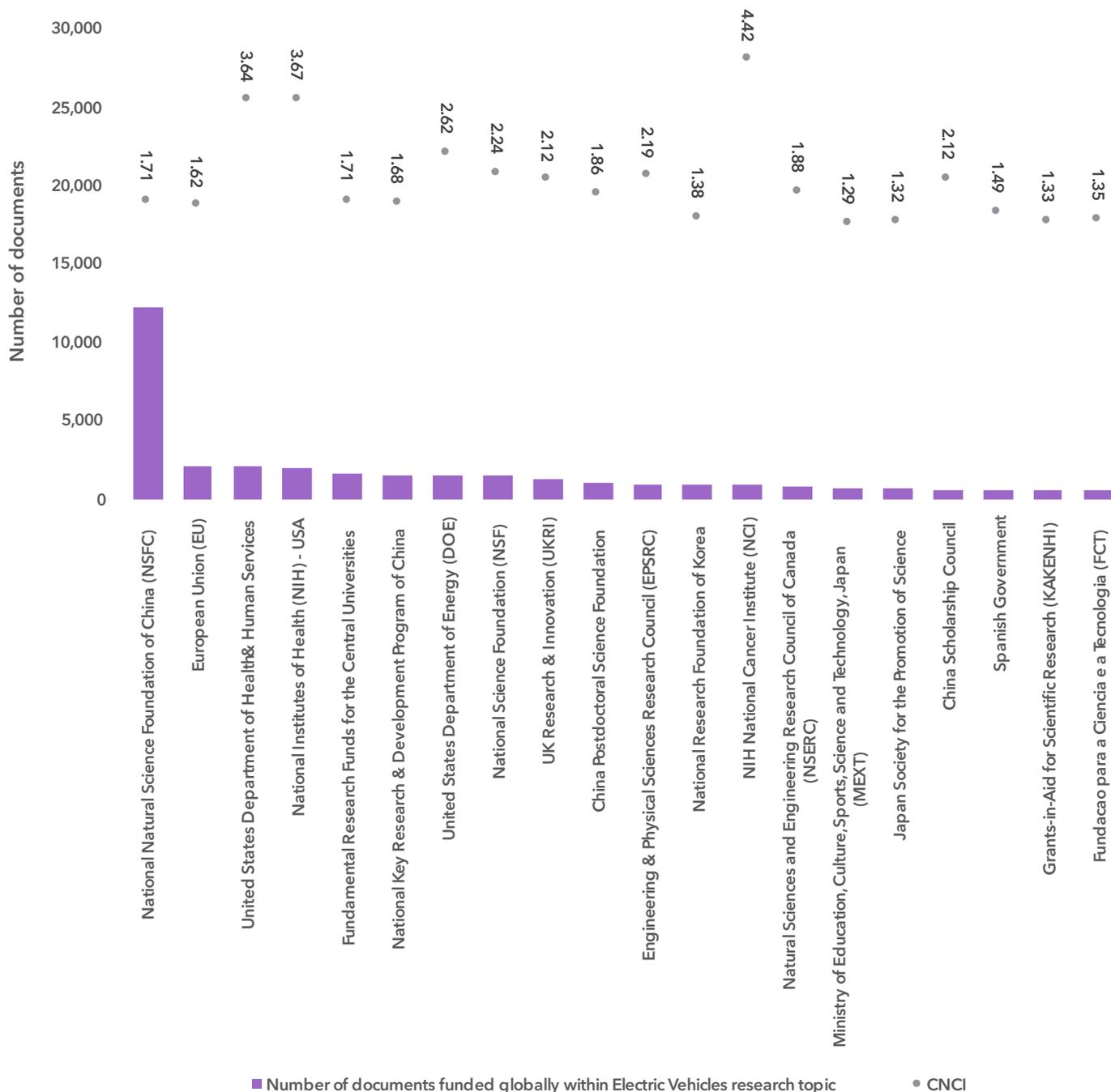


Figure 73: Top 20 funding organizations globally publications in the research topic Electric Vehicles in terms of number of publications in the period 2014-2023

#### 4.1.6.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section, we investigate the emerging trends globally and in Saudi Arabia in the research topic of Electric Vehicles. For more information on the methodology used to identify emerging trends, please see the section Emerging Trends.

The top three emerging micro-topics globally in this research topic are Power Systems & Electric Vehicles, Voltage Stability followed by Security Systems, Blockchain and Artificial Intelligence & Machine Learning: Fuzzy Sets, as shown in Figure 74.

Table 22 shows the identified top 10 micro-topics in Saudi Arabia research output in this research topic. Saudi Arabia has publications in the following identified global emerging topics: Power Systems & Electric Vehicles, Voltage Stability and Security Systems, and Blockchain.

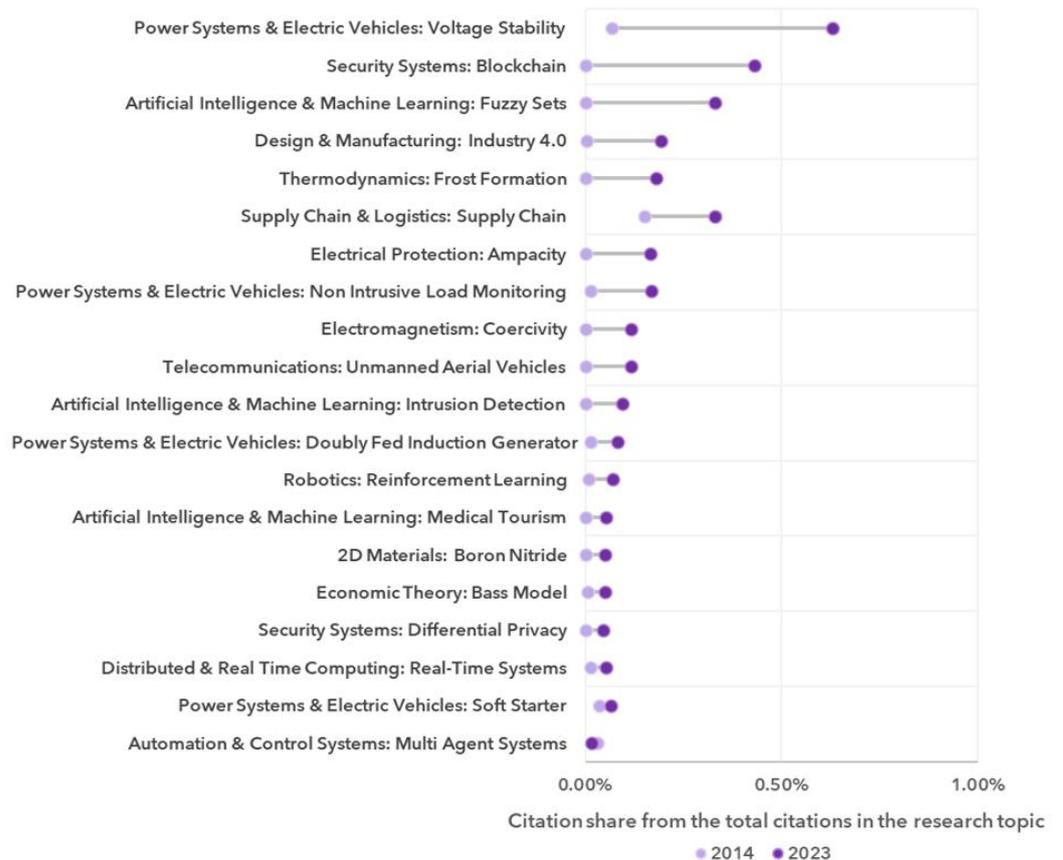


Figure 74: Top 20 emerging micro-topics globally in the research topic Electric Vehicles in the period 2014-2023

Table 22: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Electric Vehicles in the period 2014-2023

Topic	Number of Saudi Arabian publications in the period 2014-2023
Electric Vehicle research topic	1082
Power Systems & Electric Vehicles: Distributed Generation	337
Power Systems & Electric Vehicles: Electric Vehicles	122
Electrochemistry: Lithium-Ion Battery	96
Power Systems & Electric Vehicles: Voltage Stability	40
Power Systems & Electric Vehicles: DC-DC Converter	39
Power Systems & Electric Vehicles: Induction Motor	37
Security Systems: Blockchain	32
Immunology: PD-1	32
Electrochemistry: Supercapacitor	26
Wireless Technology: Wireless Power Transfer	25

## 4.1.7 Waste Landfill

### 4.1.7.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabian publications from global publications in the research topic had an oscillating evolution from 2014 to 2018, followed by a period of vigorous increase from 2019 to 2023, as shown in Figure 75. This shows that Saudi Arabia was not only able to increase the number of publications on this research topic but also had a growth higher than the global growth rate. This is evident as the share of Saudi Arabian publications in the research topic is growing.

The CNCI of Saudi Arabian publications in this research topic was higher than 1 in five out of the period of ten years, indicating a citation impact performance higher than the global average. The CNCI ranged from 0.39 to 2.31, at its highest value in 2023. The impact growth is observed in a period of high publication growth when it is expected to have a small decrease or flat evolution.

This means the new publications consolidated and positively contributed to the country's impact as measured by CNCI. Overall, Saudi Arabia's publications increased with a higher growth rate than the global average in this research topic and had a relatively good citation impact, as measured by the CNCI. Nevertheless, after this high growth rate in terms of publications, one should focus on increasing the citation impact and maintaining the pace of publications.

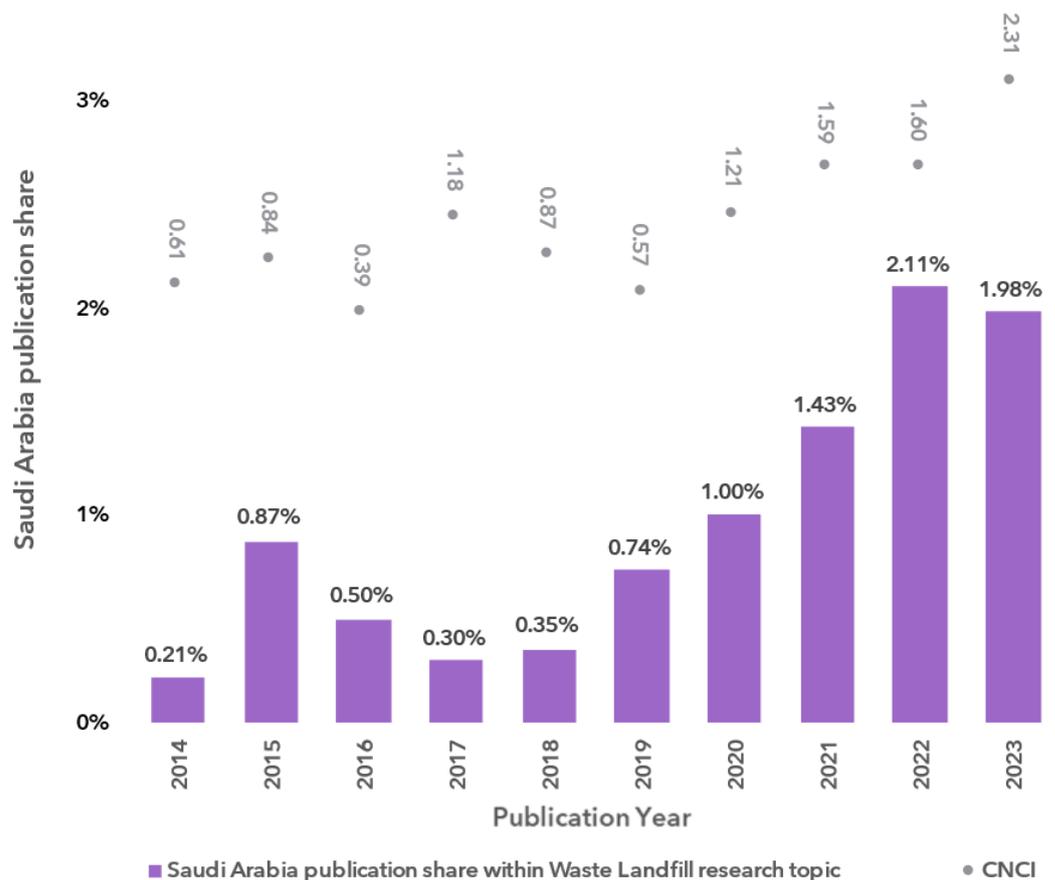


Figure 75: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabian publications in the research topic

### 4.1.7.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating country with Saudi Arabia in this research topic from 2014-2023 is Egypt, followed by Mainland China and India with 36, 34 and 32 publications, respectively, as shown in Figure 76.

Regarding citation impact measured by the CNCI publications published in collaboration with France, Egypt and the United States had the highest CNCI with 2.41, 1.99 and 1.86, respectively. Nevertheless, all publications with the top 10 collaborating countries had a CNCI higher than 1, reflecting a performance higher than the global average.

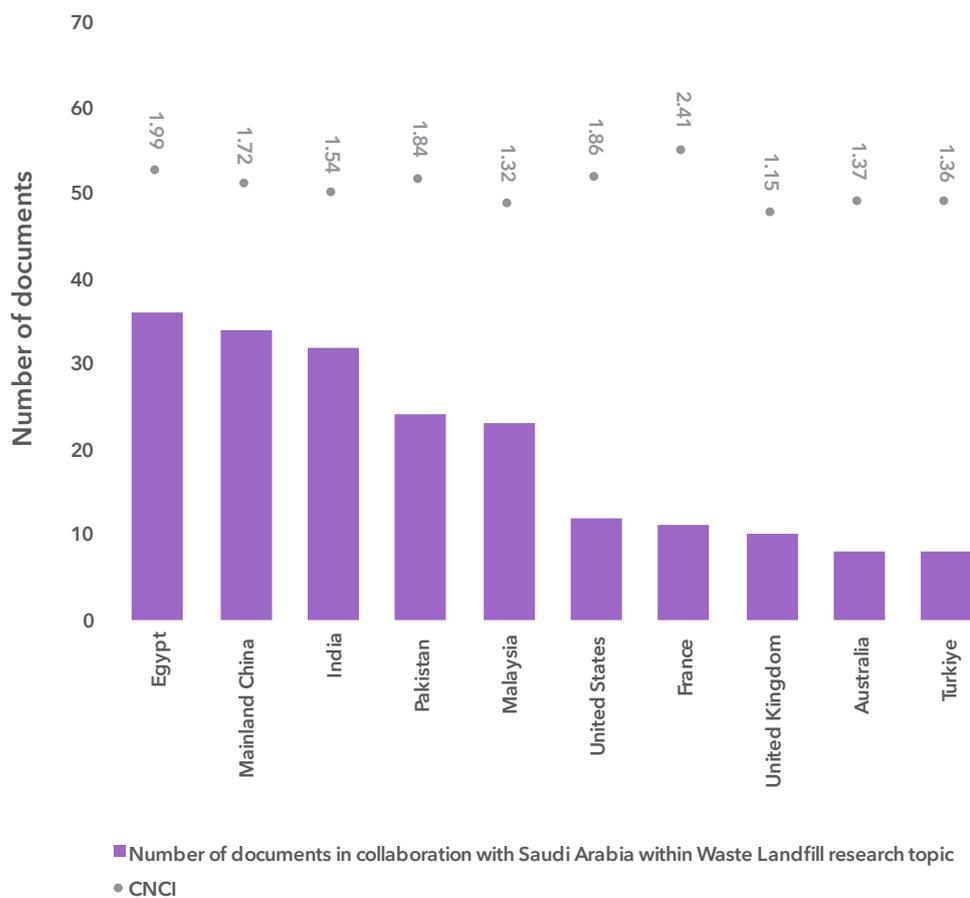


Figure 76: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications on the research topic Waste Landfill in the period 2014-2023

#### 4.1.7.3 Top 20 funders of Saudi publications by number of publications

The top three funding organizations of Saudi Arabia publications in this research topic in terms of the number of publications mentioning the organization in the funding text from 2014-2023 are King Saud University followed by the National Natural Science Foundation of China (NSFC) and Princess Nourah bint Abdulrahman University with 27, 12 and 4 publications respectively as shown in Figure 77.

Publications funded by the Swedish Research Council - Formas, Princess Nourah bint Abdulrahman University and the National Natural Science Foundation of China (NSFC) had the highest citation impact measured by the CNCI with 3.66, 2.92 and 2.73, respectively.

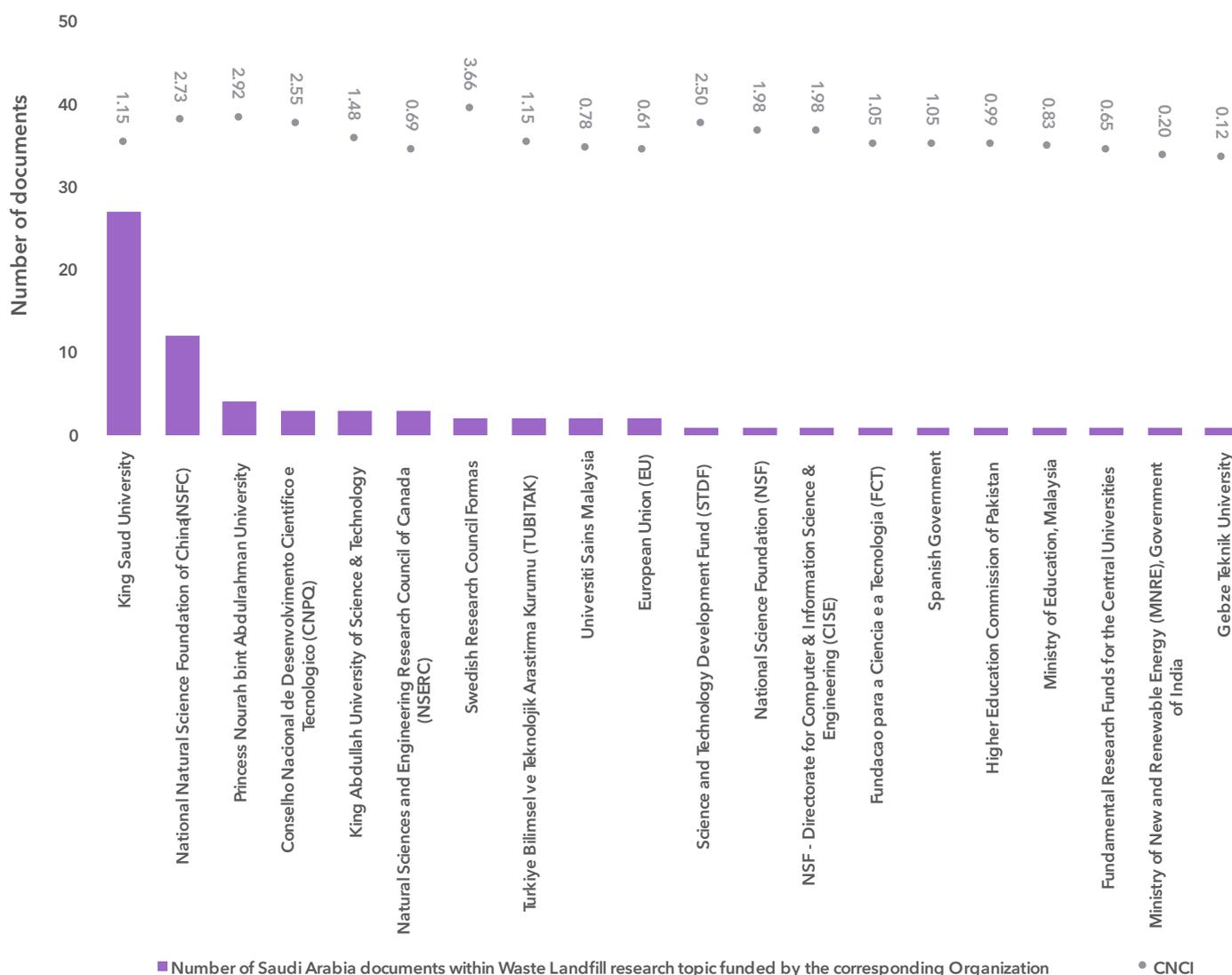


Figure 77: Top 20 funding organizations of Saudi Arabian publications in the research topic Waste Landfill in terms of number of publications in the period 2014-2023

#### 4.1.7.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top three organizations in terms of publications published in this research topic between 2014-2023 are King Saud University followed by King Abdulaziz University and King Khalid University with 46, 20 and 14 publications, respectively, as shown in Figure 78.

Regarding citation impact as measured by the CNCI, the University of Jeddah, followed by Prince Sattam Bin Abdulaziz University and Princess Nourah bint Abdulrahman University had the highest CNCI with 3.87, 3.21 and 2.92, respectively.

Nevertheless, all top 20 organizations except Imam Mohammad Ibn Saud Islamic University (IMSIU), King Fahd University of Petroleum & Minerals and King Abdulaziz City for Science & Technology had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

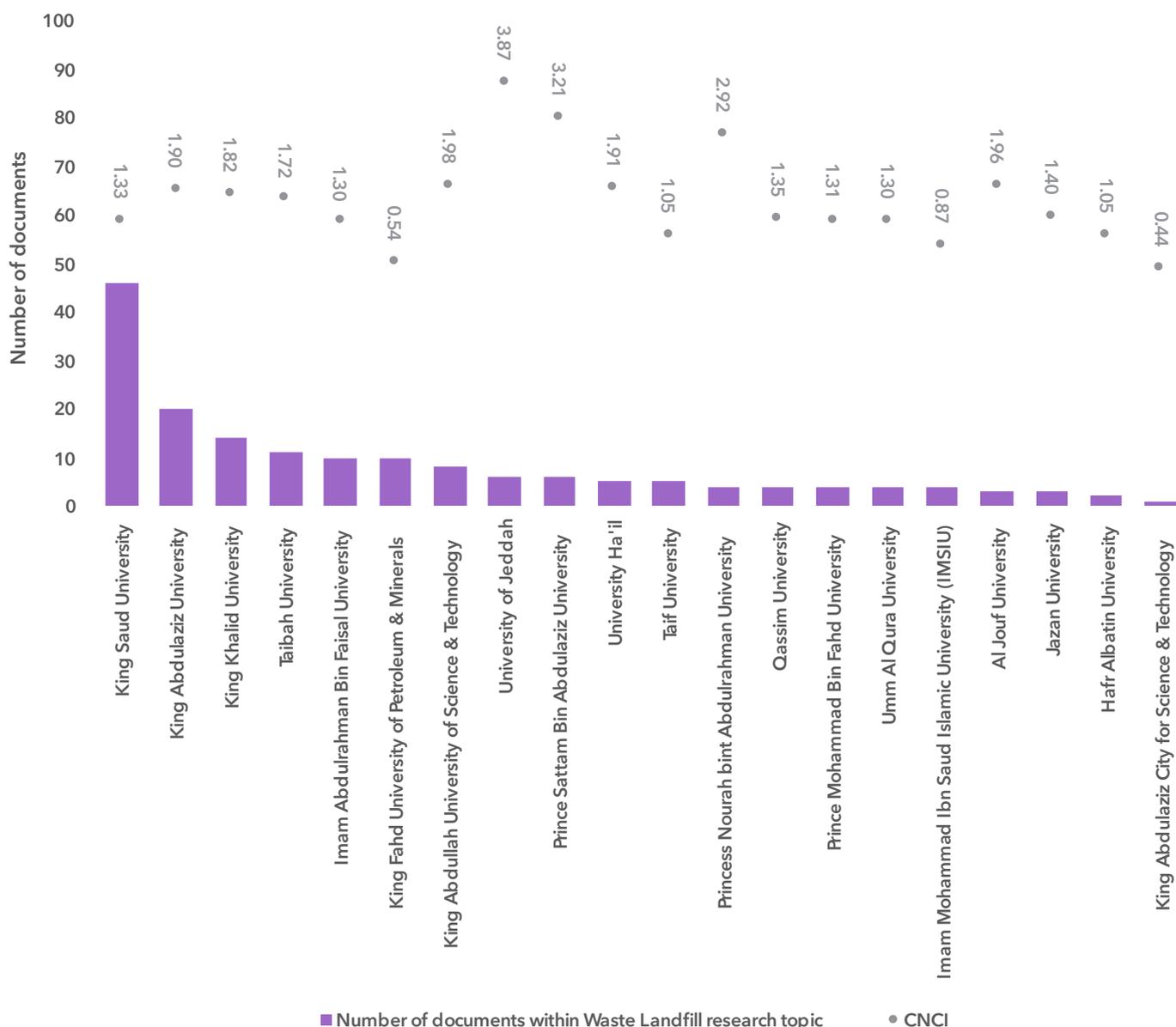


Figure 78: Top 20 Saudi organizations in terms of publications published in the research topic Waste Landfill in the period 2014-2023 and their corresponding CNCI

#### 4.1.7.5 The top 20 researchers are affiliated with Saudi organizations in terms of the number of publications they publish

The highest number of publications are published by Abdulaziz Ibrahim Almohana, affiliated with King Saud University, followed by Cevat Yaman, affiliated with Imam Abdulrahman Bin Faisal University, and Sattam Fahad Almojil, affiliated with King Saud University, with six, five and four publications, respectively as shown in Table 23.

The highest CNCI is achieved by publications published by Abdelfattah Amari affiliated with King Khalid University with a CNCI of 5.41. The highest number of Top 10% publications was achieved by Khalid Z. Elwakeel affiliated with University of Jeddah with 3 publications. None of the top 20 researchers affiliated with Saudi organizations had publications in top 1% in their field.

Table 23: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published on the research topic Waste Landfill in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%
<b>Almohana, Abdulaziz Ibrahim</b>	King Saud University	6	0.51	0	0
<b>Yaman, Cevat</b>	Imam Abdulrahman Bin Faisal University	5	0.83	0	1
<b>Almojil, Sattam Fahad</b>	King Saud University	4	0.26	0	0
<b>Elwakeel, Khalid Z.</b>	University of Jeddah	4	3.21	0	3
<b>Alali, Abdulrhman Fahmi</b>	King Saud University	3	0.30	0	0
<b>Althumayri, Khalid</b>	Taibah University	3	1.52	0	1
<b>Khursheed, Anwar</b>	King Saud University	3	1.28	0	0
<b>Naushad, Mu.</b>	King Saud University	3	2.71	0	2
<b>Ahamad, Tansir</b>	King Saud University	2	0.96	0	0
<b>Ahmad, Munir</b>	King Saud University	2	2.20	0	1
<b>Al-Mohaimeed, Amal M.</b>	King Saud University	2	0.63	0	0
<b>Al-Shamrani, Mosleh Ali</b>	King Saud University	2	1.21	0	0
<b>Aldahri, Tahani</b>	Taibah University	2	1.13	0	0
<b>Alghamdi, Huda Ahmed</b>	King Khalid University	2	0.33	0	0
<b>Amari, Abdelfattah</b>	King Khalid University	2	5.41	0	2
<b>Chaudhary, Anis Ahmad</b>	Imam Mohammad Ibn Saud Islamic University (IMSIU)	2	0.62	0	0
<b>Elkady, Tamer Y.</b>	King Saud University	2	0.89	0	0
<b>Faisal, Kamil</b>	King Abdulaziz University	2	0.87	0	0
<b>Pugazhendi, Arulazhagan</b>	King Abdulaziz University	2	1.57	0	1
<b>Rafique, Muhammad Imran</b>	King Saud University	2	2.20	0	1

#### 4.1.7.6 Top 10 countries in terms of publications

The highest number of publications published on this research topic is published by Mainland China (4,429 publications), followed by the United States (1,856 publications) and India (1,105 publications), as shown in Figure 79.

The highest citation impact measured by the CNCI is achieved by publications published by Australia, United Kingdom and Malaysia with a CNCI of 1.40, 1.20 and 1.17 respectively. Six of the top 10 countries in terms of number of publications published in the research topic are also among the top 10 collaborators with Saudi Arabia. These are Australia, United Kingdom, Malaysia, Mainland China, India and the United States.

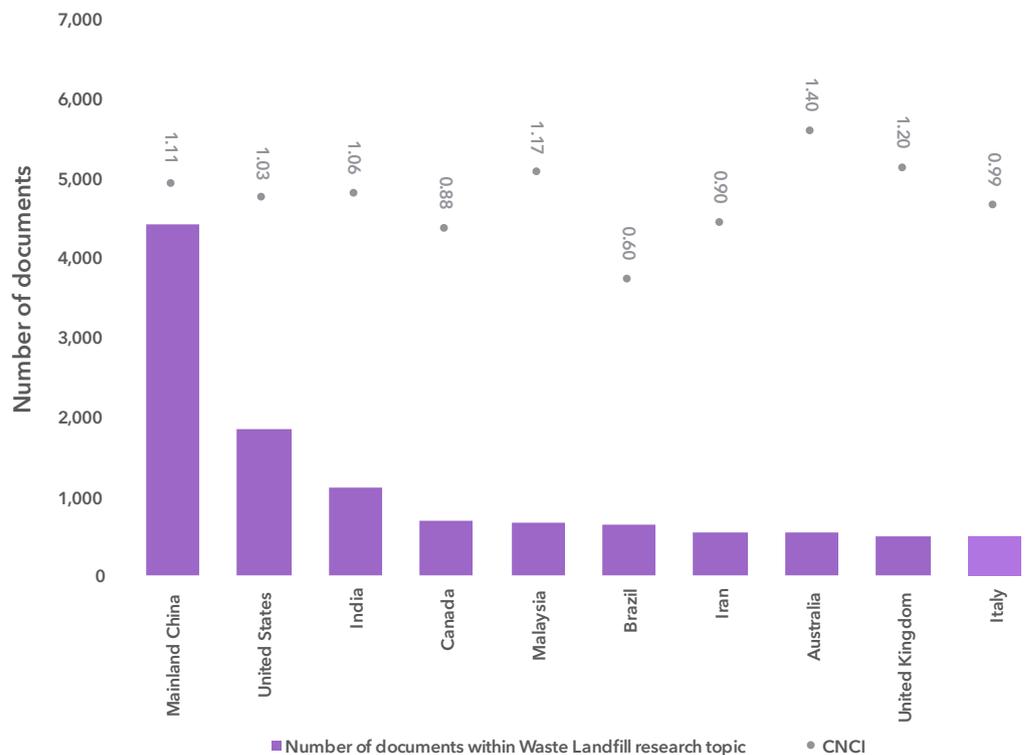


Figure 79: Top 10 countries in terms of the number of publications in the Waste Landfill in the period 2014-2023 and their corresponding CNCI

#### 4.1.7.7 Top 20 organizations globally in terms of number of publications

The top three organizations in terms of number of publications published on this research topic from 2014-2023 are the Chinese Academy of Sciences (490 publications) followed by Zhejiang University (227 publications) and Tongji University (221 publications) as shown in Figure 80.

Regarding citation impact measured by the CNCI, Tsinghua University, Beijing University of Technology, and Harbin Institute of Technology had the highest CNCI with 1.48, 1.47 and 1.45, respectively.

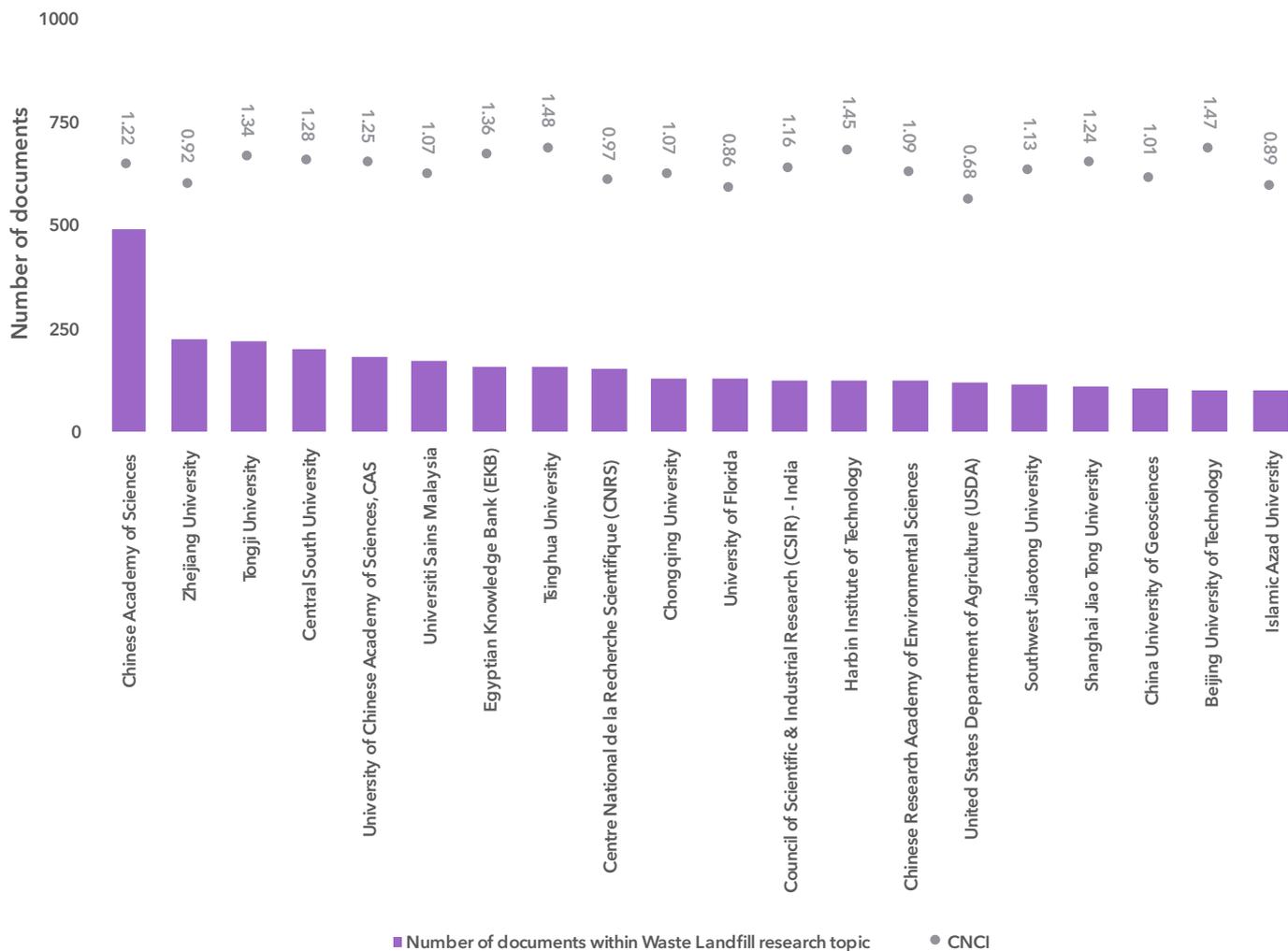


Figure 80: Top 20 organizations globally in terms of the number of publications published in the research topic Waste Landfill in the period 2014-2023 and their corresponding CNCI

#### 4.1.7.8 Top 20 researchers globally in terms of number of publications

The top three researchers globally in terms of the number of publications on this research topic are Yongzhen Peng, affiliated with Beijing University of Technology, with 64 publications, followed by Hamidi Abdul Aziz, affiliated with Universiti Sains Malaysia, with 63 publications, and Krishna R. Reddy, affiliated with the University of Illinois, Chicago with 59 publications as shown in Table 24.

The highest CNCI is achieved by Bing Xie affiliated with East China Normal University with 5.86.

The latter researcher achieved also the highest number of Top 1% with 2 publications on par with Yongzhen Peng affiliated with Beijing University of Technology who is also the researcher with the highest number of Top 10% with 25 publications.

Table 24: Top 20 researchers globally in terms of the number of publications published on the research topic Waste Landfill in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%	Country
<b>Peng, Yongzhen</b>	Beijing University of Technology	64	1.79	2	25	Mainland China
<b>Aziz, Hamidi Abdul</b>	Universiti Sains Malaysia	63	1.00	1	5	Malaysia
<b>Reddy, Krishna R.</b>	University of Illinois Chicago	59	0.83	0	2	United States
<b>Li, Qibin</b>	Southwest Jiaotong University	49	1.47	0	11	Mainland China
<b>Townsend, Timothy G.</b>	University of Florida	49	1.08	0	9	United States
<b>Rowe, R. Kerry</b>	Queens University - Canada	47	1.10	0	3	Canada
<b>Long, Yuyang</b>	Zhejiang Gongshang University	43	0.81	0	4	Mainland China
<b>Feng, Shi-Jin</b>	Tongji University	38	0.80	0	2	Mainland China
<b>Chiemchaisri, Chart</b>	Kasetsart University	36	0.57	0	0	Thailand
<b>Xie, Bing</b>	East China Normal University	35	1.89	2	10	Mainland China
<b>Chen, Weiming</b>	Southwest Jiaotong University	34	1.63	0	10	Mainland China
<b>Shen, Dongsheng</b>	Zhejiang Gongshang University	33	0.88	0	3	Mainland China
<b>Bashir, Mohammed J. K.</b>	Universiti Tunku Abdul Rahman (UTAR)	32	1.65	1	10	Malaysia
<b>Binnemans, Koen</b>	KU Leuven	31	1.59	1	6	Belgium
<b>Sun, Dezhi</b>	Beijing Forestry University	31	1.74	1	8	Mainland China
<b>Yusoff, Mohd Suffian</b>	Universiti Sains Malaysia	30	0.98	0	4	Malaysia
<b>Chiemchaisri, Wilai</b>	Kasetsart University	29	0.57	0	0	Thailand
<b>Daud, Zawawi</b>	University of Tun Hussein Onn Malaysia	29	0.71	0	0	Malaysia
<b>Lou, Ziyang</b>	Shanghai Jiao Tong University	27	0.85	0	0	Mainland China
<b>Vaverkova, Magdalena Daria</b>	Mendel University in Brno	27	1.14	0	3	Czech Republic

#### 4.1.7.9 Top 20 global funders globally in terms of number of publications

The top three organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC) with 2533 publications, followed by the National Key Research & Development Program of China with 344 publications, and Fundamental Research Funds for the Central Universities with 317 publications as shown in Figure 81.

The highest citation impact measured by the CNCI is observed in publications funded by the China Postdoctoral Science Foundation, the United States Department of Energy (DOE) and the National Research Foundation of Korea, with 1.61, 1.36 and 1.34, respectively. Among the top 20 global funding organizations, eight are also among the top 20 funding organizations of Saudi publications in this research topic.

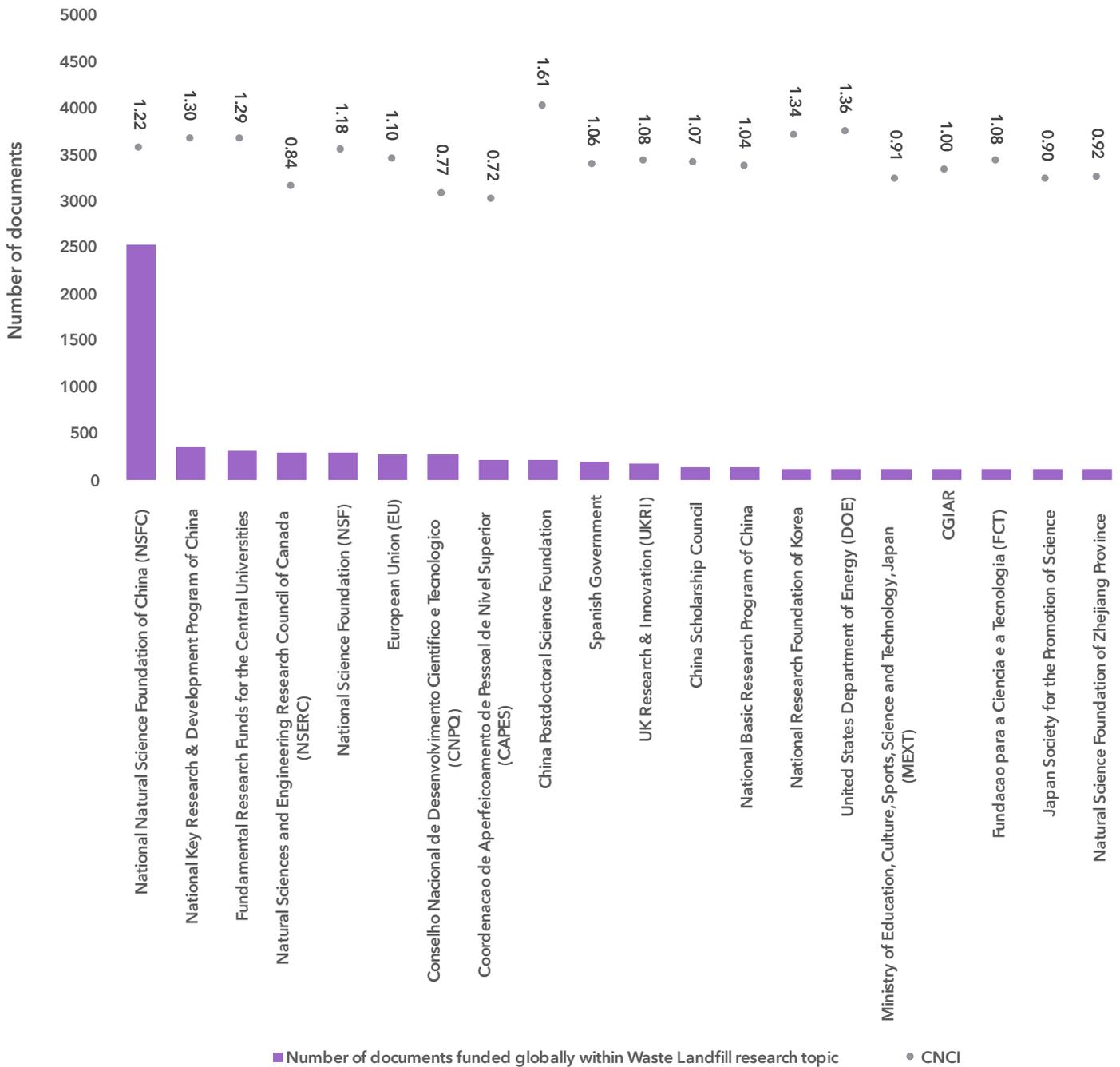


Figure 81: Top 20 funding organizations globally publications in the research topic Waste Landfill in terms of number of publications in the period 2014-2023

#### 4.1.7.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section we investigate the emerging trends globally and in Saudi Arabia in the research topic Waste Landfill. For more information on the methodology used to identify emerging trends, please see the section Emerging Trends.

The top three emerging micro-topics globally in this research topic are Herbicides, Pesticides & Ground Poisoning: Microplastics, Pesticides & Ground Poisoning: PFOS followed by Herbicides, Pesticides & Ground Poisoning: PFOS and Electrochemistry: Lithium-Ion Battery as shown in Figure 82.

Table 25 shows the identified top 10 micro-topics in Saudi Arabia research output in this research topic. Among those, Spectrometry & Separation: Solvent Extraction is also an identified global emerging topic.

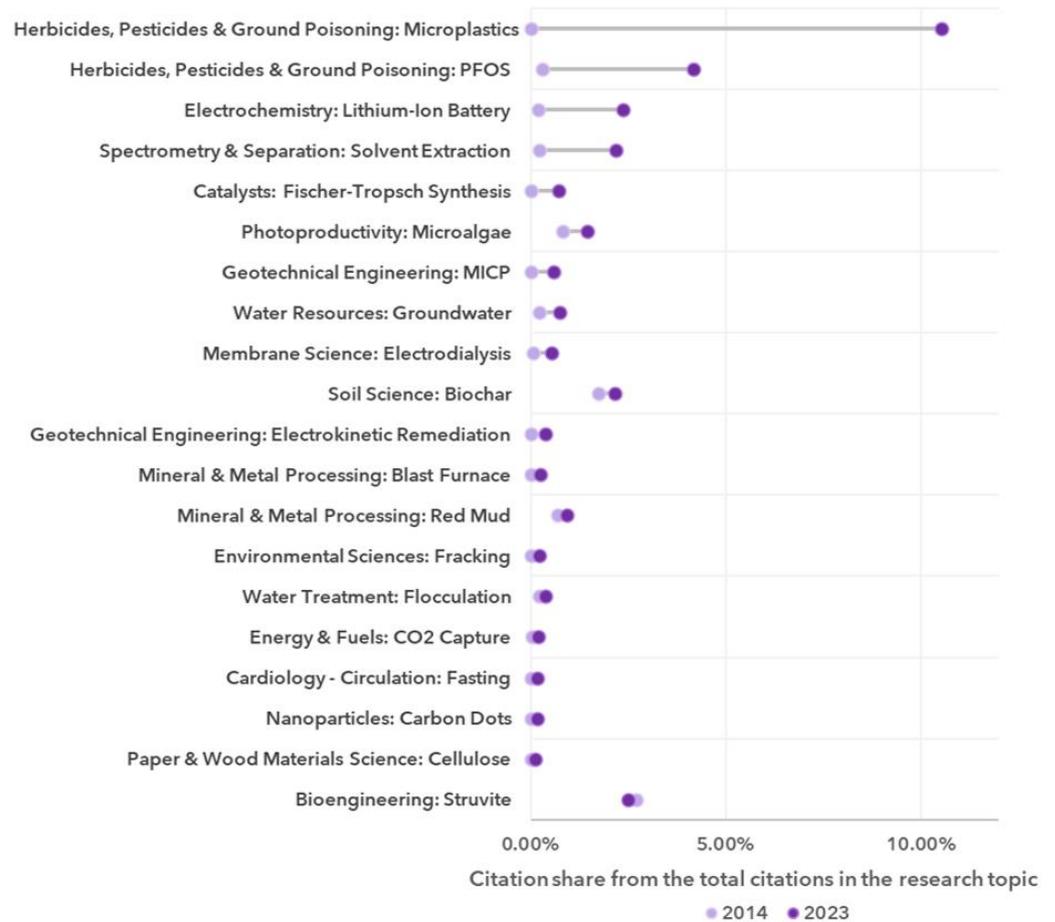


Figure 82: Top 20 emerging micro-topics globally in the research topic Waste Landfill in the period 2014-2023

Table 25: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Waste Landfill in the period 2014-2023

Topic	Number of Saudi Arabian publications in the period 2014-2023
Waste Landfill research topic	157
Sustainability Science: Municipal Solid Waste	30
Water Treatment: Adsorption	21
Water Treatment: Electrocoagulation	10
Contamination & Phytoremediation: Heavy Metals	7
Bioengineering: Activated Sludge	7
Concrete Science: Compressive Strength	5
Bioengineering: Anaerobic Digestion	5
Spectrometry & Separation: Solvent Extraction	5
Membrane Science: Nanofiltration	5
Sensors & Tomography: Ground Penetrating Radar	5

## 4.1.8 Wastewater Purification

### 4.1.8.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabian publications from global publications on the research topic was growing at a slow pace from 2014 to 2019, followed by a vigorous growth from 2020 to 2023, as shown in Figure 83. This shows that Saudi Arabia was not only able to increase the number of publications on this research topic but also had a growth higher than the global growth rate. This is evident as the share of Saudi Arabian publications in the research topic is growing.

The CNCI of Saudi Arabian publications in this research topic were in all years higher than 1, oscillating between 1.57 to 1.84, indicating a citation impact performance 84% higher than the global average at its peak. It is important to mention that the highest impact value was achieved in 2013, the year with the highest value in the share of publications for Saudi Arabia in this research topic.

This means that the growth in publications helped consolidate the CNCI values seen in the early years rather than dilute them as is expected in periods with high productivity growth. Overall, Saudi Arabia's publications increased with a higher growth rate than the global average in this research topic and had a relatively good citation impact, as measured by the CNCI. Nevertheless, after this high growth rate in terms of publications, one should focus on increasing the citation impact and publication pace.

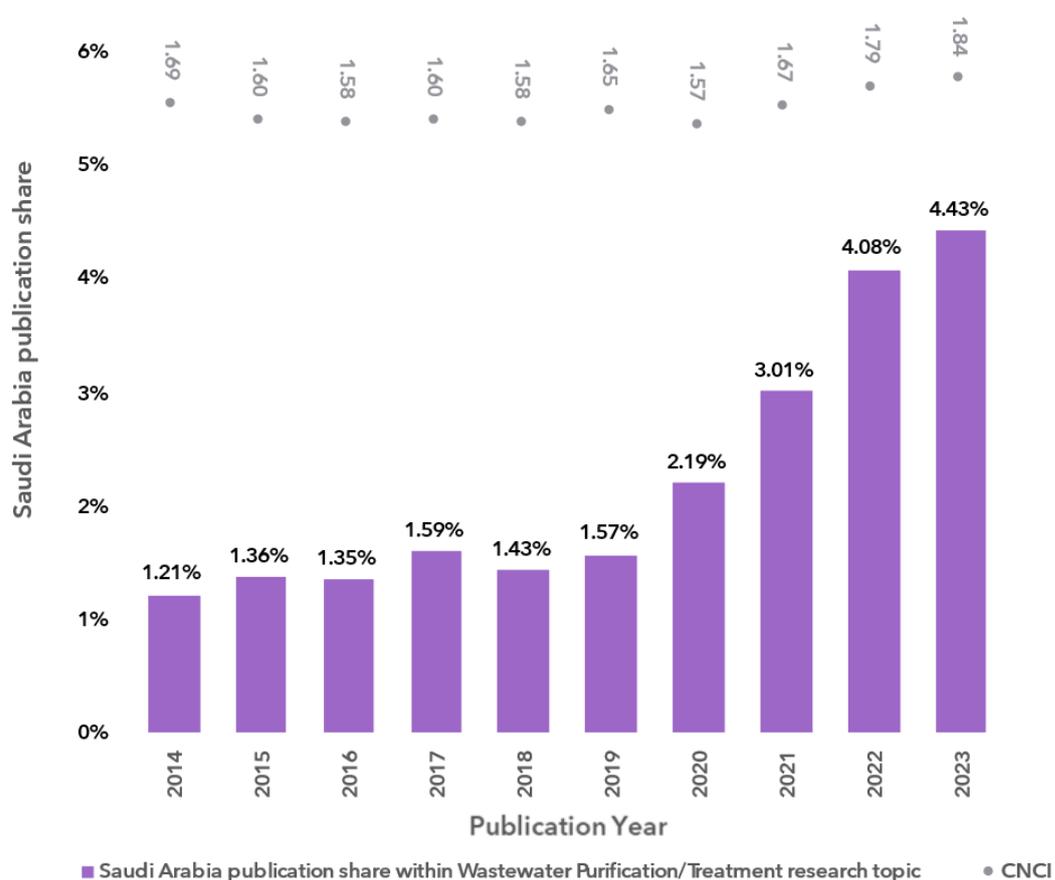


Figure 83: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabian publications in the research topic

### 4.1.8.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating countries with Saudi Arabia in this research topic from 2014-2023 are Egypt, followed by Mainland China and India, with 36, 34 and 32 publications, respectively, as shown in Figure 84. Regarding citation impact measured

by the CNCI publications published in collaboration with France, Egypt, and the United States had the highest CNCI with 2.41, 1.99 and 1.86, respectively.

Nevertheless, all publications with the top 10 collaborating countries had a CNCI higher than 1, ranging from 1.15 to 2.41, reflecting a performance at least 15% higher than the global average.

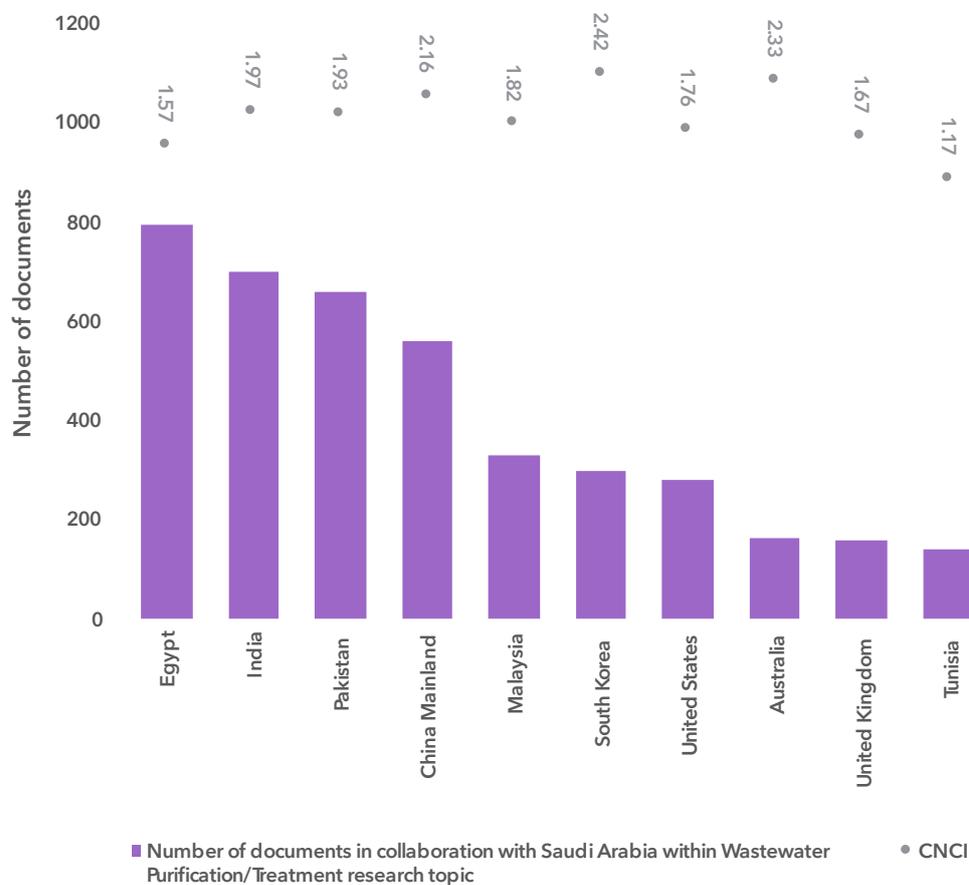


Figure 84: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications in the research topic Wastewater Purification in the period 2014-2023

#### 4.1.8.3 Top 20 funders of Saudi publications by number of publications

The top three funding organizations of Saudi Arabia publications in this research topic in terms of the number of publications mentioning the organization in the funding text from 2014-2023 are King Saud University followed by the National Natural Science Foundation of China (NSFC) and Princess Nourah bint Abdulrahman University with 563, 181 and 110 publications respectively as shown in Figure 85.

Publications funded by Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT), the European Union (EU) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPQ) had the highest citation impact measured by the CNCI with 7.33, 4.85 and 2.62 respectively.

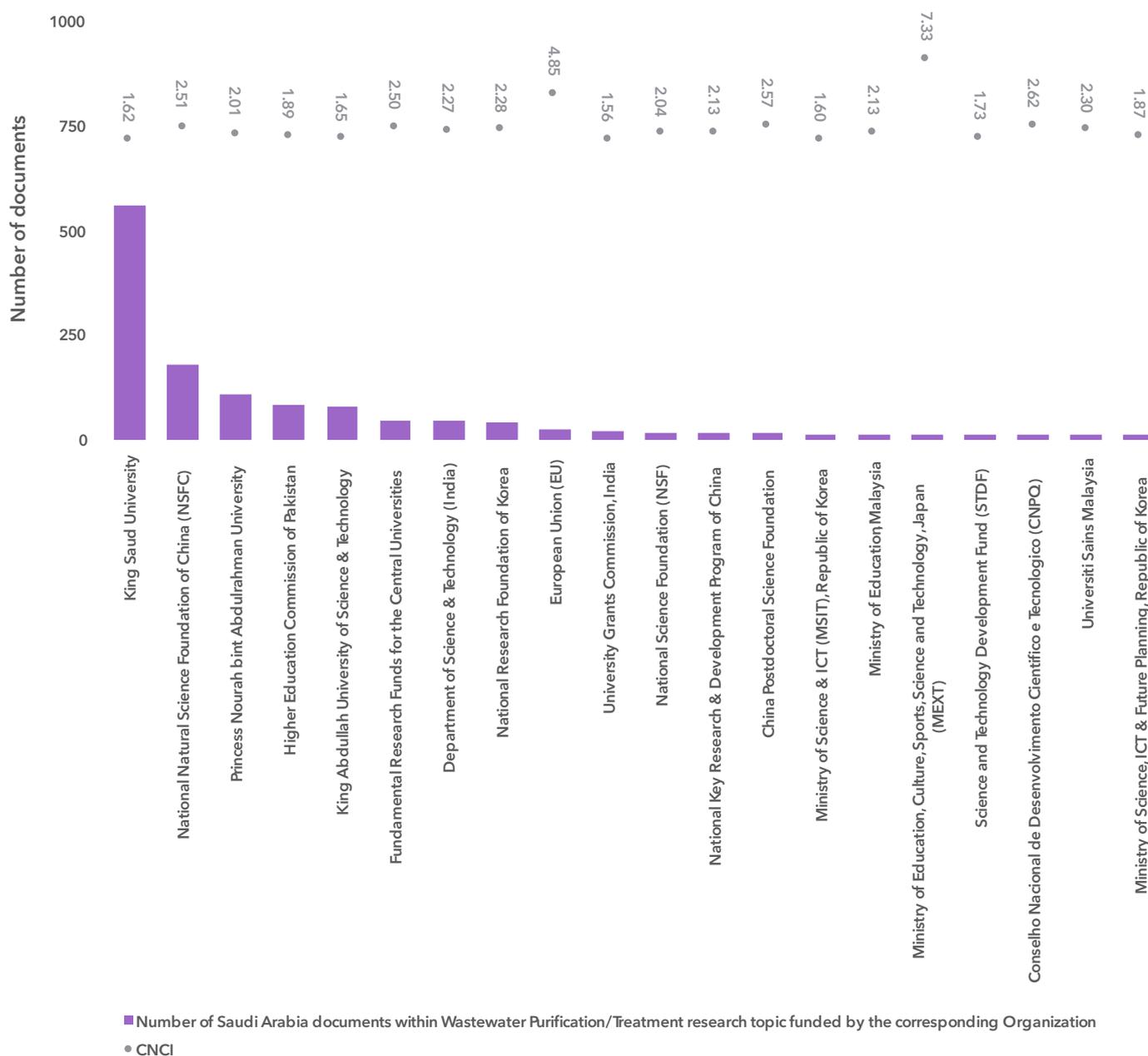


Figure 85: Top 20 funding organizations of Saudi Arabian publications in the research topic Wastewater Purification in terms of number of publications in the period 2014-2023

#### 4.1.8.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top three organizations in terms of publications published in this research topic between 2014-2023 are King Saud University, followed by King Abdulaziz University and King Fahd University of Petroleum & Minerals, with 925, 606 and 339 publications, respectively, as shown in Figure 86.

In terms of citation impact, as measured by the CNCI, Jazan University, followed by King Fahd University of Petroleum & Minerals and the University of Tabuk, had the highest CNCI with 2.52, 2.27 and 2.17, respectively. Nevertheless, all top 20 organizations except had a CNCI higher than 1, ranging from 1.14 to 2.52, reflecting a citation impact performance at least 14% higher than the global average.



Table 26: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published in the research topic Wastewater Purification in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%
<b>Saleh, Tawfik A.</b>	King Fahd University of Petroleum & Minerals	53	2.99	6	23
<b>Hong, Pei-Ying</b>	King Abdullah University of Science & Technology	42	1.15	0	6
<b>Asiri, Abdullah M.</b>	King Abdulaziz University	40	2.79	7	12
<b>Naushad, Mu.</b>	King Saud University	40	2.43	2	17
<b>Hayat, Tasawar</b>	King Abdulaziz University	39	2.86	1	22
<b>Ghaffour, Noreddine</b>	King Abdullah University of Science & Technology	35	1.66	1	10
<b>Kumar, Rajeev</b>	King Abdulaziz University	34	1.23	0	6
<b>Naushad, Mu</b>	King Saud University	34	3.81	5	16
<b>Alsaedi, Ahmed</b>	King Abdulaziz University	29	2.62	1	14
<b>Naz, Iffat</b>	Qassim University	29	0.96	0	2
<b>ALothman, Zeid A.</b>	King Saud University	27	1.75	1	8
<b>Saikaly, Pascal E.</b>	King Abdullah University of Science & Technology	27	2.10	2	10
<b>Barakat, M. A.</b>	King Abdulaziz University	26	1.37	0	6
<b>Leiknes, TorOve</b>	King Abdullah University of Science & Technology	25	2.12	2	7
<b>Zubair, Mukarram</b>	Imam Abdulrahman Bin Faisal University	25	2.08	1	9
<b>Umar, Ahmad</b>	Najran University	22	1.30	0	5
<b>Khan, Sher Bahadar</b>	King Abdulaziz University	21	1.62	0	5
<b>Amari, Abdelfattah</b>	King Khalid University	20	1.50	0	4
<b>Mu'azu, Nuhu Dalhat</b>	Imam Abdulrahman Bin Faisal University	20	1.68	0	5
<b>Ihsanullah, Ihsanullah</b>	King Fahd University of Petroleum & Minerals	19	2.77	2	10

#### 4.1.8.6 Top 10 countries in terms of publications

The highest number of publications published on this research topic is published by Mainland China (46,939 publications), followed by the United States (13,152 publications) and India (12,457 publications), as shown in Figure 87. The highest citation impact measured by the CNCI is achieved by publications published by Australia, South Korea and Mainland China with a CNCI of 1.65, 1.46 and 1.41 respectively.

Five of the top 10 countries in terms of number of publications published in the research topic are also among the top 10 collaborators with Saudi Arabia. These are Mainland China, the United States, India, Australia and Malaysia.

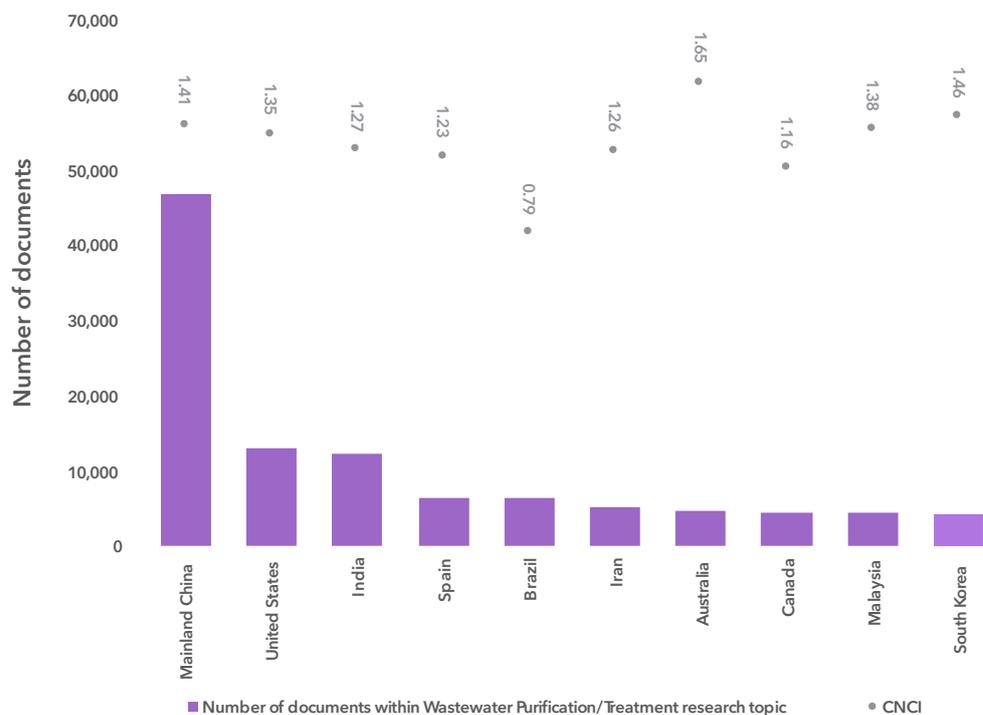


Figure 87: Top 10 countries in terms of number of publications in the Wastewater Purification in the period 2014-2023 and their corresponding CNCI

#### 4.1.8.7 Top 20 organizations globally in terms of number of publications

The top three organizations in terms of the number of publications published on this research topic from 2014-2023 are the Chinese Academy of Sciences (5313 publications) followed by the Indian Institute of Technology System (IIT System) (2342 publications) and the Harbin Institute of Technology (2229 publications) as shown in Figure 88.

Regarding citation impact measured by the CNCI, Tsinghua University, Harbin Institute of Technology, and Nanjing University had the highest CNCI with 1.66, 1.64 and 1.60, respectively.

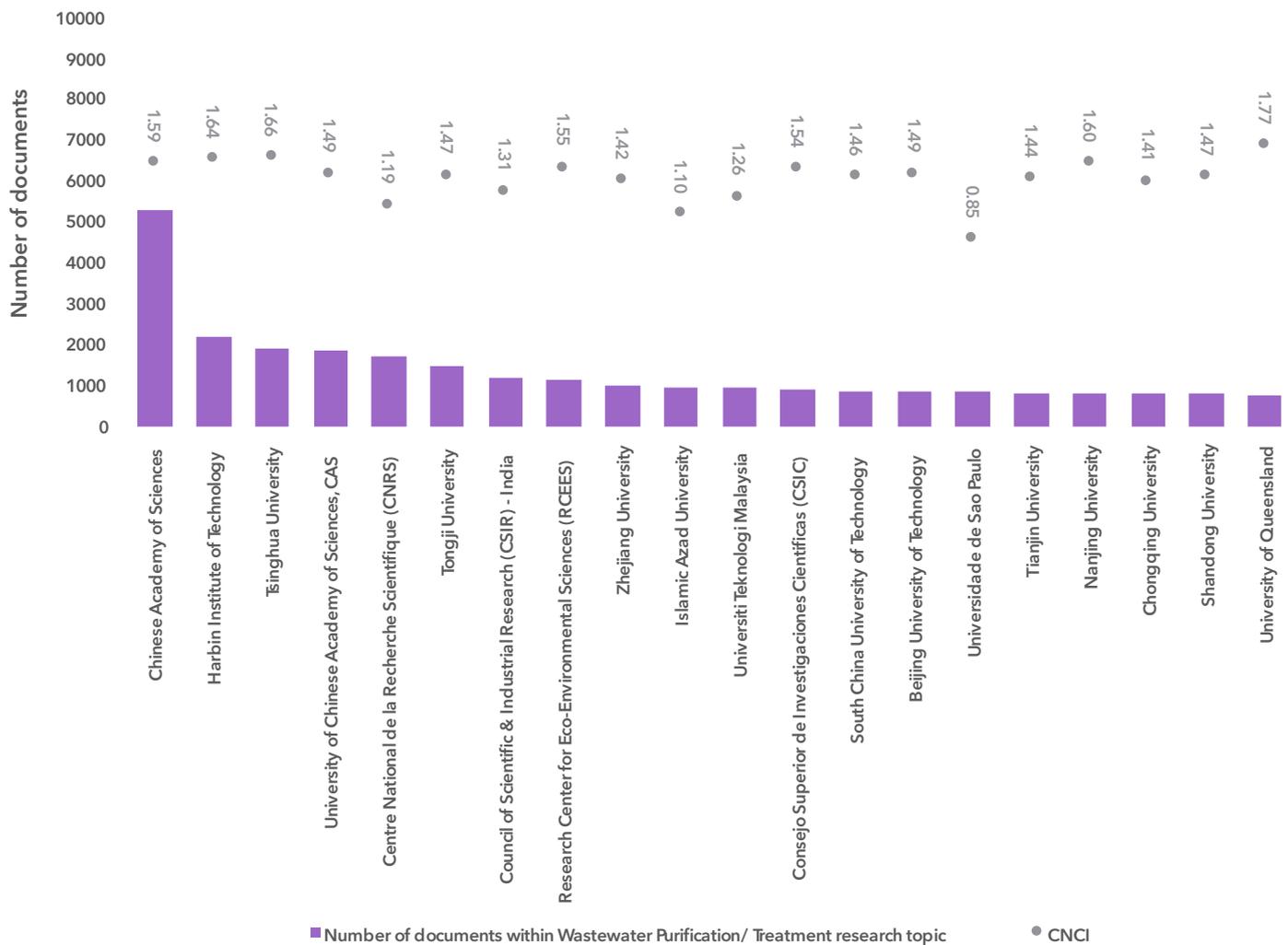


Figure 88: Top 20 organizations globally in terms of number of publications published in the research topic Wastewater Purification in the period 2014-2023 and their corresponding CNCI

#### 4.1.8.8 Top 20 researchers globally in terms of number of publications

The top three researchers globally in terms of the number of publications in this research topic are Yongzhen Peng, affiliated with Beijing University of Technology, with 315 publications, followed by Guangming Zeng, affiliated with Hunan University, with 201 publications, and Xiaohu Dai, affiliated with Tongji University, with 172 publications as shown in Table 27.

The highest CNCI is achieved by Guangming Zeng, affiliated with Hunan University, with 3.70.

The latter also achieved the highest number of Top 1% while the Top 10% publications' highest number was achieved by Yongzhen Peng, affiliated with Beijing University of Technology, who was mentioned before as the researcher with the highest overall number of papers.

Table 27: Top 20 researchers globally in terms of the number of publications published on the research topic Wastewater Purification in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%	Country
<b>Peng, Yongzhen</b>	Beijing University of Technology	315	1.96	17	119	Mainland China
<b>Zeng, Guangming</b>	Hunan University	201	3.70	34	114	Mainland China
<b>Dai, Xiaohu</b>	Tongji University	172	2.06	12	53	Mainland China
<b>Huang, Xia</b>	Tsinghua University	161	1.77	7	44	Mainland China
<b>Yuan, Zhiguo</b>	University of Queensland	160	1.97	10	57	Australia
<b>Ren, Hongqiang</b>	Nanjing University	152	1.24	0	29	Mainland China
<b>Li, Yu-You</b>	Tohoku University	151	1.60	4	47	Japan
<b>Kumar, P. Senthil</b>	SSN College of Engineering	142	2.36	10	47	India
<b>Guo, Wenshan</b>	University of Technology Sydney	136	2.20	7	51	Australia
<b>Ma, Jun</b>	Harbin Institute of Technology	133	2.03	9	39	Mainland China
<b>Wang, Dongbo</b>	Hunan University	130	2.43	10	56	Mainland China
<b>Barcelo, Damia</b>	Consejo Superior de Investigaciones Cientificas (CSIC)	125	2.20	3	46	Spain
<b>Wang, Jianlong</b>	Tsinghua University	125	3.19	15	69	Mainland China
<b>Ngo, Huu Hao</b>	University of Technology Sydney	122	1.99	6	35	Australia
<b>Wang, Zhiwei</b>	Tongji University	122	1.52	0	37	Mainland China
<b>Dionysiou, Dionysios D.</b>	University of Cincinnati	121	2.81	13	64	United States
<b>Ismail, Ahmad Fauzi</b>	Universiti Teknologi Malaysia	114	1.12	2	14	Malaysia
<b>van Loosdrecht, Mark C. M.</b>	Delft University of Technology	114	2.28	5	42	Netherlands
<b>Ren, Nanqi</b>	Harbin Institute of Technology	112	1.70	4	30	Mainland China
<b>Gao, Baoyu</b>	Shandong University	108	1.40	1	26	Mainland China

#### 4.1.8.9 Top 20 global funders globally in terms of number of publications

The top three organizations in terms of funded publications in this research topic are the United National Natural Science Foundation of China (NSFC) with 27628 publications, followed by Fundamental Research Funds for the Central Universities with 3941 publications, and the European Union (EU) with 3774 publications as shown in Figure 89.

The highest citation impact measured by the CNCI is observed in publications funded by the China Postdoctoral Science Foundation, UK Research & Innovation (UKRI) and Natural Science Foundation of Jiangsu Province, with 1.70, 1.64 and 1.63, respectively. Among the top 20 global funding organizations, ten are also among the top 20 funding organizations of Saudi publications in this research topic.

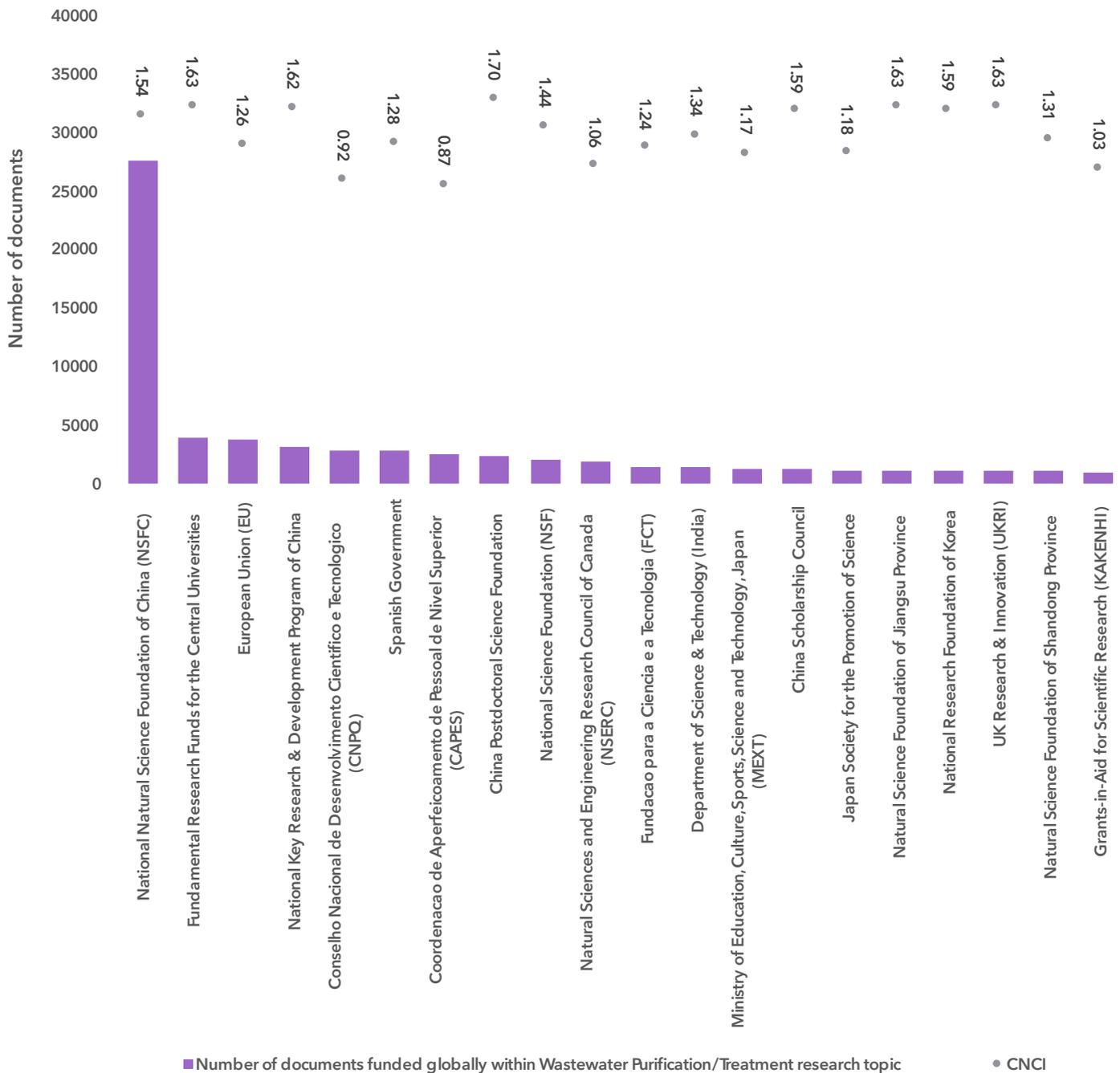


Figure 89: Top 20 funding organizations globally publications in the research topic Wastewater Purification/Treatment research topic in terms of number of publications in the period 2014-2023

#### 4.1.8.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section we investigate the emerging trends globally and in Saudi Arabia in the research topic Wastewater Purification. For more information on the methodology used to identify emerging trends, please see the section Emerging Trends.

The top three emerging micro-topics globally in this research topic are Thermodynamics: Solar Still followed by Herbicides, Pesticides & Ground Poisoning, Microplastics and Electrochemistry: Oxygen Reduction Reaction as shown in Figure 90.

Table 28 shows the identified top 10 micro-topics in Saudi Arabia research output in this research topic.

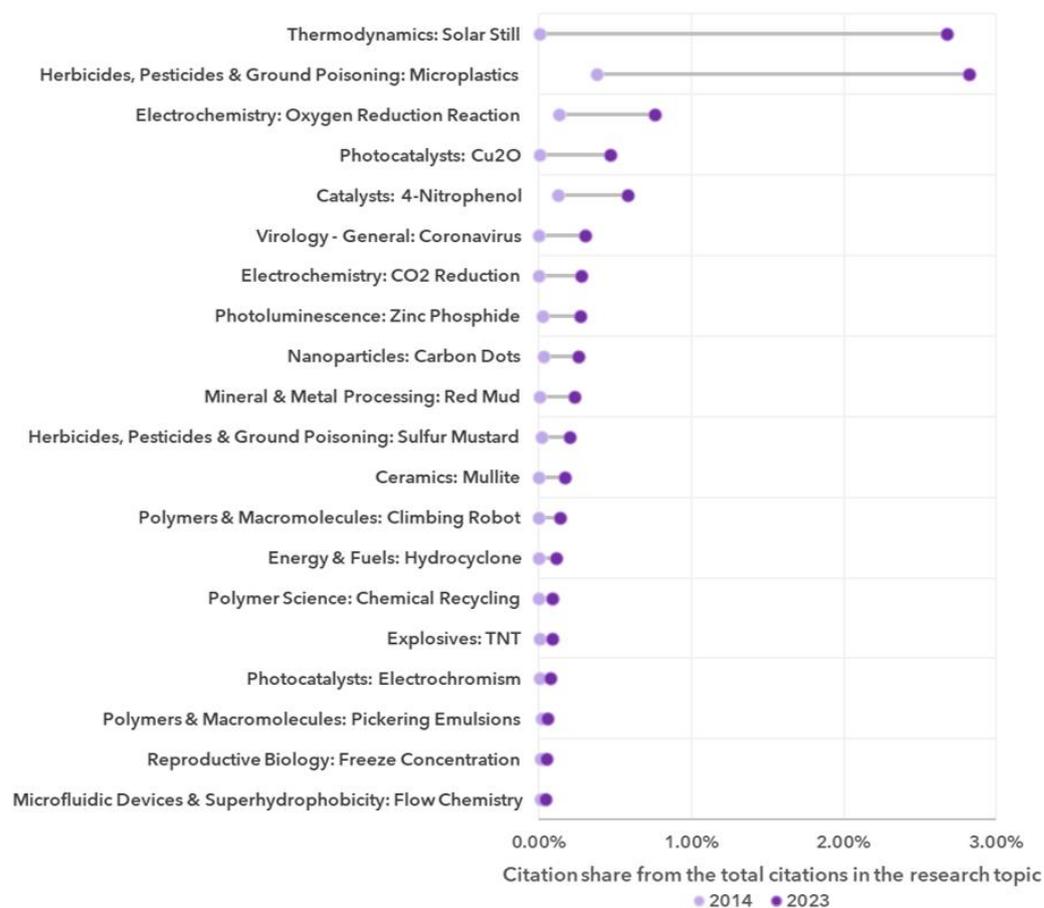


Figure 90: Top 20 emerging micro-topics globally in the research topic Wastewater Purification in the period 2014-2023

Table 28: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Wastewater Purification in the period 2014-2023

Name	Number of Saudi Arabian publications in the period 2014-2023
Wastewater Purification research topic	3574
Water Treatment: Adsorption	973
Photocatalysts: Photocatalysis	280
Membrane Science: Nanofiltration	216
Water Treatment: Electrocoagulation	168
Bioengineering: Activated Sludge	101
Nanoparticles: Silver Nanoparticles	100
Herbicides, Pesticides & Ground Poisoning: Bisphenol A	95
Bioengineering: Microbial Fuel Cell	88
Photoproductivity: Microalgae	84
Contamination & Phytoremediation: Heavy Metals	79

## 4.1.9 Water Desalination

### 4.1.9.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabian publications from global publications in the research topic had an oscillating and descending trend from 2014 to 2019, followed by an important growth from 2014 to 2023, as shown in Figure 91. This shows that Saudi Arabia was not only able to increase the number of publications on this research topic but also had a growth higher than the global growth rate. This is evident as the share of Saudi Arabian publications in the research topic is growing.

The CNCI of Saudi Arabian publications in this research topic were in all years higher than 1, ranging from 1.21 to 1.74, indicating a citation impact performance higher than the global average. On the other hand, the CNCI decreased from 1.74 in 2014 to 1.44 in 2023, yet still indicating a 44% higher citation impact performance than the global average. In a high publication period, it is usually observed that the citation impact decreases, which is observed in this case. It is worth mentioning that the CNCI value change was smaller in amplitude than the change seen in the share of Saudi publications, indicating a consistent research quality dynamic.

Overall, Saudi Arabia's publications increased with a higher growth rate than the global average in this research topic and had a relatively good citation impact, as measured by the CNCI. Nevertheless, after this high growth rate in terms of publications, one should focus on increasing the citation impact and publication pace.

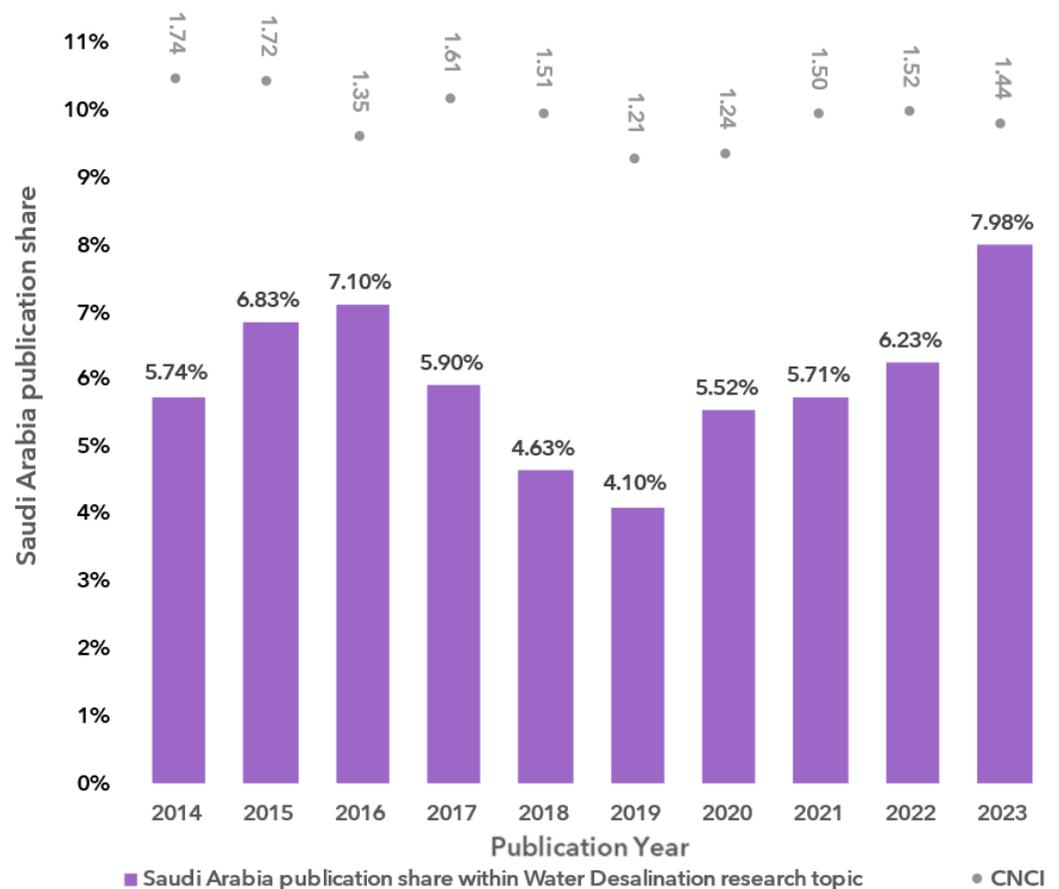


Figure 91: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabian publications in the research topic

#### 4.1.9.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating country with Saudi Arabia in this research topic from 2014-2023 was Egypt followed by the United States and Mainland China with 382, 253 and 225 publications, respectively, as shown in Figure 92.

Regarding citation impact measured by the CNCI publications published in collaboration with Mainland China, South Korea and Australia had the highest CNCI with 2.22, 2.02 and 1.87, respectively. Nevertheless, all publications with the top 10 collaborating countries had a CNCI higher than 1, ranging from 1.30 to 2.22, reflecting a performance higher than the global average.

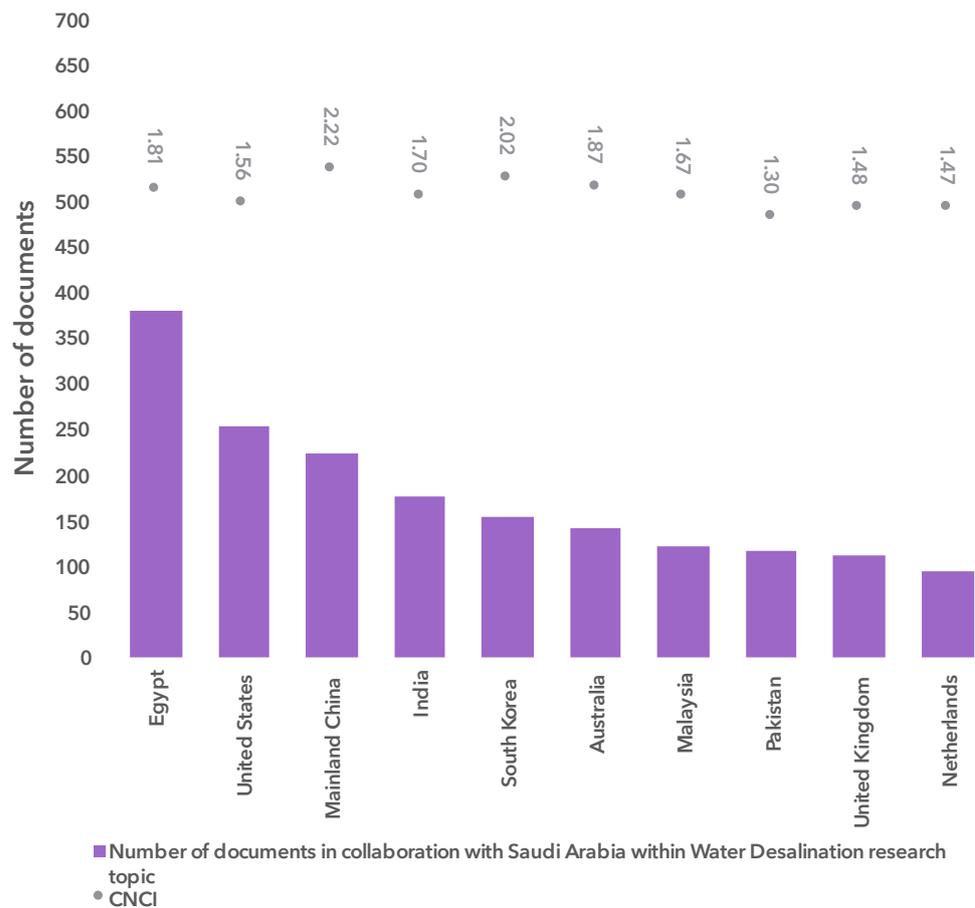


Figure 92: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications on the research topic Water Desalination in the period 2014-2023

#### 4.1.9.3 Top 20 funders of Saudi publications by number of publications

The top three funding organizations of Saudi Arabia publications in this research topic in terms of the number of publications mentioning the organization in the funding text from 2014-2023 are King Abdullah University of Science & Technology followed by King Saud University and National Natural Science Foundation of China (NSFC) with 243, 174 and 88 publications respectively as shown in Figure 93.

Publications funded by Grants-in-Aid for Scientific Research (KAKENHI), Japan Society for the Promotion of Science and United States Department of Energy (DOE) had the highest citation impact measured by the CNCI with 6.23, 4.98 and 4.75 respectively.

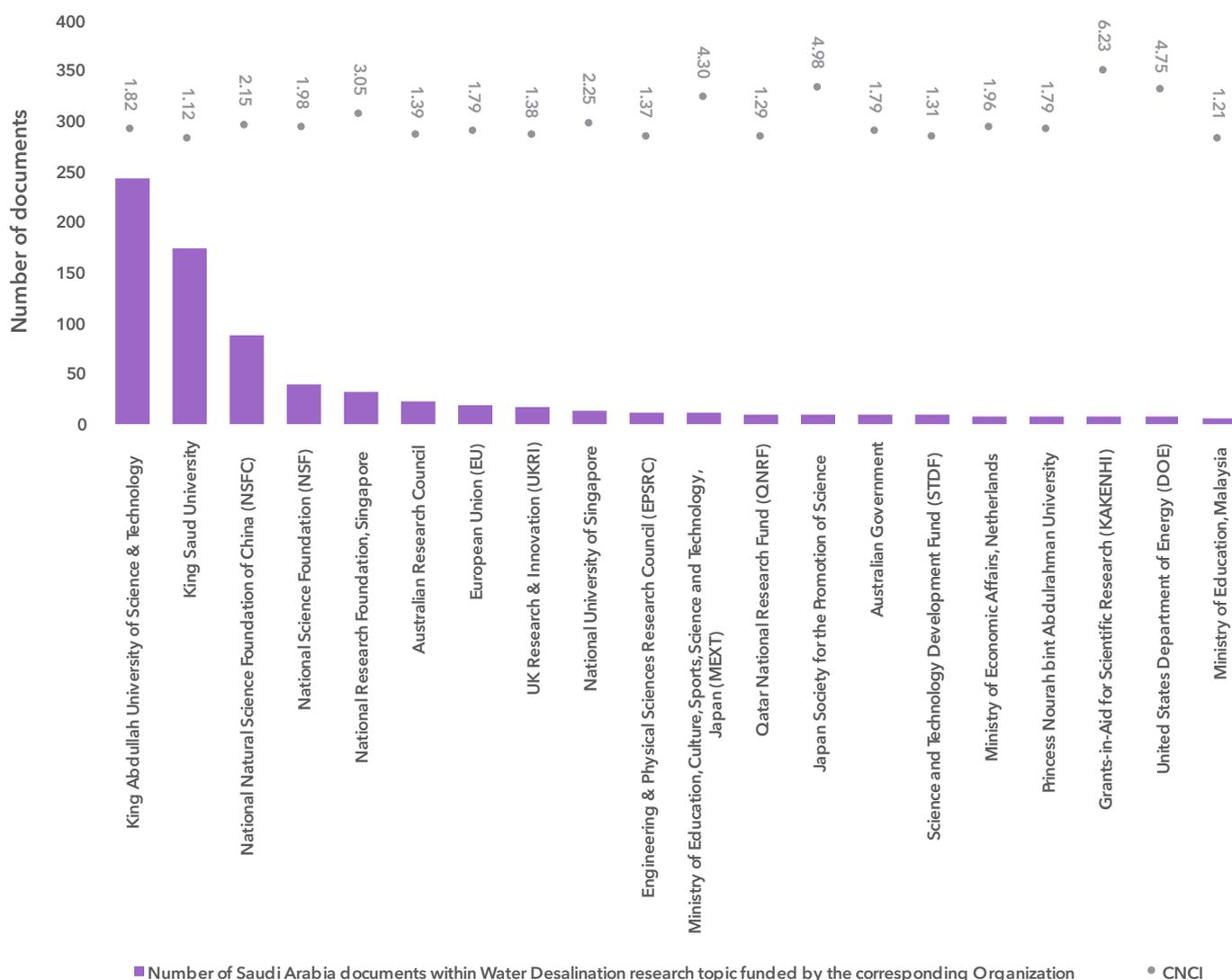


Figure 93: Top 20 funding organizations of Saudi Arabian publications in the research topic Water Desalination in terms of number of publications in the period 2014-2023

#### 4.1.9.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top three organizations in terms of publications published on this research topic from 2014-2023 are King Abdullah University of Science & Technology, followed by King Fahd University of Petroleum & Minerals and King Saud University with 582, 412 and 347 publications, respectively as shown in Figure 94. Regarding citation impact as measured by the CNCI, Prince Sattam Bin Abdulaziz University, followed by King Abdullah University of Science & Technology and University Ha'il, had the highest CNCI with 2.08, 1.84 and 1.69, respectively.

Nevertheless, all top 20 organizations except King Abdulaziz City for Science & Technology, Qassim University, Saline Water Conversion Corporation (SWCC) and Imam Mohammad Ibn Saud Islamic University (IMSIU) had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

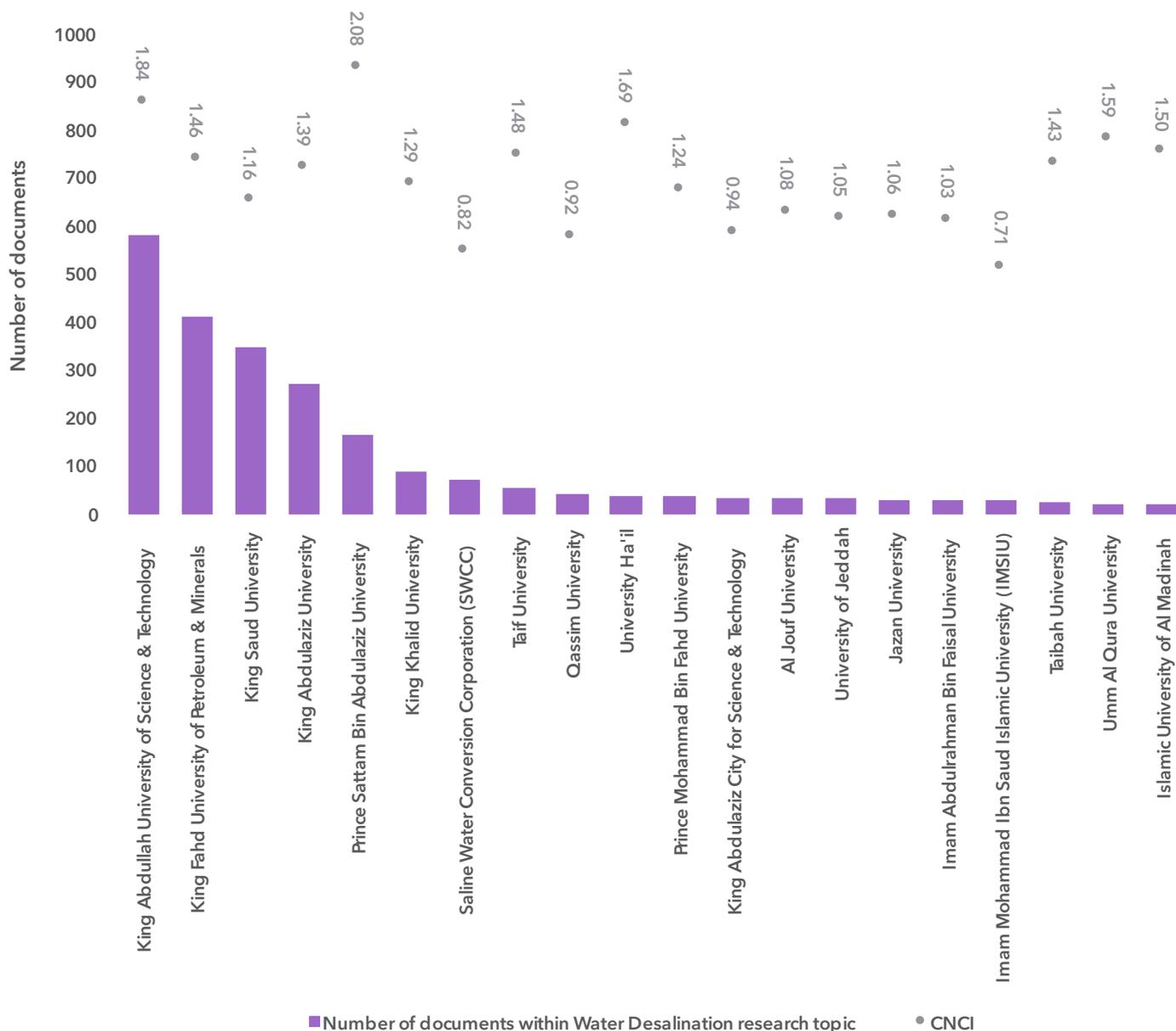


Figure 94: Top 20 Saudi organizations in terms of publications published in the research topic Water Desalination in the period 2014-2023 and their corresponding CNCI

#### 4.1.9.5 The top 20 researchers are affiliated with Saudi organizations in terms of the number of publications they publish

The highest number of publications are published by Tawfik A. Saleh, affiliated with King Fahd University of Petroleum & Minerals, followed by Pei-Ying Hong, affiliated with King Abdullah University of Science & Technology, and Abdullah M. Asiri, affiliated with King Abdulaziz University, with 53, 42 and 40 publications respectively as shown in Table 29. The highest CNCI is achieved by publications published by Mu. Naushad is affiliated with King Saud University with a CNCI of 3.81.

The highest number of Top 1% was achieved by Abdullah M. Asiri, affiliated with King Abdulaziz University, with seven publications, while Tawfik A. Saleh, affiliated with King Fahd University of Petroleum & Minerals, has the highest number of Top 10% publications, with 23 publications, which also the researcher with the highest overall number of publications.

Table 29: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published on the research topic of Water Desalination in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%
<b>Saleh, Tawfik A.</b>	King Fahd University of Petroleum & Minerals	53	2.99	6	23
<b>Hong, Pei-Ying</b>	King Abdullah University of Science & Technology	42	1.15	0	6
<b>Asiri, Abdullah M.</b>	King Abdulaziz University	40	2.79	7	12
<b>Naushad, Mu.</b>	King Saud University	40	2.43	2	17
<b>Hayat, Tasawar</b>	King Abdulaziz University	39	2.86	1	22
<b>Ghaffour, Noreddine</b>	King Abdullah University of Science & Technology	35	1.66	1	10
<b>Kumar, Rajeev</b>	King Abdulaziz University	34	1.23	0	6
<b>Naushad, Mu</b>	King Saud University	34	3.81	5	16
<b>Alsaedi, Ahmed</b>	King Abdulaziz University	29	2.62	1	14
<b>Naz, Iffat</b>	Qassim University	29	0.96	0	2
<b>ALothman, Zeid A.</b>	King Saud University	27	1.75	1	8
<b>Saikaly, Pascal E.</b>	King Abdullah University of Science & Technology	27	2.10	2	10
<b>Barakat, M. A.</b>	King Abdulaziz University	26	1.37	0	6
<b>Leiknes, TorOve</b>	King Abdullah University of Science & Technology	25	2.12	2	7
<b>Zubair, Mukarram</b>	Imam Abdulrahman Bin Faisal University	25	2.08	1	9
<b>Umar, Ahmad</b>	Najran University	22	1.30	0	5
<b>Khan, Sher Bahadar</b>	King Abdulaziz University	21	1.62	0	5
<b>Amari, Abdelfattah</b>	King Khalid University	20	1.50	0	4
<b>Mu'azu, Nuhu Dalhat</b>	Imam Abdulrahman Bin Faisal University	20	1.68	0	5
<b>Ihsanullah, Ihsanullah</b>	King Fahd University of Petroleum & Minerals	19	2.77	2	10

#### 4.1.9.6 Top 10 countries in terms of publications

The highest number of publications published on this research topic is published by Mainland China (11,620 publications), followed by the United States (5,634 publications) and India (2,761 publications), as shown in Figure 95. The highest citation impact measured by the CNCI is achieved by publications published in Australia, Egypt and Mainland China with a CNCI of 1.77, 1.72 and 1.67, respectively.

Seven of the top 10 countries, in terms of the number of publications published on the research topic, are also among the top 10 collaborators with Saudi Arabia. These are Australia, Egypt, Mainland China, the United Kingdom, the United States, South Korea and India.

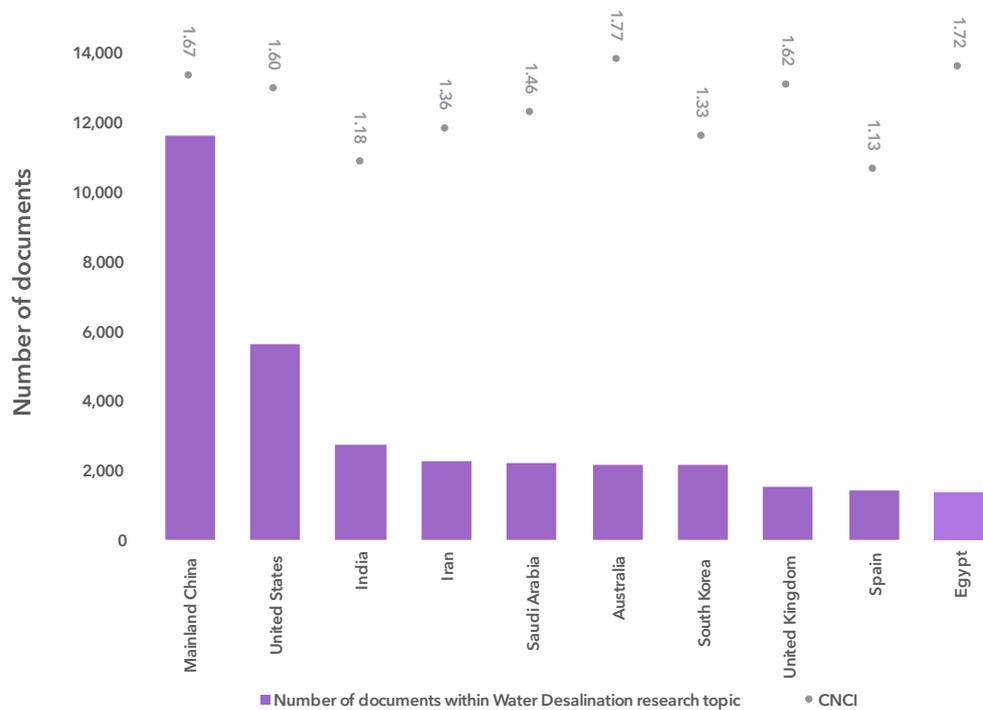


Figure 95: Top 10 countries in terms of the number of publications in Water Desalination in the period 2014-2023 and their corresponding CNCI

#### 4.1.9.7 Top 20 organizations globally in terms of number of publications

The top three organizations in terms of number of publications published on this research topic from 2014-2023 are the Chinese Academy of Sciences (1448 publications) followed by Tsinghua University (576 publications) and the University of Chinese Academy of Sciences, CAS (528 publications) as shown in Figure 96.

Regarding citation impact measured by the CNCI, Tanta University, National University of Singapore and Massachusetts Institute of Technology (MIT) had the highest CNCI with 2.83, 2.34 and 2.13 respectively.

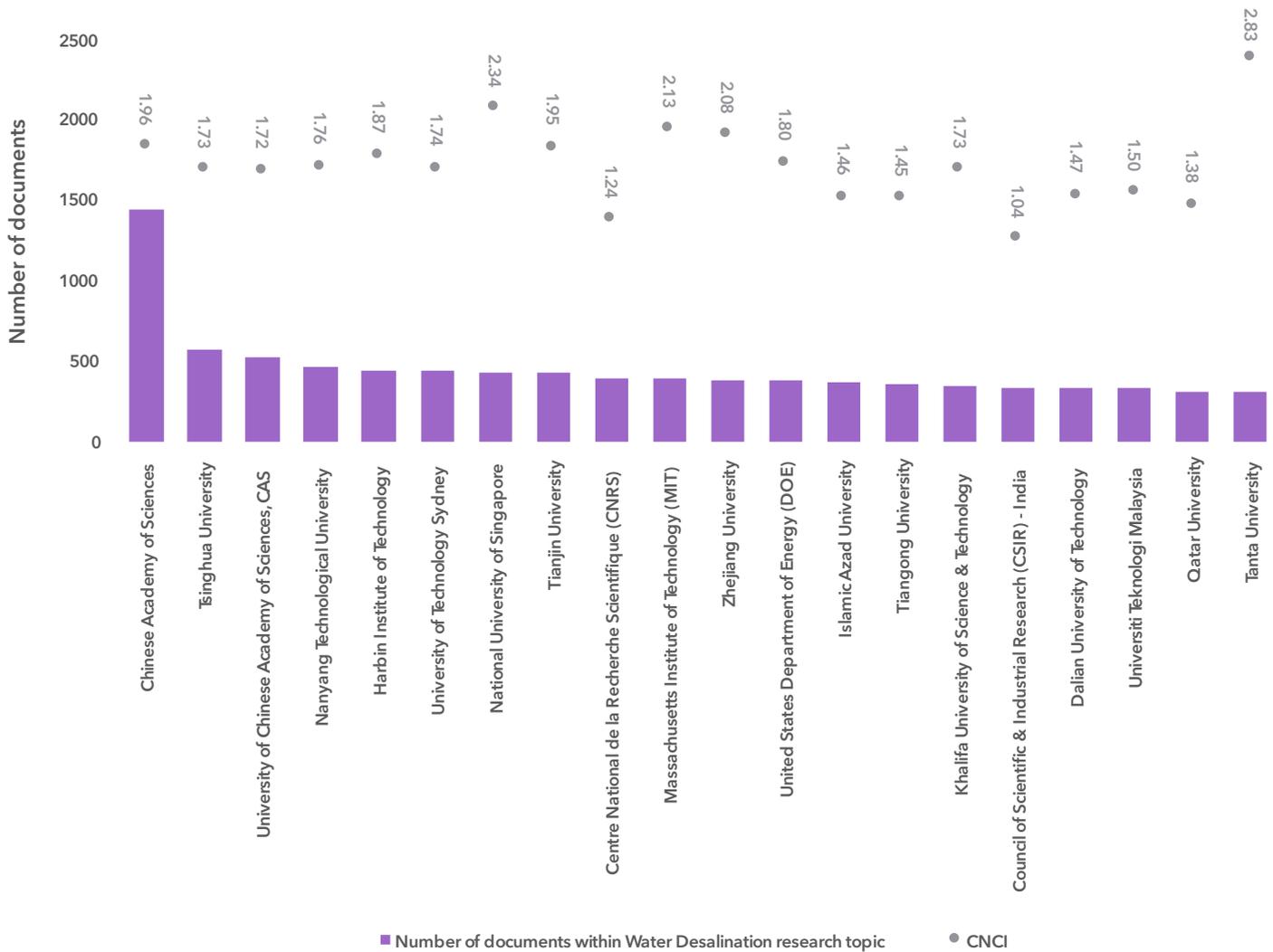


Figure 96: Top 20 organizations globally in terms of number of publications published in the research topic Water Desalination in the period 2014-2023 and their corresponding CNCI

#### 4.1.9.8 Top 20 researchers globally in terms of number of publications

The top three researchers globally in terms of the number of publications in this research topic are Ho Kyong Shon, affiliated with the University of Technology Sydney, with 174 publications, followed by Menachem Elimelech, affiliated with Yale University, with 167 publications, and Chuyang Y. Tang, affiliated with the University of Hong Kong, with 150 publications as shown in Table 30.

The highest CNCI is achieved by Menachem Elimelech, affiliated with Yale University, with 3.79.

The latter also achieved the highest number of Top 1% and Top 10% publications, with 22 and 118, respectively.

Table 30: Top 20 researchers globally in terms of the number of publications published on the research topic of Water Desalination in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%	Country
<b>Shon, Ho Kyong</b>	University of Technology Sydney	174	2.11	11	57	Australia
<b>Elimelech, Menachem</b>	Yale University	167	3.79	22	118	United States
<b>Tang, Chuyang Y.</b>	University of Hong Kong	150	2.69	11	83	Hong Kong
<b>Ghaffour, Noredine</b>	King Abdullah University of Science & Technology	150	1.83	5	44	Saudi Arabia
<b>Matsuyama, Hideto</b>	Kobe University	140	1.39	1	35	Japan
<b>Kabeel, A. E.</b>	Tanta University	132	2.95	14	77	Egypt
<b>Ismail, Ahmad Fauzi</b>	Universiti Teknologi Malaysia	119	1.12	3	14	Malaysia
<b>Hong, Seungkwan</b>	Korea University	113	1.80	3	38	South Korea
<b>Chung, Tai-Shung</b>	National University of Singapore	108	2.33	4	56	Singapore
<b>Wang, Rong</b>	Nanyang Technological University	107	2.11	2	47	Singapore
<b>Drioli, Enrico</b>	Consiglio Nazionale delle Ricerche (CNR)	104	1.83	6	31	Italy
<b>Van der Bruggen, Bart</b>	KU Leuven	99	2.07	5	37	Belgium
<b>Lee, Sangho</b>	Kookmin University	92	0.95	1	13	South Korea
<b>Gao, Congjie</b>	Zhejiang University of Technology	89	1.85	5	28	Mainland China
<b>Ismail, A. F.</b>	Universiti Teknologi Malaysia	86	2.45	8	35	Malaysia
<b>Wang, Rong</b>	Danish Hydraulic Institute (DHI)	84	2.27	2	40	Denmark
<b>Liang, Heng</b>	Harbin Institute of Technology	79	2.12	5	32	Mainland China
<b>Lienhard, John H.</b>	Massachusetts Institute of Technology (MIT)	75	2.17	5	27	United States
<b>Phuntsho, Sherub</b>	University of Technology Sydney	75	1.74	3	22	Australia
<b>Hilal, Nidal</b>	Swansea University	73	2.10	3	23	Wales

#### 4.1.9.9 Top 20 global funders globally in terms of number of publications

The top three organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC), with 7,348 publications, followed by the National Science Foundation (NSF), with 1,349 publications, and Fundamental Research Funds for the Central Universities with 1,212 publications, as shown in Figure 97.

The highest citation impact measured by the CNCI is observed in publications funded by the Natural Science Foundation of Jiangsu Province, China Scholarship Council, and Australian Research Council, with 2.56, 2.52 and 2.28, respectively. Among the top 20 global funding organizations, seven are also among the top 20 funding organizations of Saudi publications in this research topic.

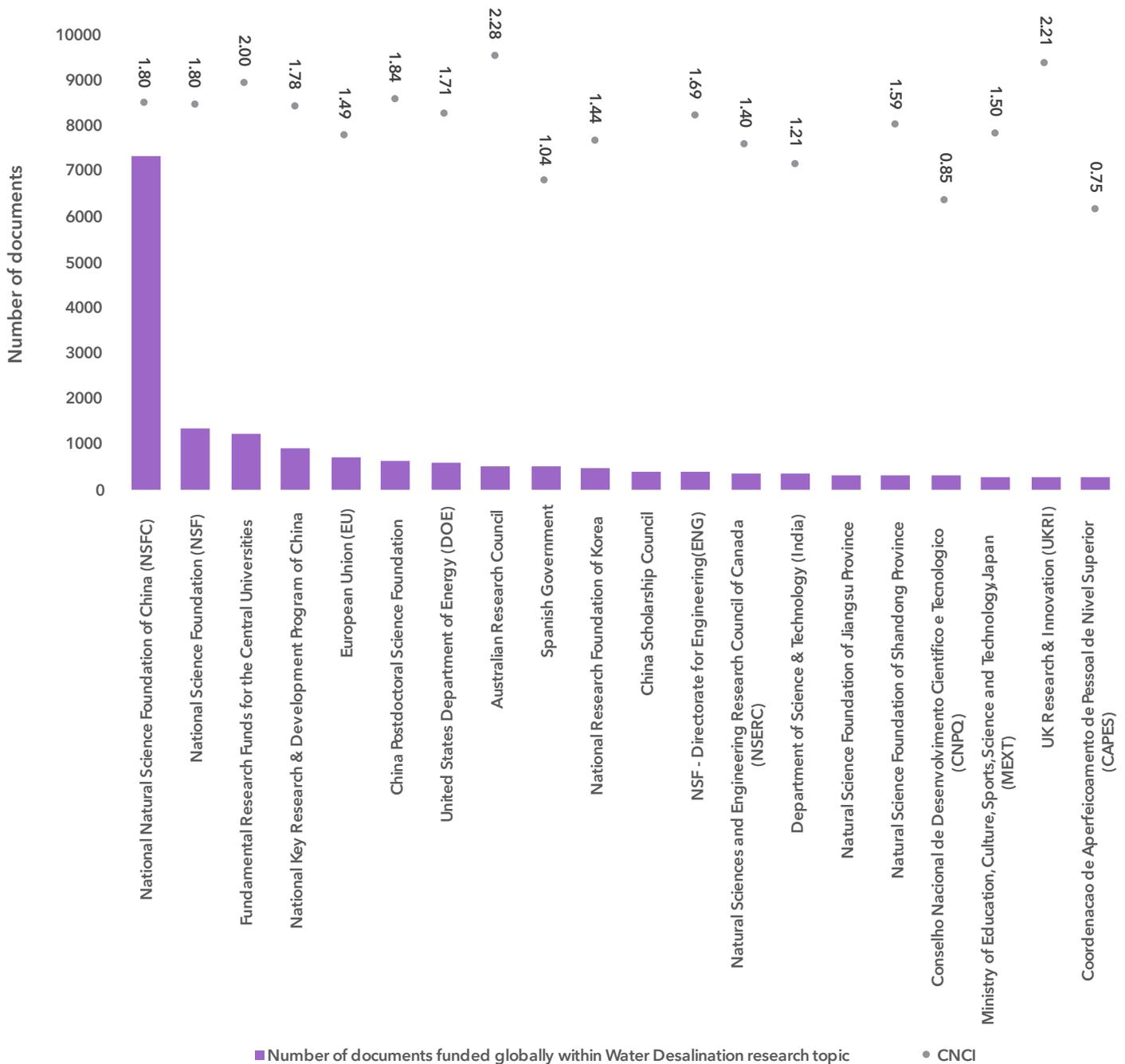


Figure 97: Top 20 funding organizations globally publications in the research topic Water Desalination in terms of number of publications in the period 2014-2023

#### 4.1.9.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section we investigate the emerging trends globally and in Saudi Arabia in the research topic Water Desalination. For more information on the methodology used to identify emerging trends, please see the section Emerging Trends.

The top three emerging micro-topics globally in this research topic are Thermodynamics: Solar Still followed by Inorganic & Nuclear Chemistry: Metal-Organic Frameworks and Thermodynamics: Liquid Desiccant, as shown in Figure 98.

Table 31 shows the identified top 10 micro-topics in Saudi Arabia research output in this research topic. Among those, Thermodynamics: Solar Still and Thermodynamics: Liquid Desiccant are also among the top 20 identified global emerging micro-topics.

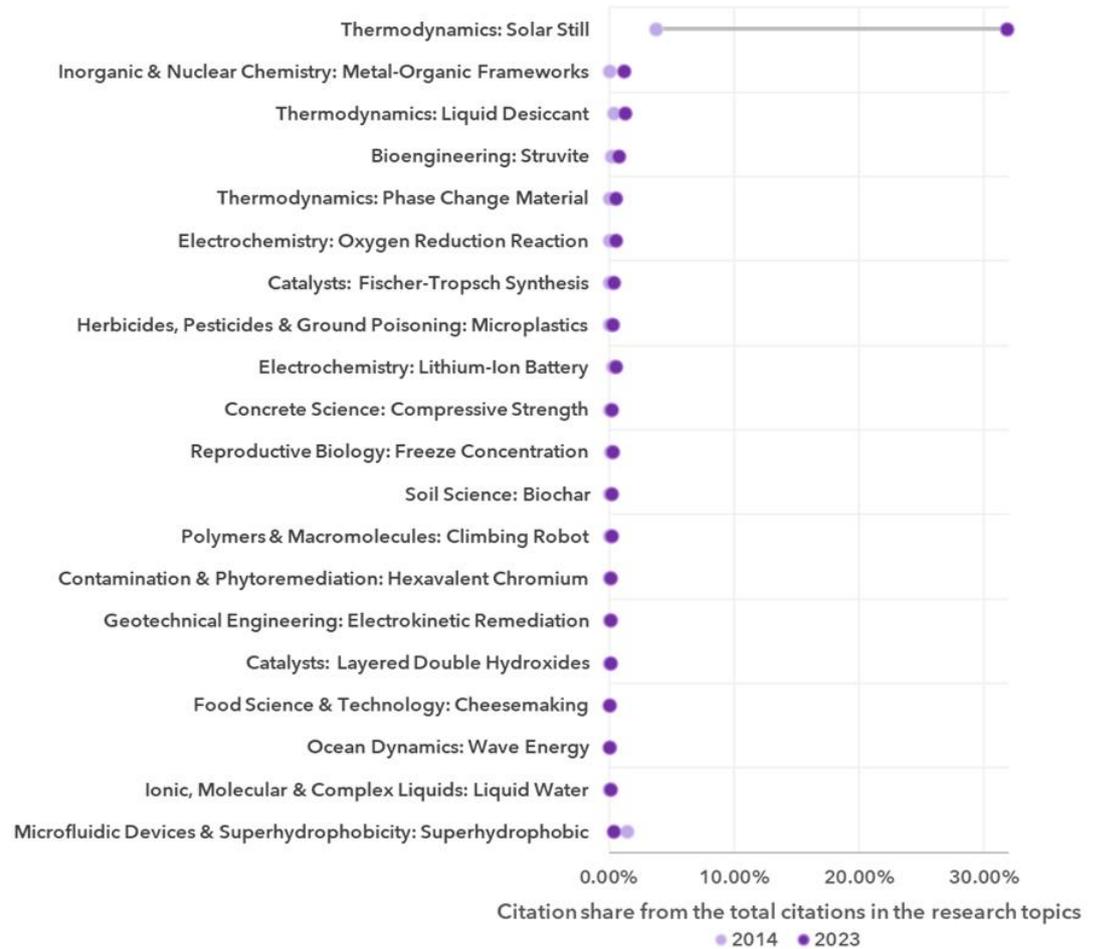


Figure 98: Top 20 emerging micro-topics globally in the research topic Water Desalination in the period 2014-2023

Table 31: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Water Desalination in the period 2014-2023

Topic	Number of Saudi Arabian publications in the period 2014-2023
Water Desalination research topic	2236
Membrane Science: Nanofiltration	1015
Thermodynamics: Solar Still	384
Thermodynamics: Organic Rankine Cycle	95
Electrochemistry: Supercapacitor	76
Thermodynamics: Liquid Desiccant	48
Membrane Science: Electrodialysis	30
Water Treatment: Adsorption	29
Power Systems & Electric Vehicles: Unit Commitment	26
Corrosion & Deposition Chemistry: Corrosion	25
Water Treatment: Trihalomethanes	21

## 4.1.10 Water - Conservation Management

### 4.1.10.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabian publications from global publications in the research topic shows an oscillating evolution and decreasing trend from 2014 to 2018, followed by a vigorous increase from 2019 to 2023, as shown in Figure 99. This shows that Saudi Arabia was not only able to increase the number of publications on this research topic but also had a growth higher than the global growth rate.

This is evident as the share of Saudi Arabian publications in the research topic is growing. The CNCI of Saudi Arabian publications in this research topic was higher than 1 in eight out of ten years of the analyzed period, indicating a citation impact performance higher than the global average. In the first five years, the CNCI oscillations in values were very high but also reached the highest levels in the years, with the lowest share of publications for Saudi Arabia. The following years show a decreasing trend during a high publication growth, which is usually observed.

Overall, Saudi Arabia's publications increased with a higher growth rate than the global average in this research topic and had a relatively good citation impact, as measured by the CNCI. Nevertheless, after this high growth rate in terms of publications, one should focus on increasing the impact of citations.

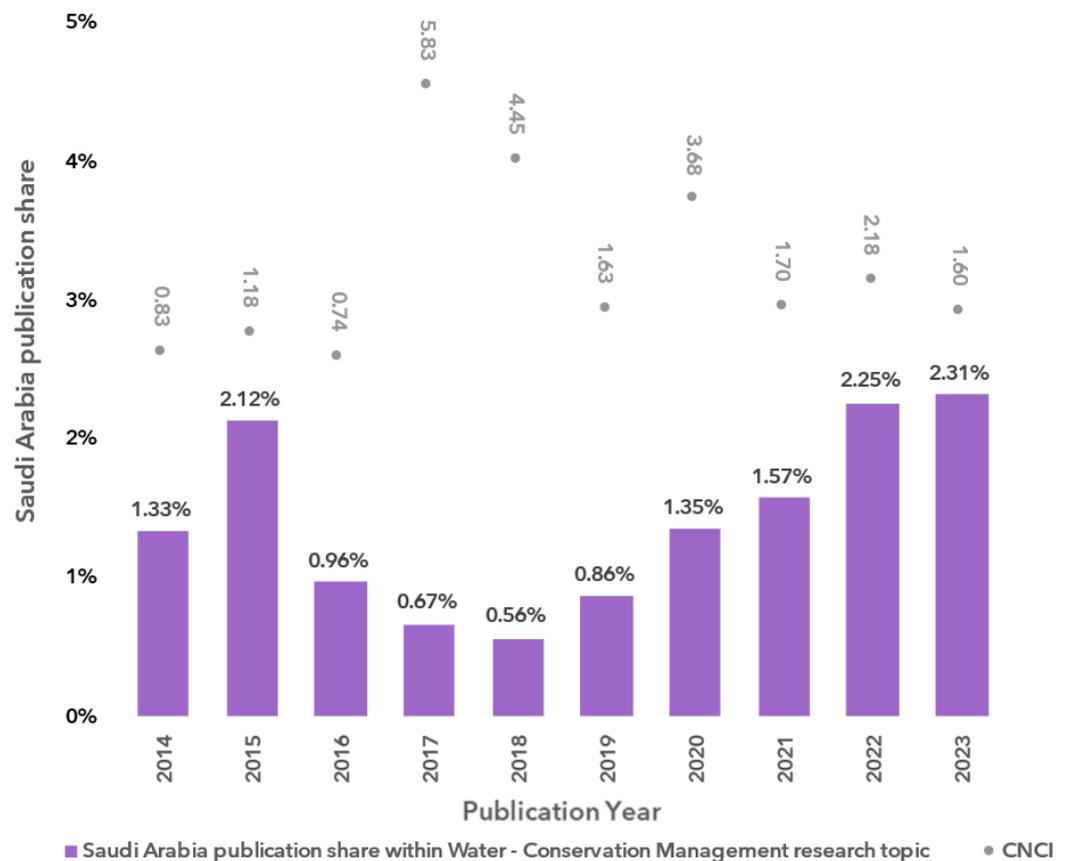


Figure 99: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabian publications in the research topic

### 4.1.10.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating country with Saudi Arabia in this research topic from 2014-2023 is Egypt followed by the United States and India with 30, 29 and 14 publications, respectively, as shown in Figure 100.

Regarding citation impact measured by the CNCI publications published in collaboration with Hong Kong followed by Mainland China and the United States had the highest CNCI with 5.41, 4.83 and 4.14 respectively. Except for Mexico, Malaysia and Canada, the countries from the ten collaborations with Saudi Arabia had a CNCI higher than 1, reflecting a performance higher than the global average.

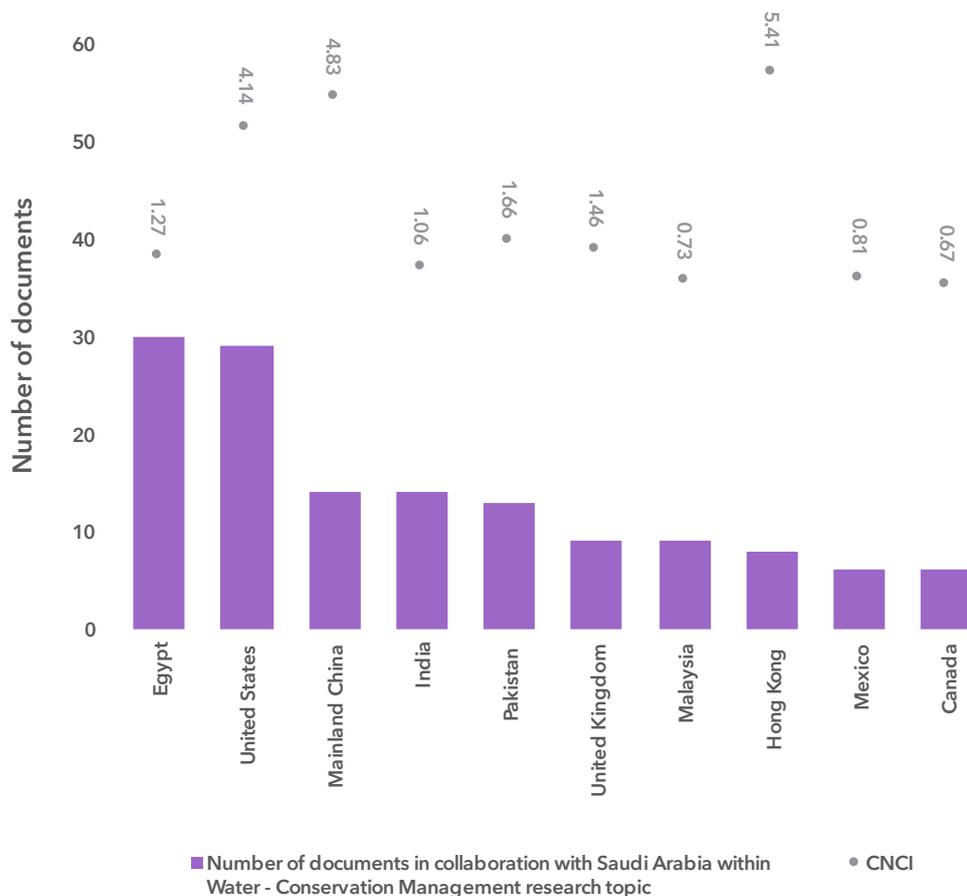


Figure 100: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications in the research topic Water - Conservation Management in the period 2014-2023

#### 4.1.10.3 Top 20 funders of Saudi publications by number of publications

The top three funding organizations of Saudi Arabia publications in this research topic in terms of the number of publications mentioning the organization in the funding text from 2014-2023 are King Saud University followed by King Abdullah University of Science & Technology and the United States Department of Energy (DOE) with 9, 7 and 6 publications respectively as shown in Figure 101.

Publications funded by Samsung, the United States Department of Energy (DOE) and the United States Department of Health & Human Services had the highest citation impact measured by the CNCI with 22.66, 5.76 and 5.38, respectively.

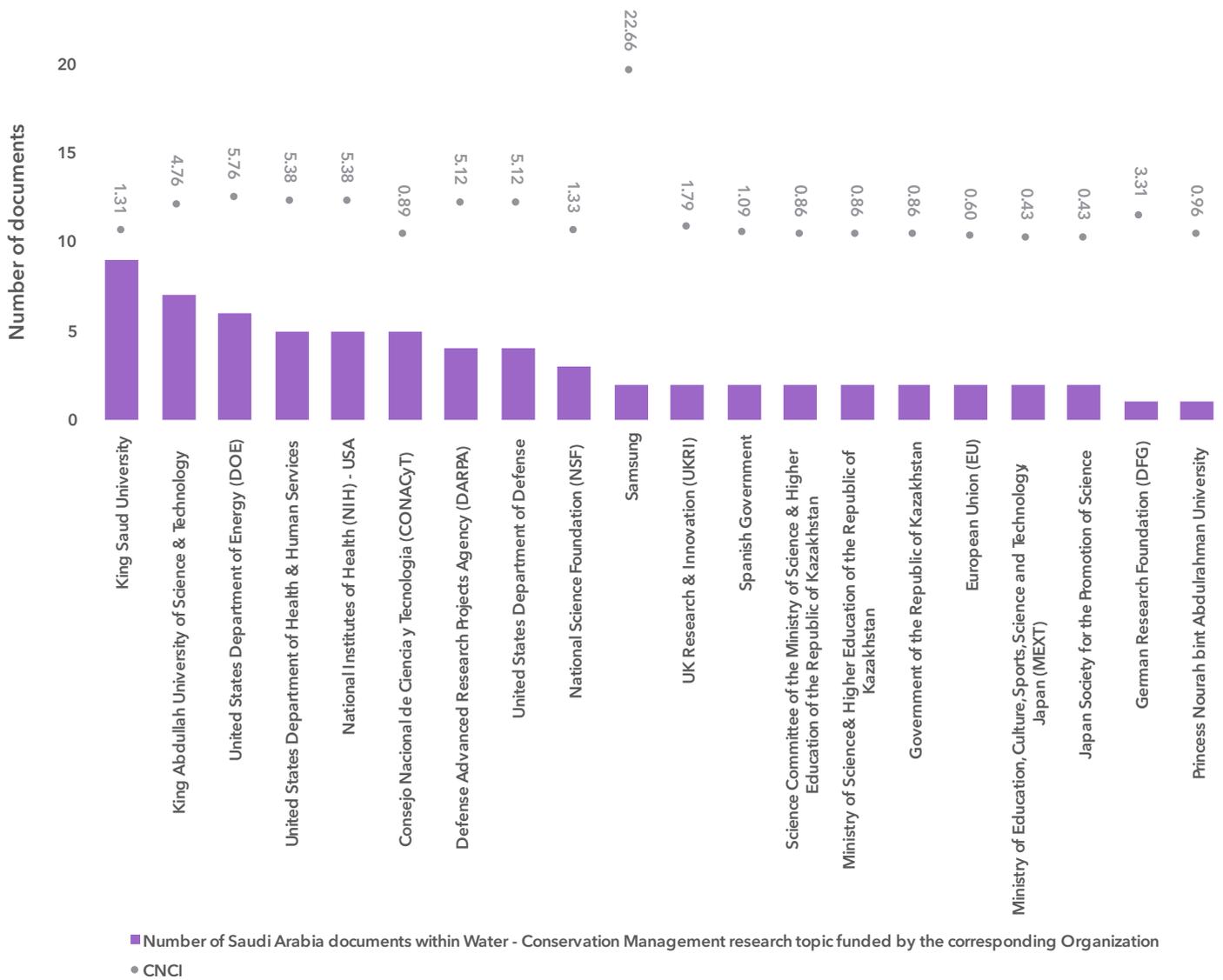


Figure 101: Top 20 funding organizations of Saudi Arabian publications in the research topic Water - Conservation Management in terms of number of publications in the period 2014-2023

#### 4.1.10.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top three organizations in terms of publications published in this research topic between 2014-2023 are King Saud University, followed by King Abdullah University of Science & Technology and King Abdulaziz University with 38, 25 and 24 publications, respectively, as shown in Figure 102.

Regarding citation impact as measured by the CNCI, King Abdulaziz City for Science & Technology, followed by Taif University and King Abdullah University of Science & Technology, had the highest CNCI with 12.68, 11.76 and 2.92, respectively.

Nevertheless, ten out of the Top 20 Saudi Arabian organizations had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

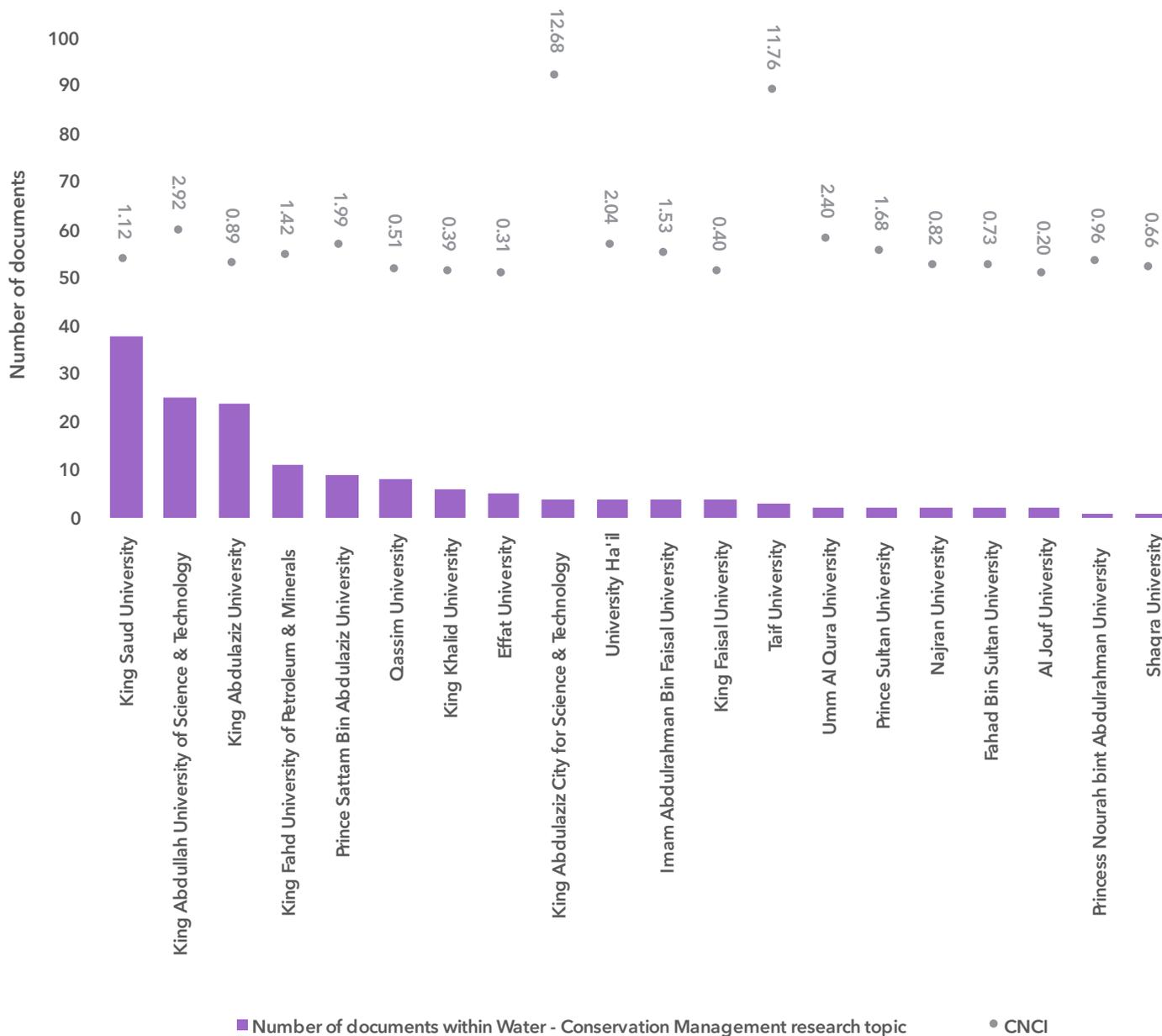


Figure 102: Top 20 Saudi organizations in terms of publications published in the research topic Water - Conservation Management in the period 2014-2023 and their corresponding CNCI

#### 4.1.10.5 The top 20 researchers are affiliated with Saudi organizations in terms of the number of publications they publish

The highest number of publications are published by Peng Wang, affiliated with King Abdullah University of Science & Technology, followed by A. A. Alazba, affiliated with King Saud University, and Shereif H. Mahmoud, affiliated with King Saud University, with 11, 10 and 9 publications, respectively as shown in Table 32. The highest CNCI is achieved by publications published by Mengchun Wu, affiliated with King Abdullah University of Science & Technology, with a CNCI of 7.27.

The latter researcher also has the highest number of Top 1% with four publications, same as Renyuan Li, affiliated with King Abdullah University of Science & Technology. The highest number of Top 10% publications was achieved by Peng Wang, affiliated with King Abdullah University of Science & Technology, with eight publications which is also the researcher with the highest number of overall publications mentioned above.

Table 32: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published on the research topic Water - Conservation Management in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%
Wang, Peng	King Abdullah University of Science & Technology	11	4.97	4	8
Alazba, A. A.	King Saud University	10	1.14	0	1
Mahmoud, Shereif H.	King Saud University	9	0.86	0	0
Li, Renyuan	King Abdullah University of Science & Technology	8	6.19	4	7
Wu, Mengchun	King Abdullah University of Science & Technology	6	7.27	4	6
El-Amin, Mohamed F.	Effat University	5	0.31	0	0
Shi, Yusuf	King Abdullah University of Science & Technology	5	6.78	3	5
Haider, Husnain	Qassim University	4	0.59	0	0
Han, Yu	King Abdullah University of Science & Technology	4	1.61	0	2
Radwan, Farid	King Saud University	4	1.36	0	1
Wang, Wenbin	King Abdullah University of Science & Technology	4	4.90	1	3
Alazba, Abdulrahman Ali	King Saud University	3	0.26	0	0
Aleid, Sara	King Abdullah University of Science & Technology	3	6.05	1	3
Alharbi, Fawaz	Qassim University	3	0.39	0	0
Almoshaogeh, Meshal	Qassim University	3	0.39	0	0
Brahimi, Tayeb	Effat University	3	0.26	0	0
Djouider, Fathi	King Abdulaziz University	3	0.27	0	0
Pan, Tingting	King Abdullah University of Science & Technology	3	1.95	0	2
Shafiquzzaman, Md.	Qassim University	3	0.48	0	0
Yang, Kaijie	King Abdullah University of Science & Technology	3	1.95	0	2

#### 4.1.10.6 Top 10 countries in terms of publications

The highest number of publications published on this research topic is published by Mainland China (2,799 publications), followed by the United States (2,055 publications) and India (858 publications), as shown in Figure 103. The highest citation impact measured by the CNCI is achieved by publications published by Italy, the United States and Mainland China with a CNCI of 1.51, 1.30 and 1.28 respectively.

Four of the top 10 countries in terms of number of publications published in the research topic are also among the top 10 collaborators with Saudi Arabia. These are the United States, Mainland China, the United Kingdom and India.

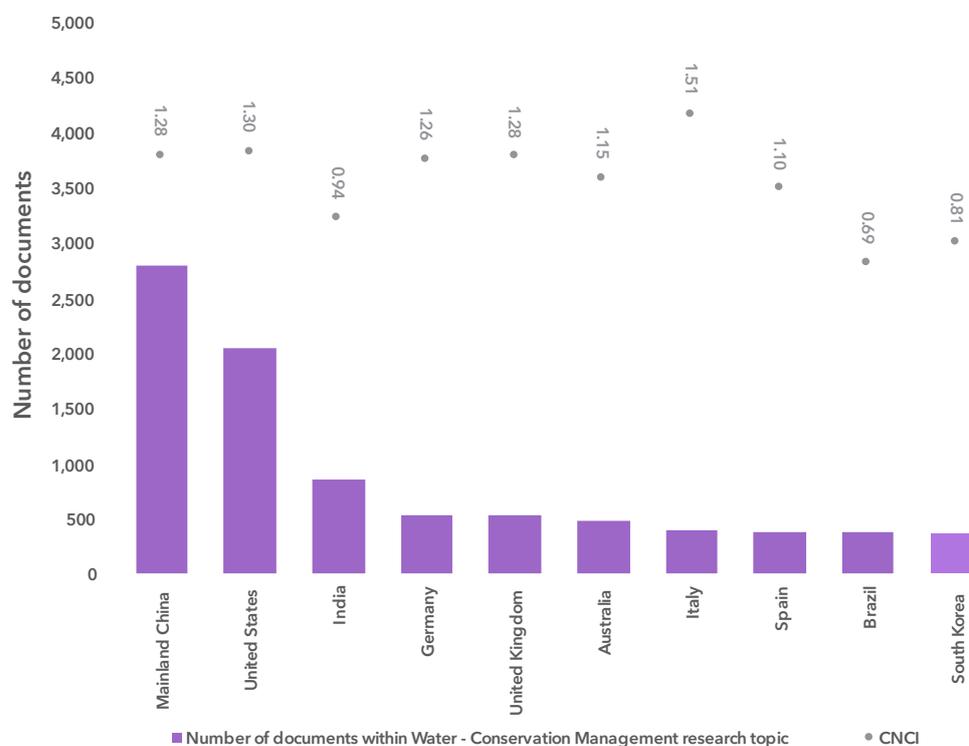


Figure 103: Top 10 countries in terms of the number of publications in the Water - Conservation Management in the period 2014-2023 and their corresponding CNCI

#### 4.1.10.7 Top 20 organizations globally in terms of number of publications

The top three organizations in terms of the number of publications published on this research topic from 2014-2023 are the Chinese Academy of Sciences (400 publications), followed by Centre National de la Recherche Scientifique (CNRS) (183 publications) and the University of Chinese Academy of Sciences, CAS (161 publications) as shown in Figure 104.

Regarding citation impact measured by the CNCI, the United States Department of Energy (DOE), Swiss Federal Institutes of Technology Domain and California Institute of Technology had the highest CNCI with 2.22, 2.11 and 2.11 respectively.

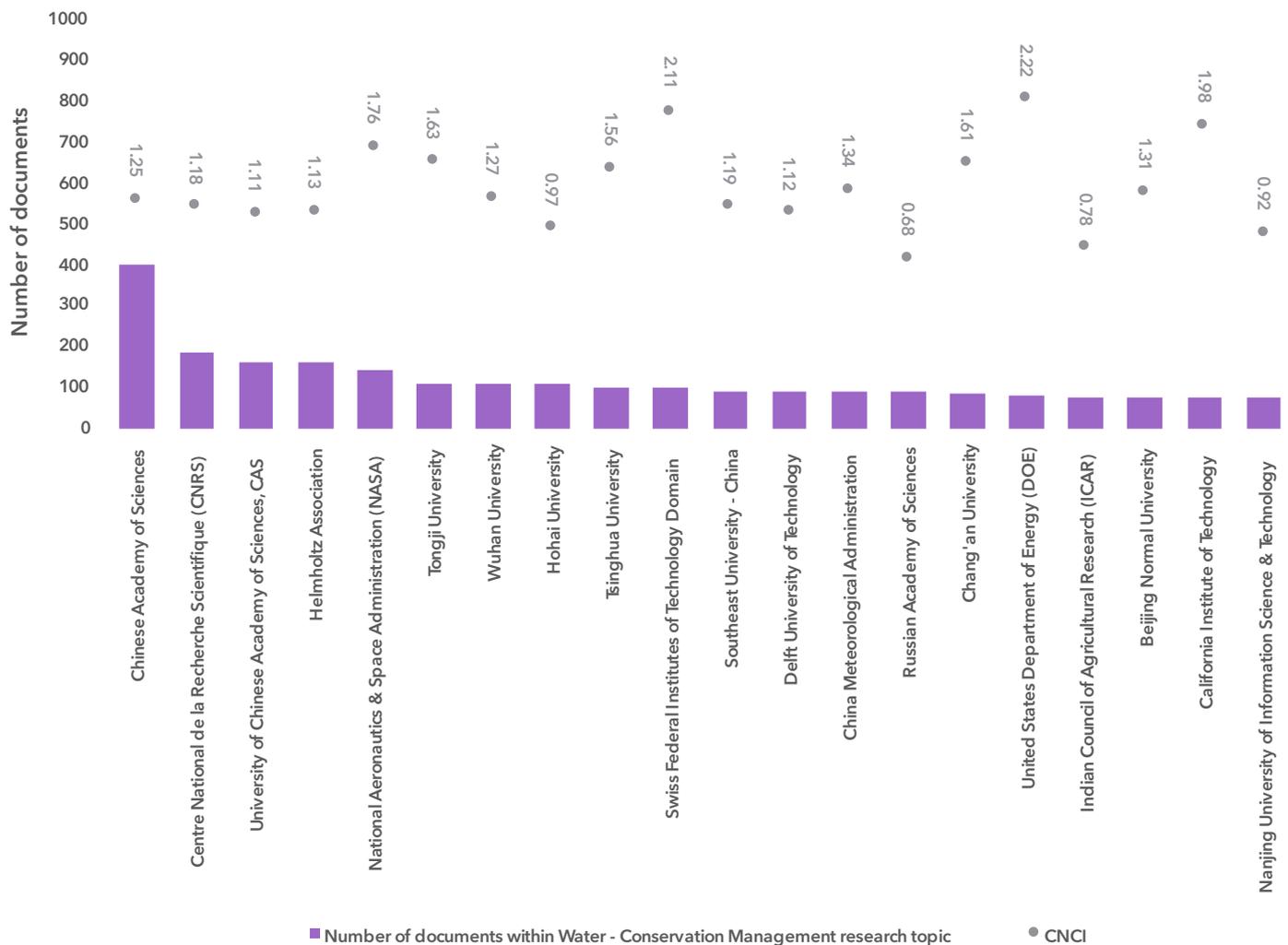


Figure 104: Top 20 organizations globally in terms of the number of publications published in the research topic Water - Conservation Management in the period 2014-2023 and their corresponding CNCI

#### 4.1.10.8 Top 20 researchers globally in terms of number of publications

The top three researchers globally in terms of the number of publications on this research topic are Enedir Ghisi, affiliated with Universidade Federal de Santa Catarina (UFSC), with 41 publications, followed by Ruzhu Wang, affiliated with Shanghai Jiao Tong University, with 35 publications, and Ataur Rahman affiliated with Western Sydney University with 31 publications as shown in Table 33.

The highest CNCI is achieved by Ruzhu Wang, affiliated with Shanghai Jiao Tong University, with 3.14. The latter has also achieved the highest number of Top 1% with three publications and the Top 10% with 19 publications.

Table 33: Top 20 researchers globally in terms of the number of publications published in the research topic Water - Conservation Management in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%	Country
<b>Ghisi, EneDir</b>	Universidade Federal de Santa Catarina (UFSC)	41	0.75	0	1	Brazil
<b>Wang, Ruzhu</b>	Shanghai Jiao Tong University	35	3.14	3	19	Mainland China
<b>Rahman, Ataur</b>	Western Sydney University	31	0.94	0	5	Australia
<b>Li, Hui</b>	Tongji University	29	1.81	1	8	Mainland China
<b>Biligiri, Krishna Prapoorna</b>	Indian Institute of Technology System (IIT System)	24	1.36	0	4	India
<b>Oeser, Markus</b>	RWTH Aachen University	22	1.19	0	4	Germany
<b>Wang, Qi</b>	Gansu Agricultural University	21	0.78	0	1	Mainland China
<b>Yao, Yibin</b>	Wuhan University	20	1.35	0	3	Mainland China
<b>Zhang, Dengkui</b>	Gansu Agricultural University	19	0.64	0	0	Mainland China
<b>Zhang, Jiong</b>	Shandong University	19	1.07	0	2	Mainland China
<b>Zhao, Qingzhi</b>	Xi'an University of Science & Technology	19	1.37	0	4	Mainland China
<b>Butler, David</b>	University of Exeter	18	1.29	0	2	England
<b>Chui, Ting Fong May</b>	University of Hong Kong	17	1.57	1	2	Hong Kong
<b>Han, Mooyoung</b>	Seoul National University (SNU)	17	0.66	0	1	South Korea
<b>Rodriguez-Hernandez, Jorge</b>	Universidad de Cantabria	17	0.71	0	1	Spain
<b>Zhou, Xujiao</b>	Gansu Agricultural University	17	0.65	0	0	Mainland China
<b>Jia, Zhikuan</b>	Northwest A&F University - China	16	2.05	0	6	Mainland China
<b>Koivusalo, Harri</b>	Aalto University	16	1.67	0	5	Finland
<b>Li, Jiake</b>	Xi'an University of Technology	16	1.36	0	5	Mainland China
<b>Lucke, Terry</b>	University of the Sunshine Coast	16	1.04	0	1	Australia

#### 4.1.10.9 Top 20 global funders globally in terms of number of publications

The top three organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC), with 1602 publications, followed by the National Science Foundation (NSF), with 373 publications, and National Key Research & Development Program of China with 247 publications as shown in Figure 105.

The highest citation impact measured by the CNCI is observed in publications funded by United States Department of Energy (DOE), China Postdoctoral Science Foundation and National Aeronautics & Space Administration (NASA) with 2.15, 1.91 and 1.76 respectively. Among the top 20 global funding organizations, 8 are also among the top 20 funding organizations of Saudi publications in this research topic.

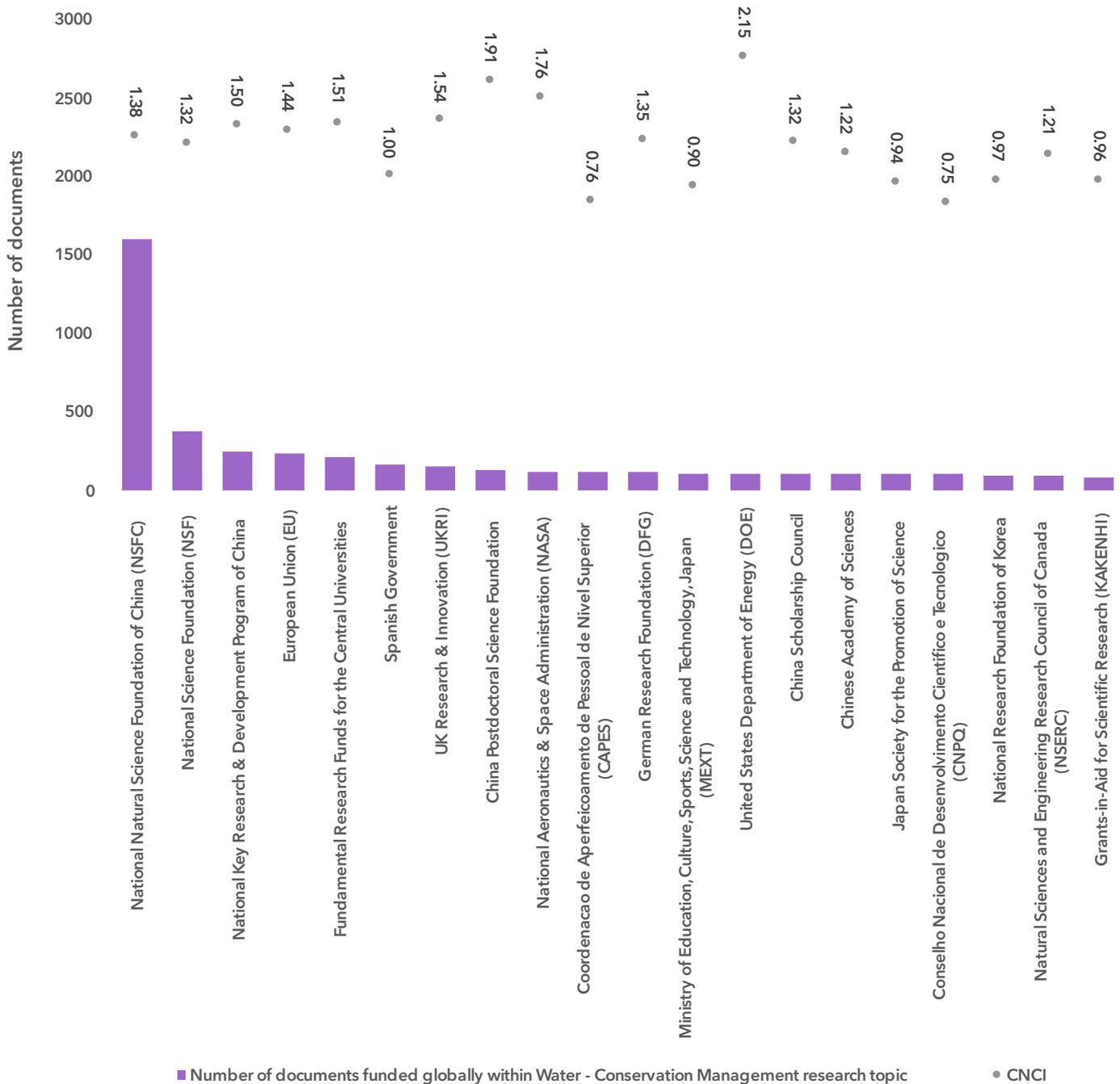


Figure 105: Top 20 funding organizations globally publications in the research topic Water - Conservation Management in terms of number of publications in the period 2014-2023

#### 4.1.10.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section we investigate the emerging trends globally and in Saudi Arabia in the research topic Water - Conservation Management. For more information on the methodology used to identify emerging trends, please see the section Emerging Trends.

The top three emerging micro-topics globally in this research topic are Thermodynamics: Solar Still followed by Electrical - Harvesting & Discharging: Energy Harvesting, Energy Harvesting and Microfluidic Devices, & Superhydrophobicity: Superhydrophobic, as shown in Figure 105.

Table 34 shows the identified top 10 micro-topics in Saudi Arabia's research output on this research topic. Among those, Thermodynamics: Solar Still, Inorganic & Nuclear Chemistry: Metal-Organic Frameworks and Microfluidic Devices & Superhydrophobicity: Superhydrophobic are also among the top 20 identified global micro-topics.

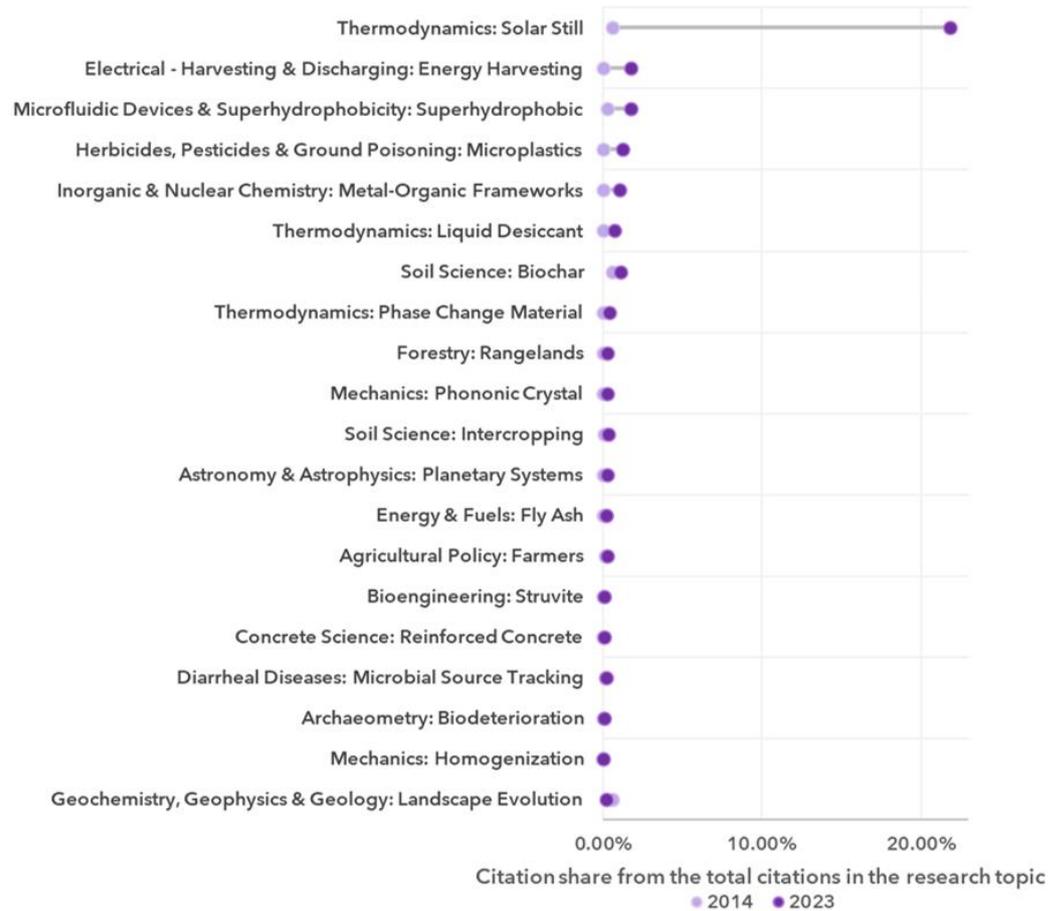


Figure 106: Top 20 emerging micro-topics globally in the research topic Water - Conservation Management in the period 2014-2023

Table 34: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Water - Conservation Management in the period 2014-2023

Topic	Number of Saudi Arabian publications in the period 2014-2023
Water - Conservation Management research topic	153
Climate Change: Stormwater	29
Thermodynamics: Solar Still	28
Concrete Science: Compressive Strength	13
Oceanography, Meteorology & Atmospheric Sciences: Evapotranspiration	11
Inorganic & Nuclear Chemistry: Metal-Organic Frameworks	9
Microfluidic Devices & Superhydrophobicity: Superhydrophobic	5
Bioengineering: Constructed Wetlands	3
Water Resources: Groundwater	3
Climate Change: Climate Change Adaptation	2
Numerical Methods: Fractional Calculus	2

## 4.1.11 Water Leakage

### 4.1.11.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabian publications from global publications in the research topic had a high oscillating evolution from 2014 till 2023 but still reached levels ranging from 1.29% to 3.69% except for 2018 when the share was 0, as shown in Figure 107. This shows that Saudi Arabia was able to increase the number of publications on this research topic and also had growth higher than the global growth rate, except for 2018. The CNCI of Saudi Arabian publications on this research topic were mostly below 1, indicating a citation impact performance below the global average. On the other hand, the CNCI reached levels above 1 in three years, 2014, 2019 and 2022, indicating potential for citation performance higher than the global average.

Overall, Saudi Arabia's publication increase had a relatively good growth rate but lacked consistency. This also influenced the evolution of the citation impact as measured by the CNCI, having high fluctuations ranging from 0.65 to 1.62.



Figure 107: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabian publications in the research topic

### 4.1.11.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating country with Saudi Arabia in this research topic from 2014-2023 is Egypt, followed by the United States and Tunisia with eight, seven and six publications, respectively, as shown in Figure 108. Regarding citation impact measured by the CNCI publications published in collaboration with Australia, Germany and Mainland China had the highest CNCI with 3.07, 3.03 and 2.62, respectively.

Only five out of the top 10 countries collaborating with Saudi Arabia had a CNCI higher than 1, reflecting a performance higher than the global average.

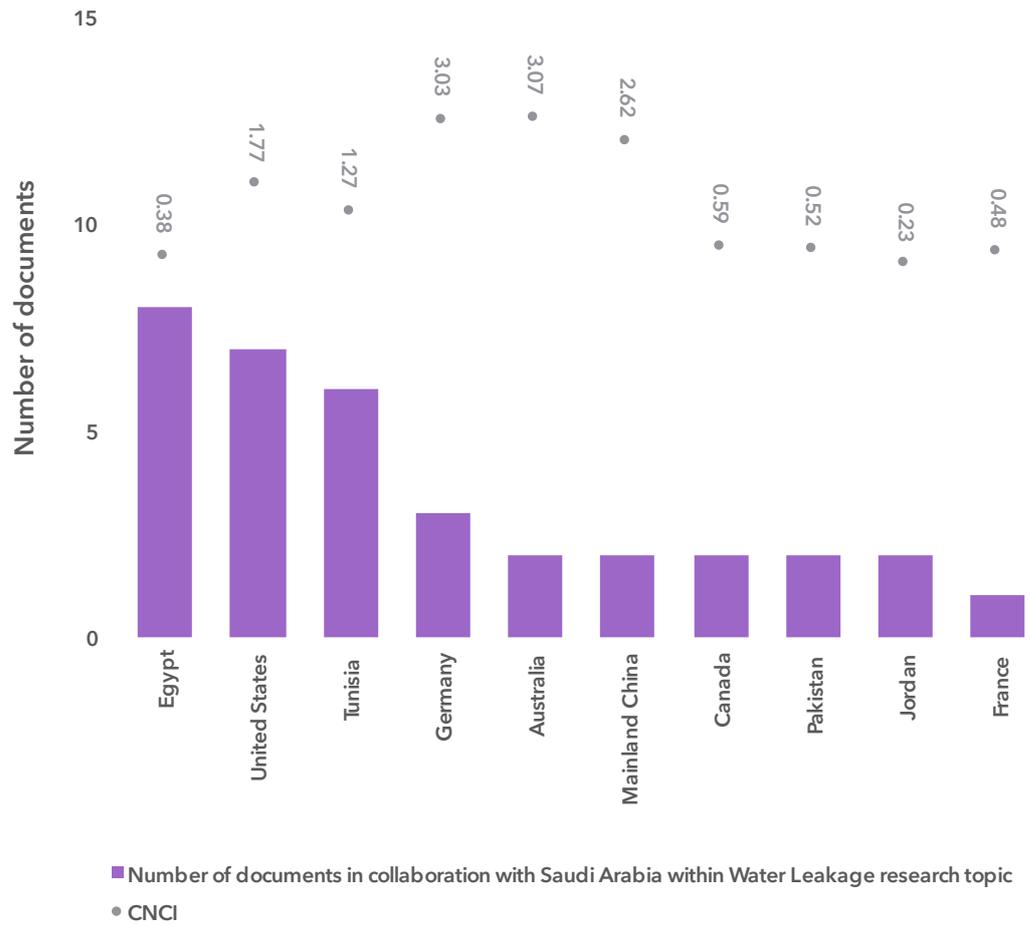


Figure 108: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications on the research topic of Water Leakage in the period 2014-2023

#### 4.1.11.3 Top 20 funders of Saudi publications by number of publications

The top three funding organizations of Saudi Arabia publications in this research topic in terms of the number of publications mentioning the organization in the funding text from 2014-2023 are King Abdullah University of Science & Technology, followed by King Saud University and Princess Nourah bint Abdulrahman University with 3, 2 and 1 publications respectively as shown in Figure 109.

Publications funded by Australian Research Council, United States Department of Energy (DOE) and King Abdullah University of Science & Technology had the highest citation impact measured by the CNCI with 5.07, 3.10 and 1.45 respectively.



Figure 109: Top 20 funding organizations of Saudi Arabian publications in the research topic Water Leakage in terms of number of publications in the period 2014-2023

#### 4.1.11.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top three organizations in terms of publications published on this research topic between 2014-2023 are King Fahd University of Petroleum & Minerals, followed by King Abdulaziz University and King Abdullah University of Science & Technology, with 14, 8 and 7 publications, respectively as shown in Figure 110.

Regarding citation impact as measured by the CNCI, King Abdullah University of Science & Technology, followed by King Abdulaziz City for Science & Technology and Imam Abdulrahman Bin Faisal University, had the highest CNCI with 2.09, 1.72 and 1.66, respectively.

Only five out of the top 20 Saudi Arabian institutions in terms of the number of publications had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

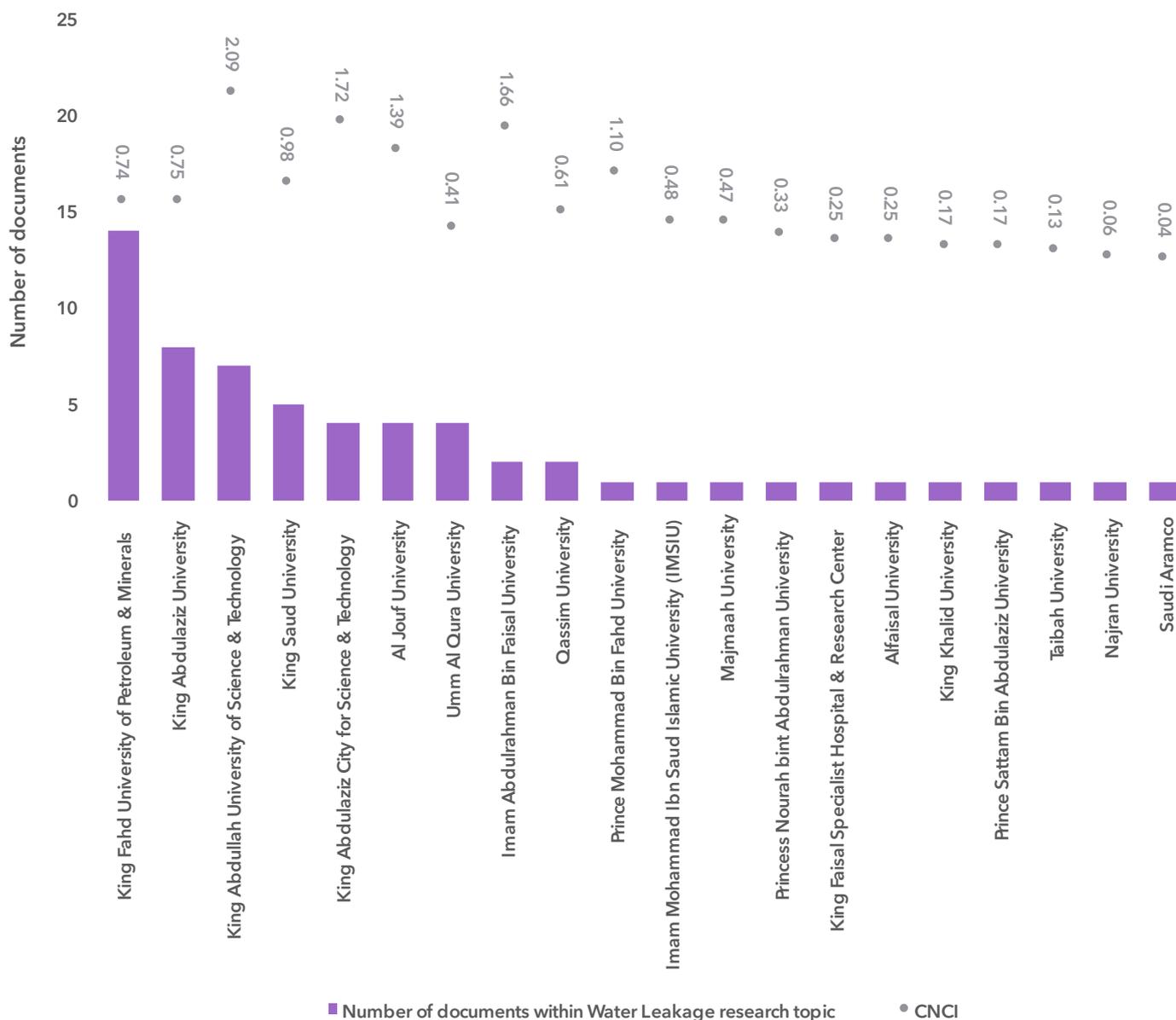


Figure 110: Top 20 Saudi organizations in terms of publications published in the research topic Water Leakage in the period 2014-2023 and their corresponding CNCI

#### 4.1.11.5 The top 20 researchers are affiliated with Saudi organizations in terms of the number of publications they publish

The highest number of publications are published by Muhammad Mysorewala Faizan, affiliated with King Fahd University of Petroleum & Minerals, and by Lahouari Cheded, affiliated with King Fahd University of Petroleum & Minerals, with the same value of 3 publications, as shown in Table 35.

The highest CNCI is achieved with one document published by Mark Tester affiliated with King Abdullah University of Science & Technology with a CNCI of 5.07. None of the researchers from Top 20 researchers affiliated with Saudi organizations in terms of number of publications had publications in top 1%.

Table 35: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published on the research topic of Water Leakage in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%
<b>Mysorewala, Muhammad Faizan</b>	King Fahd University of Petroleum & Minerals	3	0.59	0	0
<b>Cheded, Lahouari</b>	King Fahd University of Petroleum & Minerals	3	0.41	0	0
<b>BenSalah, M. S.</b>	King Abdulaziz City for Science & Technology	2	2.50	0	1
<b>Ghorbel, Oussama</b>	Al Jouf University	2	2.50	0	1
<b>BenSaleh, Mohammed S.</b>	King Abdulaziz City for Science & Technology	2	0.94	0	0
<b>Obeid, Abdulfattah M.</b>	King Abdulaziz City for Science & Technology	2	0.94	0	0
<b>Haider, Husnain</b>	Qassim University	2	0.61	0	0
<b>Shafiquzzaman, Md.</b>	Qassim University	2	0.61	0	0
<b>Mysorewala, Muhammad</b>	King Fahd University of Petroleum & Minerals	2	0.27	0	0
<b>Baroudi, Uthman</b>	King Fahd University of Petroleum & Minerals	2	0.25	0	0
<b>Tester, Mark</b>	King Abdullah University of Science & Technology	1	5.07	0	1
<b>Abdulkader, Afifi M.</b>	King Abdullah University of Science & Technology	1	3.20	0	1
<b>Yan, Bicheng</b>	King Abdullah University of Science & Technology	1	3.20	0	1
<b>Santamarina, J. Carlos</b>	King Abdullah University of Science & Technology	1	3.10	0	1
<b>Ahmed, Rashad</b>	King Fahd University of Petroleum & Minerals	1	2.93	0	1
<b>Iqbal, Sardar Zafar</b>	Imam Abdulrahman Bin Faisal University	1	2.93	0	1
<b>Jan, Farmanullah</b>	Imam Abdulrahman Bin Faisal University	1	2.93	0	1
<b>Min-Allah, Nasro</b>	Imam Abdulrahman Bin Faisal University	1	2.93	0	1
<b>Saeed, Saqib</b>	Imam Abdulrahman Bin Faisal University	1	2.93	0	1
<b>Al-Nasheri, Ahmed Y.</b>	King Saud University	1	2.11	0	0

#### 4.1.11.6 Top 10 countries in terms of publications

The highest number of publications published on this research topic is published by Mainland China (498 publications), followed by the United States (463 publications) and the United Kingdom (156 publications), as shown in Figure 111. The highest citation impact measured by the CNCI is achieved by publications published in Italy, Germany and Australia with a CNCI of 1.13, 1.09 and 1.02, respectively.

Six of the top 10 countries, in terms of the number of publications published on the research topic, are also among the top 10 collaborators with Saudi Arabia. These are Germany, Australia, Mainland China, Canada, France and the United States.

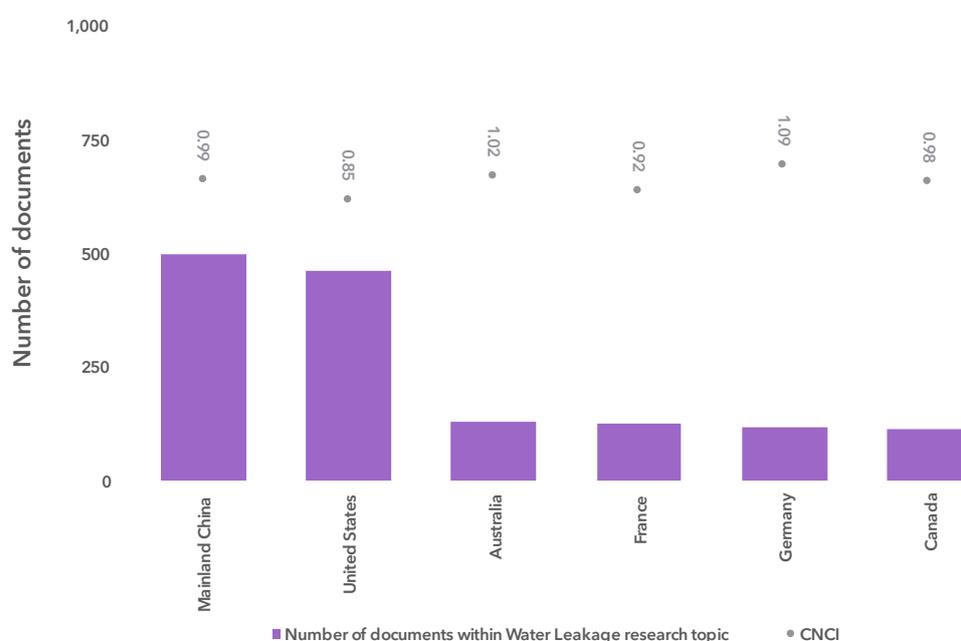


Figure 111: Top 10 countries in terms of the number of publications on Water Leakage in the period 2014-2023 and their corresponding CNCI

#### 4.1.11.7 Top 20 organizations globally in terms of number of publications

The top three organizations in terms of the number of publications published on this research topic from 2014-2023 are Centre National de la Recherche Scientifique (CNRS) (63 publications), followed by Hong Kong Polytechnic University (60 publications) and the Chinese Academy of Sciences (57 publications) as shown in Figure 112.

Regarding citation impact measured by the CNCI, Consejo Superior de Investigaciones Cientificas (CSIC), Hong Kong Polytechnic University and University of Chinese Academy of Sciences, CAS had the highest CNCI with 2.11, 1.51 and 1.46 respectively.

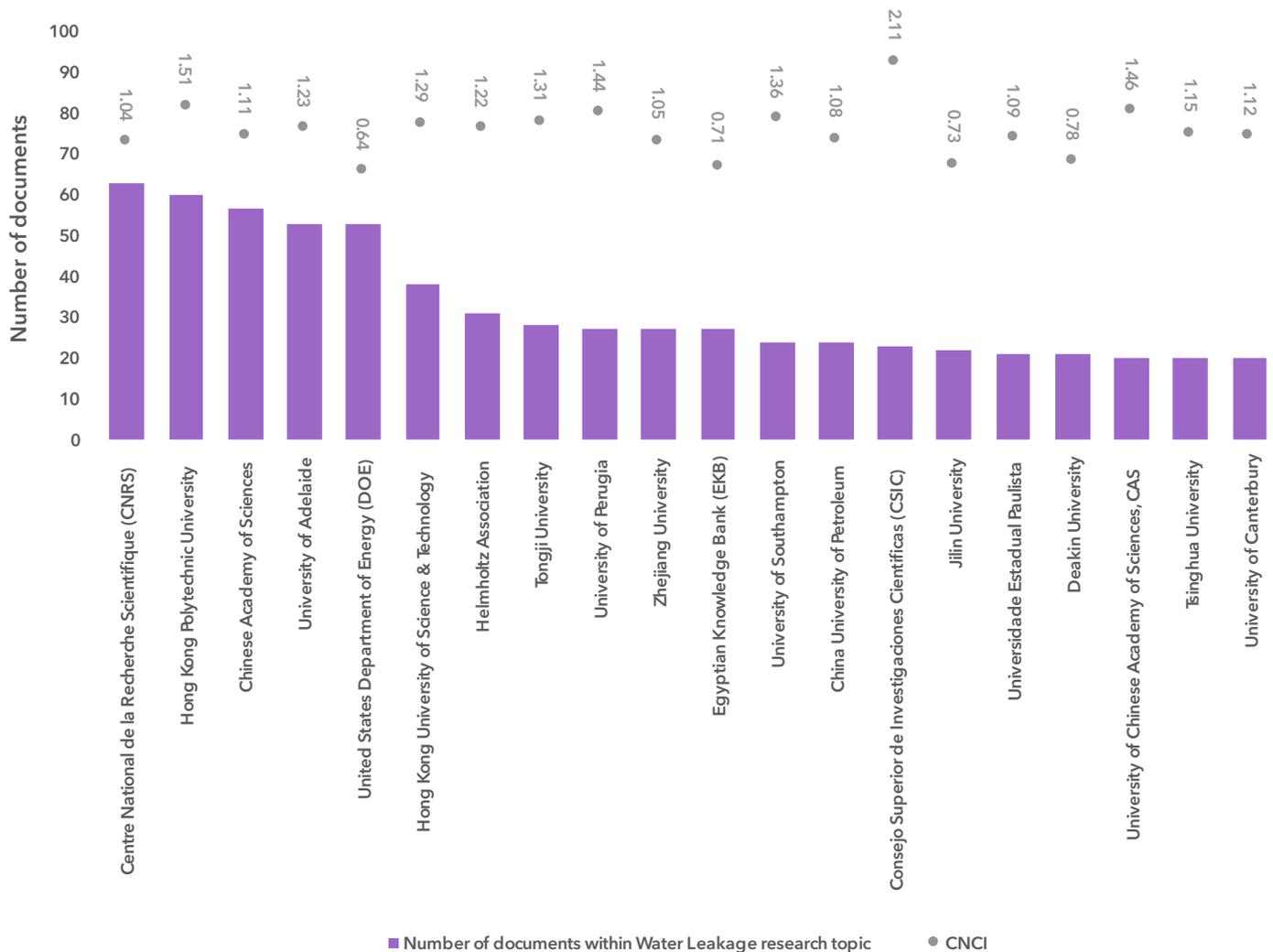


Figure 112: Top 20 organizations globally in terms of number of publications published in the research topic Water Leakage in the period 2014-2023 and their corresponding CNCI

#### 4.1.11.8 Top 20 researchers globally in terms of number of publications

The top three researchers globally in terms of the number of publications in this research topic are Martin F. Lambert followed by Angus R. Simpson and Aaron C. Zecchin, all affiliated with the University of Adelaide with 32, 27 and 26 publications, respectively, as shown in Table 36. The highest CNCI is achieved by Xun Wang, affiliated with the Hong Kong University of Science & Technology, with 2.21.

The highest number of the Top 1% is achieved by Huan-Feng Duan, affiliated with Hong Kong Polytechnic University, with one document.

The highest number of Top 10% publications is achieved by Huan-Feng Duan, affiliated with Hong Kong Polytechnic University, with the same number of 7 publications as Martin F. Lambert, affiliated with the University of Adelaide, mentioned before also as the researcher with the highest number of overall publications.

Table 36: Top 20 researchers globally in terms of the number of publications published on the research topic of Water Leakage in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%	Country
Lambert, Martin F.	University of Adelaide	32	1.30	0	7	Australia
Simpson, Angus R.	University of Adelaide	27	1.25	0	5	Australia
Zecchin, Aaron C.	University of Adelaide	26	1.18	0	5	Australia
Gong, Jinzhe	University of Adelaide	24	1.31	0	5	Australia
Duan, Huan-Feng	Hong Kong Polytechnic University	21	1.73	1	7	Hong Kong
Ghidaoui, Mohamed S.	Hong Kong University of Science & Technology	18	1.67	0	5	Hong Kong
Brunone, Bruno	University of Perugia	17	1.31	0	2	Italy
Meniconi, Silvia	University of Perugia	17	1.31	0	2	Italy
Zayed, Tarek	Hong Kong Polytechnic University	17	1.45	0	5	Hong Kong
Gao, Yan	Institute of Acoustics, CAS	16	1.38	0	3	Mainland China
Keramat, Alireza	Hong Kong Polytechnic University	12	1.04	0	1	Hong Kong
Puig, Vicenc	Universitat Politecnica de Catalunya	12	1.28	0	3	Spain
Ferrante, Marco	University of Perugia	11	0.91	0	1	Italy
Wang, Xun	Hong Kong University of Science & Technology	11	2.21	0	4	Hong Kong
Capponi, Caterina	University of Perugia	10	0.76	0	1	Italy
Cazzolato, Benjamin S.	University of Adelaide	10	0.70	0	0	Australia
Zeng, Wei	University of Adelaide	10	0.67	0	0	Australia
Zhang, Chi	University of Adelaide	10	1.16	0	2	Australia
Brennan, M. J.	Universidade Estadual Paulista	9	1.04	0	2	Brazil
Li, Shuaiyong	Chongqing University of Posts & Telecommunications	9	1.33	0	0	Mainland China

#### 4.1.11.9 Top 20 global funders globally in terms of number of publications

The top three organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC), with 258 publications, followed by the National Science Foundation (NSF), with 78 publications, and the Australian Research Council, with 53 publications, as shown in Figure 113.

The highest citation impact measured by the CNCI is observed in publications funded by Ministry of Education, Universities and Research (MIUR), Hong Kong Research Grants Council and National Key Research & Development Program of China with 1.81, 1.61 and 1.36 respectively. Among the top 20 global funding organizations, 4 are also among the top 20 funding organizations of Saudi publications in this research topic.

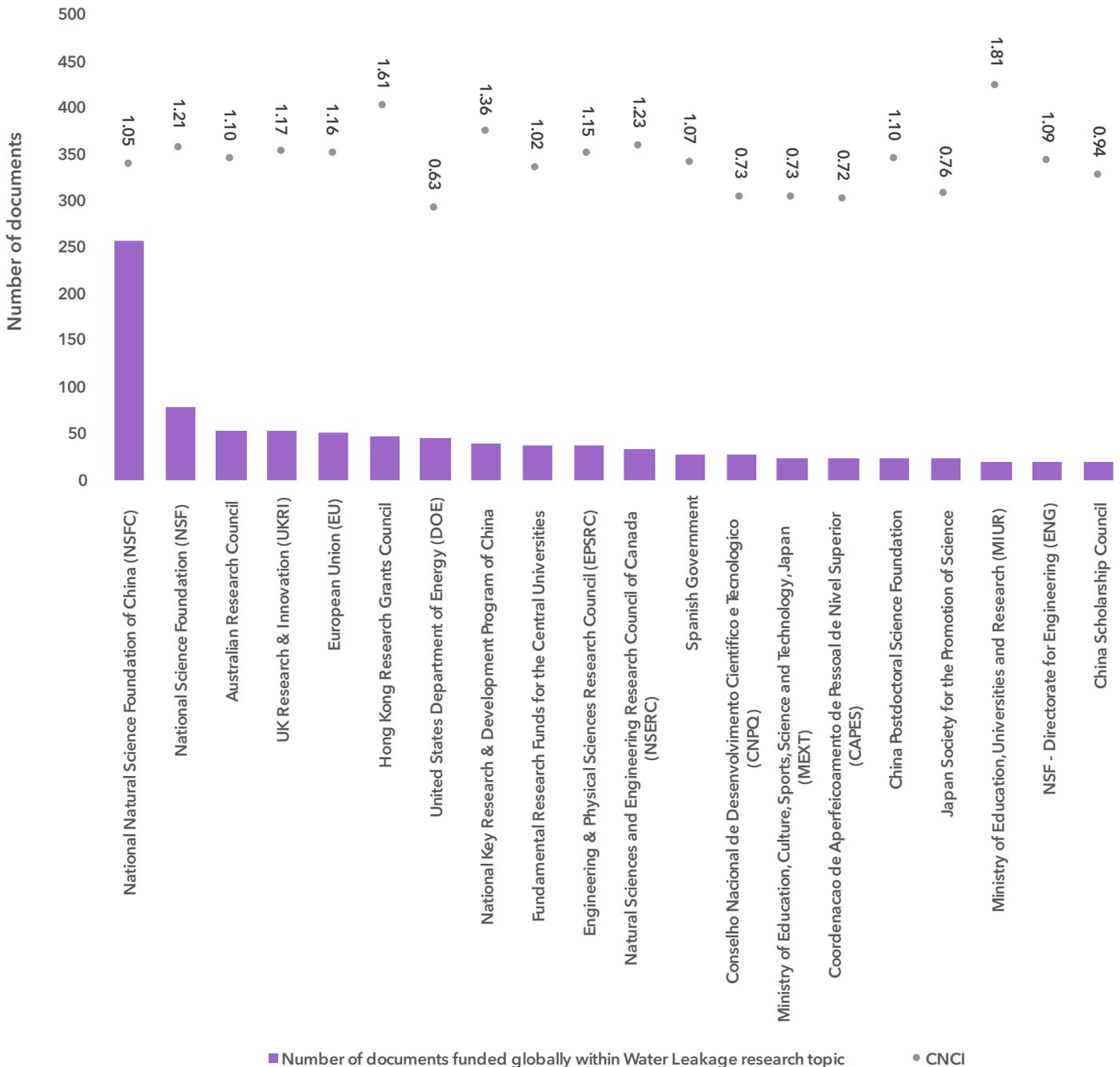


Figure 113: Top 20 funding organizations globally publications in the research topic Water Leakage in terms of number of publications in the period 2014-2023

#### 4.1.11.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section we investigate the emerging trends globally and in Saudi Arabia in the research topic Water Leakage. For more information on the methodology used to identify emerging trends, please see the section Emerging Trends.

The top three emerging micro-topics globally in this research topic are Climate Change: Water Distribution Systems followed by Water Resources: Groundwater and Geotechnical Engineering: Liquefaction, as shown in Figure 114.

Table 37 shows the identified top 10 micro-topics in Saudi Arabia's research output on this research topic. Among those, Climate Change: Water Distribution Systems and Bioengineering: Constructed Wetlands are also among the top 20 identified global emerging micro-topics.



Figure 114: Top 20 emerging micro-topics globally in the research topic Water Leakage in the period 2014-2023

Table 37: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Water Leakage in the period 2014-2023

Topic	Number of Saudi Arabian publications in the period 2014-2023
Water - leakage research topic	54
Climate Change: Water Distribution Systems	19
Water Resources: Enhanced Oil Recovery	3
Corrosion & Deposition Chemistry: Corrosion	3
Membrane Science: Nanofiltration	2
Bioengineering: Constructed Wetlands	1
Energy & Fuels: Hydrocyclone	1
Nuclear Physics: Neutron Spectrometry	1
Mechanics: Autofrettage	1
Climate Change: Reservoir Operation	1
Telecommunications: Internet Of Things	1

## 4.1.12 Water - Domestic Purification

### 4.1.12.1 Evolution of Saudi publication share of global publications in the research topic

The share of Saudi Arabian publications from global publications in the research topic had small fluctuations in dynamic from 2014 to 2019, followed by strong growth from 2020 to 2023, as shown in Figure 115. This shows that Saudi Arabia was not only able to increase the number of publications on this research topic but also had a growth higher than the global growth rate. This is evident as the share of Saudi Arabian publications in the research topic is growing.

The CNCI of Saudi Arabian publications on this research topic show variations on higher scales, ranging between 3.38 and 0.72 in the first half of the observed period, followed by more stable and steady progress from 2019 to 2023.

Overall, Saudi Arabia's publications increased with a higher growth rate than the global average in this research topic and had a consistent citation impact evolution in the second half of the analyzed period. Nevertheless, after this high growth rate in terms of publications, one should focus on increasing the impact of citations.

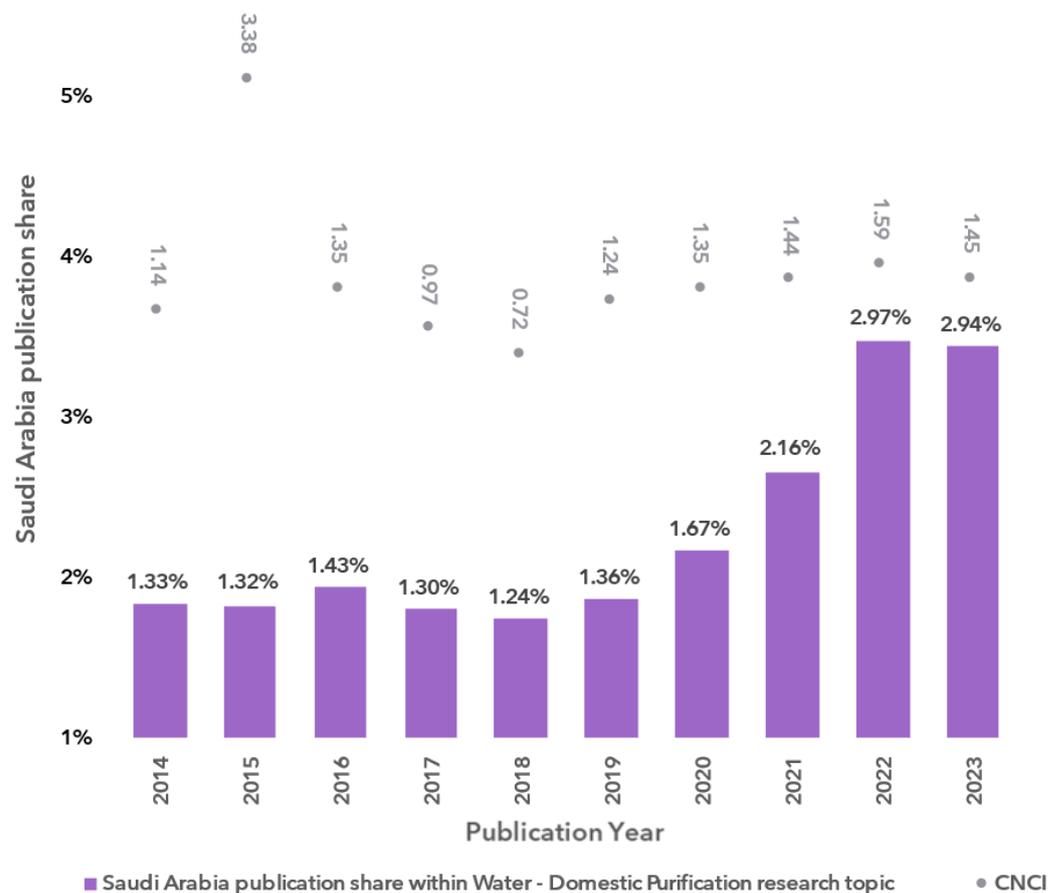


Figure 115: The share of Saudi Arabia from global publications in the research topic and the CNCI of Saudi Arabian publications in the research topic

### 4.1.12.2 Top 10 countries collaborating with Saudi Arabia

The top collaborating country with Saudi Arabia in this research topic from 2014-2023 is Egypt, followed by India and Pakistan with 202, 117 and 104 publications, respectively, as shown in Figure 116.

Regarding citation impact measured by the CNCI publications published in collaboration with South Korea followed by Germany and Netherlands had the highest CNCI with 4.65, 4.33 and 3.45 respectively. Nevertheless, all publications with

the top 10 collaborating countries had a CNCI higher than 1, ranging from 1.78 to 4.65, reflecting a performance at least 78% higher than the global average.

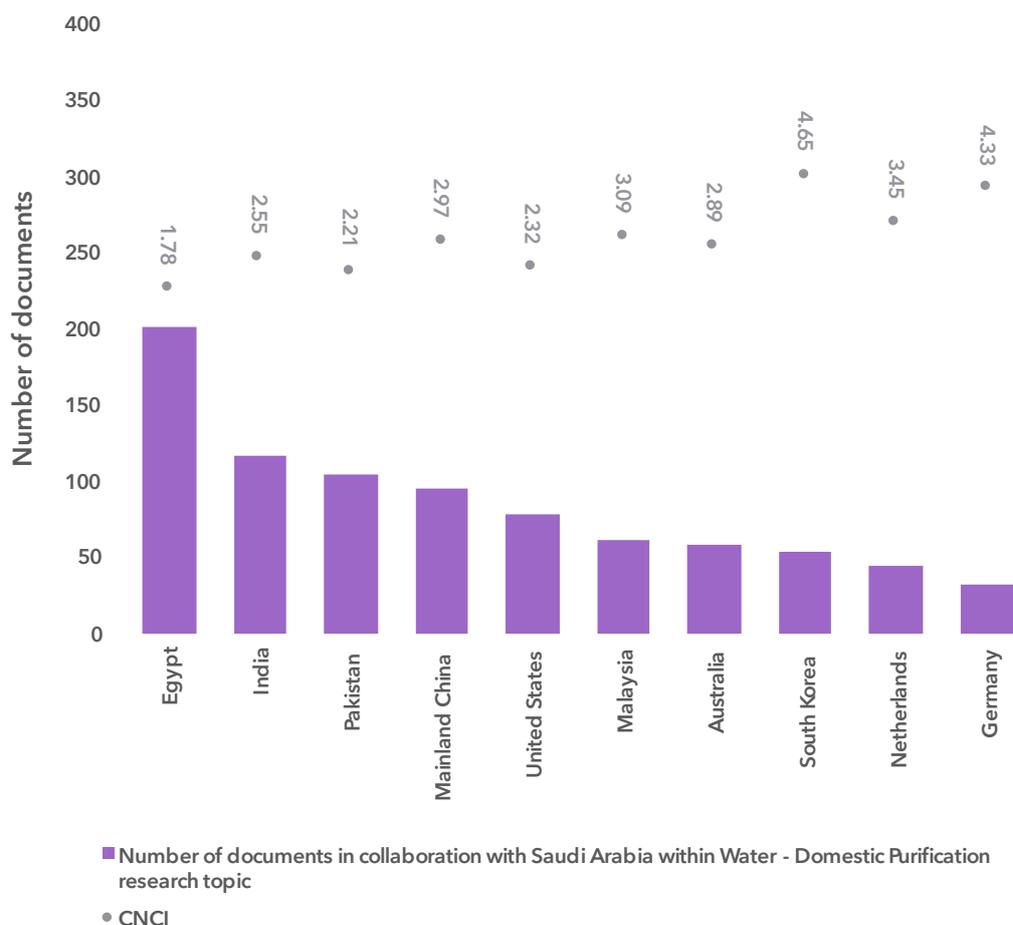


Figure 116: Top 10 collaborating countries with Saudi Arabia in terms of the number of publications in the research topic Water - Domestic Purification in the period 2014-2023

#### 4.1.12.3 Top 20 funders of Saudi publications by number of publications

The top three funding organizations of Saudi Arabia publications in this research topic in terms of the number of publications mentioning the organization in the funding text from 2014-2023 are King Saud University followed by King Abdullah University of Science & Technology and National Natural Science Foundation of China (NSFC) with 83, 56 and 24 publications respectively as shown in Figure 117.

Publications funded by Medical Research Council UK (MRC), UK Research & Innovation (UKRI) and Department of Science & Technology (India) had the highest citation impact measured by the CNCI with 30.99, 19.36 and 3.25 respectively.

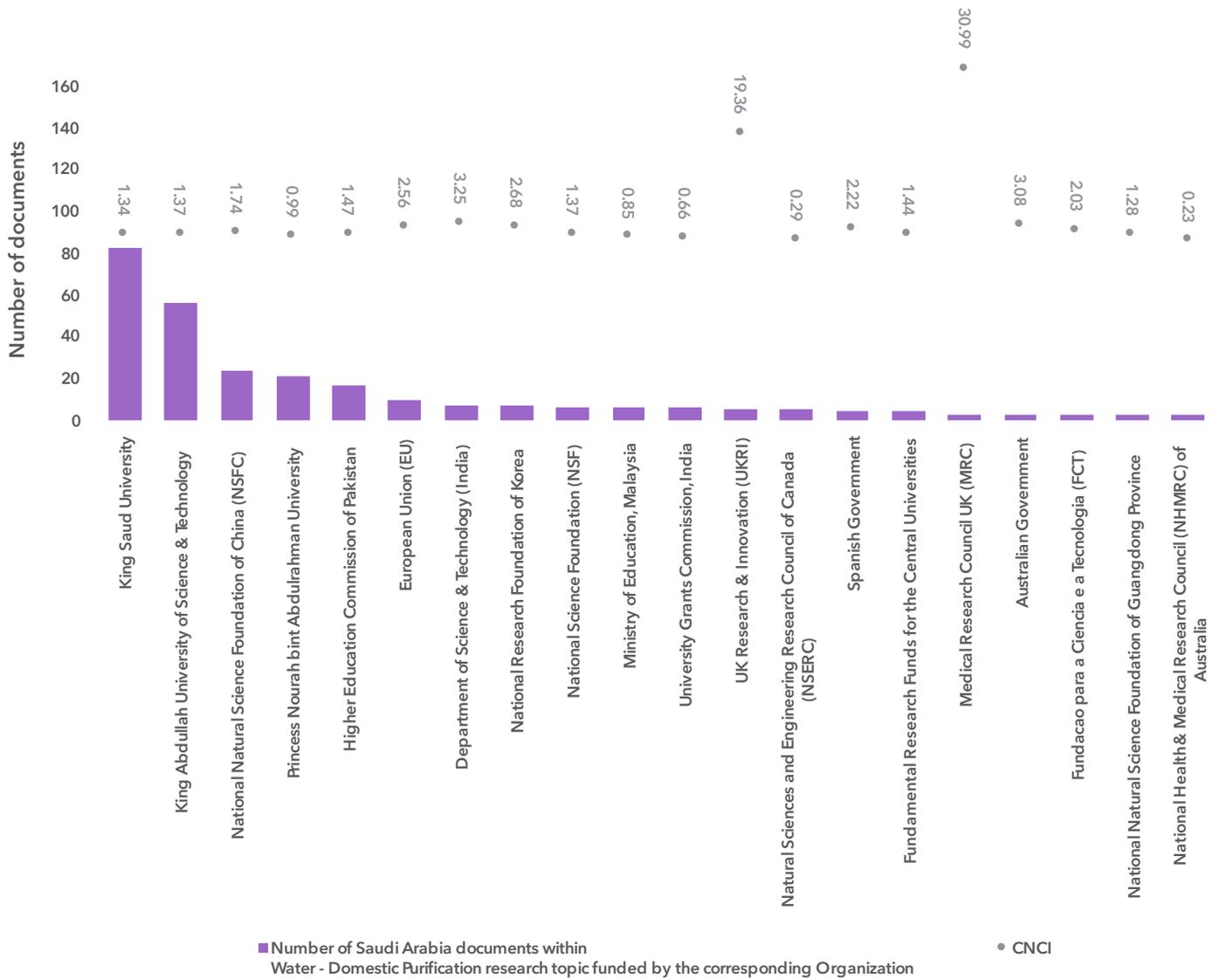


Figure 117: Top 20 funding organizations of Saudi Arabian publications in the research topic Water - Domestic Purification in terms of number of publications in the period 2014-2023

#### 4.1.12.4 Top 20 Saudi Arabia organizations in terms of number of publications

The top three organizations in terms of publications published in this research topic between 2014-2023 are King Saud University, followed by King Abdullah University of Science & Technology and King Abdulaziz University with 194, 133 and 126 publications, respectively, as shown in Figure 118.

Regarding citation impact as measured by the CNCI, University of Tabuk followed by Jazan University and Al Jouf University had the highest CNCI with 2.81, 2.77 and 2.28 respectively.

Nevertheless, majority of top 20 organizations except Hafr Albatin University, Qassim University and University Ha'il, had a CNCI higher than 1, reflecting a citation impact performance higher than the global average.

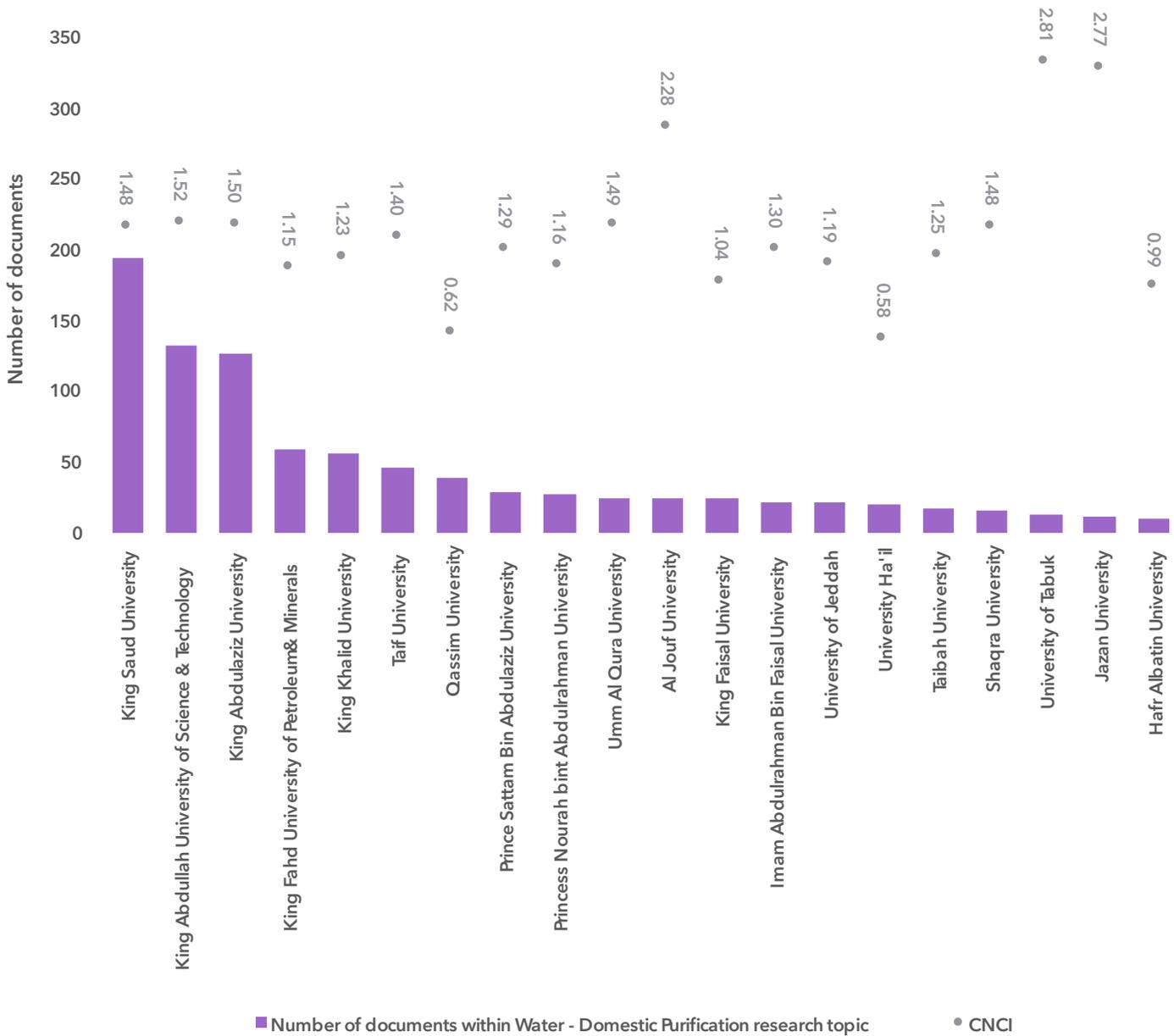


Figure 118: Top 20 Saudi organizations in terms of publications published in the research topic Water - Domestic Purification in the period 2014-2023 and their corresponding CNCI

#### 4.1.12.5 The top 20 researchers are affiliated with Saudi organizations in terms of the number of publications they publish

The highest number of publications are published by Noredine Ghaffour, affiliated with King Abdullah University of Science & Technology, and Husnain Haider, affiliated to Qassim University, with 17 publications, followed by J. S. Vrouwenvelder, affiliated with King Abdullah University of Science & Technology, with 16 publications and Pei-Ying Hong affiliated with King Abdullah University of Science & Technology with 15 publications as shown in Table 38.

The highest CNCI is achieved by publications published by Abdullah M. Asiri, affiliated with King Abdulaziz University, with a CNCI of 4.82. The latter researcher and J. S Vrouwenvelder, affiliated with King Abdullah University of Science & Technology, have the highest number of Top 1% with two publications.

Table 38: Top 20 researchers affiliated with Saudi organizations in terms of the number of publications published in the research topic Water - Domestic Purification in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%
<b>Ghaffour, Noreddine</b>	King Abdullah University of Science & Technology	17	1.54	0	6
<b>Haider, Husnain</b>	Qassim University	17	0.59	0	0
<b>Vrouwenvelder, J. S.</b>	King Abdullah University of Science & Technology	16	2.36	2	8
<b>Hong, Pei-Ying</b>	King Abdullah University of Science & Technology	15	1.48	0	4
<b>Dehwah, Abdullah H. A.</b>	King Abdullah University of Science & Technology	12	0.64	0	2
<b>Shafiquzzaman, Md.</b>	Qassim University	12	0.57	0	0
<b>Saikaly, Pascal E.</b>	King Abdullah University of Science & Technology	8	1.63	1	2
<b>Leiknes, TorOve</b>	King Abdullah University of Science & Technology	8	1.46	0	2
<b>Al-Ghobari, Hussein M.</b>	King Saud University	8	1.12	0	1
<b>AlSaleem, Saleem S.</b>	Qassim University	8	0.58	0	0
<b>Ghernaout, Djamel</b>	University Ha'il	8	0.29	0	0
<b>Fortunato, Luca</b>	King Abdullah University of Science & Technology	7	1.39	0	1
<b>Ghumman, Abdul Razzaq</b>	Qassim University	7	0.75	0	0
<b>Chowdhury, Shakhawat</b>	King Fahd University of Petroleum & Minerals	7	0.46	0	0
<b>Naz, Iffat</b>	Qassim University	7	0.40	0	0
<b>Asiri, Abdullah M.</b>	King Abdulaziz University	6	4.82	2	3
<b>Ali, Esmat F.</b>	Taif University	6	1.53	0	2
<b>Alamri, Saad</b>	King Khalid University	6	1.44	1	1
<b>Al-Mashharawi, Samir</b>	King Abdullah University of Science & Technology	6	1.02	0	2
<b>Rajmohan, Natarajan</b>	King Abdulaziz University	6	0.55	0	0

#### 4.1.12.6 Top 10 countries in terms of publications

The highest number of publications published on this research topic is published by Mainland China (10,665 publications), followed by the United States (7,420 publications) and India (3,286 publications), as shown in Figure 119. The highest citation impact measured by the CNCI is achieved by publications published in Australia, Italy and the United Kingdom with a CNCI of 1.45, 1.38 and 1.37, respectively.

Five of the top 10 countries, in terms of the number of publications published on the research topic, are also among the top 10 collaborators with Saudi Arabia. These are Australia, Germany, Mainland China, India and the United States.

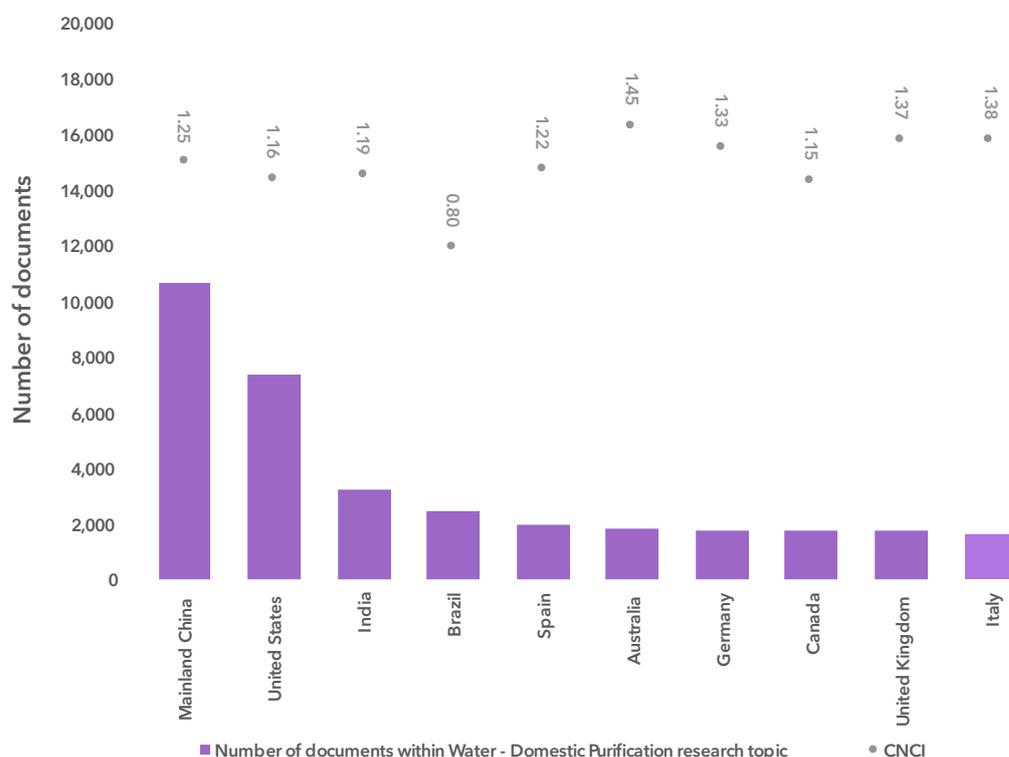


Figure 119: Top 10 countries in terms of the number of publications in the Water - Domestic Purification in the period 2014-2023 and their corresponding CNCI

#### 4.1.12.7 Top 20 organizations globally in terms of number of publications

The top three organizations in terms of the number of publications published on this research topic from 2014-2023 are the Chinese Academy of Sciences (1356 publications) followed by the University of Chinese Academy of Sciences, CAS (570 publications) and the Harbin Institute of Technology (523 publications) as shown in Figure 120.

Regarding citation impact measured by the CNCI, Helmholtz Association, Wageningen University & Research and Swiss Federal Institutes of Technology Domain had the highest CNCI with 2.03, 1.89 and 1.76, respectively.

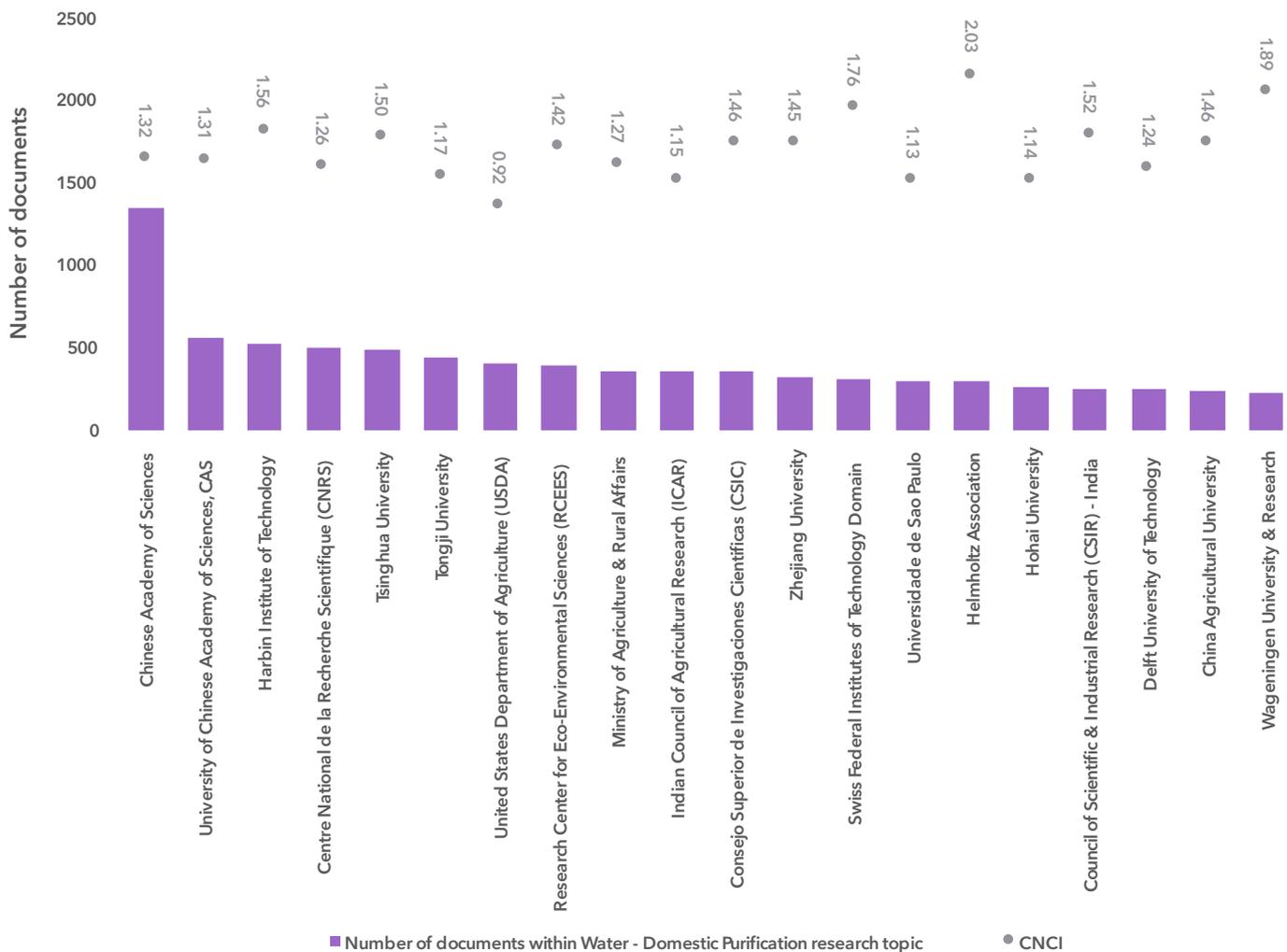


Figure 120: Top 20 organizations globally in terms of the number of publications published in the research topic Water - Domestic Purification in the period 2014-2023 and their corresponding CNCI

#### 4.1.12.8 Top 20 researchers globally in terms of number of publications

The top three researchers globally in terms of the number of publications on this research topic are Heng Liang with 82, followed by Jun Ma with 78, and Guibai Li with 66, all three affiliated with the Harbin Institute of Technology, as shown in Table 39.

The highest CNCI is achieved by Urs von Gunten affiliated with Ecole Polytechnique Federale de Lausanne with 2.63.

The highest number of Top 1% is achieved by Jun Ma affiliated with Harbin Institute of Technology while highest number of Top 10% publications is achieved by Gang Yu affiliated with Tsinghua University.

Table 39: Top 20 researchers globally in terms of the number of publications published in the research topic Water - Domestic Purification in the period 2014-2023

Name	Affiliation	Web of Science Publications	CNCI	Publications in top 1%	Publications in the top 10%	Country
<b>Liang, Heng</b>	Harbin Institute of Technology	82	1.59	3	24	Mainland China
<b>Ma, Jun</b>	Harbin Institute of Technology	78	1.92	7	22	Mainland China
<b>Li, Guibai</b>	Harbin Institute of Technology	66	1.53	2	17	Mainland China
<b>Westerhoff, Paul</b>	Arizona State University	49	1.58	1	11	United States
<b>Chu, Wenhai</b>	Tongji University	48	1.29	0	13	Mainland China
<b>Gao, Naiyun</b>	Tongji University	47	1.38	0	14	Mainland China
<b>Barbeau, Benoit</b>	Universite de Montreal	46	0.81	0	5	Canada
<b>Qu, Jiuhui</b>	Chinese Academy of Sciences	45	2.04	3	16	Mainland China
<b>Yu, Gang</b>	Tsinghua University	44	2.31	3	24	Mainland China
<b>Qu, Jiuhui</b>	Research Center for Eco-Environmental Sciences (RCEES)	44	2.05	3	16	Mainland China
<b>Dionysiou, Dionysios D.</b>	University System of Ohio	43	2.23	2	19	United States
<b>Xu, Bin</b>	Tongji University	41	1.17	0	8	Mainland China
<b>Hu, Hong-Ying</b>	Tsinghua University	40	1.75	2	8	Mainland China
<b>Chen, Wei</b>	Hohai University	40	1.17	1	3	Mainland China
<b>Wang, Yujue</b>	Tsinghua University	39	2.26	3	23	Mainland China
<b>Gagnon, Graham A.</b>	Dalhousie University	38	0.60	0	1	Canada
<b>von Gunten, Urs</b>	Ecole Polytechnique Federale de Lausanne	37	2.63	4	14	Switzerland

#### 4.1.12.9 Top 20 global funders globally in terms of number of publications

The top three organizations in terms of funded publications in this research topic are the National Natural Science Foundation of China (NSFC) with 5562 publications, followed by the European Union (EU) with 1180 publications, and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPQ) with 996 publications as shown in Figure 121.

The highest citation impact measured by the CNCI is observed in publications funded by China Postdoctoral Science Foundation, UK Research & Innovation (UKRI) and Mainland China Scholarship Council with 1.64, 1.60 and 1.55, respectively. Among the top 20 global funding organizations, nine are also among the top 20 funding organizations of Saudi publications in this research topic.

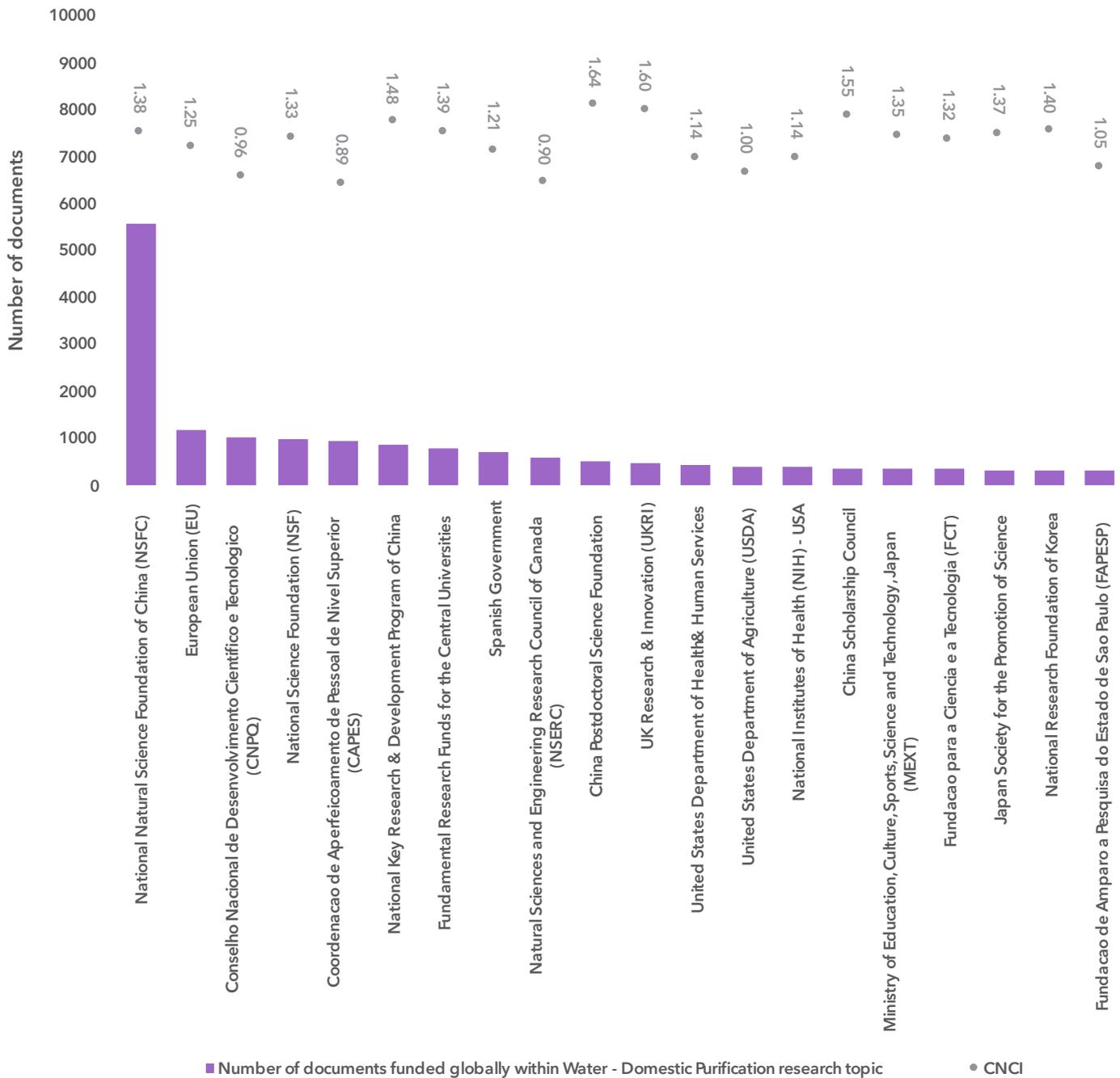


Figure 121: Top 20 funding organizations globally publications in the research topic Water - Domestic Purification in terms of number of publications in the period 2014-2023

#### 4.1.12.10 Emerging trends in the research topic globally and in Saudi Arabia

In this section we investigate the emerging trends globally and in Saudi Arabia in the research topic Water - Domestic Purification. For more information on the methodology used to identify emerging trends, please see the section Emerging Trends.

The top three emerging micro-topics globally in this research topic are Herbicides, Pesticides & Ground Poisoning: Microplastics followed by Thermodynamics: Solar Still and Herbicides, Pesticides & Ground Poisoning: PFOS as shown in Figure 122.

Table 40 shows the identified top 10 micro-topics in Saudi Arabia research output in this research topic.

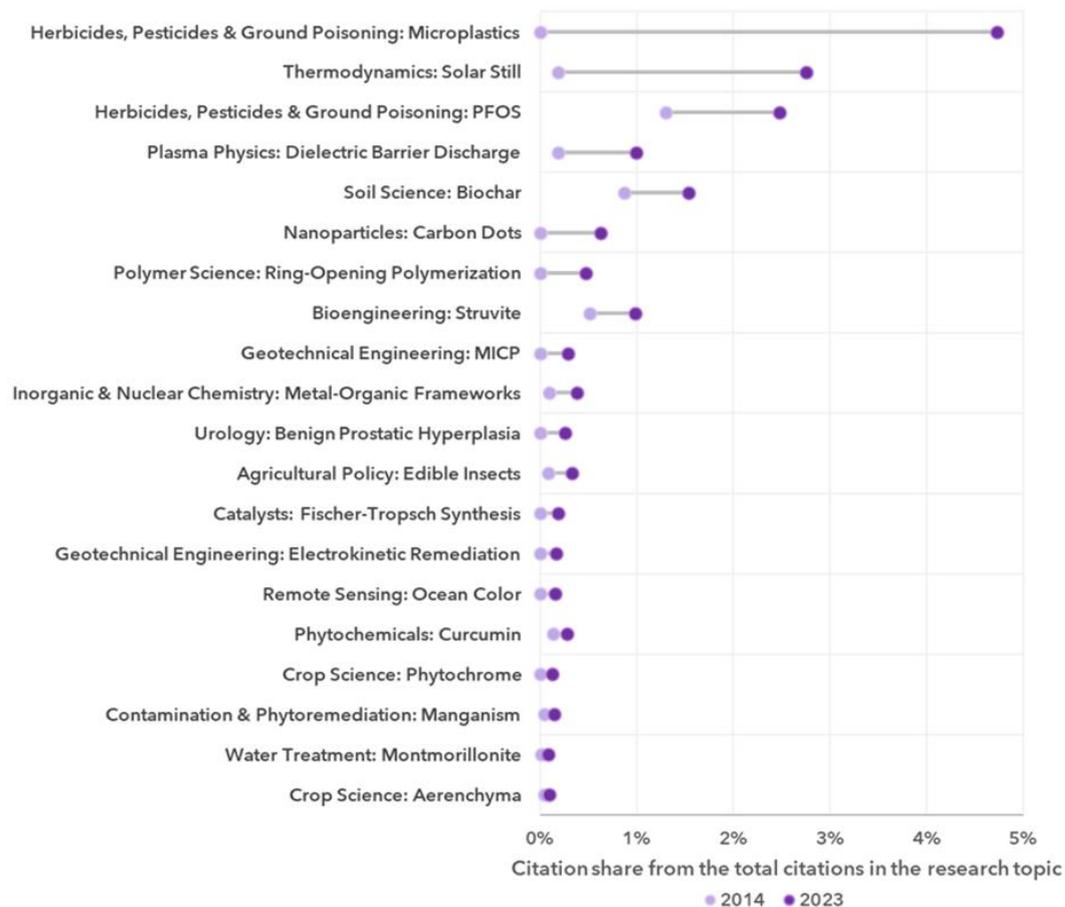


Figure 122: Top 20 emerging micro-topics globally in the research topic Water - Domestic Purification in the period 2014-2023

Table 40: Top 10 Micro-topics identified in Saudi Arabia research output in the research topic Water - Domestic Purification in the period 2014-2023

Topic	Number of Saudi Arabian publications in the period 2014-2023
Water - Domestic Purification research topic	855
Membrane Science: Nanofiltration	124
Water Treatment: Adsorption	61
Water Treatment: Trihalomethanes	38
Water Treatment: Electrocoagulation	33
Crop Science: Salt Stress	31
Bioengineering: Constructed Wetlands	30
Water Resources: Groundwater	26
Herbicides, Pesticides & Ground Poisoning: Bisphenol A	24
Bioengineering: Activated Sludge	23
Soil Science: Nitrous Oxide	14

## 4.2 Invention Performance in the Selected Priority Research Topics

In Figure 123, Saudi Arabia's applied research has more established sustained strength within the Sustainability and Essential Needs priority within technologies such as Flood Protection, Carbon Capture, Wastewater purification/treatment, and Waste-to-Energy, in the top left quadrant.

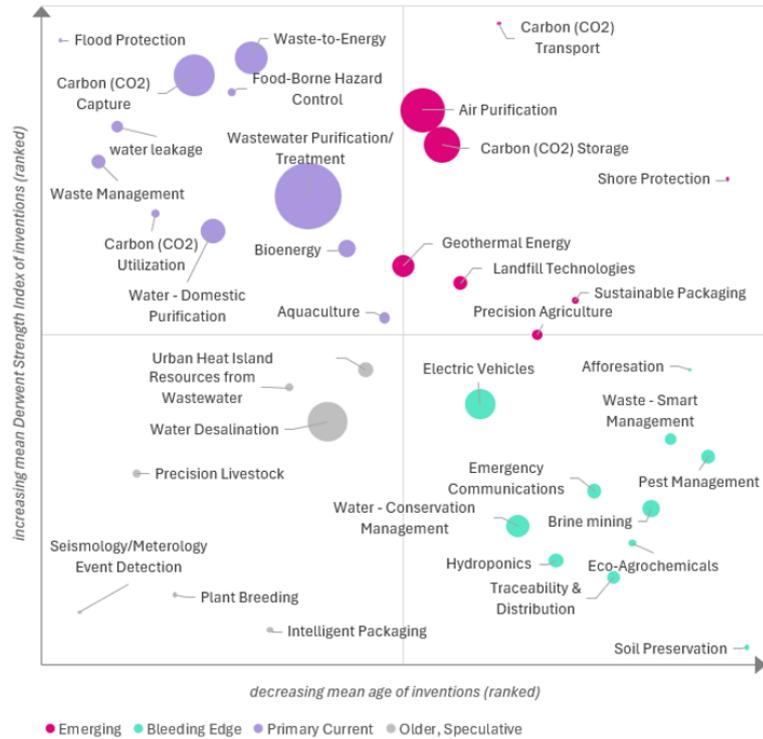


Figure 123: Technical dynamics model for the technologies within the Sustainability and Essential Needs priority area from Saudi Arabian organizations

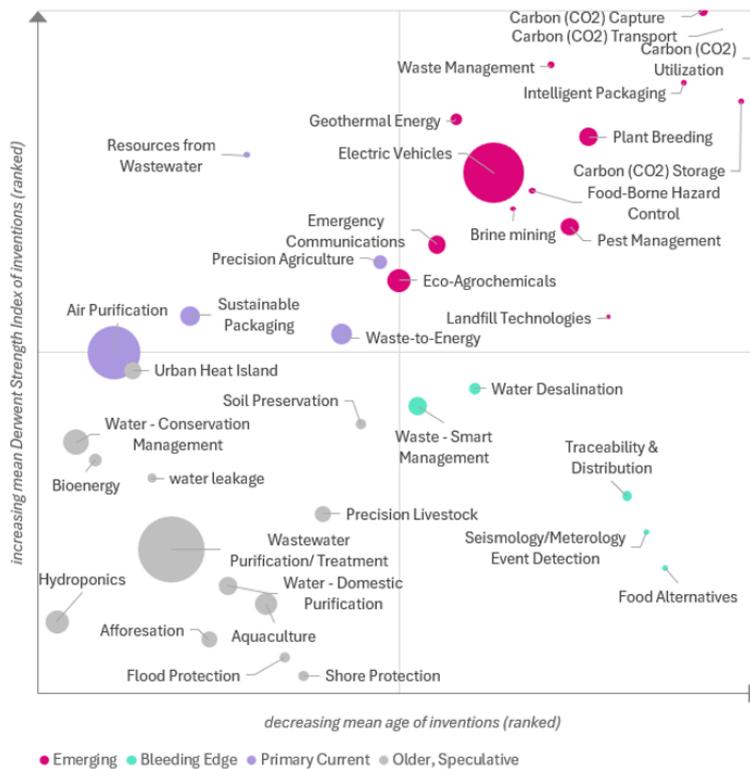


Figure 124: Technical dynamics model for the technologies within the Sustainability and Essential Needs priority area from global organizations

Recently, there has been high invention strength investment into technologies such as Air Purification and Carbon Storage. Water desalination is a lower-strength older portfolio for Saudi Arabia compared to other Sustainability and Essential Needs technologies; however, due to its unique geography, it is a very important process for supplying water to Saudi Arabia's growing population.

The analysis in Figure 124 differs from the global applied research dynamics due to the geographical needs of Saudi Arabia. For example, Wastewater purification/ treatment is an established strong portfolio for Saudi Arabian innovators, whereas, on a global scale, it is a high volume, established portfolio; however, on average, it has lower invention strength. Air Purification is a high-strength and volume portfolio for Saudi Arabia in a more recent top-right emerging quadrant, whereas globally, Air purification is a more established innovation area of median strength. Electric Vehicles is a top-right emerging quadrant globally and a bleeding edge technology for Saudi Arabia; recent collaborations include PIF-funding of Lucid Group, establishing Saudi Arabia's first Electric Vehicle manufacturing site. Alternatively, Carbon Capture is an established, high-strength technology portfolio for Saudi Arabia, whereas it is only a very recent high-strength technology globally.

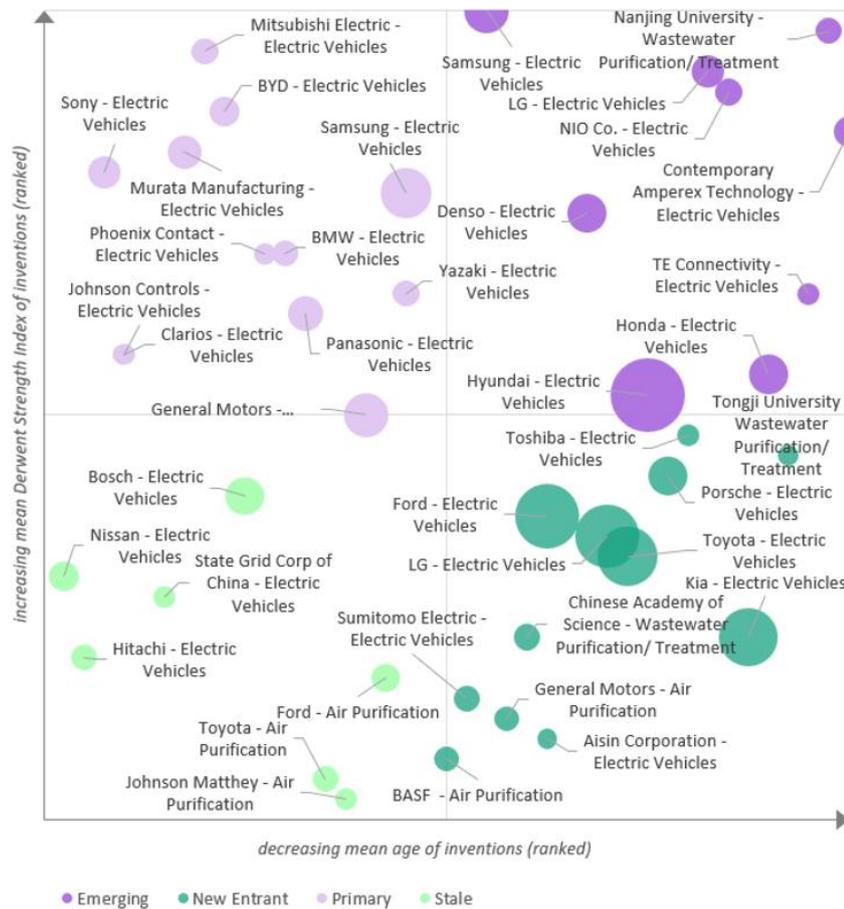


Figure 125: A view of the top forty global organizations with the strongest inventions awarded a score of 80+/100 Derwent Strength Index within the priority area of Sustainability and Essential Needs

In the top left quadrant of Figure 125, which denotes primary technologies with older portfolios of high invention strength, all of the invention portfolios are for Electric Vehicles, interestingly despite historically strong automotive sector, only two organizations, Johnson Controls and BMW are headquartered in Europe. Similarly in the emerging sector it is again dominated by electric vehicle technology portfolios mainly from Mainland China, South Korea and Japan. Hyundai holds the largest high-strength invention portfolio across Sustainability and Essential Needs.

The lower two quadrants of differing recency, and relatively lower high invention strength covers Electric Vehicles, Air Purification and Water - Wastewater Purification/Treatment. The only public organizations are State Grid Corporation of China, the Chinese Academy of Sciences and Tongji University, which showcases public research in Electric Vehicles and Water - Wastewater Purification/Treatment from Mainland China.

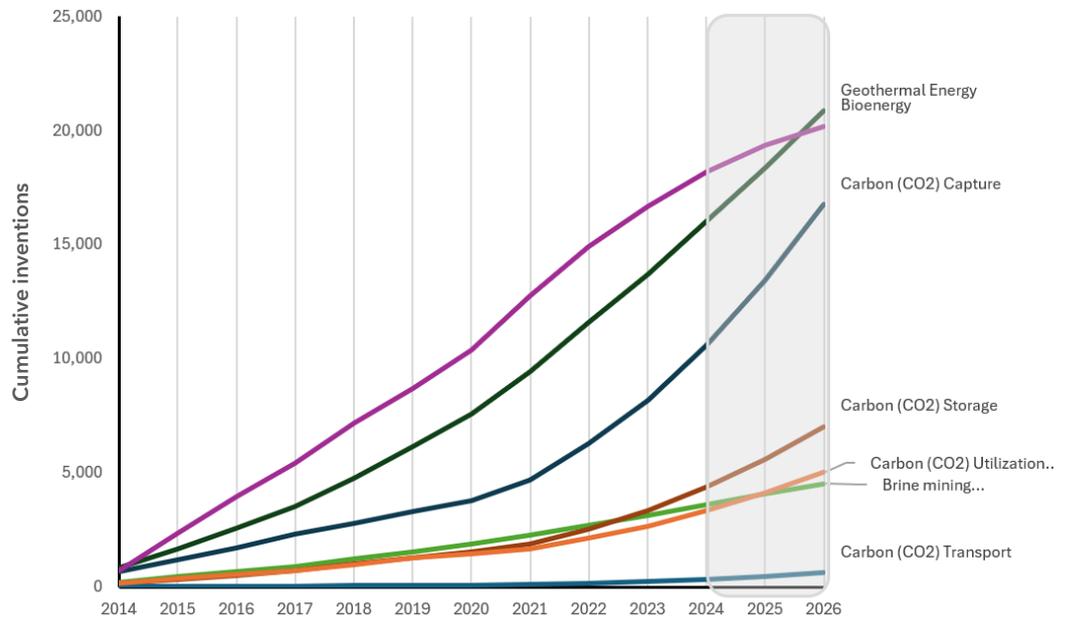


Figure 126: Cumulative inventions globally between 2014-2023 across Carbon, Brine Mining, Bioenergy and Geothermal research topics within the Sustainability and Essential Needs priority area

Bioenergy has the highest volume of inventions in Figure 126, however due to the relative growth trajectories compared to Geothermal Energy, it is predicted that Geothermal energy will have higher volumes by 2026. Carbon (CO2) Capture has a very high growth trajectory and is also predicted to catch up to Bioenergy invention volumes between 2026-2030.

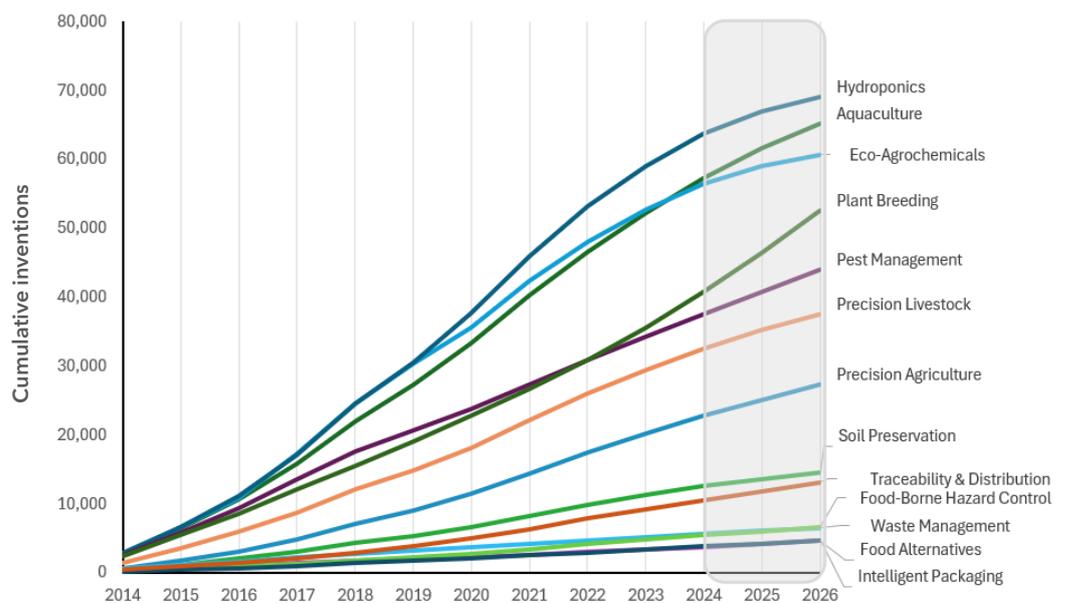


Figure 127: Cumulative inventions globally between 2014-2023 across Agriculture and Food research topics within the Sustainability and Essential Needs priority area

Agriculture Hydroponics currently has the highest invention volumes in Figure 127, however, due to the growth rates of Aqua Culture, Eco-Agrochemicals and Plant Breeding, it is likely that Plant Breeding and Aquaculture will overtake Eco-Agrochemicals and Hydroponics in the next 5-10 years.

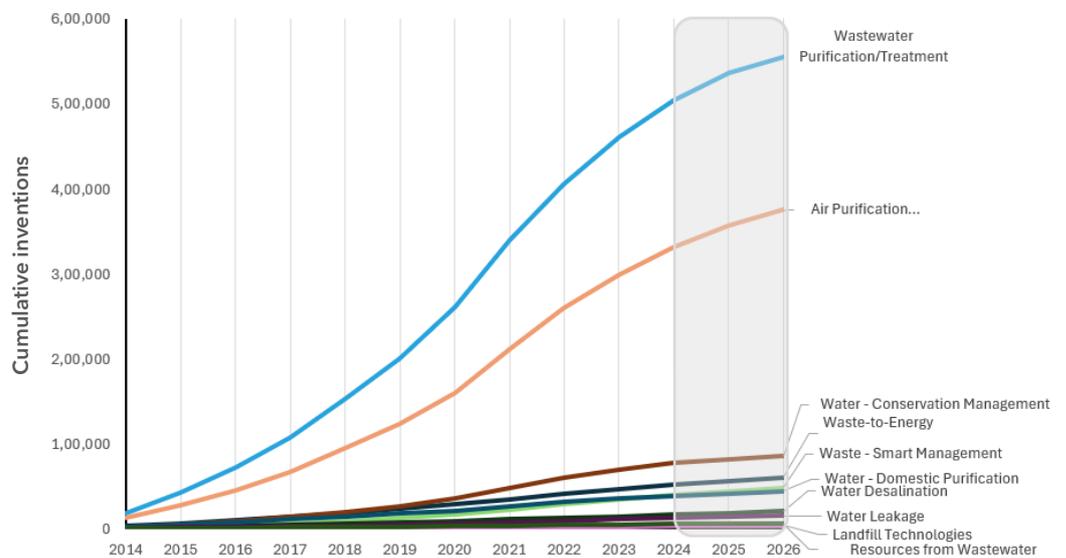


Figure 128: Cumulative inventions globally between 2014-2023 across Water, Waste and Air Purification research topics within the Sustainability and Essential Needs priority area

Water - Wastewater Purification/Treatment has the highest volume and growth rate of all Water and Waste technologies in Sustainability and Essential Needs in Figure 128. This is followed by Air purification, which is set to double its invention volumes between 2020 - 2026.

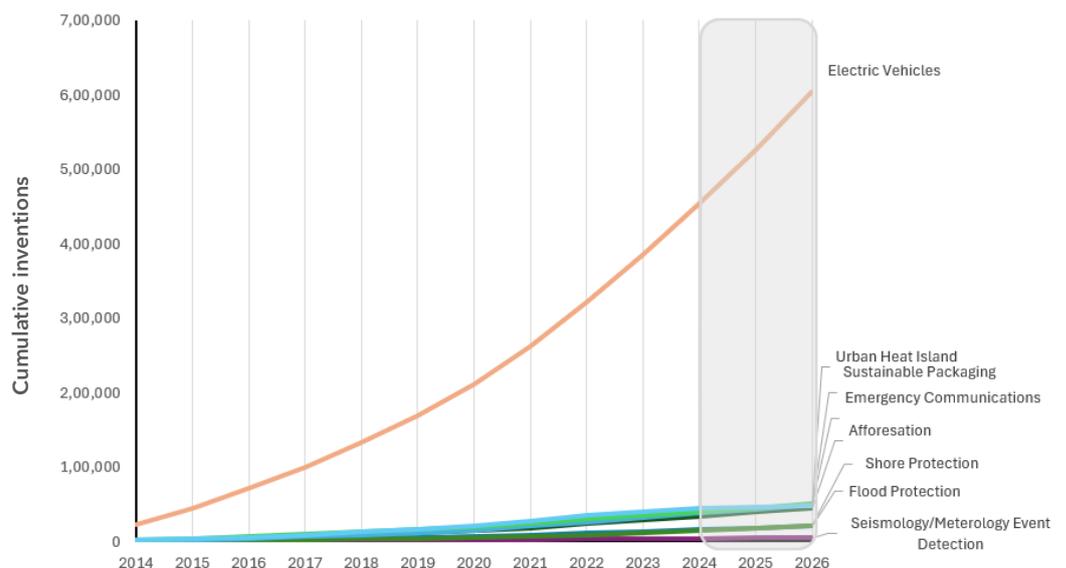


Figure 129: Cumulative inventions globally between 2014-2023 across Electric Vehicles, Adaptations, Emergency Communications, Sustainable Packaging and Seismology research topics within the Sustainability and Essential Needs priority area

Electric Vehicles have significantly higher volumes and growth rate prediction than all Sustainability and Essential Needs technologies except for Water-Wastewater Purification/ Treatment in Figure 129.

### 4.2.1 Food Alternatives

In Figure 130, Mainland China is the leading source of Food Alternatives technology inventions between 2014 - 2024 producing 2,175 inventions. Followed by Japan with 335 inventions, South Korea with 255 inventions, the US with 227 inventions, and Russia with 54 inventions.



Figure 130: Global distribution of inventions related to Food Alternatives. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction.

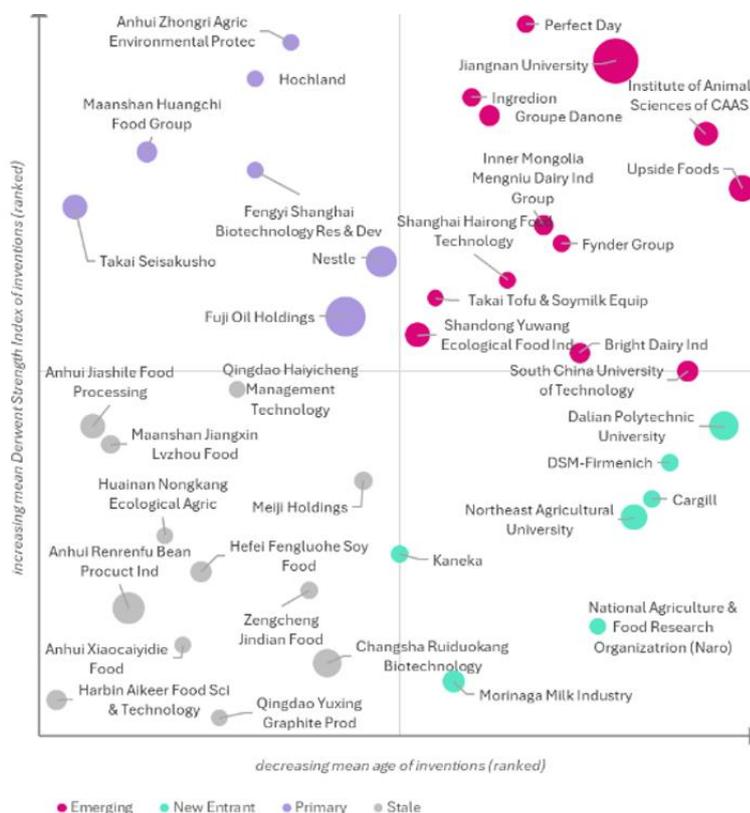


Figure 131: Commercial dynamics model for the top global patent assignees in the technology area of Food Alternatives

Jiangnan University holds the highest number of high-strength recent inventions globally within Food Alternatives technology, with 51 inventions shown in Figure 131. Followed by Upside Foods with 18 inventions, and Shandong Yuwang Ecological Food Ind with 15 inventions. Fuji Oil Holdings has 39 more established high-strength inventions, alongside Nestle with 25 inventions.

#### 4.2.2 Eco-Agrochemicals

Mainland China is the leading source of Eco-Agrochemicals technology inventions between 2014 - 2024, producing 49,962 inventions shown in Figure 132. Followed by South Korea with 493 inventions, Russia with 382 inventions, India with 359 inventions, and US with 216 inventions.



Figure 132: Global distribution of inventions related to Eco-Agrochemicals. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction.

The Institute of Animal Sciences of CAAS holds the largest number of recent high-strength inventions globally for Eco-Agrochemicals technology, with 348 inventions seen in Figure 133, followed by the Chinese Academy of Science with 284 inventions, and Guangxi Zhuang Autonomous Region Inst.

Within the top left quadrant for a more established high-strength invention portfolio, Shangdong Sunway Gardening Technology with 171 inventions, followed by Guangdong Fengkang Biotechnology with 75 inventions and Shandong Agricultural University with 71 inventions.

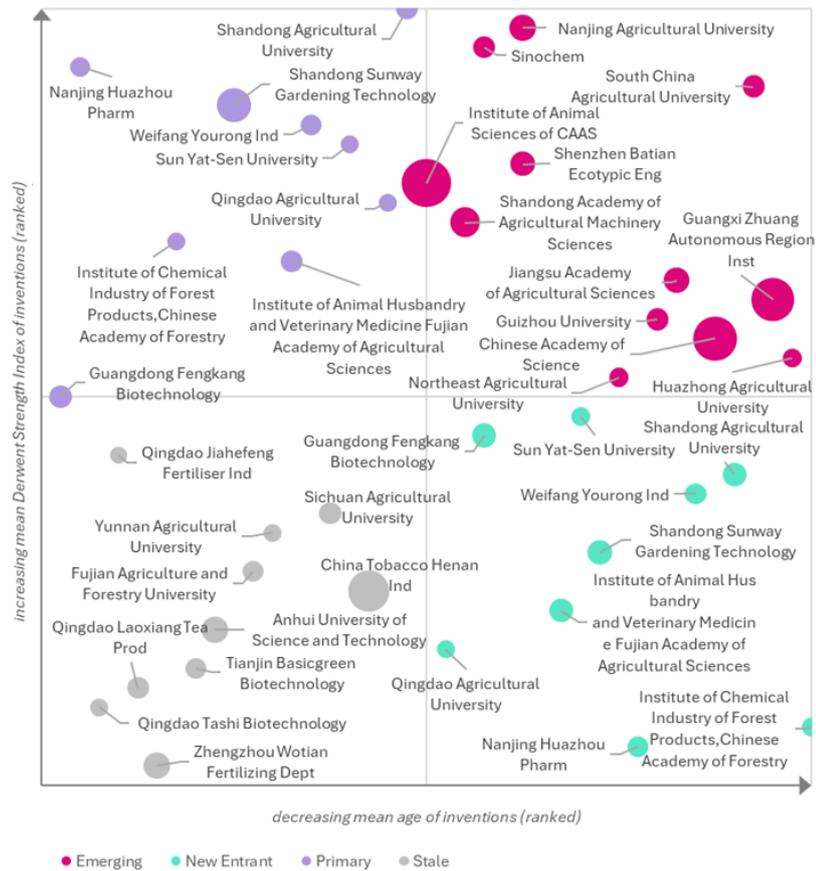


Figure 133: Commercial dynamics model for the top global patent assignees in the technology area of Eco-Agrochemicals

### 4.2.3 Food Traceability & Distribution

In Figure 134, Mainland China is the leading source of Food Traceability & Distribution technology inventions between 2014 - 2024, producing 5,926 inventions. Followed by the US with 872 inventions, South Korea with 643 inventions, India with 498 inventions, and Japan with 288 inventions.



Figure 134: Global distribution of inventions related to Food - Traceability & Distribution. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction

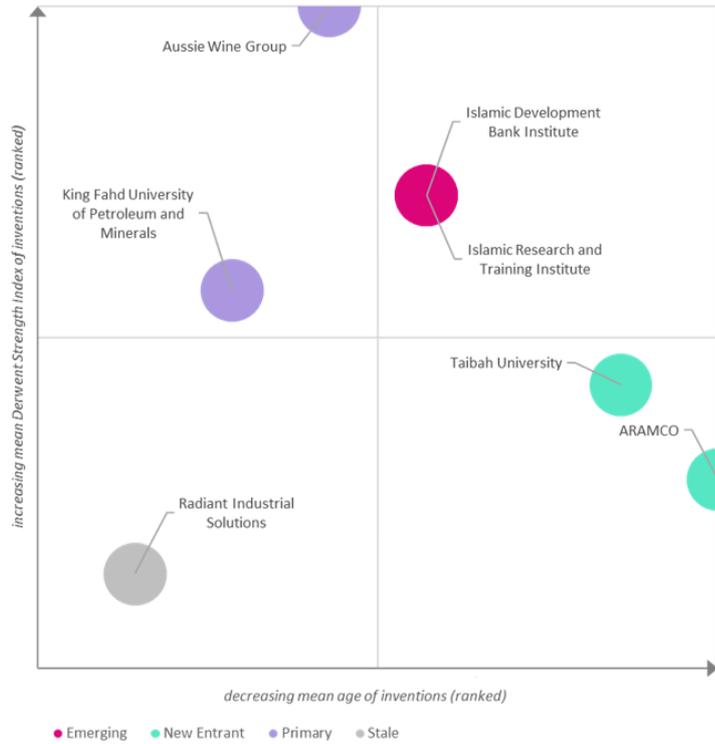


Figure 135: Commercial dynamics model for the top patent assignees active in Saudi Arabia in the technology area of Food Traceability & Distribution

The Islamic Research and Training Institute holds the highest strength in invention from Saudi Arabia with a score of 49, joint with the Islamic Development Bank Institute, shown in Figure 135. This is followed by KFUPM with an invention scoring 47.

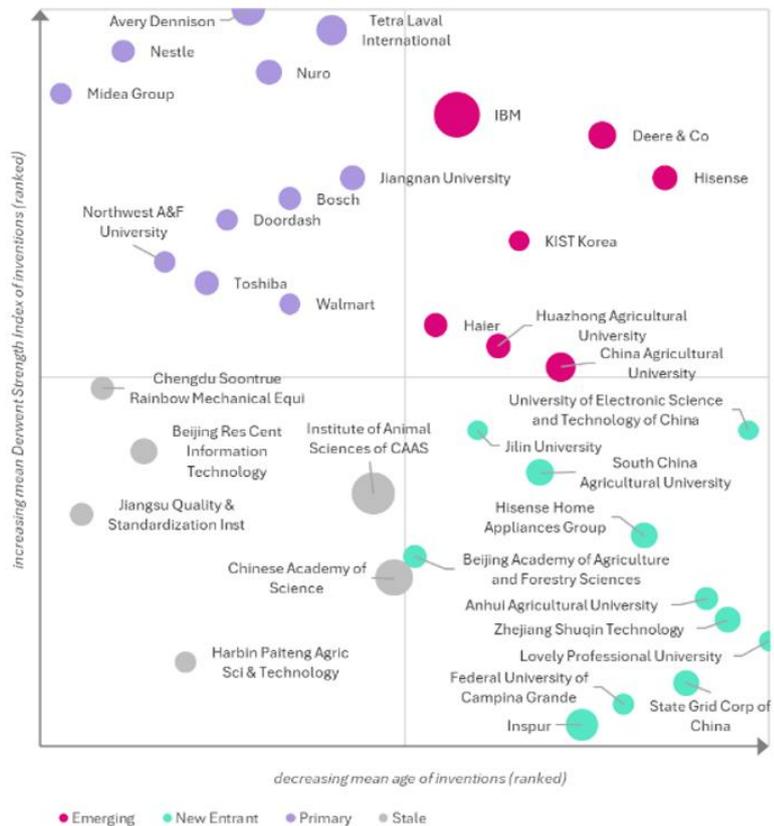


Figure 136: Commercial dynamics model for the top global patent assignees in the technology area of Food Traceability & Distribution

IBM holds the largest number of recent high-strength inventions globally in Food Traceability & Distribution with 56 inventions, followed by China Agricultural University with 23 inventions, and Deere & Co. with 20 inventions shown in Figure 136. Found within the top left quadrant for more established high-strength inventions is Avery Dennison with 30 inventions, alongside Tetra Laval International with 24 inventions, and Jiangnan University with 17 inventions.

#### 4.2.4 Food-Borne Hazard Control

In Figure 137, Mainland China was the leading source of Food-Borne Hazard Control technology inventions between 2014 and 2024, producing 3,234 inventions. It was followed by the US with 418 inventions, South Korea with 307 inventions, Japan with 254 inventions and India with 119 inventions.



Figure 137: Global distribution of inventions related to Food-Borne Hazard Control. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction

Jiangsu University holds the largest number of recent high-strength inventions globally within Food-Borne Hazard Control technologies, with 42 inventions shown in Figure 138, followed by China Agricultural University with 28 inventions and Huazhong Agricultural University with 24 inventions. Notably, DSM-Firmenich holds 14 inventions. Found within the top left quadrant for high-strength, more established inventions is Jiangnan University with 62 inventions, alongside Nanchang University with 20 inventions, and Sun Yat-Sen University with 14 inventions.

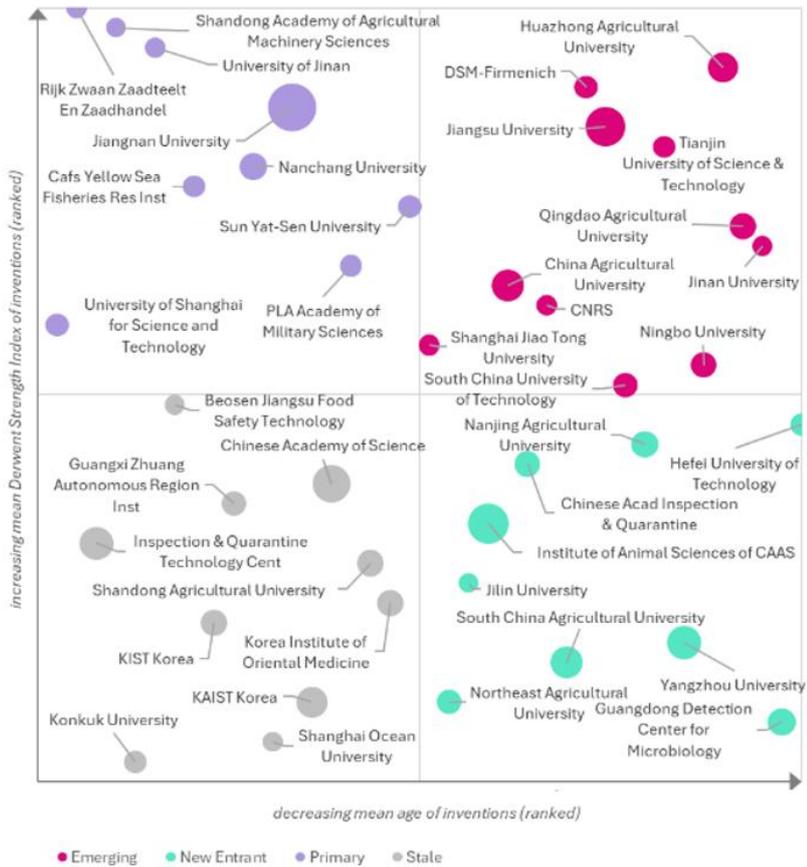


Figure 138: Commercial dynamics model for the top global patent assignees in the technology area of Food-Borne Hazard Control

#### 4.2.5 Carbon (CO2) Transport

In Figure 139, Mainland China is the leading source of Carbon (CO2) Transport technologies technology inventions between 2014 - 2024 producing 149 inventions. Followed by the US with 27 inventions, South Korea with 20 inventions, Japan with 15 inventions and Canada with seven inventions.



Figure 139: Global distribution of inventions related to Carbon (CO2) Transport. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction

China University of Mining & Technology has the highest number of high-strength recent patents globally within Carbon (CO<sub>2</sub>) Transport with six inventions, followed by Marathon Petroleum with five inventions, and Dalian University of Technology with three inventions seen in Figure 140. More established high-strength invention portfolios are held by Sinopec with six inventions, logen with four inventions and Air Liquide with three inventions.

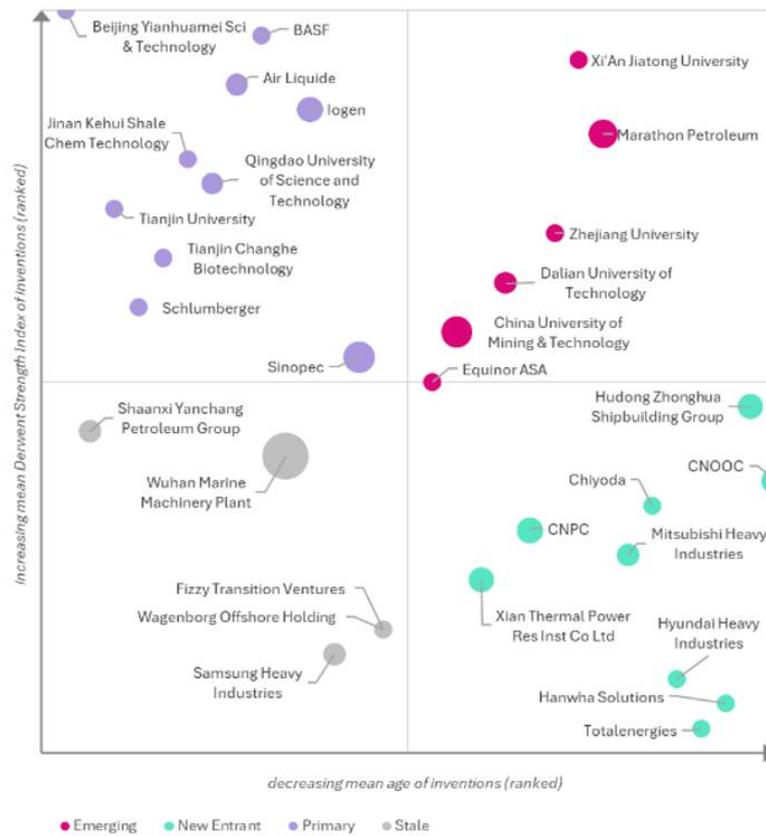


Figure 140: Commercial dynamics model for the top global patent assignees in the technology area of Carbon (CO<sub>2</sub>) Transport

#### 4.2.6 Electric Vehicles

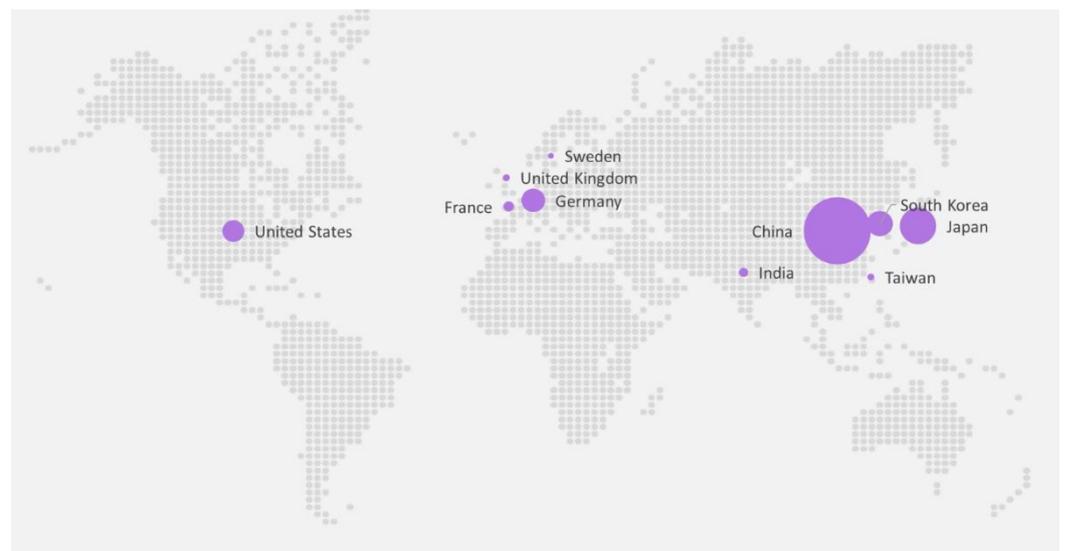


Figure 141: Global distribution of inventions related to Electric Vehicles. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction

In Figure 141, Mainland China was the leading source of Electric Vehicle technology

inventions between 2014 and 2024, producing 226,883 inventions. It was followed by Japan with 67,345 inventions, South Korea with 33,093 inventions, Germany with 27,805 inventions and the US with 24,149 inventions.

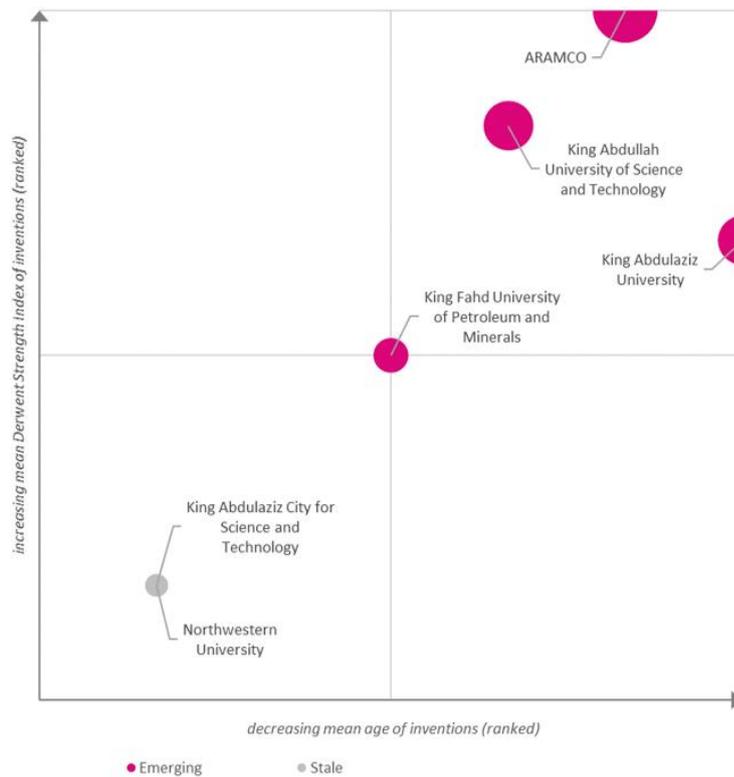


Figure 142: Commercial dynamics model for the top patent assignees active in Saudi Arabia in the technology area of Electric Vehicles

Saudi Aramco holds the largest high-strength portfolio in Saudi Arabia for Electric Vehicle technology, with 17 inventions scoring a mean invention strength score of 58.4, shown in Figure 142. It is followed by KAUST, with ten inventions scoring 56.1 and King Abdulaziz University, with ten inventions scoring 52.3.

Toyota Motor holds the largest high-strength recent portfolio globally in the field of Electric Vehicles with 15,139 inventions, followed by Hyundai Motor with 8,102 inventions, LG Chem with 5,878 inventions, and Porsche Automobile Holding with 5,554 inventions shown in Figure 143. Found within the top left quadrant containing high-strength more established portfolios are Bosch with 4,520 inventions, Ford Motor with 4,350, Denso with 3,953 and BYD with 3,017 inventions.

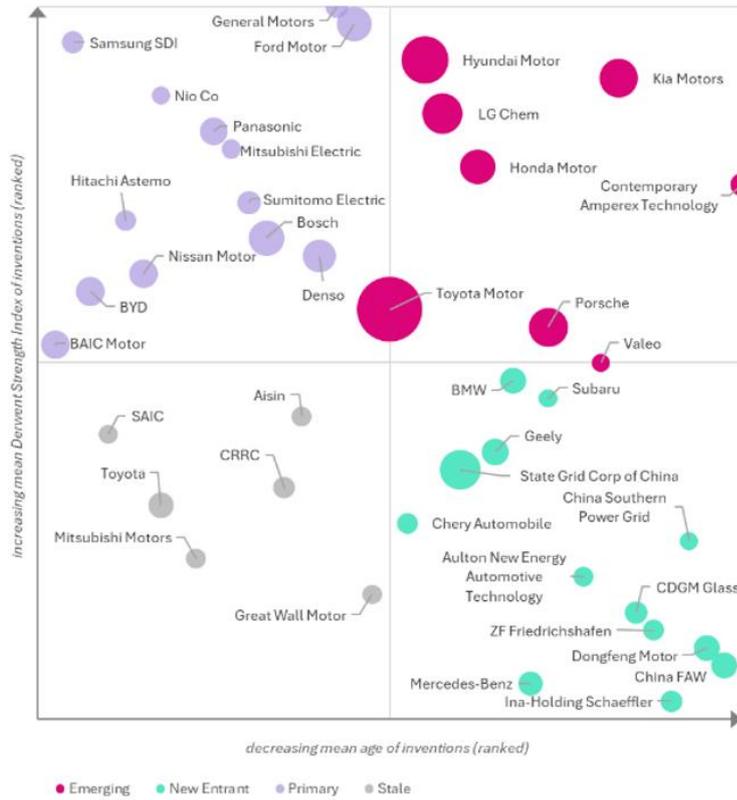


Figure 143: Commercial dynamics model for the top global patent assignees in the technology area of Electric Vehicles

#### 4.2.7 Waste Landfill

In Figure 144, Mainland China is the leading source of Waste - Landfill technologies technology inventions between 2014 - 2024 producing 1,724 inventions. Followed by the US with 203 inventions, South Korea with 137 inventions, India with 59 inventions and Japan with 43 inventions.



Figure 144: Global distribution of inventions related to Waste Landfill. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction

Saudi Arabia originated inventions in waste technology. Landfill technologies are held by Saudi Aramco, with two inventions scoring a mean of 64.5, and KFUPM, with 11 inventions scoring 48.5, found in Figure 145.

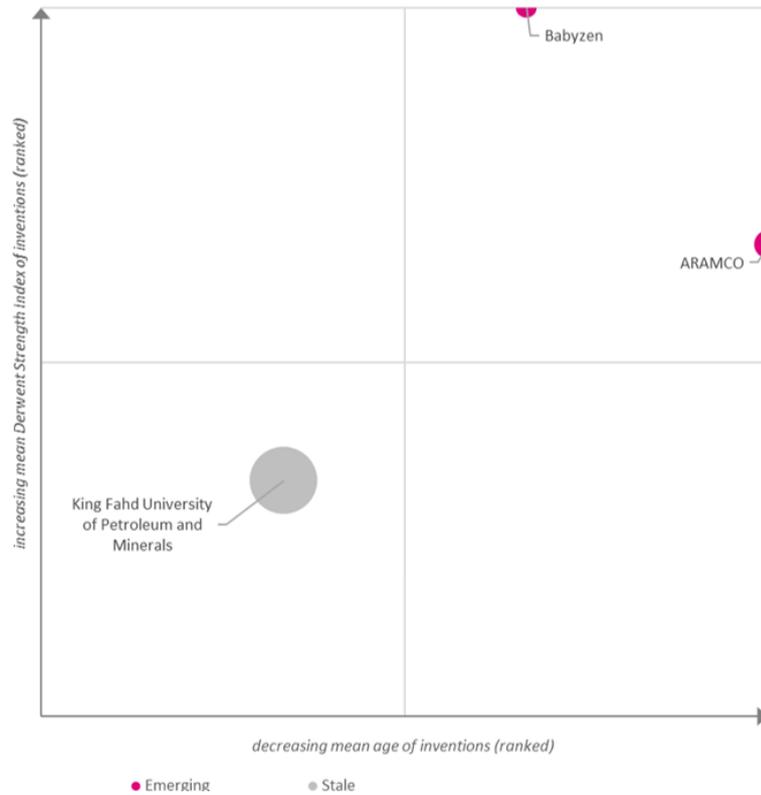


Figure 145: Commercial dynamics model for the top patent assignees active in Saudi Arabia in the technology area of Waste Landfill

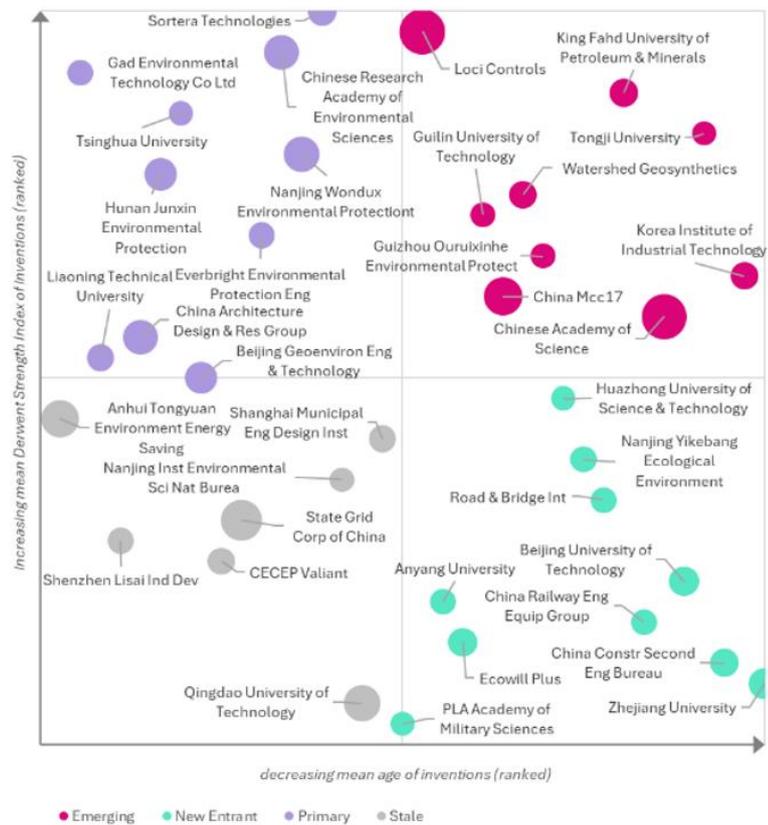


Figure 146: Commercial dynamics model for the top global patent assignees in the technology area of Waste Landfill

Loci Controls has the largest recent high-strength invention portfolio globally within Waste - Landfill Technologies, producing 28 inventions with a mean invention strength score of 50.8, shown in Figure 146, followed by the Chinese Academy of Science with 27 inventions, China MCC17 with 20 inventions, and KFUPM with 11 inventions.

Zhejiang University holds 13 inventions in the top left quadrant for more established high-strength inventions, followed by Beijing University of Technology with 12 inventions.

#### 4.2.8 Wastewater Purification

Mainland China is the leading source of Wastewater Purification technology inventions between 2014 - 2024, producing 418,912 inventions seen in Figure 147. Followed by South Korea with 11,550 inventions, Japan with 9,365 inventions, US with 7,268 inventions and India with 2,157.



Figure 147: Global distribution of inventions related to Wastewater Purification. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction

Saudi Aramco holds the largest high-strength portfolio in Saudi Arabia in the technology of Water-wastewater Purification, with 107 inventions scoring 54.5 found in Figure 148. It is followed by King Abdulaziz University with 25 inventions, scoring 58.9; Imam Abdulrahman Bin Faisal University with 17 inventions, scoring 58.2; and King Saud University with 14 inventions, scoring 54.5.

The Chinese Academy of Science has the largest portfolio of high-strength recent inventions globally in Water - Wastewater Purification, as shown in Figure 149, holding 2,721 inventions with a mean invention score of 44.8, followed by Nanjing University with 1,245 inventions and Beijing University of Technology with 1,101. Located within the top left quadrant for more established high-strength inventions, Zhejiang University holds 756 inventions, alongside China University of Mining & Technology with 673 inventions and Sinochem with 641 inventions.

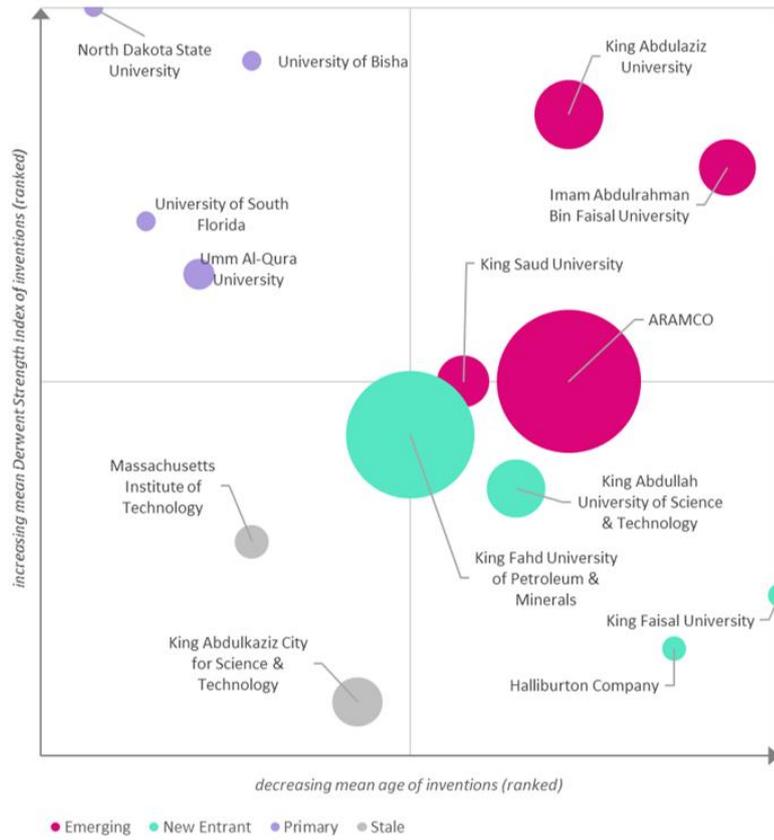


Figure 148: Commercial dynamics model for the top patent assignees active in Saudi Arabia in the technology area of Wastewater Purification

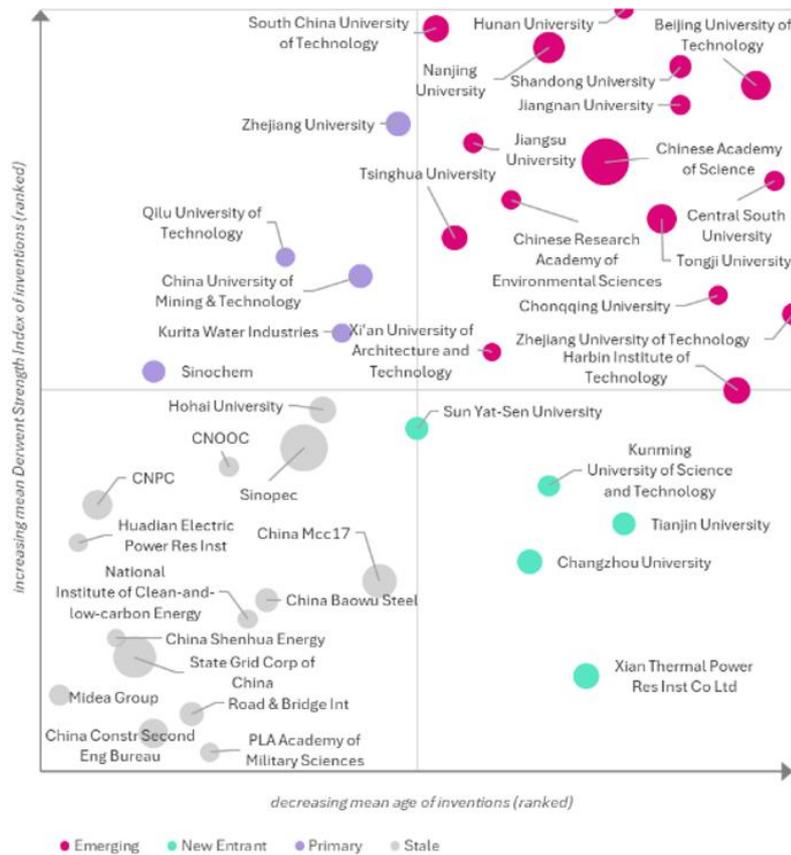


Figure 149: Commercial dynamics model for the top global patent assignees in the technology area of Wastewater Purification

## 4.2.9 Water Desalination

In Figure 150, Mainland China is the leading source of Water Desalination technology inventions between 2014 - 2024 producing 10,362 inventions. Followed by South Korea with 1,349, Japan with 1,034 inventions, the US with 661 inventions, India with 180 inventions, Germany with 168 inventions, Russia with 115 inventions and Saudi Arabia with 108 inventions.



Figure 150: Global distribution of inventions related to Water Desalination. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction

Saudi Aramco holds the largest high-strength invention portfolio from Saudi Arabia in Water Desalination, with 40 inventions with a mean invention strength score of 51.5 seen in Figure 151, followed by KFUPM with 25 inventions with an invention score 48.6, Imam Abdulrahman Bin Faisal University with two inventions with a score of 45.3 inventions, Prince Mohammad Bin Fahd University with two inventions scoring 63.1, Saline Water Conversion Corporation with four inventions scoring 40.4, King Abdulaziz University with four inventions scoring 49.4, King Saud University with four inventions scoring 52.9, KAUST with nine inventions scoring 40.7, and KACST with four inventions scoring 32.5.

The Chinese Academy of Science holds the largest portfolio of high-strength recent inventions with 246 inventions with a mean invention strength of 46.1 seen in Figure 152. This was followed by MNR Oceanography First Institute, which had 162 inventions, and Zhejiang University, which had 88 inventions. Notably, Saudi Aramco's inventions have a mean invention strength of 55.1 across 43 inventions. Located in the top left quadrant for high-strength, more established portfolios are State Grid Corp of China with 197 inventions, Toray Industries with 144 inventions, and Mitsubishi Heavy Industries with 65 inventions.

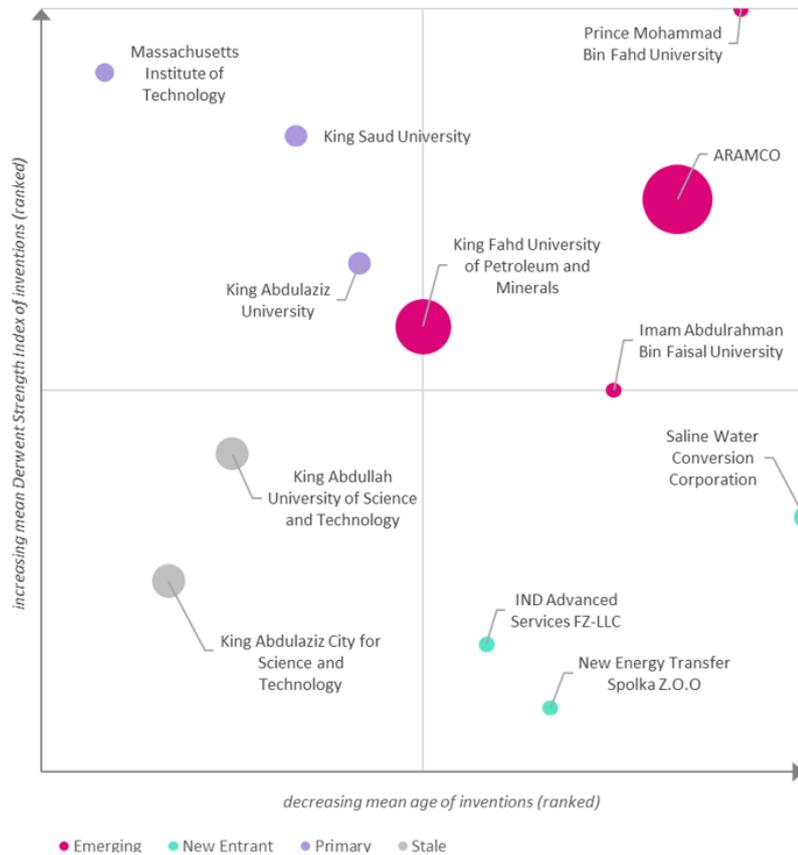


Figure 151: Commercial dynamics model for the top patent assignees active in Saudi Arabia in the technology area of Water Desalination

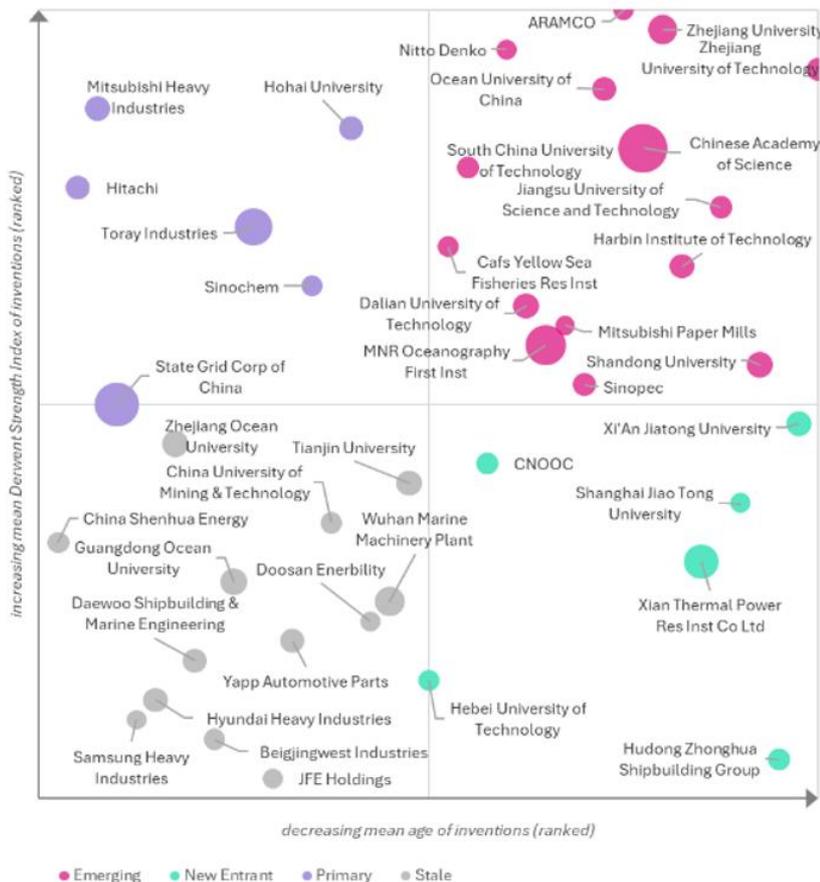


Figure 152: Commercial dynamics model for the top global patent assignees in the technology area of Water Desalination

#### 4.2.10 Water - Conservation Management

In Figure 153, Mainland China is the leading source of Water - Conservation Management technology inventions between 2014 - 2024 producing 63,683 inventions. This is followed by South Korea with 1,684 inventions, Japan with 883 inventions, US with 807 inventions and India with 505 inventions.

KAUST has the highest-strength invention portfolio from Saudi Arabia in Water - Conservation Management found in Figure 154, with three inventions scoring 67.3, which is the mean invention strength. KFUPM has seven inventions, scoring 57.4, and Saudi Aramco has 11 inventions, scoring 47.



Figure 153: Global distribution of inventions related to Water - Conservation Management. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction

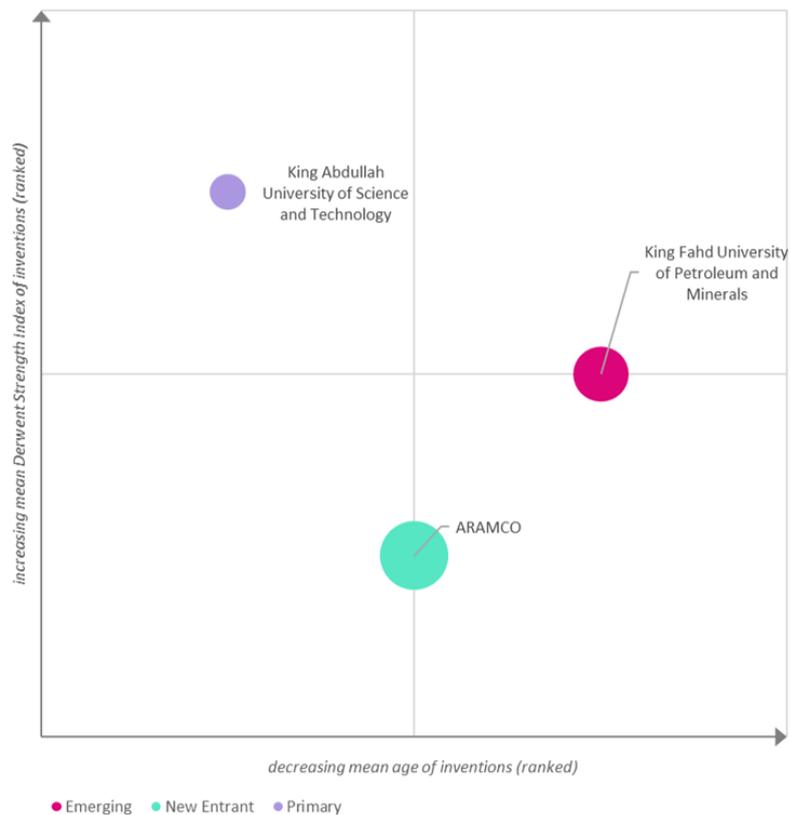


Figure 154: Commercial dynamics model for the top patent assignees active in Saudi Arabia in the technology area of Water - Conservation Management

Shandong University has produced the largest, most recent high-strength invention portfolio globally within Water - Conservation Management, as shown in Figure 155. With 157 inventions with a mean invention score of 46.4, alongside Shenyang Jianzhu University with 130 inventions, scoring 45.1 and Guangxi Zhuang Autonomous Region Institute with 82 inventions scoring 41.6.

Located within the top left quadrant are organizations with more established high-strength inventions, such as Nanjing Forestry University, holding 302 inventions with a mean invention score of 40.3; however, only, on average, 7 years of the original 20 years of protection remain. Hohai University has 172 inventions, with a score of 42.5, and Shanghai Municipal Engineering Design Institute has 123 inventions, scoring 40.6.

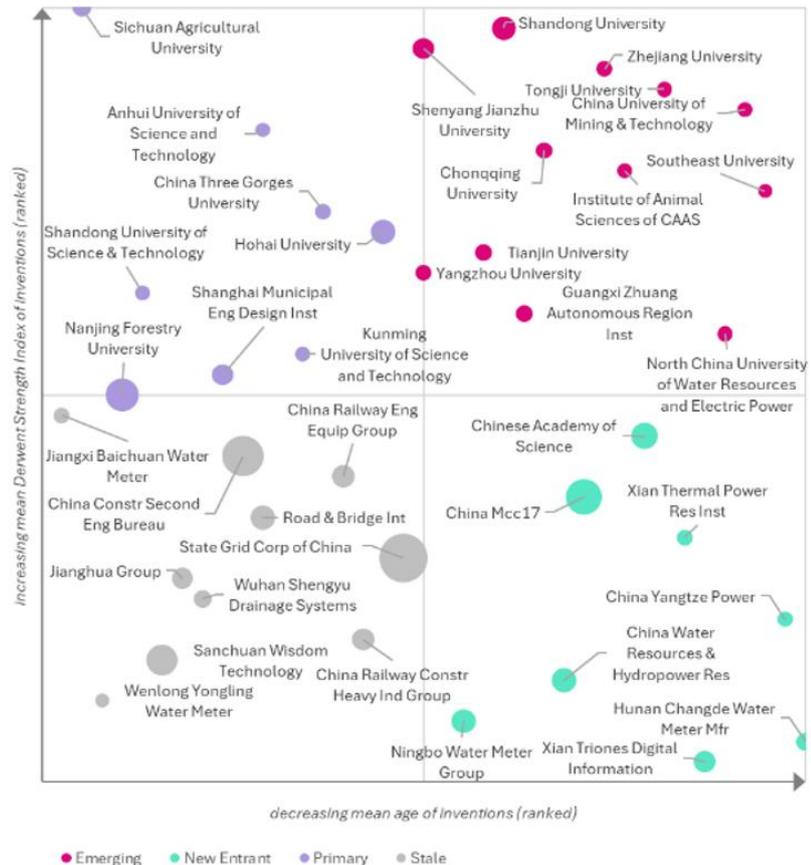


Figure 155: Commercial dynamics model for the top global patent assignees in the technology area of Water - Conservation Management

#### 4.2.11 Water Leakage

In Figure 156, Mainland China is the leading source of Water - leakage technology inventions between 2014 - 2024 producing 8,661 inventions. Followed by South Korea with 715 inventions, Japan with 383 inventions, US with 313 inventions and Germany with 77 inventions.

Saudi Aramco has the highest strength invention from Saudi Arabia in Water Leakage technologies found in Figure 157, with three inventions scoring 63.9 mean invention strength score. Followed by KFUPM with five inventions, scoring 44.5, KAUST has one invention scoring 90.

Zhejiang University has produced the largest high-strength recent invention portfolio globally in Water Leakage technologies, holding 34 inventions, with a mean invention score of 46.2, shown in Figure 158, followed by Hitachi with 33 inventions, scoring 41.5, and Tongji University with 24 inventions, scoring 44. Located within the top left quadrant for more established high-strength inventions is China MCC17 Group, with 48 inventions, scoring 41.7, however with an average of 11.4 years remaining,

compared to Zhejiang University's 14.7 years remaining. China Railway Construction Heavy Industry Corporation holds 36 inventions with a score of 43.4, and NEC has 34 inventions with a score of 48.4.



Figure 156: Global distribution of inventions related to Water - leakage. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction

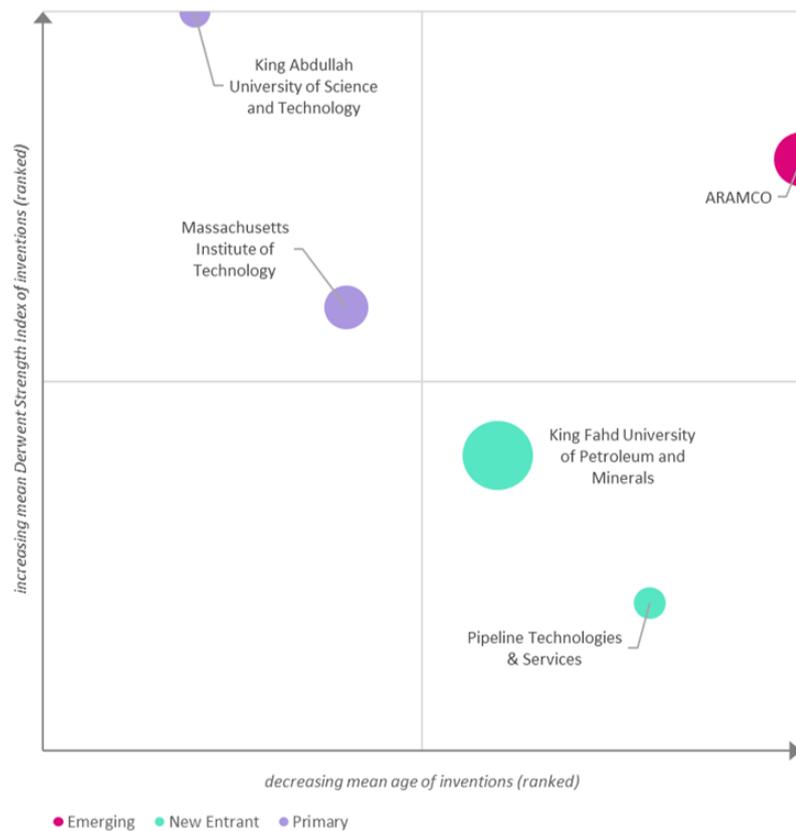


Figure 157: Commercial dynamics model for the top patent assignees active in Saudi Arabia in the technology area of Water - leakage

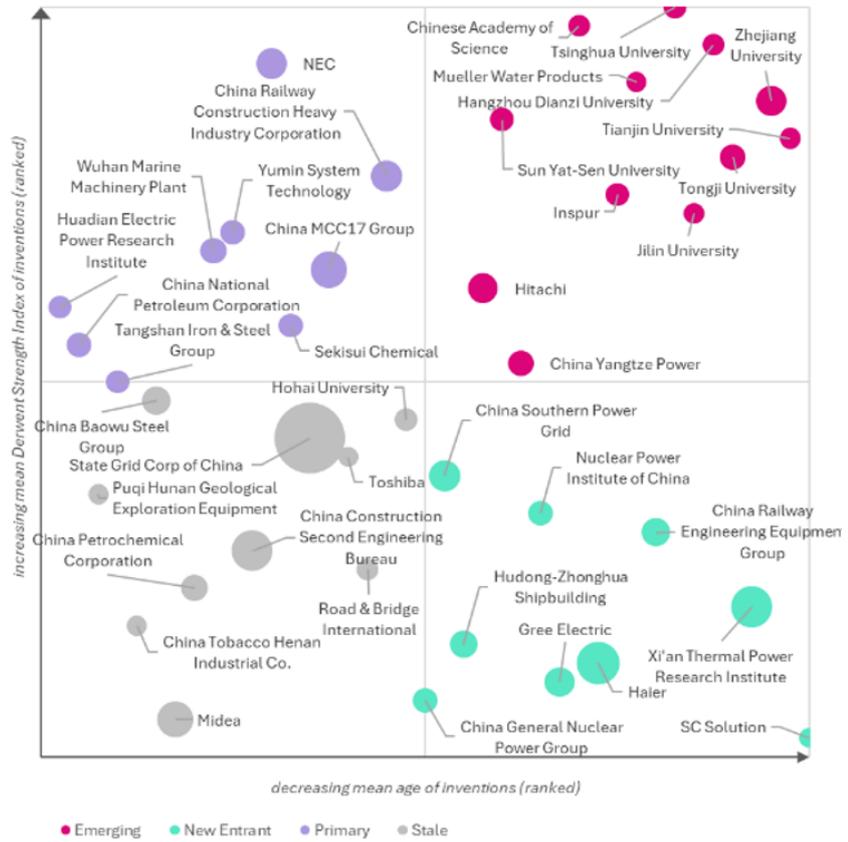


Figure 158: Commercial dynamics model for the top global patent assignees in the technology area of Water - leakage

#### 4.2.12 Water - Domestic Purification

In Figure 159, Mainland China is the leading source of Water - Domestic Purification technology inventions between 2014 - 2024 producing 28,581 inventions. Followed by South Korea with 1,281 inventions, Japan with 1,202 inventions, US with 1,091 inventions and India with 727 inventions.



Figure 159: Global distribution of inventions related to Water - Domestic Purification. The size of each bubble corresponds to the number of unique inventions published in that country or jurisdiction



Figure 160: Commercial dynamics model for the top patent assignees active in Saudi Arabia in the technology area of Water - Domestic Purification

Saudi Aramco has the largest invention portfolio from Saudi Arabia in Water – Domestic Purification technologies seen in Figure 160, holding 11 inventions, KFUPM also has 11 inventions, KAUST with six inventions, KACST with three inventions, King Saud University with three inventions, University King Abdulaziz with two inventions and Univ Imam Abdulrahman Bin Faisal with two inventions.

Midea Group Co Ltd holds the largest high-strength recent invention portfolios globally within Water - Domestic Purification Technologies shown in Figure 161 With 256 inventions with a mean invention score of 34.3, followed by the Chinese Academy of Science with 189 inventions with a score of 41.6, and the University of Beijing Technology with 182 inventions. Notable corporations found within this technology area include Haier Group with 102 inventions, Unilever with 68 inventions, Panasonic Holding Corporation with 66 inventions and Bosch with 41 inventions.

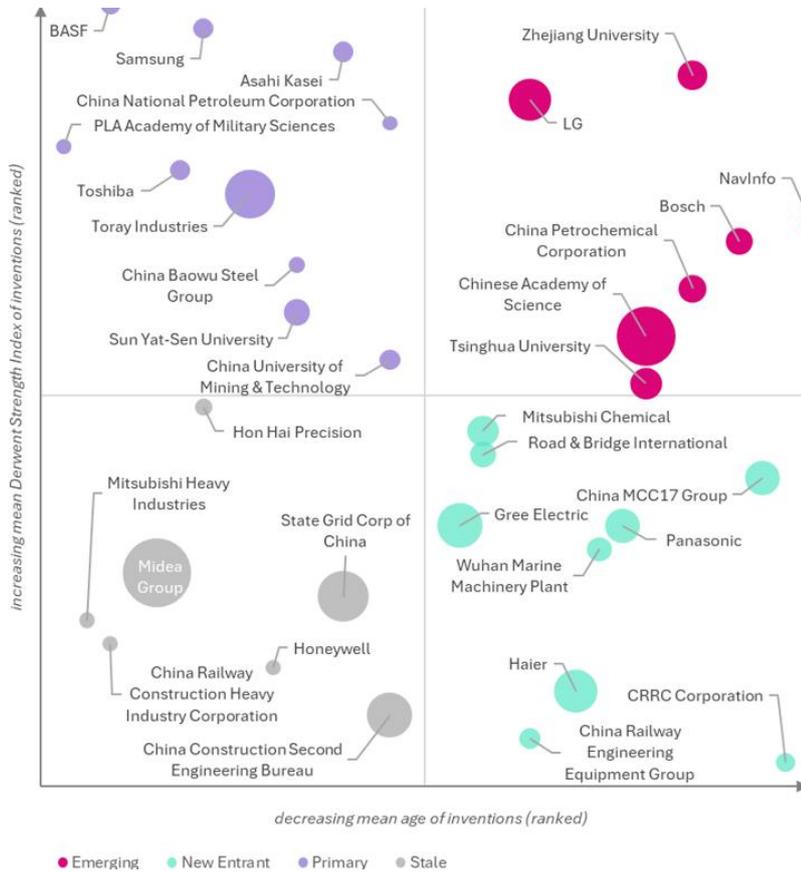


Figure 161: Commercial dynamics model for the top global patent assignees in the technology area of Water - Domestic Purification

An aerial photograph of a modern, two-story house with a white facade and dark window frames. The roof is covered with a large array of solar panels. The house has a balcony with a black metal railing on the second floor. The scene is lit with warm, golden light, suggesting sunset or sunrise. The text "5 Key findings within Sustainability and Essential Needs" is overlaid in white on the upper left portion of the image.

# 5 Key findings within Sustainability and Essential Needs

Drawing upon the insights from research and invention performance, Academic-Corporate Partnerships, and Technology Maturity evaluation for Saudi Arabian and global organizations, this section provides key findings tailored to the relative position of Saudi Arabia for each technology by using industry-leading metrics to provide the next steps. These recommendations will outline the potential of the technologies specifically for Saudi Arabia, where to invest, and ultimately, whether more academic funding is required, further academic, corporate partnerships, transfer of technology from academic to private entities, and possibly continuing the existing strategies.

Table 41: Sustainability and Essential Needs research topic scorecard

				High	Medium	Low
	Saudi Arabia's Research Strength	Saudi Arabia's Invention Strength	Saudi Arabia's Partnership Strength	Saudi Arabia's research productivity	Technology maturity	Future Predicted Growth
Eco-Agrochemicals	399	156	0.3%	2.69	5	5.1%
Carbon (CO2) Transport	893	74	2.5%	0.98	4	11.0%
Electric Vehicles	1935	2566	2.1%	2.13	7	8.3%
Food - Alternatives	142	0	0.0%	1.11	4	6.7%
Food - Food-Borne Hazard Control	1634	177	0.9%	1.02	5	7.4%
Food Traceability & Distribution	814	387	1.7%	2.78	5	7.8%
Waste Landfill	242	483	0.0%	1.42	3	8.9%
Water - Conservation Management	327	1281	1.0%	2.16	5	6.8%
Water - Desalination	3290	3571	3.6%	0.86	4	7.1%
Water - Domestic Purification	1249	1613	3.0%	0.69	6	6.3%
Water Leakage	48	314	1.6%	1.83	5	7.8%
Water - Wastewater Purification/ Treatment	6148	11912	1.2%	0.68	7	6.3%

The scorecard above contains factors analyzing Saudi Arabia's position per technology. They are defined as:

- Research Strength:** The total number of Saudi Arabian research papers is multiplied by the Category Normalized Citation Impact (CNCI). The CNCI for a document is calculated by dividing the actual count of citing items by the expected citation rate for papers of the same document type, year of publication, and subject area.
- Invention Strength:** Total number of Saudi Arabian inventions multiplied by DSI. A Clarivate metric of the strength and quality of a patented idea. Based on the impact of the invention on others (based on the frequency of downstream citation by the patent applications of third parties), the global

footprint of patents granted (based on the % of world GDP covered by the patent asset), the investment level in the invention by the applicant (based on the number of patent jurisdictions in which the applicant sought protection) and the inventions rarity (based on the number of inventions in the global database that share the same technology mix).

- **Partnership Strength:** The mean partnership % for research papers and inventions in Saudi Arabia
- **Research Productivity:** The productivity relative to global productivity is measured by the number of Saudi Arabia papers on a specific research topic divided by the number of global publications in the same research topic and period.
- **Technology Maturity:** Each of the research topics within the National Priority Areas has been mapped to individual Technology Maturity Index from 1 - least mature through 9 - most mature.
- **Future Predicted Growth:** CAGR predicted growth extrapolated from historic inventions level.

**Electric Vehicles** and **Water Desalination** score highly on research and invention output and quality. These technologies also score medium and high, respectively, on partnership levels, with an average of 2.1% and 3.6% across research publications and inventions. Electric Vehicles also score highly against research productivity and technology maturity. In comparison, Water Desalination has a technology maturity of 4/9 and only 0.86% research productivity. The future predicted growth is 8.3% and 7.1%, respectively. The above metrics are on 1,087 and 2,244 research papers and 75 and 117 inventions, respectively; it is also worth noting there are 10-20 times more research papers than inventions generated in both technologies. The level of inventions from Saudi Arabian corporates is relatively low, with representation only from Saudi Aramco.

Subsequently, for **Electric vehicles**, suitable international partners could be organizations such as Hyundai, Kia Motors or Toyota based on overall invention levels, high invention scores and high levels of academic-corporate partnerships. Existing Electric Vehicle inventions could be licensed to international corporations or considered for spinning out start-ups. It is predicted that Electric Vehicle technologies could add \$1.33 billion to Saudi Arabia's economy; if 2,500 inventions are protected in this field, the likely yield would be around 30 very strong inventions.

Due to lower technology maturity of 4/9, desalination technologies could benefit from further academic funding within local academia, such as King Fahd University of Petroleum and Minerals, KAUST, along with Saudi Aramco and Saudi Water Authority due to their size and specialism in this technology area. It is predicted that water desalination could add \$0.23 billion to Saudi Arabia's economy; if 833 inventions are protected in this field, the likely yield would be around five very strong inventions.

**Eco-Agrochemicals, Carbon (CO<sub>2</sub>) Transport** and **Food Alternatives** all have low levels of research paper volume and quality metric forming Research Strength, additionally also have lower Invention Strength derived by volume and strength of inventions. The Technology Maturity levels are 5,4 and 4, respectively, suggesting these technologies are not ready for commercial production; subsequently, these technologies could benefit from additional academic research. Carbon (CO<sub>2</sub>) transport has a high predicted growth rate of 11% and ACP in research papers of 2.52%, while eco-agrichemicals and food alternatives are lower at 5.1% and 6.7%, respectively. There is a notable difference in a research paper to invention levels across these technologies 319: 2, 436: 2, and 96:0; these ratios and no ACP inventions, further suggest additional academic research would be beneficial.

In summary, in the field of Carbon (CO<sub>2</sub>) Transport, Saudi Aramco could collaborate with international research organizations such as China University of Mining &

Technology, Sinopec or Marathon Petroleum along with King Saud University, KAUST KFUPM and King Abdulaziz University and/or other carbon tech leaders. Agriculture - Agrochemicals could further enhance academic research levels by forming partnerships between Saudi Aramco and international research leaders such as the Institute of Animal Sciences of CAAS, Chinese Academy of Science or Guangxi Zhuang Autonomous Region Institute or Shandong Sunway Gardening Technology, all of whom have over 150 inventions of the highest global average invention strength. Food Alternatives may benefit from further academic research from King Saud University, King Abdulaziz University, Umm Al Qura University and Taif University.

**Food-Borne Hazard Control** and **Traceability & Distribution** both have low invention strength scores and volumes. However, Food-Borne Hazard Control has a medium-level research score. Traceability & Distribution have medium levels of ACP and high research productivity, whereas these factors are low for Food-Borne Hazard Control. Considering the medium technology maturity and predicted invention level growth, it is suitable to provide academic research funding; however, it provide higher prioritization to other technologies within Sustainability and Essential needs such as Electric Vehicles, Water Desalination and Conservation Management. In the area of food-borne hazard control, KFUPM holds three inventions, and KACST holds only one.

**Waste - Landfill technologies** have a low level of research and invention strength and volume in Saudi Arabia; there are no ACPs and low technology maturity, but there are high predicted levels of growth. Considering the low level of research papers 159 and inventions 14, this technology is considered for ad-hoc academic research funding to existing local research institutes such as KFUPM and Saudi Aramco.

**Water Conservation Management** is a field of low research strength and high invention strength, it also has low ACP levels, high research productivity, and medium technology maturity. There are 155 research papers and 46 inventions produced in Saudi Arabia during the last 10 years; this ratio suggests investing further in academic research could yield further Saudi Arabian inventions. KAUST, KFUPM, and Saudi Aramco have all of the inventions. Therefore, the ACP between these three organizations and further funding may increase the invention yield.

**Water - Domestic purification** has low research paper strength and volume compared to medium invention volume and strength. There has been an average of 3% ACP production of research and inventions, there has been low research productivity, medium technology maturity, and low predicted invention growth. Due to the technology maturity of 6, it is recommended to utilize the existing 49 inventions, especially from Saudi Aramco, King Fahd University of Petroleum & Minerals and King Abdullah University of Science & Technology.

**Water Leakage** is a field with low research volume and strength, and low invention volume and strength in Saudi Arabia. This technology has medium ACP levels, research productivity, technology maturity, and predicted future growth. Saudi Aramco holds three inventions, along with KFUPM holding five inventions. This may be an area that requires focused academic funding or in-sourcing of technology to assist with Saudi Arabia's natural arid climate.

**Water - Wastewater Purification/Treatment** is an area of low research volume and strength; however, it has very high invention volume and strength. There has been a medium level of ACPs and low research productivity, and it is a mature technology with low predicted invention-level growth. Therefore, it is recommended to focus on applying these existing inventions in the market from local innovators: Saudi Aramco - 107, King Abdulaziz University - 25, Imam Abdulrahman Bin Faisal University - 17 and King Saud University - 14 inventions, respectively. Spinning out a start-up from these research organizations could be a successful way to commercialize the technologies. It is predicted that Water - Wastewater Purification/Treatment could add \$0.77 billion to Saudi Arabia's economy; if 4,167 inventions are protected in this field, the likely yield would be around 18 very strong inventions.

In conclusion, Sustainability and Essential needs-focused technologies in Saudi Arabia have a solid foundation of academic research linked to medium technology maturity, with only electric vehicles and water-wastewater purification classified as high technology maturity fields. Among the technologies mentioned, Saudi Arabia demonstrates the greatest invention strength in water-related technologies, with many being applied in the market through organizations such as Saudi Aramco, supported by high-quality research from institutions including, but not limited to, KAUST, KFUPM, and King Abdulaziz University. To commercialize these technologies, Saudi Arabia should concentrate on introducing them into both local and international markets, backed by intellectual property protection.

This could be achieved through start-ups, joint ventures, or existing corporations like Saudi Aramco, where there is strategic synergy with current business lines. In the electric vehicle sector, progress has been made with Lucid Group establishing Saudi Arabia's first electric vehicle manufacturing site. To fully realize the electric vehicle sector's potential, other technologies, such as battery management, should be taken into account.

The automotive industry is a highly complex and competitive field, aligning with RDIA's mission to become the fourth largest producer of EVs and EV batteries by 2035. Hyundai, Kia Motors, and Toyota possess significant invention portfolios and extensive experience in collaborative commercial research with organizations, making them suitable partners to expedite the transfer of Saudi research into the market.

Considering the natural resources and challenges that have driven the development of desalination, solar panel, and carbon transport technologies, Saudi Arabia has substantial potential to lead and achieve a significant return on investment in the field of Sustainability and Essential Needs technologies

# 6 Definitions, metrics and data sources

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## 6.1 General definitions

### Academic institution

An establishment dedicated to education and research, generally conferring academic degrees across various levels of learning. While academia can more widely be used as a term for primary education through tertiary education, we limit and define the tertiary sector only for the purposes of this study. However, note that we further expand the definition of academia in this study to government research institutions more generally.

### Academic-Corporate Partnership

Refers to a collaborative arrangement between educational institutions and business entities, aiming to leverage their respective strengths for mutual benefit, often in the realms of research, technology development, and knowledge exchange. The relationship typically involves shared resources, strategic alignment, and a commitment to achieving common objectives that advance both academic and corporate interests. Defined and identified in this study as a scientific publication or a patent family that contains bibliographic information as authors or inventors from organizations that are both an academic institution and a corporate entity.

### Applied Research

Refers to the process of systematic investigation that aims to solve practical problems by applying scientific knowledge. It typically involves collaboration with industry to develop tangible solutions, such as new products, technologies, or processes, that directly address specific challenges in various fields.

### Basic Research

Often also called pure or fundamental research, this refers to the process of systematic investigation aimed at gaining a deeper understanding and

knowledge of the underlying principles of phenomena and observable facts without immediate practical application in mind.

### Commercialization

Commercialization refers to the process of managing, typically via a business or corporate entity, activities in return for economic or monetary gain. It involves introducing a new product or service to the market and is often associated with the production, distribution, marketing, and sales necessary to achieve commercial success. Frequently used in the context of scaling up business operations to reach a broader market. This study is specific to understanding the level of commercialization activity and the directionality of research areas.

### Corporation

A corporate entity is a legally recognized organization designed to conduct business. Typically, a corporation is a body formed and authorized by law to act as a legal person, distinct from the natural persons owning or operating within the entity. Corporate entities can enter contracts, own assets, and are subject to taxation while providing limited liability protection to their owners.

### Innovation

Refers to the process of progressing new ideas or inventions into products, services or other economic activity that is valued and in demand by businesses or consumers. As a general principle, innovation can encompass the direction of creativity, technical knowledge, and information and can target the conversion of new and useful products and services. In this study, we focus on the definition of technical innovation and the process of developing and applying new technologies or improving existing ones to create advancements in various fields. It involves the use of technical knowledge and expertise to

address challenges, enhance efficiency, and create value through novel solutions.

### **Invention**

A novel or unique method, device, or process developed from research and experimentation, typically patented and designed to solve a specific problem or improve existing solutions. Within this study, due to the database structure of the Derwent World Patents Index, we use "invention" as synonymous with "patent family" (see definition) - an individual idea meeting the criteria of an invention, as patented at various patent offices around the world. This definition includes patent applications that have not yet been granted. This definition removes the need to deduplicate multiple patent publications surrounding the single invention/idea and, in turn, transforms the collection of multiple patent publications into metadata of invention strength.

### **Nominal Gross Domestic Product (GDP)**

Nominal Gross Domestic Product (GDP) is a macroeconomic metric that measures the total market value of all finished goods and services produced within a country's borders at a specific time, using current prices without adjusting for inflation. Presented here in US dollars.

## **6.2 Patent related definitions**

### **Patent**

A patent is a legal instrument that grants an inventor exclusive rights to use, sell, or manufacture their invention for a limited period, typically 20 years, in exchange for public disclosure of the invention.

### **Patent Assignee**

A patent assignee is the individual or entity that holds the ownership rights to a patent. This transfer of rights is typically formalized through a written contract or assignment agreement,

which grants the assignee the exclusive rights to the patented invention, including the right to make, use, sell, or license the invention. The assignee assumes all associated rights and responsibilities from the original patent holder, known as the assignor. Typically, the assignment takes place because of employment contracts that require employees to assign intellectual property rights to their employer for creating an invention during their employment.

### **Patent Family**

A patent family refers to a collection of patent applications or granted patents that are related to each other and cover the same or similar technical content. These related publications are typically filed in different countries, originating from a single priority application or a set of priority applications. The concept of a patent family is instrumental in tracking the legal protection status of inventions globally and is recognized by various patent offices and databases. The family definition used in this study is specific to the Derwent World Patents Index™, which provides for a synonymous relationship between each family and an individual invention - e.g., one specific set of claims language (the section of a patent document detailing what is protected) in each legal jurisdiction in which protection has been sought.

### **Patent Jurisdiction, Patent-Issuing Authority**

Refers to the legal authority granted to a country or region over the creation, use, and enforcement of patents within its territory. This includes the power to grant patents, determine their validity, and adjudicate disputes related to patent infringement. The jurisdiction is defined by the territorial scope within which the patent rights are applicable and enforceable, and it is typically the responsibility of national or regional

patent offices to oversee these legal rights. Notably, patents are local rights that are only valid and have exclusivity within the jurisdiction of the patent office. There are multiple "regional" patent jurisdictions, such as the European Patent Convention or the Gulf Cooperation Council Patent Office.

### **Patentability**

In order to be valid, a patent application needs to fully disclose an invention so that it can be understood by the average person with training in the technical field, and it must be novel (never seen in the public domain before), useful (typically, it must have a real world use, and must actually work) and not be an obvious extension of previous technology (typically, simply combining multiple previous ideas together).

### **Technical maturity index (TMI)**

A mathematical model that aggregates global scientific, engineering and technological structured disclosures (i.e. peer-reviewed scientific papers and patented inventions), alongside assertion of technology, to empirically measure the maturity of a technology field, approach or use case. It can be used to assess differing fields and sectors alongside each other, due to the normalization of measures incorporated into the model.

### **Technical readiness level (TRL)**

A scale is used to estimate the maturity of a technology during the acquisition phase of a program. It provides a consistent and uniform discussion of technical maturity across different types of technologies. The scale ranges from 1 to 9, with 9 being the most mature technology. TRL assessments are critical in managing the progression of technology from

conception to deployment. Originally created in the 1970s by NASA as a way of managing technical development readiness and safety for human spaceflight, the TRL system has been widely adopted by the International Standards Organization in 2013 as a qualitative measure of basic, through applied and then commercialized technology progression. In this study, TRL and TMI become synonymous - as the advanced measurement of global public science, research and technology assertion is captured and mathematically modeled so that it maps empirical measures of maturity onto (in relative terms) the structure of a TRL.

## **6.3 Research related definitions**

### **Citation**

An academic citation is a formal reference to a published or unpublished source that is used to support the author's arguments or findings in a scholarly work. It acknowledges the original creator of an idea or piece of information and provides readers with the details necessary to locate the source material themselves. Citations are essential in academic writing to avoid plagiarism, uphold intellectual honesty, and facilitate the verification of facts or ideas presented.

Patent citation is a similar process and refers to any significant document or research paper that a patent applicant, examiner, or third party cites as relevant to the content of a patent application. It serves as a formal acknowledgment of prior art and related work in the field, providing a trail of the intellectual property landscape pertinent to the invention.

In both cases, citation is a significant source of impact metadata, as the aggregation and analysis of papers, patents, topics, organizations and

economies via citation measures provides a method of assessing the preponderance of downstream reference research and innovation the work has on others, thereby reflecting the importance and impact of the cited work itself.

### **Citation Topics**

Citation Topics are named document clusters based on cited and citing relationships between publications. They are algorithmically derived citation clusters (using an algorithm developed by CWTS, Leiden). This is a three-level hierarchical document-level classification system. The three levels of the hierarchy and their content according to the 2024 clustering are:

- Macro-topics (10)
- Meso-topics (326)
- Micro-topics (2449)

Macro- and meso-topics are manually labeled based on their contents. Micro-topics are algorithmically labeled with their most significant keyword. As Citation Topics are based on citation relationships and not the content or subject matter of their constituent publications, topics are labeled by inference, and any name may not be descriptive for every document in the topic. More information and a description of the 2024 schema can be found on the Clarivate website.

### **Papers/publications/publications**

A written document that presents the results of original research or an innovative study in a systematic and standardized format. A core activity of the scientific method, the publication of research via a formal paper is intended to communicate new research and knowledge discovery to the scientific community and to contribute to global and collective knowledge. Such papers are peer-reviewed and published in academic

journals, ensuring the integrity and validity of the research presented. Clarivate abstracts publications, including research journal articles, editorials, meeting abstracts and book reviews. The terms "paper," "document," "Web of Science Document," and "publication" are often used interchangeably to refer to printed and electronic outputs of many types. In the analyses presented here, the terms used exclusively refer to substantive journal articles, reviews and proceedings papers.

### **Researcher Affiliation**

Researchers affiliated organization. A single researcher could provide several affiliations in one publication. The publication is then associated with all organizations and, correspondingly, all geographical locations in which these organizations are located.

## **6.4 Saudi Arabia-Specific Definitions**

### **Research, development and innovation (RDI)**

The Research, Development and Innovation (RDI) sector in Saudi Arabia refers to the collective activities and initiatives aimed at fostering scientific research, technological development, and innovation across various fields. This sector is pivotal to the Kingdom's Vision 2030, driving economic diversification and sustainable development. The RDI sector encompasses a network of institutions, policies, and programs that support and finance scientific research, coordinate activities of research centers, and propose legislation to nurture an environment conducive to innovation and technological advancement.

### **National Priority Areas**

Refers to the strategic objectives set by the Kingdom to guide its development and innovation efforts. These priorities

include Health and Wellness, Sustainability and Essential Needs, Energy and Industrials, and Economies of the Future. They are designed to enhance the nation's global competitiveness and align with the goals of Saudi Vision 2030.

### **Vision 2030**

Saudi Vision 2030 is a strategic framework aimed at diversifying Saudi Arabia's economy and transforming the nation into a global investment powerhouse. Launched in 2016, Vision 2030 seeks to foster economic, social, and cultural development by capitalizing on the country's strategic location and enhancing the quality of life for its citizens. It emphasizes three core pillars: a vibrant society, a thriving economy, and an ambitious nation, with a focus on public sector efficiency, private sector growth, research and innovation, and international collaboration.

## **6.5 Description of Data Sources**

### **Web of Science™**

The data used in this study came from the Clarivate Web of Science databases, which give access not only to journals but also to conference proceedings, books, patents, websites, and chemical structures, compounds and reactions.

Web of Science has a unified structure that integrates all data and search terms together and, therefore, provides a level of comparability not found in other databases. It is widely acknowledged to be the world's leading source of citation and bibliometric data. The Web of Science Core Collection is the premier resource on that platform and includes over 22k peer-reviewed, high-quality scholarly journals published worldwide (including Open Access journals), over 308k conferences, over

151k editorially selected books and 92M records going back to 1900.

Coverage is both current and retrospective in the sciences, social sciences, arts and humanities. Clarivate has extensive experience with databases on research inputs, activity and outputs and has developed innovative analytical approaches for benchmarking and interpreting international, national and institutional research impact.

### **InCites™**

Additionally, InCites Benchmarking & Analytics was used in this project to generate relevant metrics and indicators.

InCites is a customized, citation-based research evaluation tool enabling analysis of productivity and benchmarking of output against peers worldwide, with underlying data drawn from the Web of Science Core Collection™.

InCites provides disambiguated data for all publications in the Web of Science Core Collection.

### **Darts-ip™**

Darts-ip is a comprehensive database and analytics platform that provides detailed information and insights on intellectual property (IP) litigation cases globally.

### **Derwent World Patents Index™**

The Derwent World Patents Index (DWPI) is a comprehensive database that compiles patent applications and grants from 59 patent-issuing authorities worldwide. It provides abstracts in English, detailing the nature and use of inventions, and indexes them into technology categories for easy retrieval. DWPI also defines patent families, linking related patents globally around a Basic Patent (the first disclosure of the invention appearing in the database), facilitating the tracking of an invention's

protection status internationally as further applications or granted patents published in multiple patent jurisdictions.

## 6.6 Metrics

### Web of Science Documents

This is an indicator to refer to substantive journal articles, reviews and proceedings papers and excludes editorials, meeting abstracts or other types of publication. It is based on the Web of Science Core Collection™ dating till Sunday, December 31, 2023.

### Category Normalized Citation Impact

The Category Normalized Citation Impact (CNCI) of a document is calculated by dividing the actual count of citing items by the expected citation rate for publications with the same document type, year of publication and subject area. When a document is assigned to more than one subject area, an average of the ratios of the actual to expected citations is used. The CNCI of a set of publications, for example, the collected works of an individual, institution or country/region, is the average of the CNCI values for all the publications in the set. CNCI is a valuable and unbiased indicator of impact irrespective of age, subject focus, or document type. Therefore, it allows comparisons between entities of different sizes and different subject mixes.

- A CNCI value of 1 represents performance at par with the global average.
- Values above 1 are considered above average.
- Values below 1 are considered below average.
- A CNCI value of 2 is considered twice the global average.

CNCI is an ideal indicator for benchmarking at all organizational levels (institution, region etc). When dealing with small sets of publications though, for example, the publications of one individual, the CNCI values may be inflated by a single highly cited paper. More information can be found on InCites website.

### Growth and Average Growth

In this study, we visualize the evolution of the number of Web of Science publications for a certain entity and period. In order to quantify the change in the number of publications from one year to another, we use the growth. The growth is then the number of publications in the most recent year (Ny2) subtracted from the number of publications in an earlier year (Ny1) and divided by it and represented as a percentage:

$$G = (Ny2 - Ny1) / Ny1$$

The average growth over a certain period is the arithmetic average of the growth from one year to another in that period. Sometimes, a considered entity does not have publications in a certain year, causing division problems for the considered year. In such cases, the growth for that year is excluded from the arithmetic average.

### Funding Acknowledgment

The Funding Agencies Explorer in InCites, which includes more than 1000 unified funding organizations found in and curated from Web of Science funding acknowledgments, was utilized to identify publications with funding acknowledgment and the corresponding funding agencies.

### Industry Collaboration

Papers that contain two or more Organizations with at least one Organization listing its organization type as corporate or global corporate. An industry collaborative publication is one that lists its organization type as

"corporate" or "global corporate" for one or more of the co-author's affiliations. It's not possible to unify data for every affiliation of all publications in InCites; therefore, only unified entities have an organization type. There will be corporate affiliations that are not yet unified and without an organization type. As such, these affiliations will not identify as an industrial collaboration. Clarivate Analytics has made considerable efforts to identify the largest corporations and unify them; however, these efforts tend to focus on large multinational corporations and may lead to regional bias.

### **International Collaboration**

Papers that contain one or more international co-authors.

### **Invention Strength**

A Clarivate metric of the strength and quality of a patented idea. Based on the impact of the invention on others (based on the frequency of downstream citation by the patent applications of third parties), the global footprint of patents granted (based on the % of world GDP covered by the patent asset), the investment level in the invention by the applicant (based on the number of patent jurisdictions in which the applicant sought protection) and the inventions rarity (based on the number of inventions in the global database that share the same technology mix).

### **Emerging Trend**

To investigate emerging trends globally and in Saudi Arabia in a research topic, we use the micro-topics as defined in the Citation Topics schema that is explained in the section.

### **Citation Topics.**

To identify the emerging trends, we identify the top 20 micro-topics in the research topic in terms of the growth of the number of publications in the

micro-topic from 2014 to 2023. We then rank the top 20 micro-topics in terms of difference in the share of citations from total citations in the research topic between 2014 and 2023. The growth in terms of publications identifies micro-topics within the research topic that have grown fastest within the considered period. The difference in citation share from the total citations in the research topic identifies micro-topics that have also grown their relative number of citations in the research topic, which reflects that these topics are also trending among the researchers active in the research topic.

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