

## A Bibliometric Analysis of Research on Sustainable Development Goals by the G20 Countries

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United Nations Sustainable Development Goals (SDGs) and their targets are highly interconnected and require international collaboration. In this context, the G20 organization of 20 countries/units, founded in 1999 holds an important position being an important political and economic platform for addressing various developmental concerns. With 75% of global population, the Group Nations accounts for 85% of the global GDP and about 75% of the global trade. Considering the strength, resources and representation of these countries, they hold the major part of the responsibility towards achieving the SDGs. Scientific and technological research is a major requirement for achieving the SDGs. Given that the G20 has about 88.8% of the world's researchers, 93.2% of research spending and produce about 90.6% of scientific publications, it would be interesting to analyse what quantum of this research is focused on achieving the SDGs. However, there are no existing studies on this aspect. This study, therefore, attempts to bridge this research gap by presenting a quantitative analysis of research on SDGs by the G20 member countries. Important patterns are identified, which can be useful for different policy perspectives.

**Keywords:** G20, Quantitative analysis, Research collaboration, Scientometrics, Sustainable development goals

### Introduction

The discussion about sustainability started at the global platform with the formation of the United Nations Framework Convention for Climate Change (UNFCCC) in 1992, at Earth Summit, Rio de Janeiro. The Rio Declaration, Agenda 21 and Forest Principles adopted ultimately led to the development of the Millennium Development Goals (MDGs), Kyoto Protocol and Paris Agreement. The 2030 Agenda for Sustainable Development, adopted by all the United Nations member nations in 2015 provides a shared blueprint for peace and prosperity for people living on the planet, now and into the future (<https://sdgs.un.org/goals>). It comprises the 17 SDGs, which are an urgent call for action by all countries in a global partnership. It is stated that the SDGs “*recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests*” (<https://sdgs.un.org/goals>).

The presidency of the G20 group of countries was with India for the year 2023 and it attracted a high

level of attention with several events happening across the country. India is the most populous country, and largest democracy<sup>1</sup> of the world. It is a potential hub for skilled human resources<sup>2,3</sup>, and has a major role to play in discussions around the opportunities and challenges in different target areas of G20.<sup>(4,5)</sup> The G20 was founded in 1999 and over the years has become an important platform to discuss and act on various developmental concerns ([www.g20.org](http://www.g20.org)). The G20 countries taken together inhabit 75% of global population, account for 85% of the global Gross Domestic Product (GDP), and about 75% of the global trade. At the same time, the total carbon dioxide emissions from G20 countries together is 80% of the global emissions of carbon dioxide.<sup>6</sup> Considering the strength, resources and representation of these countries, the G20 countries have a crucial role in advancing the SDGs, as they can mobilize resources, influence policies and foster partnerships for sustainable development. Some of the key areas where the G20 countries can contribute to the SDGs are Climate action, Financing for development, Health, Education and Trade.<sup>7</sup> Scientific and technological research is a major requirement for achieving the SDGs. Given that the G20 has about 88.8% of the world's researchers, 93.2% of research

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spending and produce about 90.6% of scientific publications<sup>8</sup>, it would be interesting to analyse what quantum of this research is focused on achieving the SDGs.

The various coalitions between the G20 Countries and the role they have played in cohesion of the members of the group together have been studied and their positive impacts on international programs have been outlined.<sup>9,10</sup> Earlier studies have underlined the requirement of promoting activities in innovation, technology development and applications of technology, especially among the G20 countries. Many countries (e.g., in EU, India, China) have formulated Mission-oriented public policies, and committed resources and knowledge resources towards the activities for societal goals.<sup>11</sup> The role of technology in achievement of SDGs has been studied and underlined.<sup>12</sup> However, there are no existing studies on the quantum of research work being done by various member countries related to the SDGs. It is not very well-known, which member countries are focusing on what aspect of SDGs. What are the major areas and themes related to SDGs pursued by researchers in these countries? Are there any collaborations happening between the different member countries for such research? These are some questions which need to be explored in more detail. Therefore, this article attempts to bridge the research gap by trying to measure and characterize the research on SDGs from the G20 countries. More specifically, the article attempts to answer the following research questions:

**RQ 1:** What quantum of research publications from different G20 countries is focused on SDGs?

**RQ 2:** Do the different countries in G20 have differential focus on the various SDGs?

**RQ 3:** How much do G20 countries collaborate with each other for research on SDGs?

#### **Related Work**

After the adoption of the SDG framework, some studies relating to G20 countries and SDGs have been published. Researchers have explored the potential roles of G20 in achieving SDG targets.<sup>13</sup> One study identified major required transformations and challenges related to SDGs for the G20 countries.<sup>14</sup> It underlined the areas which should be focused by the G20 member countries based on their competence. Another study identified variations and shortcomings in healthcare related policies and commitments of countries of the BRICS, G7 and G20 w.r.t. SDG 3 (Good Health and Well Being).<sup>15</sup> A region specific

study focused on China looked at its domestic and international capabilities in the areas financing and stakeholder actions w.r.t. SDGs.<sup>16</sup>

The studies exploring the factors affecting or affected by the economic growth, technological development and carbon emissions of the G20 countries are also plenty. A subgroup of literature looks at the effects of economic growth and development activities on the energy generation in G20 countries. These include studies which evaluate funding mechanisms for clean energy production project<sup>17</sup>, comparison of sustainability indicators for electricity generation systems<sup>18</sup>, impact of shifting to clean energy alternatives on economic output of countries<sup>19</sup> etc. Similar studies have also been conducted for other groups, such as ASEAN-5 countries<sup>20</sup> and BRICS countries.<sup>21</sup> Besides these, popular indicator-based systems such as the World Development Indicators (<https://databank.worldbank.org/source/world-development-indicators>), and SDG index (Sustainable Development Solutions Network) also provide estimations of activities and their contributions towards meeting the SDG targets. There are a few studies which have looked at country and technology-specific, SDG research.<sup>22,23</sup>

However, the existing studies are largely domain-specific, qualitative in nature, and have addressed some particular topics related to a SDG. There are virtually no quantitative studies on exploring the research publications on SDGs among the G20 countries and the collaboration between these countries for such research. Considering the pivotal role of research and technology development in SDGs and the relative strength of G20 countries in research as well as resource availability, it is important to measure their research activity in SDGs. Therefore, this article attempts to address this gap in the literature by analysing the publications from G-20 countries that are directly connected to the Sustainable Development Goals (SDGs). We look at the relative importance given to the different SDGs by the G20 countries, the main areas of interest for the research on SDGs, and the collaboration patterns among the G20 countries for such research.

#### **Data and Methodology**

The study being quantitative in nature, the research publication metadata for the G20 countries for the period 2016-2021 was obtained from the Dimensions database. The Dimensions database provides an SDG classification for the publication records where

publications connected to a specific SDG are associated with the SDG tag. This SDG classification is derived by processing the text of research articles using advanced computational techniques. A total of 2,975,141 publication records were retrieved that were found tagged to one or more SDGs. The search query used is specified below for reference.

#### Search Query

Search publications where year [2016:2021] and research\_org\_countries in ["AR", "AU", "BR", "CA", "CN", "FR", "DE", "IN", "ID", "IT", "JP", "MX", "KR", "RU", "SA", "ZA", "TR", "GB", "US"] and type in ["article", "proceeding"] and category\_sdg in ["40001", "40002", "40003", "40004", "40005", "40006", "40007", "40008", "40009", "40010", "40011", "40012", "40013", "40014", "40015", "40016", "40017"] return publications [id+doi+title+authors\_count+times\_cited+category\_sdg+concepts\_scores+year+type+research\_org\_countries+open\_access]

The records fetched comprised a total of 11 metadata fields for each record as per the selection during the data download. These include publication id, DOI (unique identifier associated with publication), authors\_count (number of authors), times\_cited (number of citations of publication), year (year of publication), type (category of publication: article, review article, open\_access (yes/no)). The most important fields out of these were 'category\_sdg', 'research\_org\_countries', and 'concepts\_scores'. The 'category\_sdg' field contains the SDGs which are tagged in the concerned publication record, the 'research\_org\_countries' contains the list of the countries to which the authors are affiliated, and the 'concepts\_scores' is a composite field containing the list of concepts assigned to the publication along with corresponding confidence score for those concepts. The concept is also one of the Dimensions custom-tailored entities that is extracted from the text of the scholarly data using advanced computational techniques. These concepts try to capture themes of the content in words/ concepts. Each extracted concept has a related confidence score demonstrating its relevance to the content. Here, the analysis has used only those concepts that have relevance scores higher than 0.7.

The data described above was fetched using dimensions API and stored in a local database for further analysis. The quantitative analysis done afterwards involved writing custom code in the Python programming language. A brief description of

the methodology used for result preparation is as follows.

- a. *Research output volume and growth (TP, CAGR):* The net research volume produced in the areas relating to SDGs by the G-20 member countries was analyzed quantitatively. The input used here was the counts of total publications (TP) produced by different member countries that related to one or more of the SDGs. The Compounded Annual Growth Rate (CAGR) of each country in the SDG-related publications for the period was computed.
- b. *SDG-wise TP of each country:* This result discusses the focus of various countries toward 17 SDGs. The research output produced in individual SDGs by the member countries was the input data for this analysis. The numbers have to be normalized for a fair comparison as smaller countries have relatively lesser research output. Hence they were divided with the respective country's output in all SDGs combined. This resulted in values being converted to a scale of 0 to 1.
- c. *Country collaboration network:* This result analyses the collaboration pattern observed in the G20 countries in SDG-related publications. The research\_org\_countries of metadata served as the input at this stage. "What percentage of SDG research publications a country is co-authored with the rest 18 countries?" was the formulation used behind this result. The collaboration network between countries was drawn using VoSviewer.

## Results and Discussion

### Research on SDGs Across the G20 Countries

The overall research publications from the G20 countries contribute to about 57.75 % of the global research publications for the concerned period. On average, about 19.79 percent of publications from G20 countries are related to one or more SDGs. The total research output of the 19 countries, its growth between 2016 to 2021, the cumulative average growth rate of research publications both at overall level as well as for publications related to one or more SDGs are shown in Table 1. In addition, the proportionate share of SDG-related publications with respect to the overall publications from the selected countries is also presented.

Among the countries, South Africa has the highest percentage of its total publications related to SDGs (35%), followed by Australia (27%), Indonesia (25%) and UK (25%). The overall proportion of SDG-related

Table 1 — Research output volume and growth rate of G-20 countries

Country	Overall Research Trends				Trends in SDG Research				Change	
	TP Total	TP 2016	TP 2021	CAGR %	TP_SDG	TPSDG 2016	TP SDG 2021	CAGR %2	TPSDG/TP (2016)	TPSDG/TP (2021)
United States	4244635	651182	755203	3.01	972912	125649	201439	9.9	19.3	26.67
China	3444701	395570	765591	14.12	626044	52294	164295	25.73	13.22	21.46
United Kingdom	1286078	194069	240782	4.41	316936	39797	70046	11.97	20.51	29.09
Japan	1097570	157935	185352	3.25	122651	15340	25804	10.96	9.71	13.92
Germany	1094473	164111	205662	4.62	179608	22577	39481	11.83	13.76	19.2
India	958757	132654	215317	10.17	203343	22658	54888	19.36	17.08	25.49
France	713823	116191	124546	1.4	118746	15741	24468	9.22	13.55	19.65
Italy	707599	102483	137712	6.09	142477	16566	33278	14.97	16.16	24.16
Canada	691785	103332	128525	4.46	169408	21203	36613	11.54	20.52	28.49
Brazil	641724	88910	121246	6.4	125116	15861	28581	12.5	17.84	23.57
Russia	637939	68429	147534	16.61	92417	6500	26500	32.45	9.5	17.96
Australia	630817	92295	118884	5.19	176344	22034	37808	11.4	23.87	31.8
South Korea	511309	78799	92672	3.3	88022	10895	19259	12.07	13.83	20.78
Indonesia	408901	23707	108709	35.61	103314	5256	29213	40.92	22.17	26.87
Turkey	260080	39353	54896	6.88	46928	5661	12467	17.1	14.39	22.71
Saudi Arabia	164809	18804	44020	18.54	35565	3017	11533	30.76	16.04	26.2
Mexico	148717	21128	29288	6.75	31956	3595	7637	16.26	17.02	26.08
South Africa	145778	20168	28832	7.41	51897	6259	11326	12.59	31.03	39.28
Argentina	92935	13070	18043	6.66	18499	2088	4253	15.29	15.98	23.57

publications has changed by 7.45% from 2016 to 2021 and ranges from 4.0% (Indonesia) to 10.16% (Saudi Arabia). The CAGR for SDG research was highest for Indonesia (40%) and lowest for France (9%) from 2016 to 2021. The United States has the highest number of publications and contributed 26.9% of publications related to SDGs in the analysis window. China has the second highest volume (17%) followed by the UK (8.75%), India (5.61%) and Germany (4.96%). The TPSDG/TP ratio is seen to have increased for almost all the member countries suggesting an increased research focus on SDGs in these countries. Some countries have a low percentage of research on SDGs suggesting a lower focus, Japan and Russia had less than 10% of their publications focused on SDGs in 2016 and ~14 and 17% in 2021. This can be due to a different research focus of these countries. The plausible causes for this can be further explored by analysing individual countries.

#### SDG-wise Publication Share from G20 Countries

The analysis of the number of publications related to each SDG shows patterns about the research capacities and priorities of a country. It also sheds light on the approach for promotion of R&D activities, i.e., global or regional challenges. The bar chart showing percentage/relative fraction of publications per SDG for each country (Fig. 1) shows these trends. The most attention has been given to

SDG 3 (Good Health and Well-Being), where 15 countries have the highest proportion of publications. SDG 7 (Affordable and Clean Energy) is the second most explored goal, where 3 countries have the highest proportion while several others have the second highest proportion of research publications. SDG 4 (Quality Education), SDG 13 (Climate Action), SDG 15 (Life on Land), SDG 2 (Zero Hunger), SDG 16 (Peace, Justice and Strong Institutions) and SDG 11 (Sustainable Cities and Communities) are other goals in the order of their total number of publications from G20 countries. Thus, there is a differential research focus on various SDGs, patterns of which further vary across different member countries.

The top 1000 keywords from the research publications have been analysed using VOS Viewer to identify the co-occurring concepts in the research publications from each G20 country. This analysis provided further insight into the important topics which have been receiving higher attention in each of the countries. Keywords related to ecology (climate change, species richness, genetic diversity, land use, sea level rise) are commonly used across the publications from G20 countries (12 countries), battery technologies (Li-ion, Sodium-ion, electronic/electric vehicles) are seen among technologically advanced countries (9 countries), lifestyle diseases (chronic kidney disease, pulmonary disease) are commonly used keywords in 6 countries. Health-related keywords are

among top occurring concepts such as Human Immunodeficiency Virus (HIV), chronic kidney disease, chronic obstructive pulmonary disease, body mass index and these may be correlated to the countries (Table 2). Looking at the narrative of G20 meetings across India, the research areas are in line with the impending global challenges of health care, energy (clean energy), environment conservation and international collaboration for peace, knowledge sharing etc.

Concepts related to Education (higher education, learning outcomes, education institutions, education process) are seen in five countries, namely, Australia, Indonesia, Russia, South Africa and the United Kingdom. Unique Keywords such as Great Barrier Reef (Australia), Atlantic Forest (Brazil), which refer to geographical features which are threatened by climate change, are among the top concepts in some countries, and may signify a higher focus on local challenges for sustainability and development.

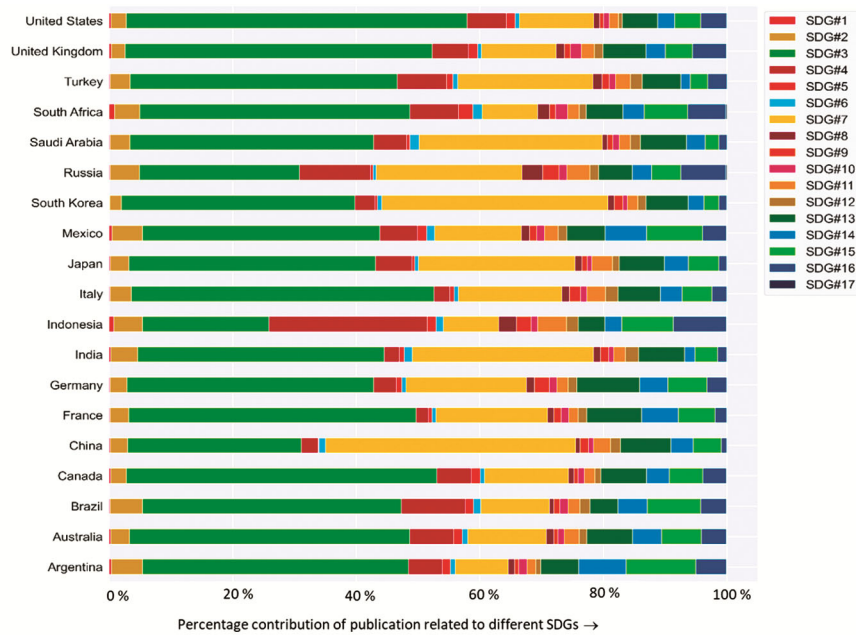


Fig. 1 — The proportionate share of publications addressing the 17 SDGs from the G-20 countries

Table 2 — Top 5 occurring concepts from each of the G-20 countries

Country	Top 5 concepts
United States	climate change, body mass index, <i>chronic kidney disease</i> , sea level rise, lithium-ion batteries
China	lithium-ion batteries, hydrogen evolution reaction, oxygen evolution reaction, evolution reaction, sodium-ion batteries
United Kingdom	climate change, young people, higher education, body mass index, <i>chronic obstructive pulmonary disease</i>
Japan	lithium-ion batteries, solar cells, climate change, <i>chronic kidney disease</i> , body mass index
Germany	climate change, land use change, species richness, lithium-ion batteries, ecosystem services
India	wireless sensor networks, sensor networks, Internet of Things, electric vehicles, X-ray diffraction
France	climate change, sea surface temperature, intensive care unit, sea level rise, species richness
Italy	climate change, <i>chronic kidney disease</i> , energy storage system, COVID-19 patients, electric vehicles
Canada	climate change, <i>chronic kidney disease</i> , electric vehicles, species richness, <i>chronic obstructive pulmonary disease</i>
Brazil	species richness, <i>Atlantic Forest</i> , land use change, climate change, grain yield
Russia	Russian Federation, legal regulation, educational process, higher education, higher education institutions
Australia	climate change, young people, higher education, species richness, <i>Great Barrier Reef</i>
South Korea	lithium-ion batteries, solar cells, hydrogen evolution reaction, oxygen evolution reaction, evolution reaction
Indonesia	Data collection techniques, learning outcomes, learning model, high school students, student learning outcomes
Turkey	economic growth, intensive care unit, pre-service teachers, wireless sensor networks, electric vehicles
Saudi Arabia	wireless sensor networks, Internet of Things, solar cells, sensor networks, X-ray diffraction
Mexico	species richness, land use change, climate change, genetic diversity, <i>chronic kidney disease</i>
South Africa	South Africa, <i>human immunodeficiency virus</i> , higher education institutions, climate change, species richness
Argentina	South America, land use change, species richness, climate change, land use

### Collaboration in G20 Countries on SDG Related Research

SDG action and research is a multi-disciplinary and multi-stakeholder undertaking, which requires collaboration among the different countries. G20 group consists of countries with the most advanced research infrastructure and human resources. In order to estimate the amount of collaboration activities between these countries, a collaboration network was drawn using VOS viewer. The most collaboration linkages were seen for the United States (US), followed by the United Kingdom and China. Other than these three, most collaboration linkages are seen for Canada, Australia, Germany and France. Although, total number of publications in SDGs is higher for India (Table 1), when compared to Germany, Canada and France, but the total number of collaborative papers is lower.

The collaboration network of G20 countries, drawn using the normalized collaboration strength of papers published by the country is shown in Fig. 2. Based on affiliation of all the authors of the publication, it shows collaboration as co-authored papers by authors from the countries by a line. Thicker the line connecting two countries, higher their collaboration strength (i.e., number of co-authored publications). It is observed that Canada's publications with the US show an intensity of 0.25, indicating that almost 25% of the overall publications from Canada are in collaboration with authors from the US. In contrast, only 0.05 (i.e., 5%) of the publications from the US

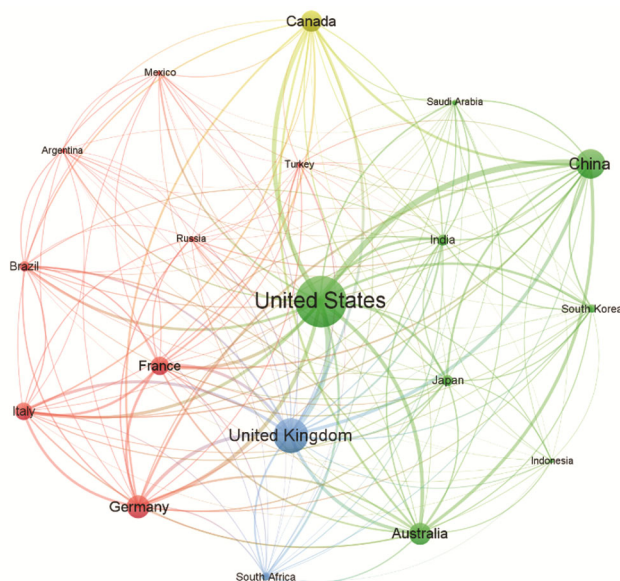


Fig. 2 — Collaboration Network of G-20 countries on SDG related research

have co-authors from Canada. Looking at this, it can be postulated that the US is a preferred collaboration partner for Canada while, since the US has a relatively larger number of publications, publications from US with Canadian collaboration contribute little for US. It has been observed that most of the countries are collaborating with the US in the area of SDGs. The UK is the second most favoured country in terms of collaborations in SDGs research. Besides these, the most favoured collaboration partners for countries are Australia for Indonesia, Brazil for Argentina, China for Australia, Japan and South Korea, Germany for France and Italy, and India for Saudi Arabia.

In summary, these findings highlight some salient features of G20 research activity on SDGs. The US has the most number of publications, with a large and influential collaboration network. All member countries taken together on average contribute about a quarter of research publications from G20 are focused on SDGs. The top 5 countries contributing to SDG-related research are the US, China, UK, India and Germany (**RQ1**). SDG3 (Good Health and Wellbeing) is the most studied, followed by SDG7 (Affordable and Clean Energy) and SDG4 (Quality Education) in most countries. In the case of publications from China and South Korea, SDG7 has the highest percentage and for Indonesia, it is SDG4 which has the highest number of publications. To further explore these country wise variations would be an interesting task for future studies. This exercise would require analysis of publications from specific countries and a detailed science mapping. The top keywords from publications show concepts related to ecology, battery technologies, lifestyle diseases & healthcare, education, and regional biodiversity-related topics are commonly studied (**RQ2**). Taken together the SDG focus and top keywords can be used as a proxy to draw inferences on the thematic areas important to specific countries. For instance, in China, SDG7 shows a focus on Affordable and clean energy, and keywords such as lithium-ion and sodium-ion batteries indicate that a significant portion of SDG7 research would be focused on battery technologies. In terms of collaboration between G20 countries, the US, UK and China are the major focal points with the largest number of collaborations in the same order. Collaboration of Argentina with Brazil, Australia with China, France with Germany, and Italy with Germany as other strong links that are observed in the collaboration network (**RQ3**).

## Conclusions

This study's insight onSDG research productivity patterns of each country as well as the G20 as a whole can be useful at multiple levels. On an international level, the country-wise research focuses on individual SDGs, and top concepts will be useful in deciding upon potential collaboration efforts in academia and technology sectors between these countries. The existing collaborations between identified favoured partners can be leveraged for mutual benefits. Weak collaboration between countries sharing similar and/or complementing SDG research interests can be strengthened. Countries individually can choose to pool or divert their resources into expanding or shifting the patterns of research in their desired direction based on their national priorities and needs. To further enrich this, individual collaboration patterns can be studied and SDGs, topics and agencies having higher collaboration can be identified and leveraged. The analytical results can be used in various other policy perspectives. Further research on other types of scientific outputs (such as patents, innovations etc.) may be conducted to obtain a more comprehensive picture of SDG-related research and technology development activities in the G20 countries.

## Conflict of Interest

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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