



# The Role of Engineering in Addressing Climate Change: A Review of the US and Global R&D Landscape

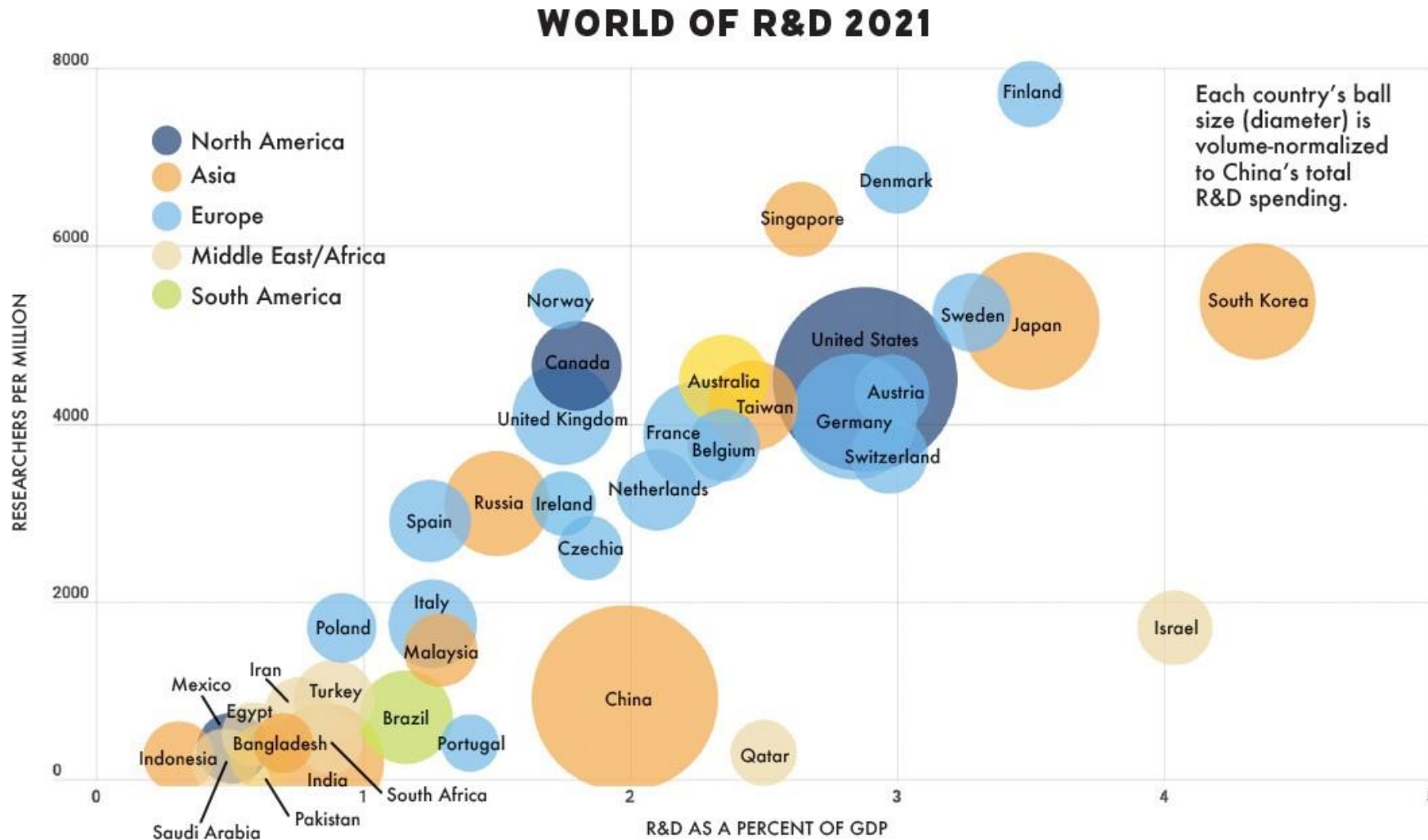
Bamini Jayabalasingham  
Head of Research Analytics, North America  
Research Intelligence, Elsevier

Daniel Calto  
Global Director of Solution Services  
Research Intelligence, Elsevier

ERVA Visioning Event  
December 7-8, 2021

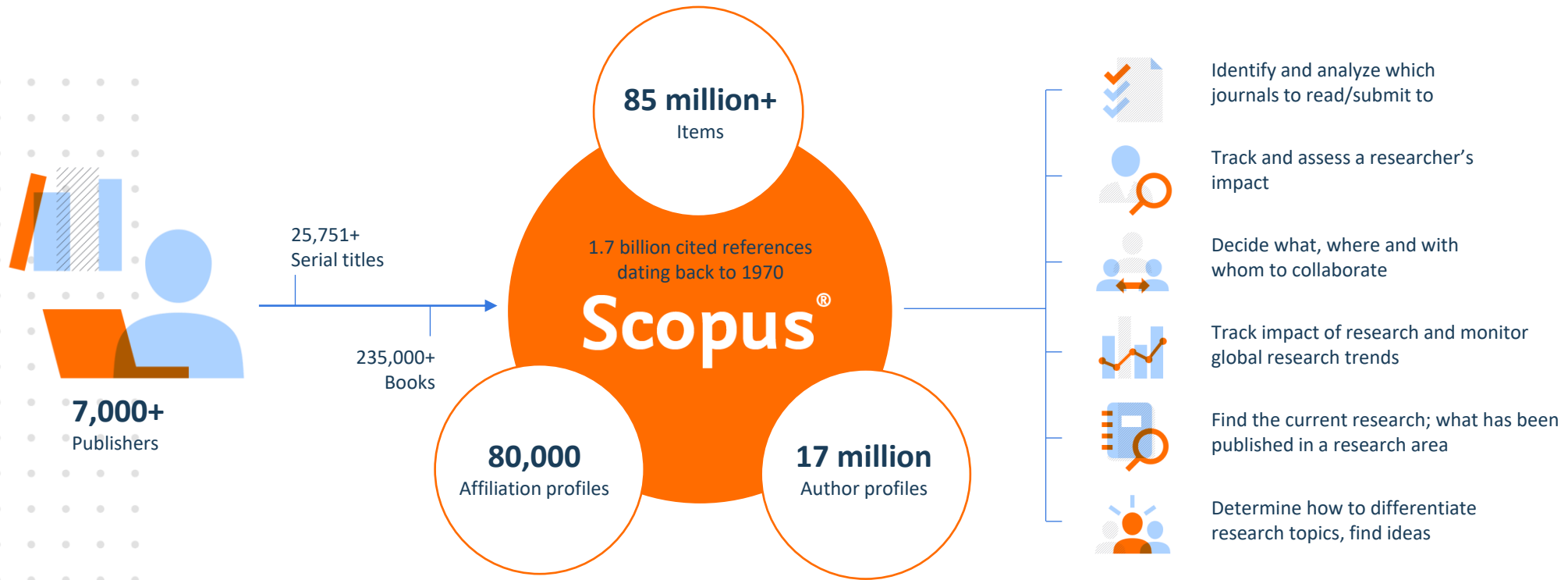


# The world spent \$2.35T USD (PPP) on R&D in 2020



- The world as a whole spent \$2.35T in R&D in 2020 (USD PPP)
- Spending was down in almost all geographies vs. 2019 due to pandemic effects, except in China, which had a \$42B increase.
- China's spending on R&D in 2021 is expected to surpass US spending for the first time ever.
- India is expected to overtake South Korea in 2021 to move into the top 5 countries.
- No major EU economy except Germany (2.84%) is on track to spend the EU goal of 3.00% of GDP in 2020
- Asia now accounts for 46% of all R&D spending globally, vs. North America at 26.4% and Europe at 19.6%

# Data Sources: Scopus



Quickly find relevant and trusted research, identify experts, and access reliable data, metrics and analytical tools to support confident decisions around research strategy – all from one database and one subscription.

# Scopus Coverage Summary (Nov 2021)

Global representation means global discovery across all subjects and content types

**84.9M** records from **26.0K** serials, **101K+** conferences and **247K** books  
from more than **7,000** publishers in **105** countries

- Updated daily—approximately **11,000** articles per day indexed
- **18.03M** open access documents
- “Articles in Press” from **>8,075** titles
- **1.06M** preprints from multiple preprint servers
- **5,656** active Gold Open Access journals indexed

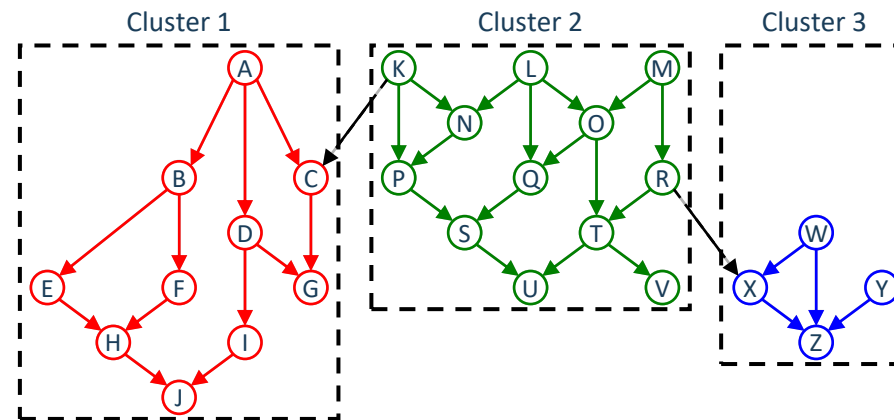
Number of journals by subject area**	Journals	Conferences	Books	Patents
<b>Physical sciences</b> <b>8,529</b>	<b>24,971**</b> active peer-reviewed journals <b>244</b> trade journals	<b>101K</b> conference events <b>10.75M</b> conference papers	<b>63.3K</b> individual book series volumes <b>250K</b> stand-alone books <b>2.08M</b> total book items	<b>47.1M</b> patents 5 major patent offices:
<b>Health sciences</b> <b>7,136</b>	<b>5,656</b> Gold OA Journals (DOAJ/ROAD) <b>16.4M</b> fully-indexed funding acknowledgements			<ul style="list-style-type: none"><li>• WIPO</li><li>• EPO</li><li>• USPTO</li><li>• JPO</li><li>• UK IPO</li></ul>
<b>Social sciences</b> <b>10,574</b>	<b>1.06M</b> preprints <ul style="list-style-type: none"><li>• Full metadata, abstracts and cited references (refs post-1970 only)</li></ul>	Mainly Engineering and Computer Sciences	Focus on Social Sciences and A&H	
<b>Life sciences</b> <b>4,915</b>	<ul style="list-style-type: none"><li>• Citations back to 1970</li></ul>			

\*Journals may be classified in multiple subject areas: this count includes current actively indexed titles only

\*\*Total number of Scopus journals in database including inactive titles is 40,804

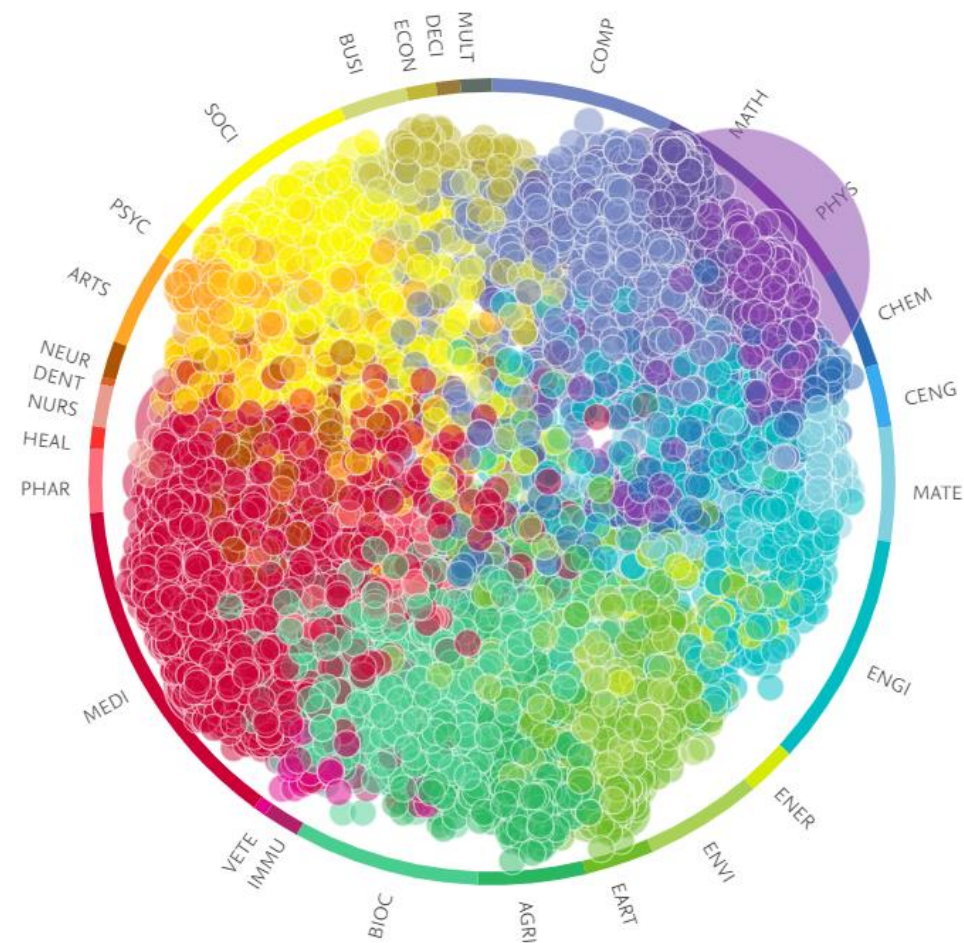
# Topics of Prominence (1/3)

- A topic is a collection of documents with a common intellectual interest – a “research problem”
- Clustering is done using the VOS methodology<sup>1</sup>
  - Create list of citing-cited (paper-reference) pairs using all of Scopus
  - Divide the documents into groups



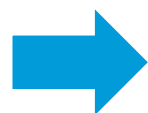
# Topics of Prominence (2/3)

- Using source data 1996-present (over 80 million documents)
- Calculated relatedness for 900 million pairs
- Result – ~97,000 topics



# Topics of Prominence (3/3)

- Any publication gets linked to a single Topic
- 95% of all Scopus publications get linked to Topics

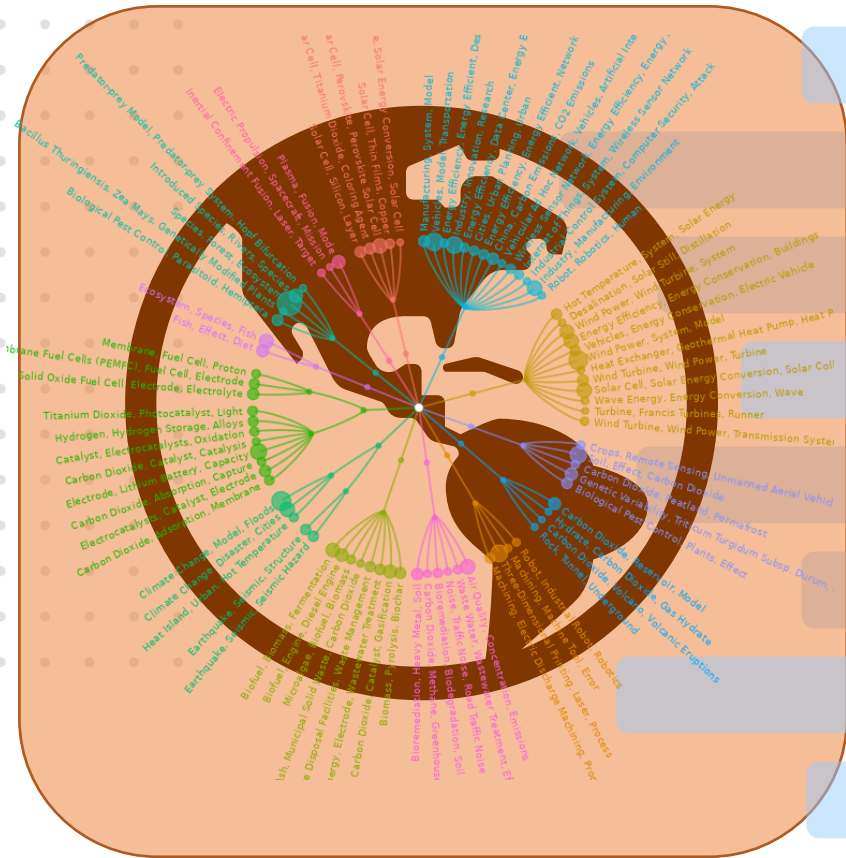


**Topics enable you to do Portfolio analysis**



**Because those Topics are global, for any Topic we can tell who are the main stakeholders and how they compare with each other**

# Issues in Climate Change: *Identifying the Relevant Research*



Solar & Renewable Energy

Energy Storage

Carbon Sequestration & GHG Capture

Decarbonizing Industries

Ecosystems & Agriculture

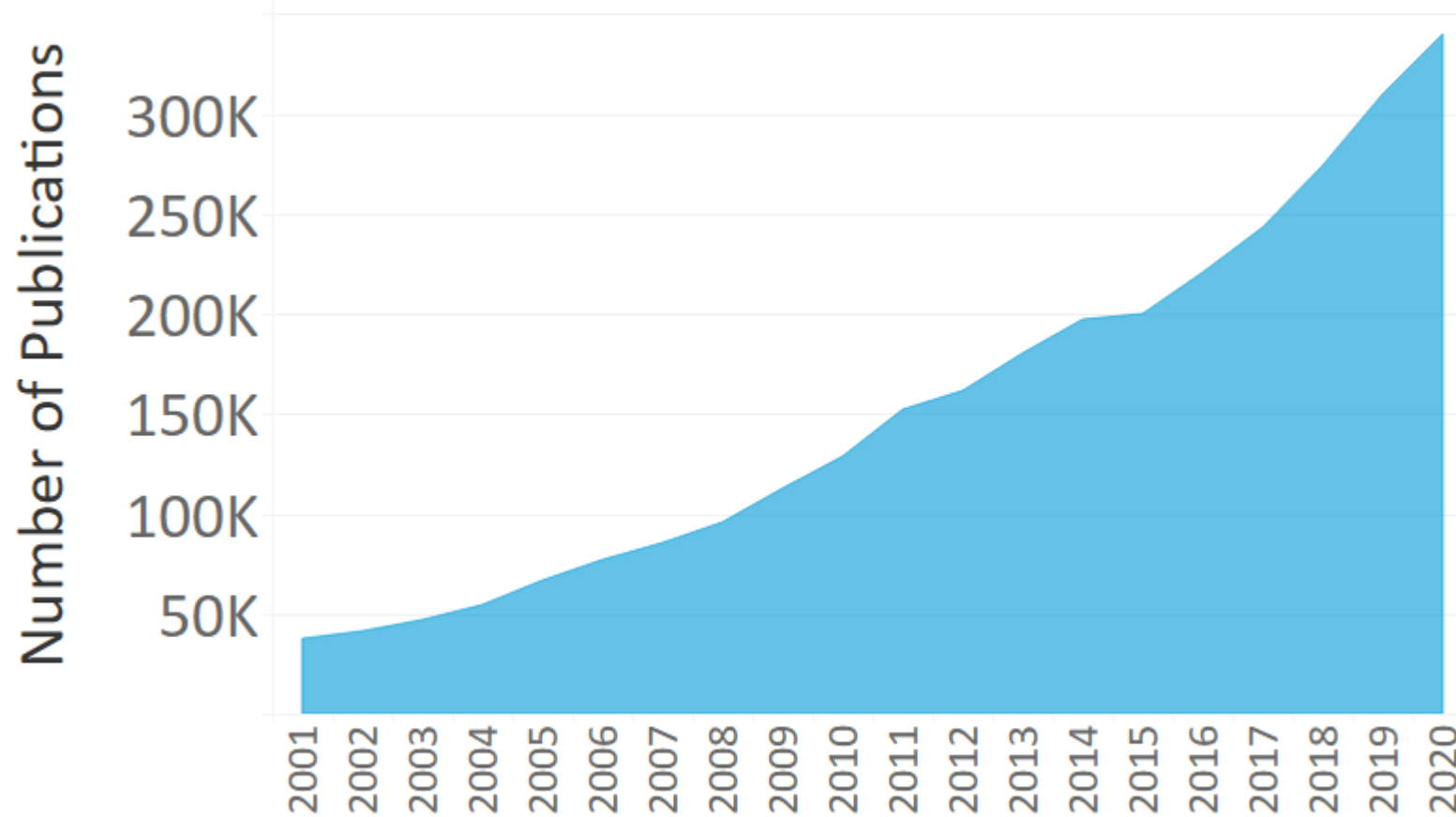
Resilient Infrastructure, Buildings and Transportation

Geoengineering

Health & Climate Change



# Research Literature Addressing Climate Change

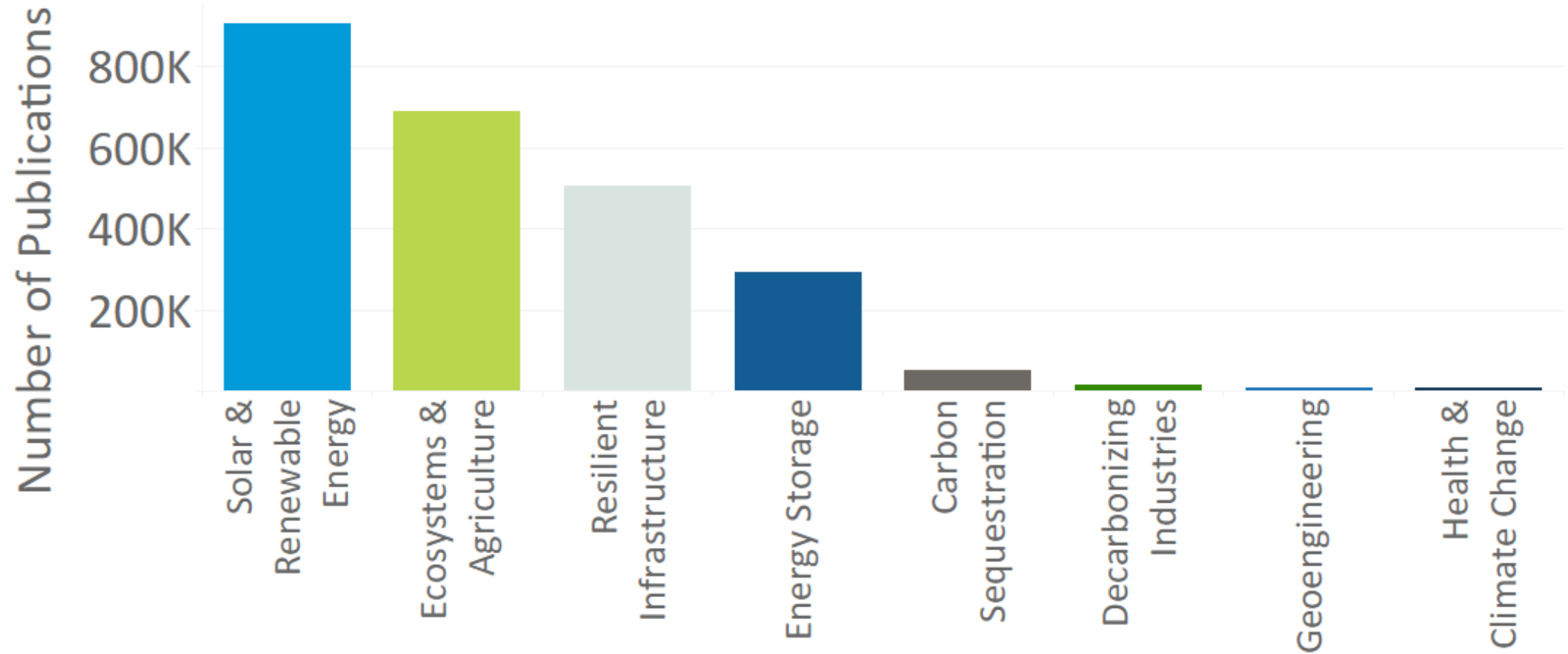


**3.03 Million**

research publications

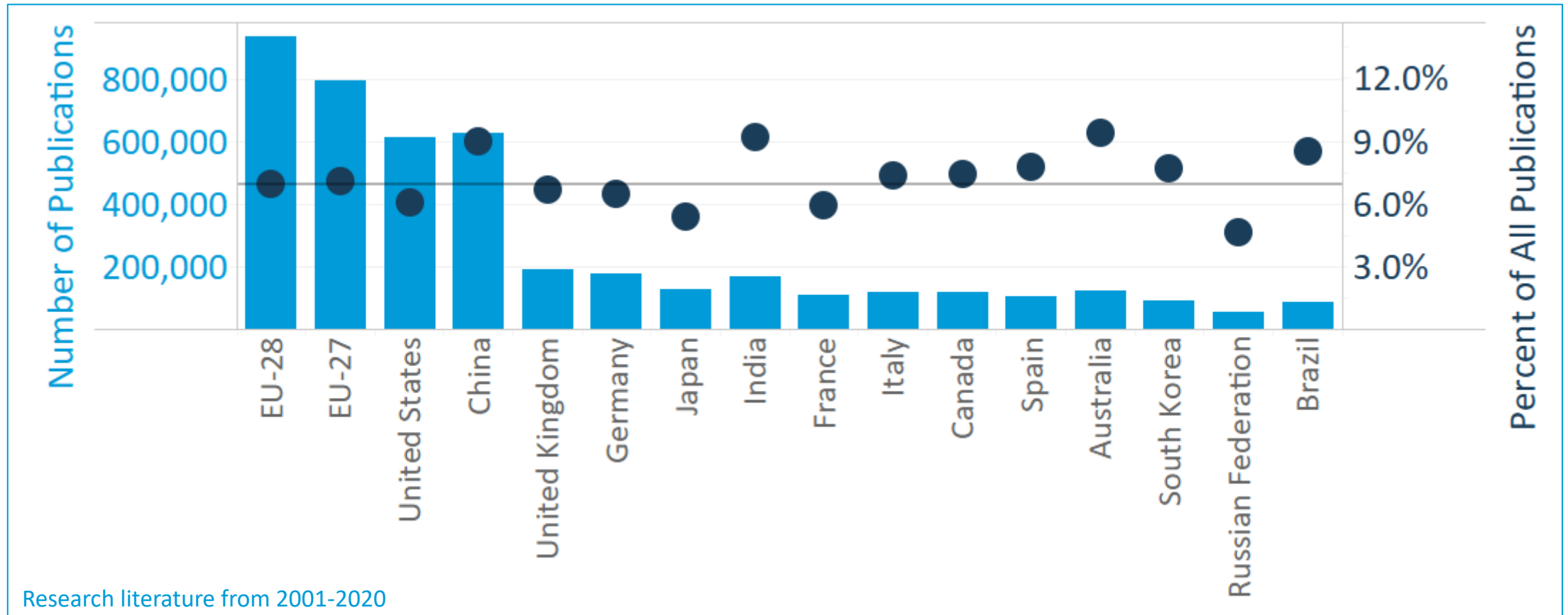
- 6.9% of all research globally
- Compound Annual Growth Rate (CAGR): 12.3%

# Distribution of Research Across Climate Issues



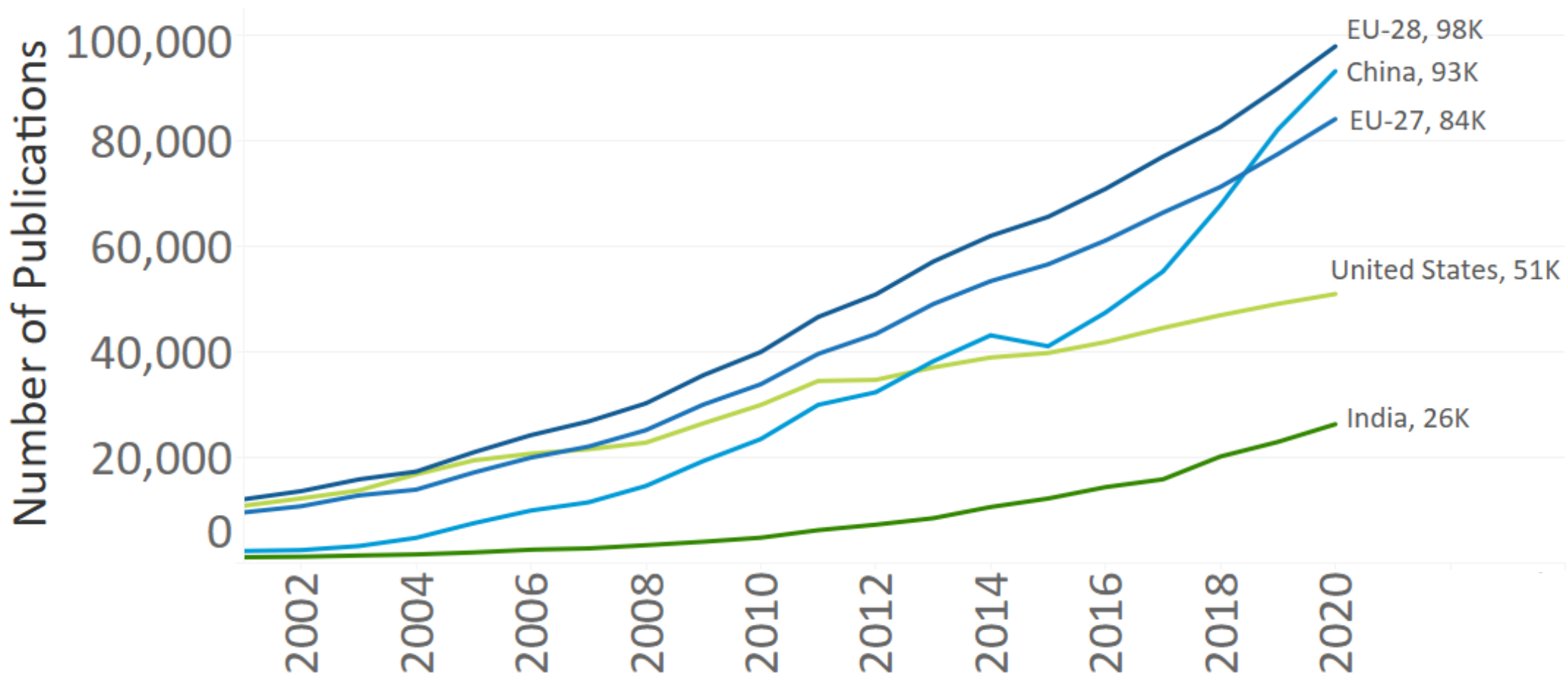
*Global research, 2001-2020*

# Leading Contributors to Climate Change Research: *Contributions by Region*

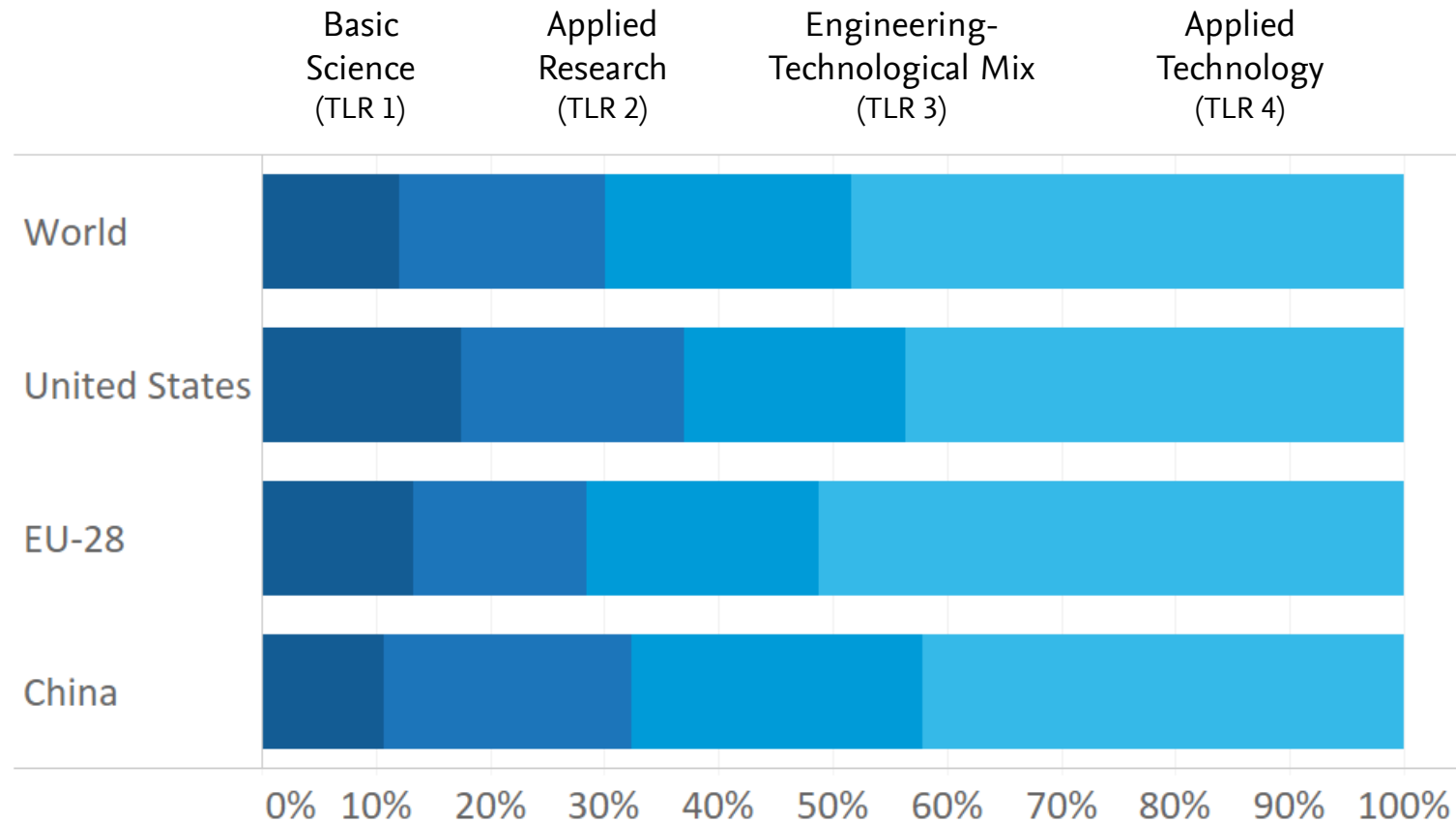


- Regions leading in contributions to the literature: EU, United States, China
- Regions with highest percent of entire research portfolio focused on climate change research: China, India, Australia, Brazil

# Leading Contributors to Climate Change Research: *Changes Over Time*



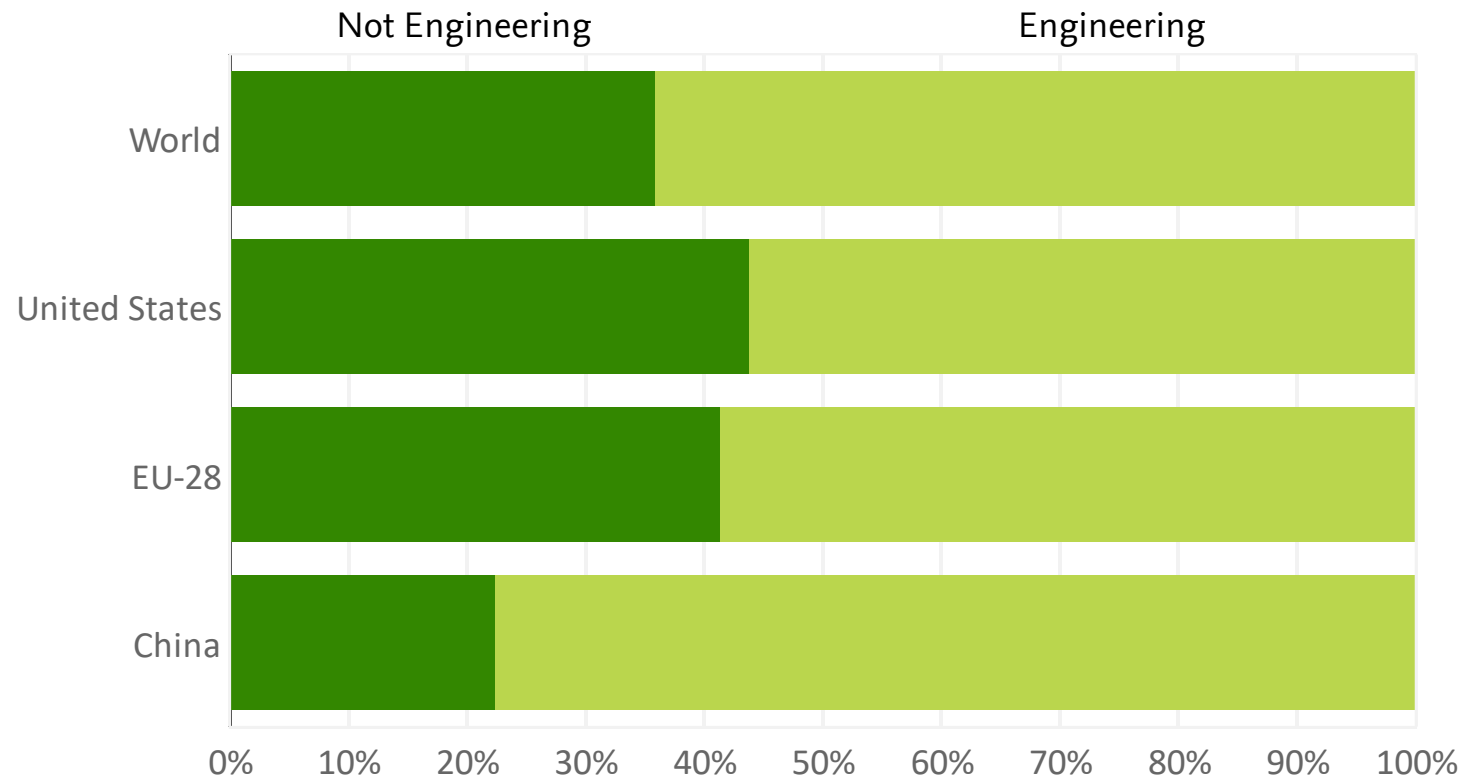
# Distribution of Climate Change Research: *Basic-to-Applied Spectrum*



Climate change research spans from basic science to applied technology, with applied technology representing the largest category and US research skewing more towards basic science than China and the EU.

Research literature from 2010-2019, categorized across the basic-to-applied spectrum of research.

# Distribution of Climate Change Research: *Engineering Approach*

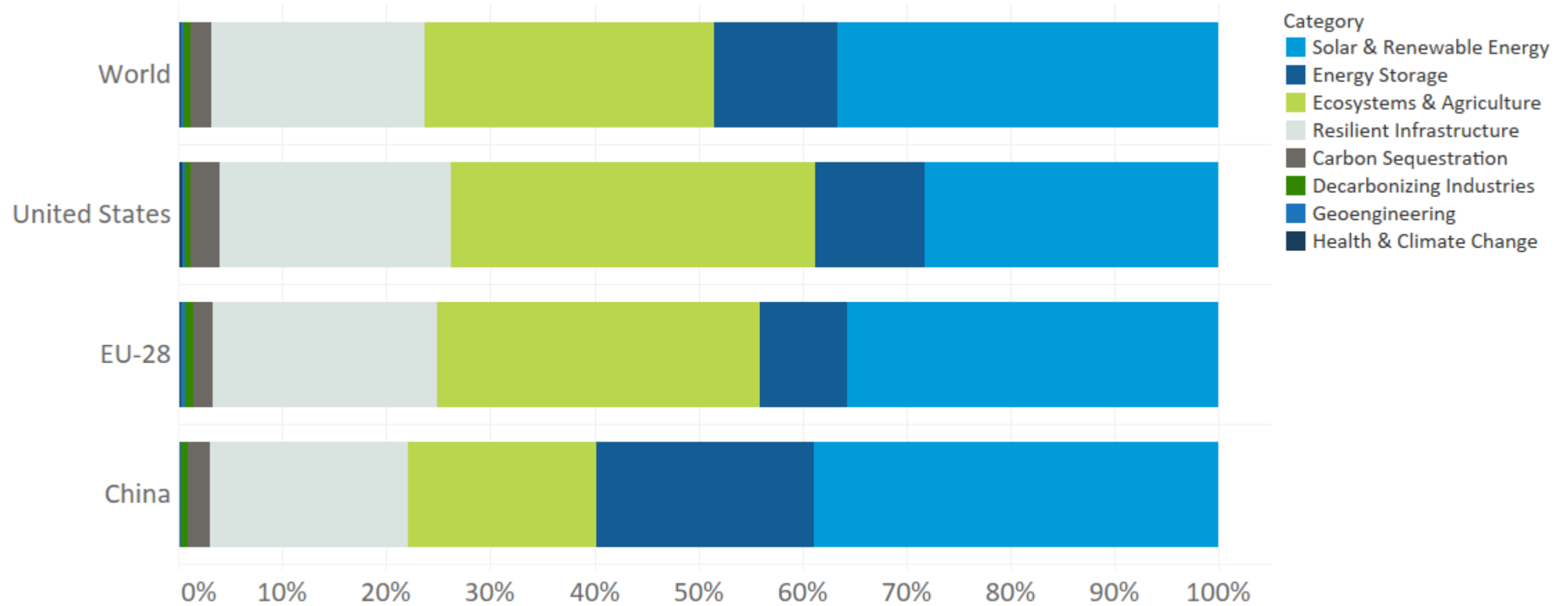


Engineering research represents 65% of climate change research globally with variations across regions:

- 57% of climate change research in the US
- 78% of climate change research in China

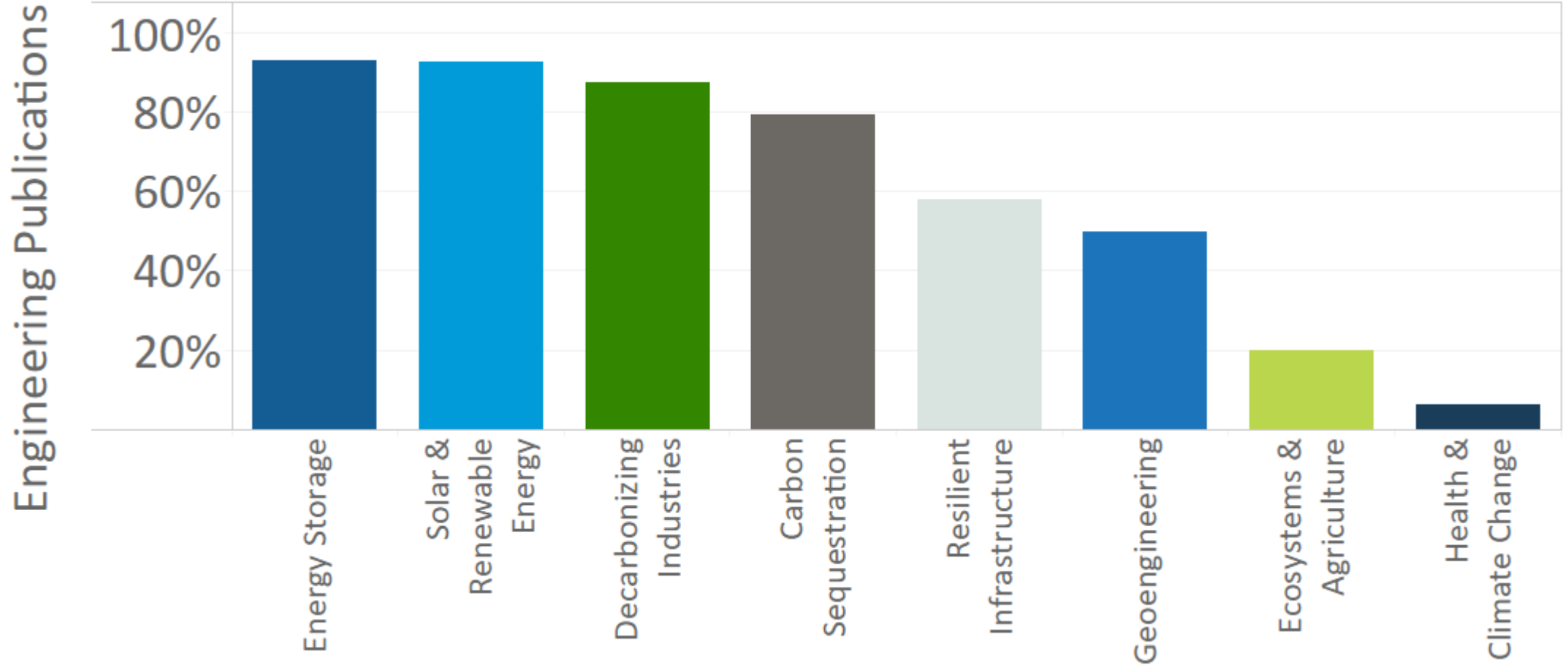
Research literature from 2010-2019, categorized as engineering or not engineering.

# Regional Research by Climate Issue



Research literature from 2001-2020, categorized by Climate Issue.

# Representation of Engineering in Research Across Climate Change Issues







# Solar & Renewable Energy

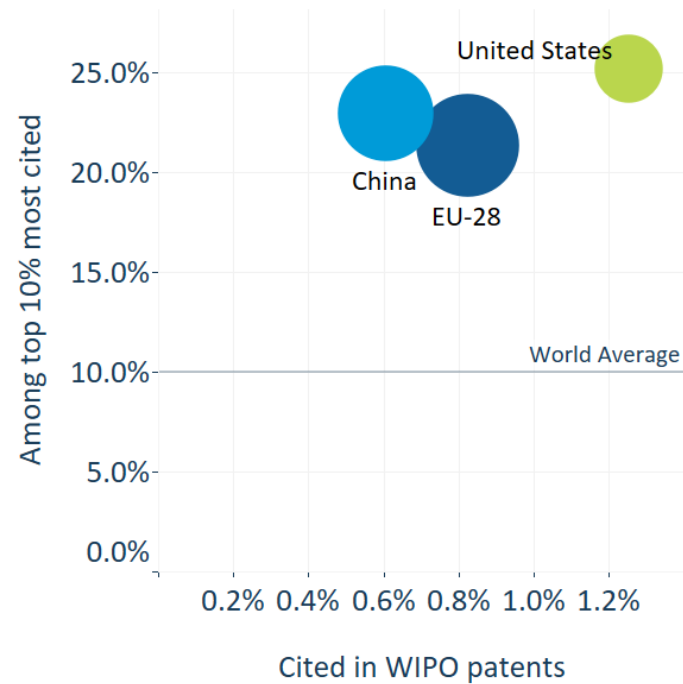
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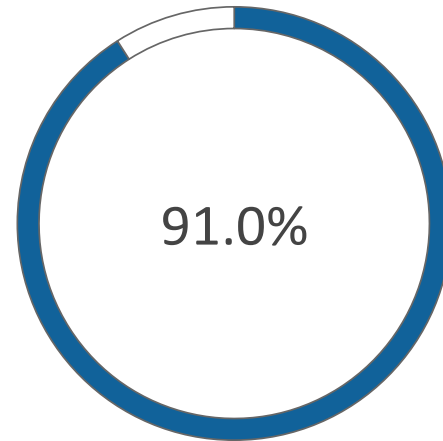


# Solar & Renewable Energy Research

## HIGH KNOWLEDGE TRANSFER



## ENGINEERING APPROACH



The percent of US publications taking an engineering approach

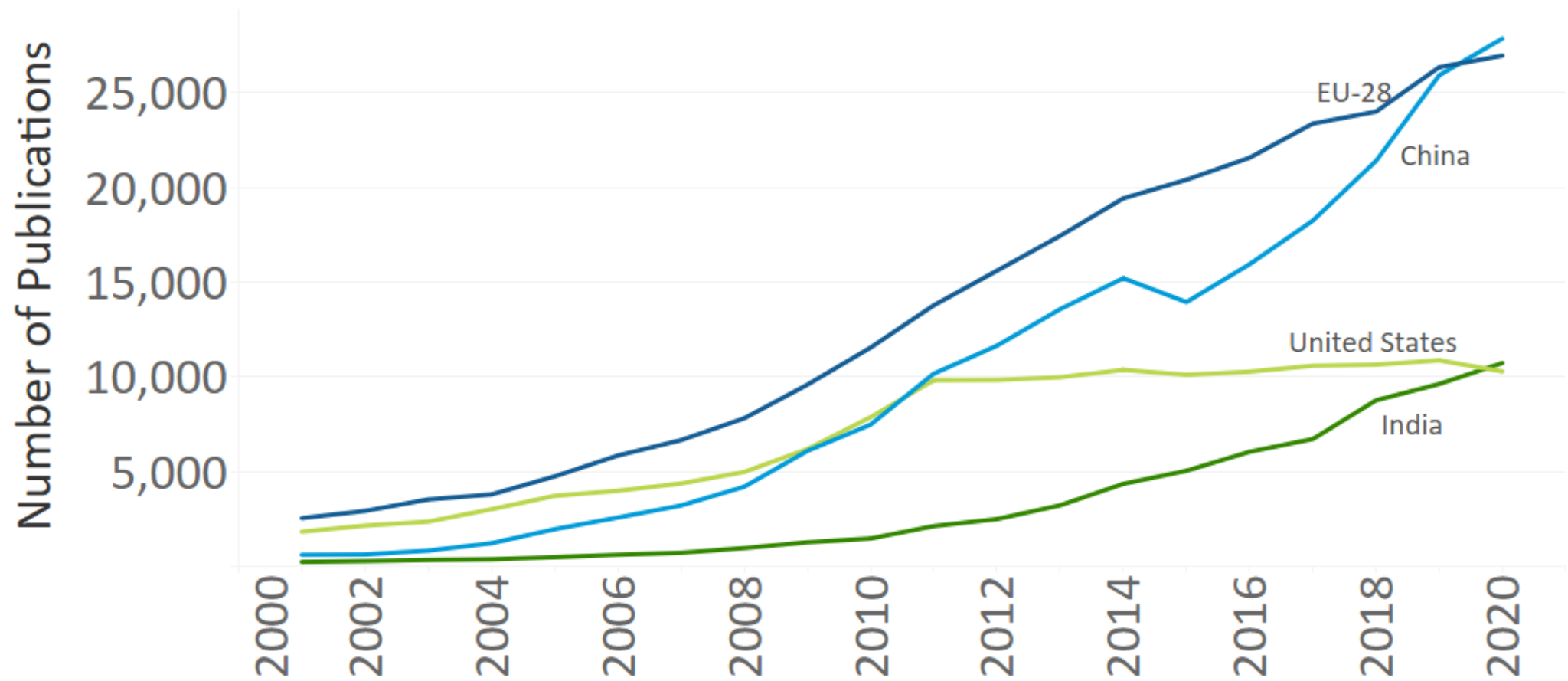
## HIGHLY MULTIDISCIPLINARY TEAMS

US RESEARCH  
MULTIDISCIPLINARITY SCORE

1.2

China multidisciplinary score = 1.0  
EU-28 multidisciplinary score = 1.1

# Regional Trends in Solar & Renewable Energy Research



# Relevant example topic with recent change in prominence

## Representative publication



Renewable and Sustainable Energy Reviews

Volume 83, March 2018, Pages 124-155



Research and developments on solar assisted compression heat pump systems – A comprehensive review (Part-B: Applications)

M. Mohanraj<sup>a, \*</sup>, Ye. Belyayev<sup>b, d</sup>, S. Jayaraj<sup>c</sup>, A. Kaltayev<sup>b, d</sup>

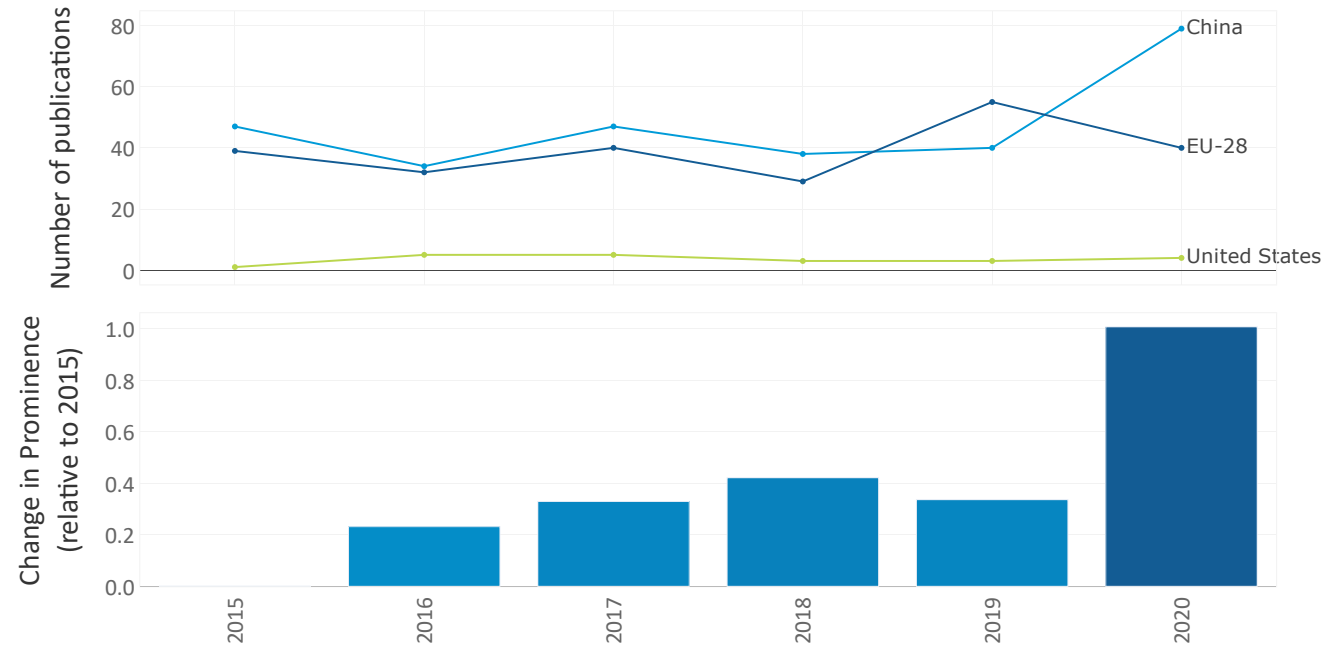
*Air Source Heat Pumps*

Topic keywords *Water Heaters*

*Solar Heating*

Currently in the **96.4th prominence percentile**

Relevant for the **Solar & Renewable Energy** topic





# Energy Storage

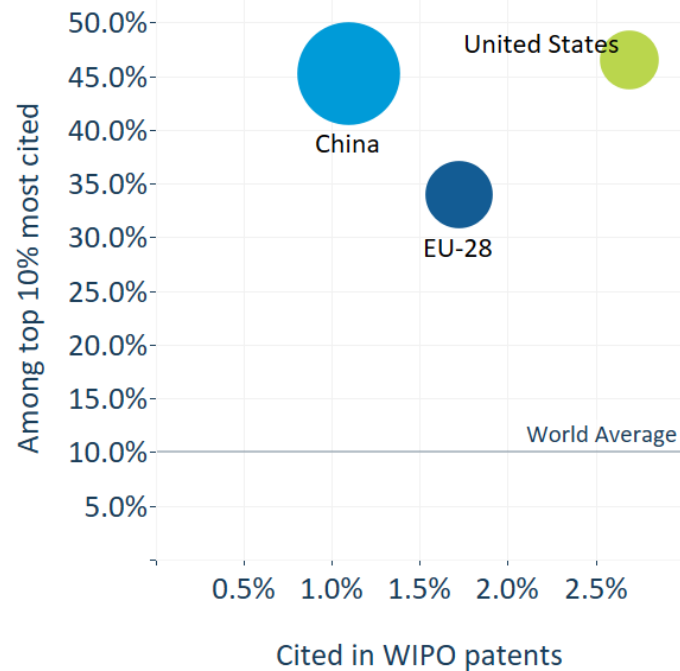
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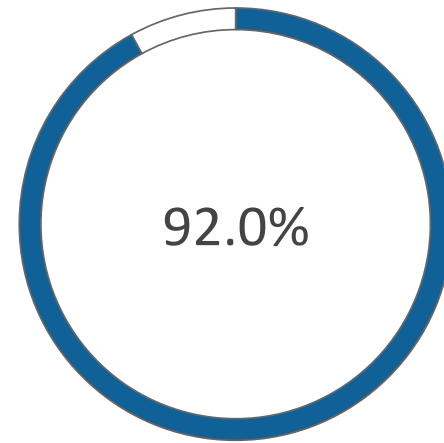


# Energy Storage Research

## HIGH KNOWLEDGE TRANSFER



## ENGINEERING APPROACH



The percent of US publications taking an engineering approach

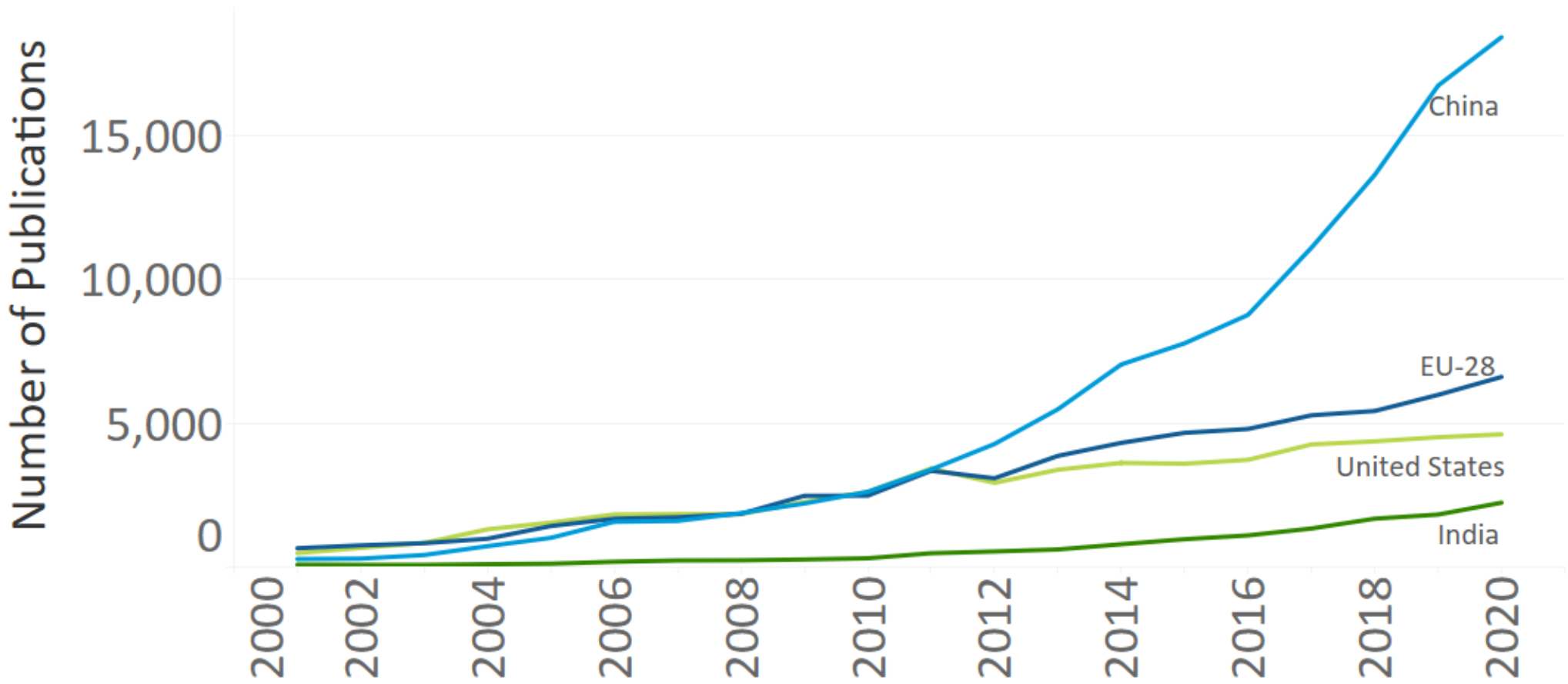
## MULTIDISCIPLINARY TEAMS

US RESEARCH  
MULTIDISCIPLINARITY SCORE

1.1

China multidisciplinary score = 1.0  
EU-28 multidisciplinary score = 1.1

# Regional Trends in Energy Storage Research



# Relevant example topic with recent change in prominence

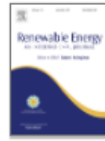
## Representative publication



ELSEVIER

Renewable Energy

Volume 113, December 2017, Pages 620-638



Review

PEM fuel cell system control: A review

W.R.W. Daud <sup>a, b</sup>, R.E. Rosli <sup>a</sup>, E.H. Majlan <sup>a</sup>, S.A.A. Hamid <sup>a</sup>, R. Mohamed <sup>c</sup>, T. Husaini <sup>a</sup>

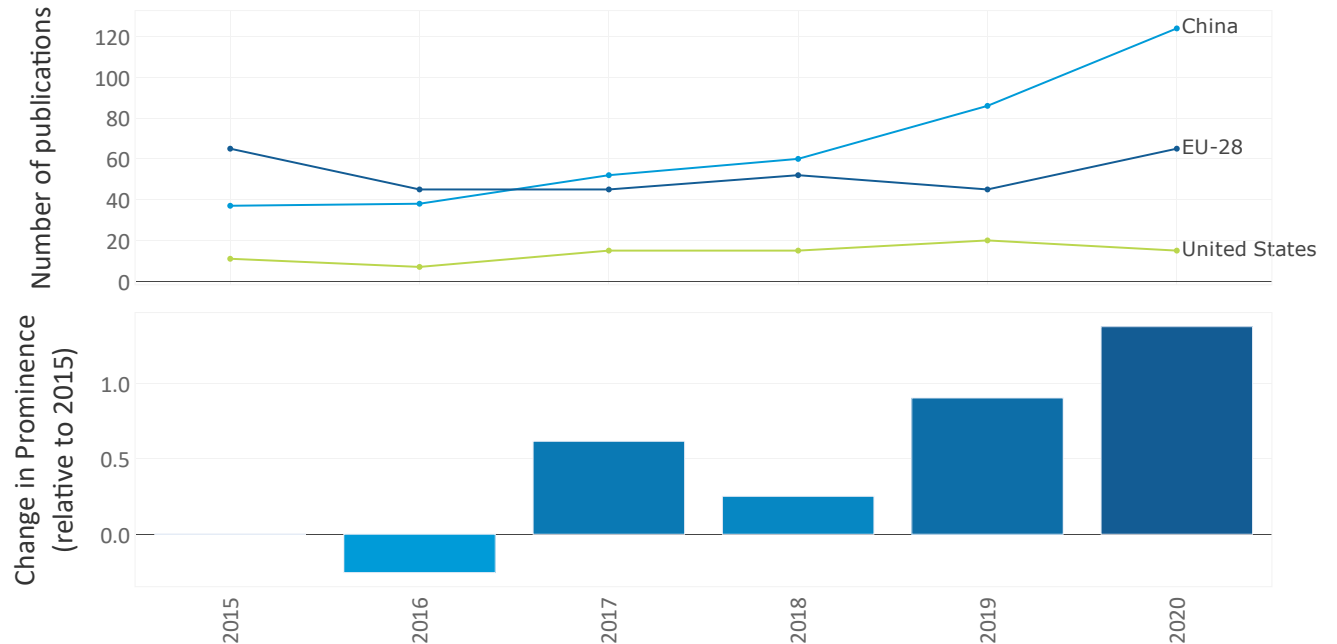
*Proton Exchange Membrane Fuel Cell*

Topic keywords *Powerpoint*

*DC-DC Converter*

Currently in the **98.4th prominence percentile**

Relevant for the **Energy Storage** topic







# Decarbonizing Industries

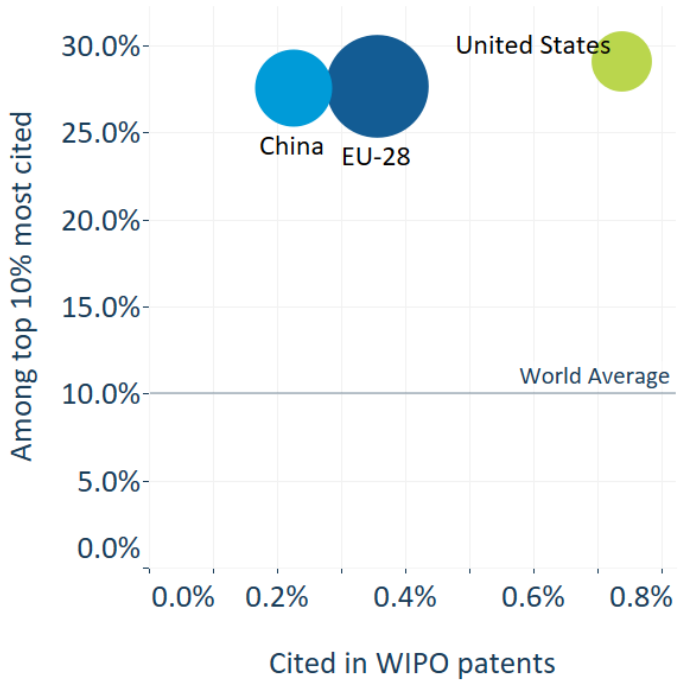
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Visioning Alliance

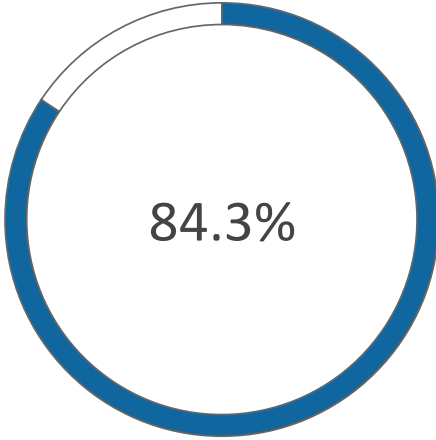


# Decarbonizing Industries Research

## HIGH KNOWLEDGE TRANSFER



## ENGINEERING APPROACH



The percent of US publications taking an engineering approach

## INTERDISCIPLINARY RESEARCH

US RESEARCH INTERDISCIPLINARITY SCORE

1.3

US research is more interdisciplinary  
China interdisciplinarity score = 1.1  
EU-28 interdisciplinarity score = 1.1

# Relevant example topic with recent change in prominence

## Representative publication



Renewable and Sustainable Energy Reviews

Volume 54, February 2016, Pages 838-845



The dynamic impact of renewable energy consumption on CO<sub>2</sub> emissions: A revisited Environmental Kuznets Curve approach

Faik Bilgili<sup>a</sup>, Emrah Koçak<sup>b,1</sup>, Ümit Bulut<sup>c,2</sup>

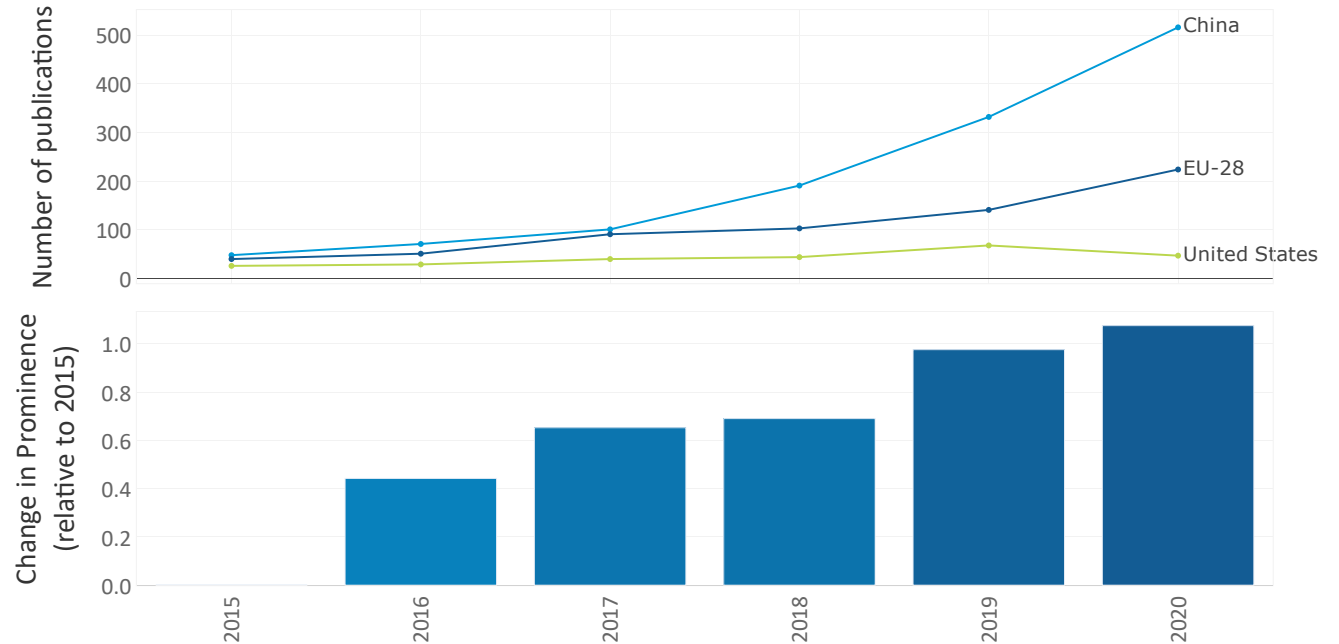
*Trade Openness*

Topic keywords: *Environmental Kuznets Curve*

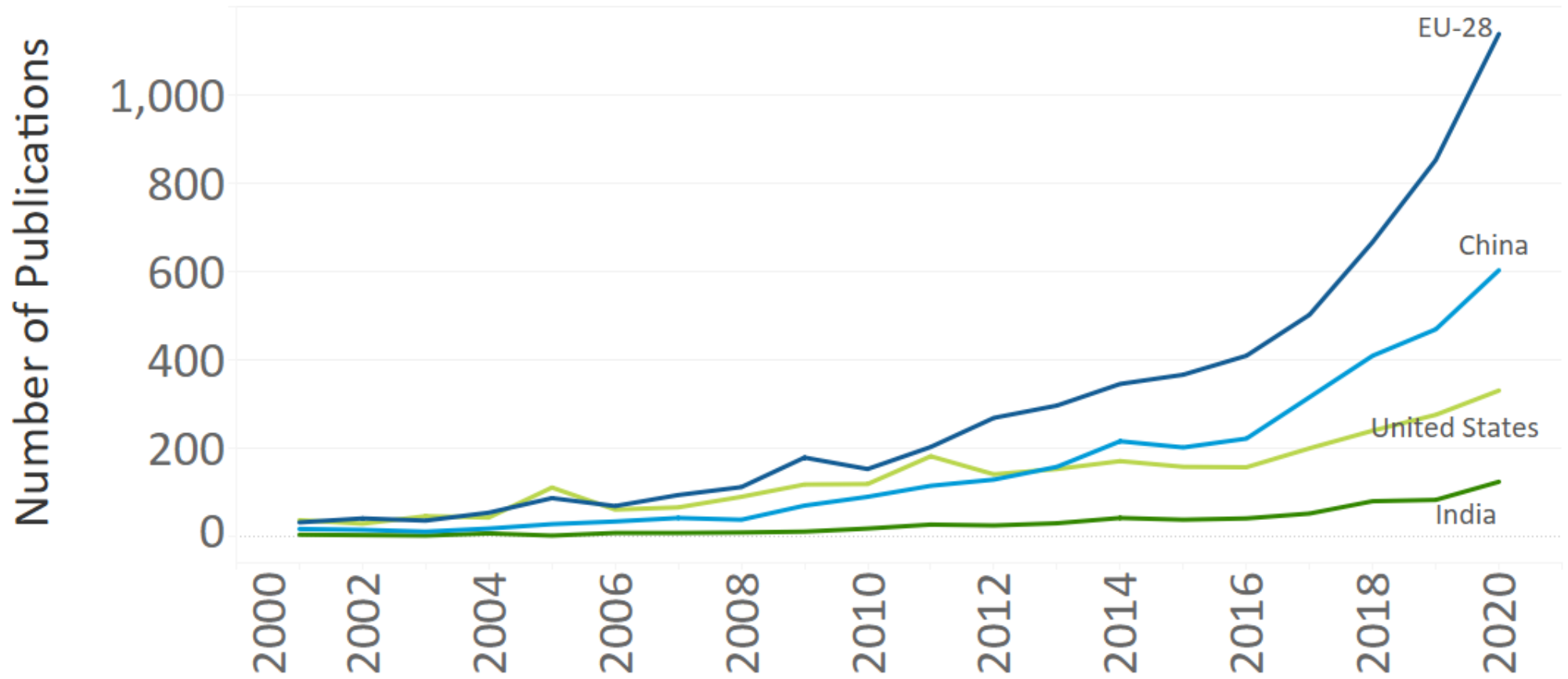
*Financial Development*


Currently in the **99.9th prominence percentile**

Relevant for the **Decarbonizing Industries** topic



# Regional Trends in Decarbonizing Industries Research





# Carbon Sequestration

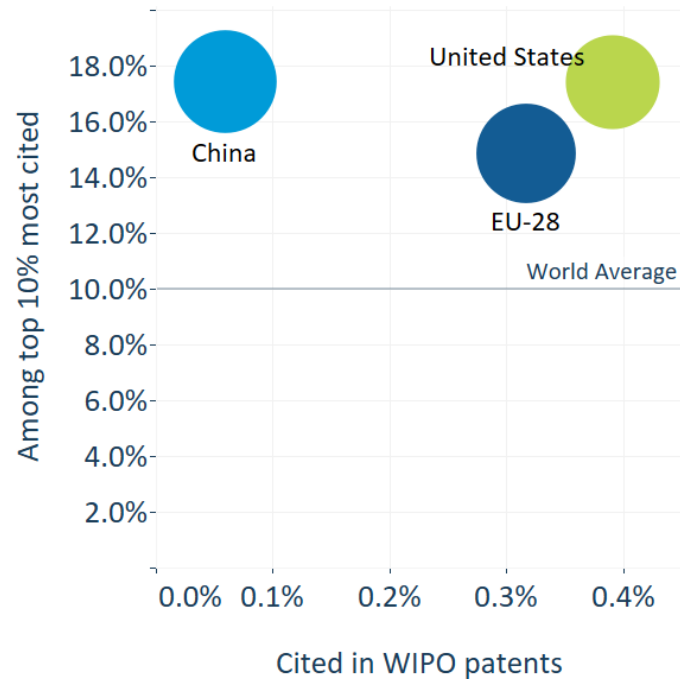
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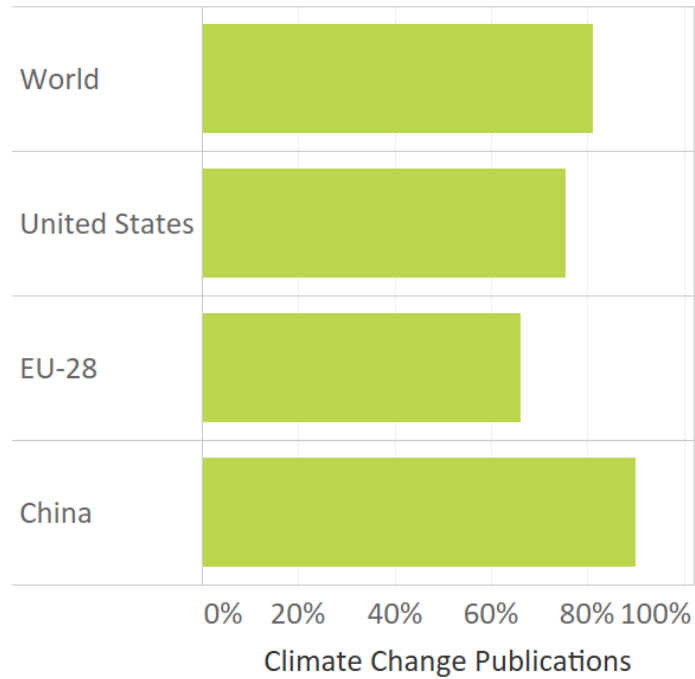


# Carbon Sequestration Research

## KNOWLEDGE TRANSFER



## ENGINEERING APPROACH



## MULTIDISCIPLINARY TEAMS

US RESEARCH  
MULTIDISCIPLINARITY SCORE

1.2

China multidisciplinary score = 1.0  
EU-28 multidisciplinary score = 1.2

# Relevant example topic with recent change in prominence

## Representative publication



ELSEVIER

Renewable and Sustainable Energy Reviews

Volume 38, October 2014, Pages 848-863



Public perception of carbon capture and storage (CCS): A review

Selma L'Orange Seigo<sup>a</sup>, Simone Dohle<sup>a, b</sup>, Michael Siegrist<sup>a</sup>

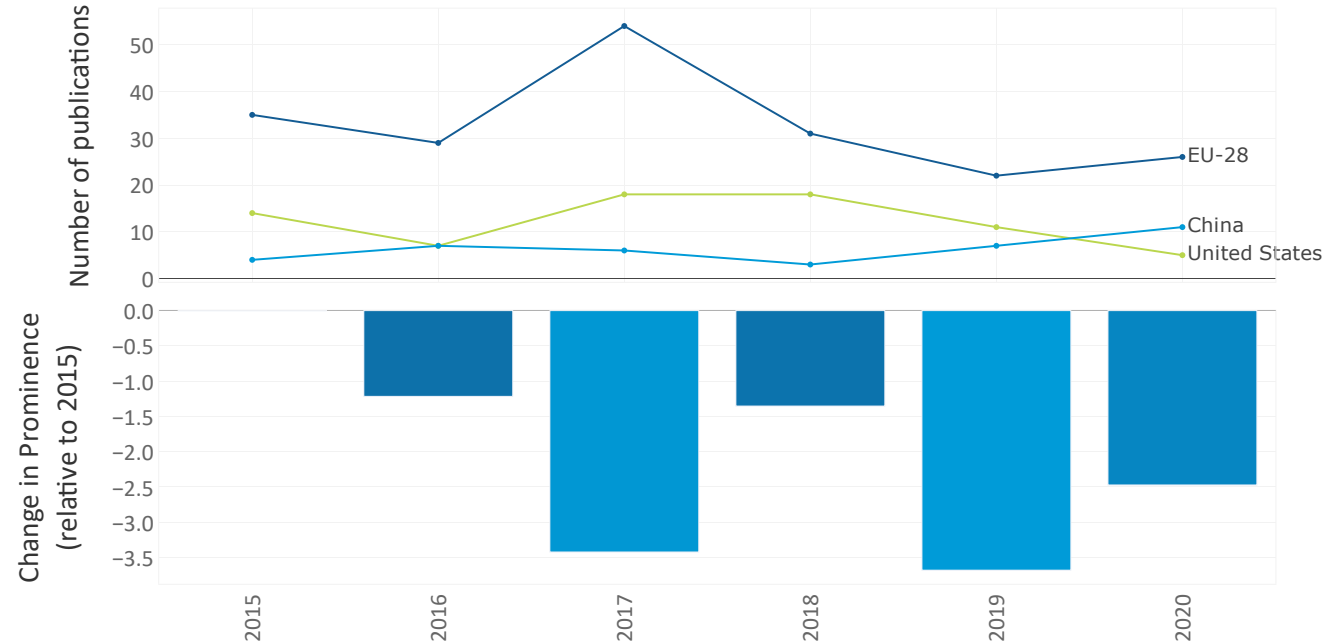
*Carbon Sequestration*

Topic keywords: *Carbon Dioxide Capture and Storage*

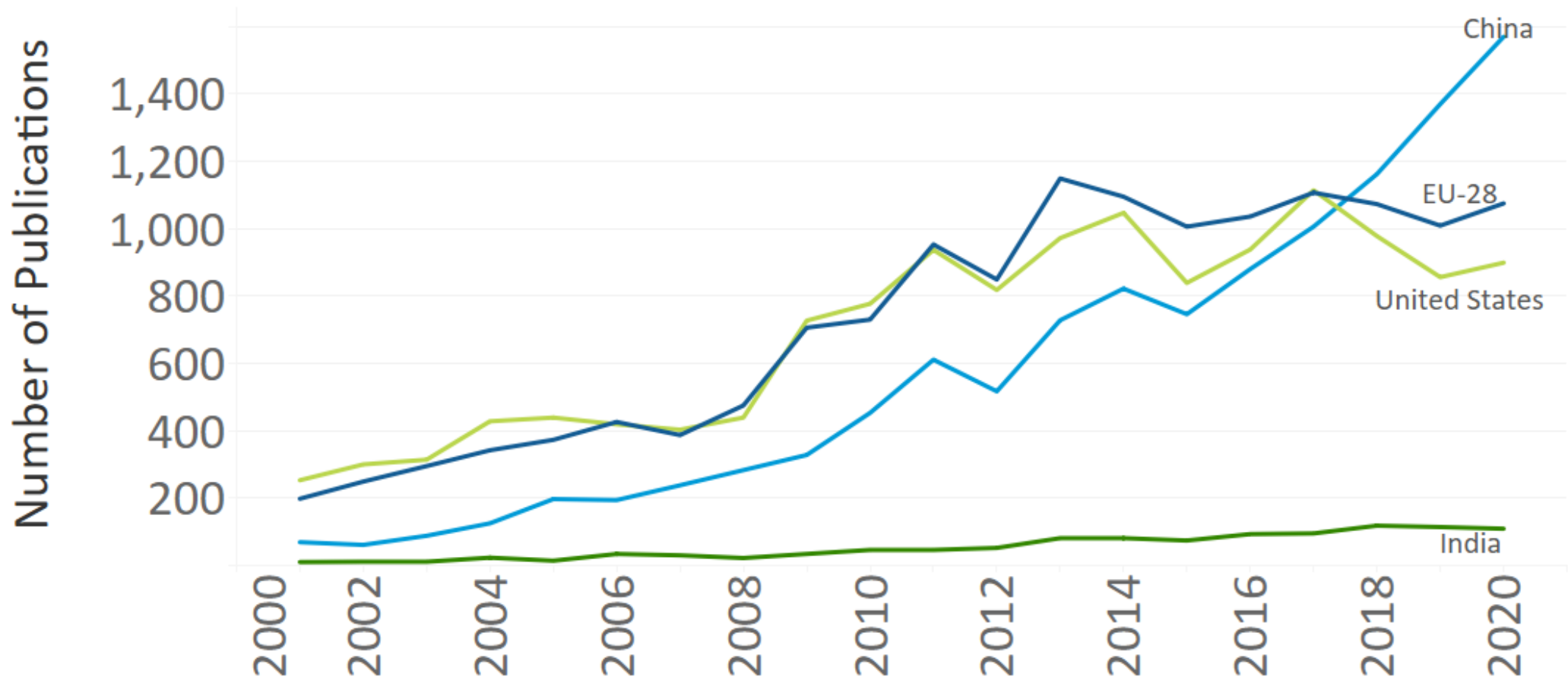
*Storage Technology*

Currently in the **90.8th prominence percentile**

Relevant for the **Carbon Sequestration** topic



# Regional Trends in Carbon Sequestration Research







# Resilient Infrastructure

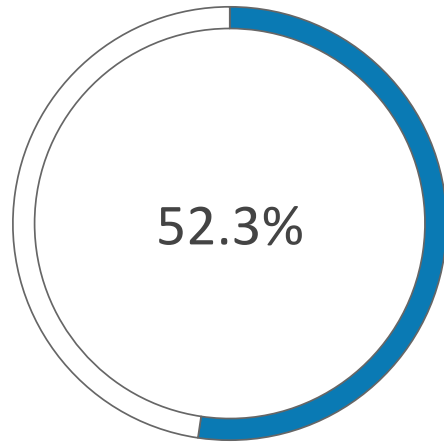
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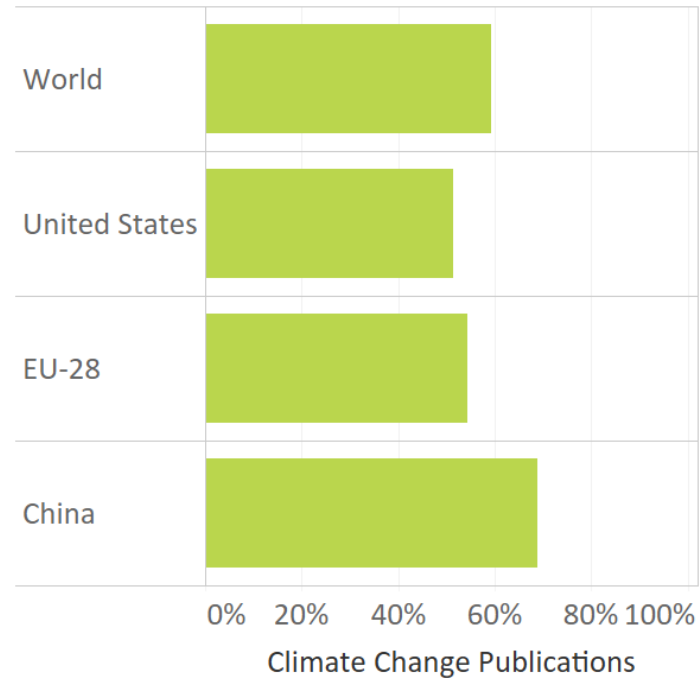


# Resilient Infrastructure Research

## ENGINEERING APPROACH



The percent of US publications taking an engineering approach



## MULTIDISCIPLINARY TEAMS

## US RESEARCH MULTIDISCIPLINARITY SCORE

1.2

China multidisciplinary score = 1.1  
EU-28 multidisciplinary score = 1.2

# Relevant example topic with recent change in prominence

## Representative publication

Open Access Article

### A Machine Learning Framework for Assessing Seismic Hazard Safety of Reinforced Concrete Buildings

by Ehsan Harirchian<sup>1,\*</sup>, Vandana Kumari<sup>1</sup>, Kirti Jadhav<sup>1</sup>, Rohan Raj Das<sup>1</sup>, Shahla Rasolzade<sup>2</sup> and Tom Lahmer<sup>1</sup>

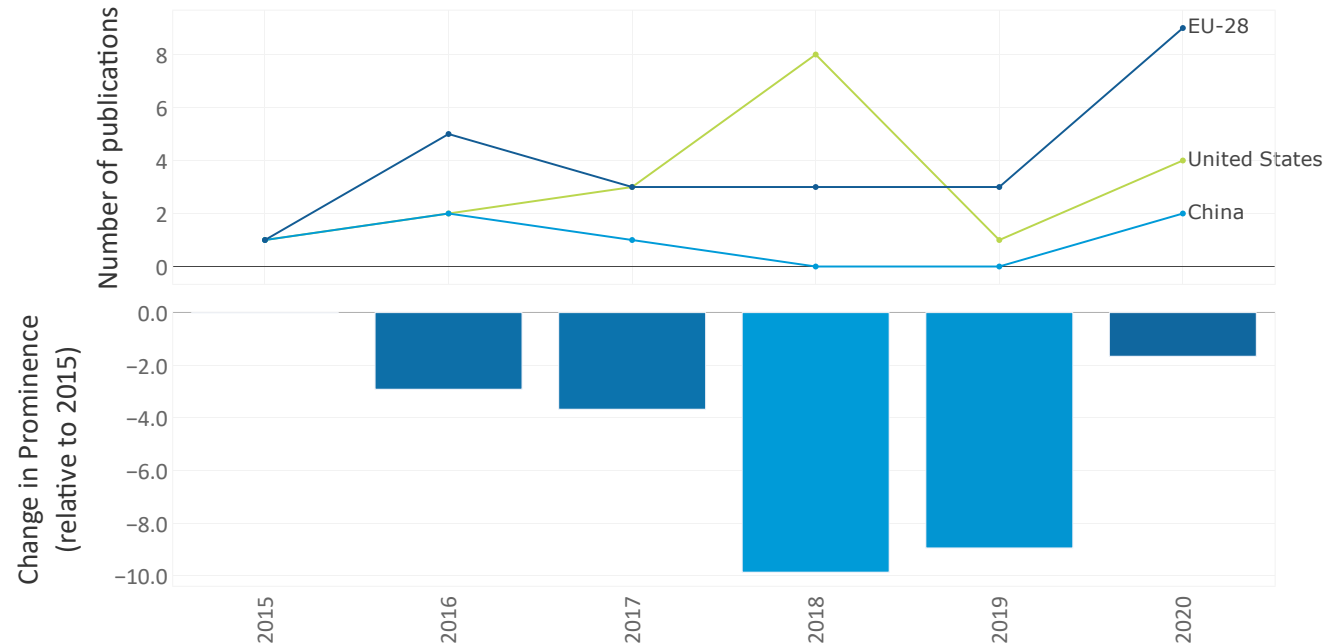
Concrete Buildings


Topic keywords: Seismic

Earthquakes

Currently in the 79.3rd prominence percentile

Relevant for the Resilient Infrastructure topic





# Ecosystems & Agriculture

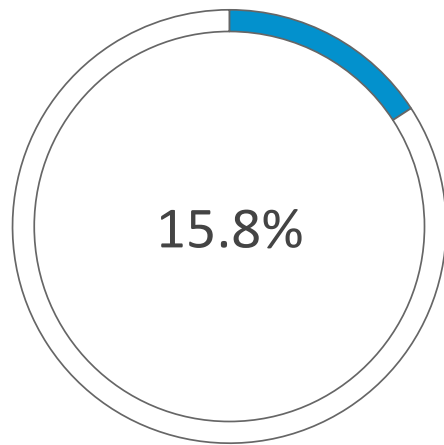
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NSF Engineering Research  
Visioning Alliance

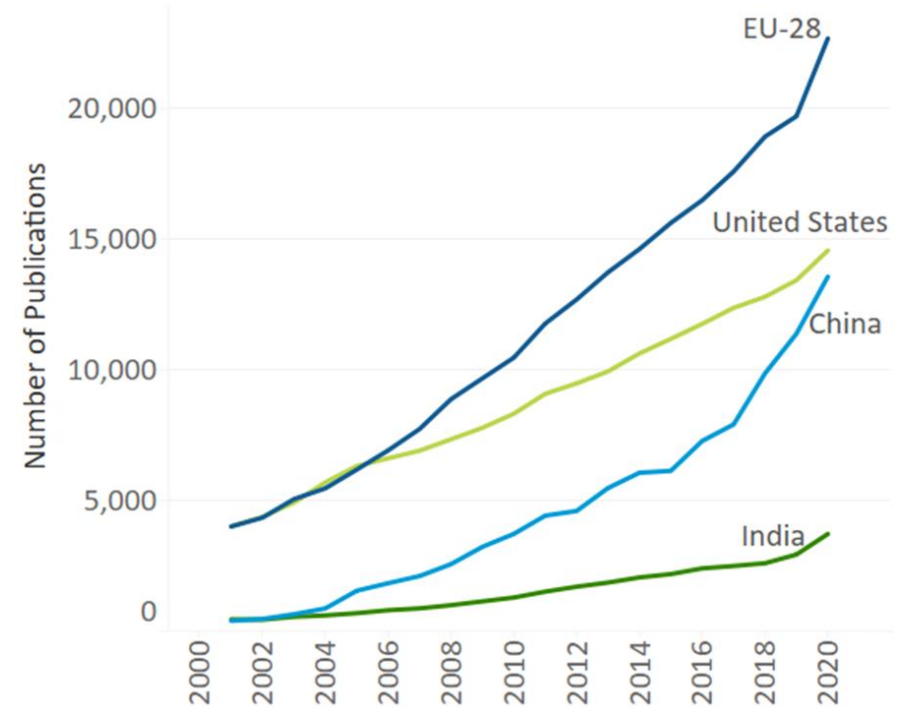
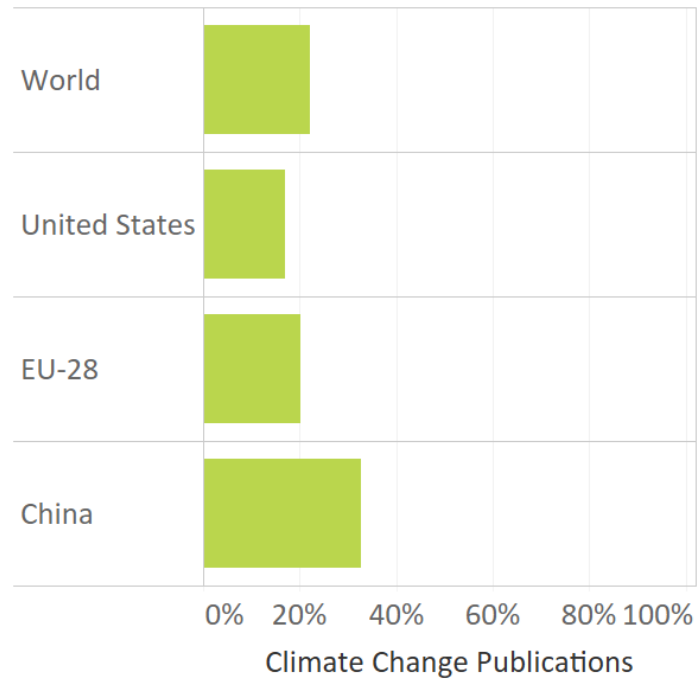


# Ecosystems & Agriculture Research

## ENGINEERING APPROACH



The percent of US publications taking an engineering approach



# Relevant example topic with recent change in prominence

## Representative publication

Journal of Biosystems Engineering

Volume 41 Issue 4 / Pages.408-417 / 2016 / 1738-1266(pISSN) / 2234-1862(eISSN)

Korean Society for Agricultural Machinery (한국농업기계학회)



### Sensing Technologies for Grain Crop Yield Monitoring Systems: A Review DOI QR Code

Chung, Sun-Ok [\[sn\]](#) (Department of Biosystems Machinery Engineering, Chungnam National University) ;  
Choi, Moon-Chan (Department of Biosystems Machinery Engineering, Chungnam National University) ;  
Lee, Kyu-Ho [\[sn\]](#) (Department of Biosystems Machinery Engineering, Chungnam National University) ;  
Kim, Yong-Joo [\[sn\]](#) (Department of Biosystems Machinery Engineering, Chungnam National University) ;  
Hong, Soon-Jung (Rural Human Development Center, Rural Development Administration) ; Li, Minzan (China Agricultural University)  
Received : 2016.11.22 Accepted : 2016.11.25 Published : 2016.12.01

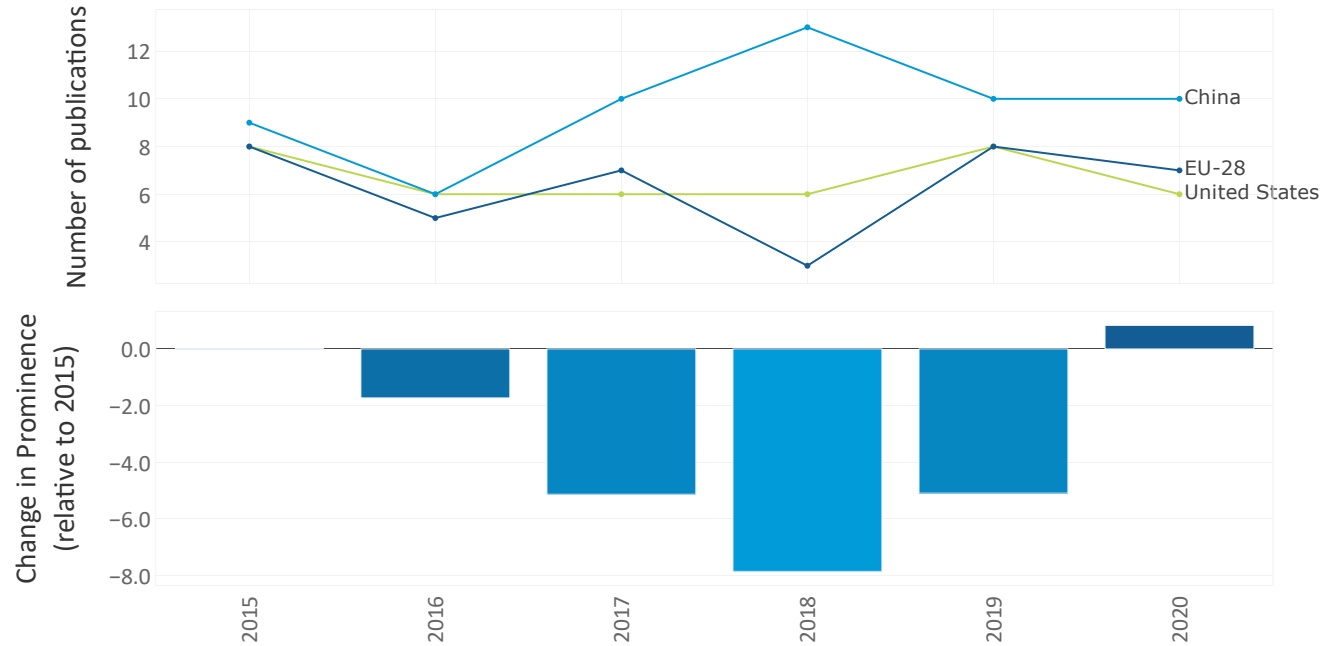
*Yield Monitoring*

Topic keywords *Combine Harvesters*

*Grain Elevators*

Currently in the **75.0th prominence percentile**

Relevant for the **Ecosystems & Agriculture** topic





# Geoengineering

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# Relevant example topic with recent change in prominence

## Representative publication



Overview | [Open Access](#) | [CC](#) | [i](#) | [S](#)

An overview of the Earth system science of solar geoengineering

Peter J. Irvine Ben Kravitz, Mark G. Lawrence, Helene Muri

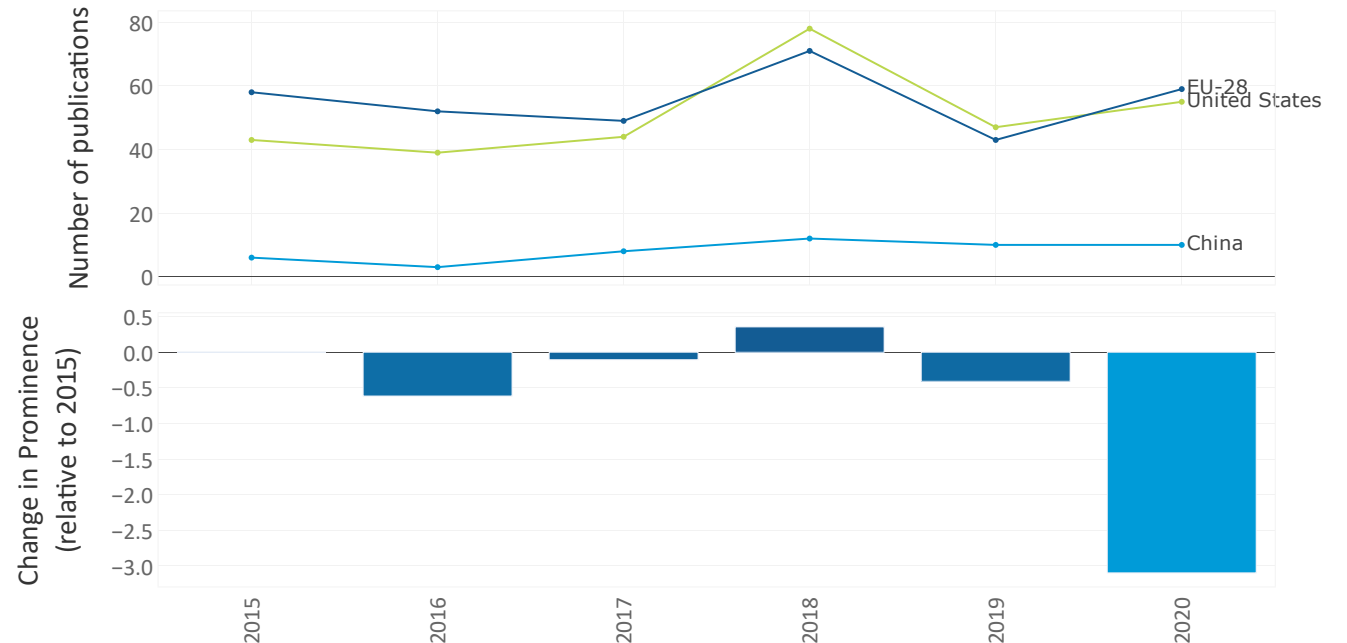
*Environmental Engineering*

Topic keywords *Stratosphere*

*Aerosols*

Currently in the **94.7th prominence percentile**

Relevant for the **Geoengineering** topic







# Health & Climate Change

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# Relevant example topic with recent change in prominence

## Representative publication



Global Environmental Change  
Volume 21, Supplement 1, December 2011, Pages S3-S11



### The effect of environmental change on human migration

Richard Black <sup>a</sup>, W. Neil Adger <sup>b</sup>, Nigel W. Arnell <sup>c</sup>, Stefan Dercon <sup>d</sup>, Andrew Geddes <sup>e</sup>, David Thomas <sup>f</sup>

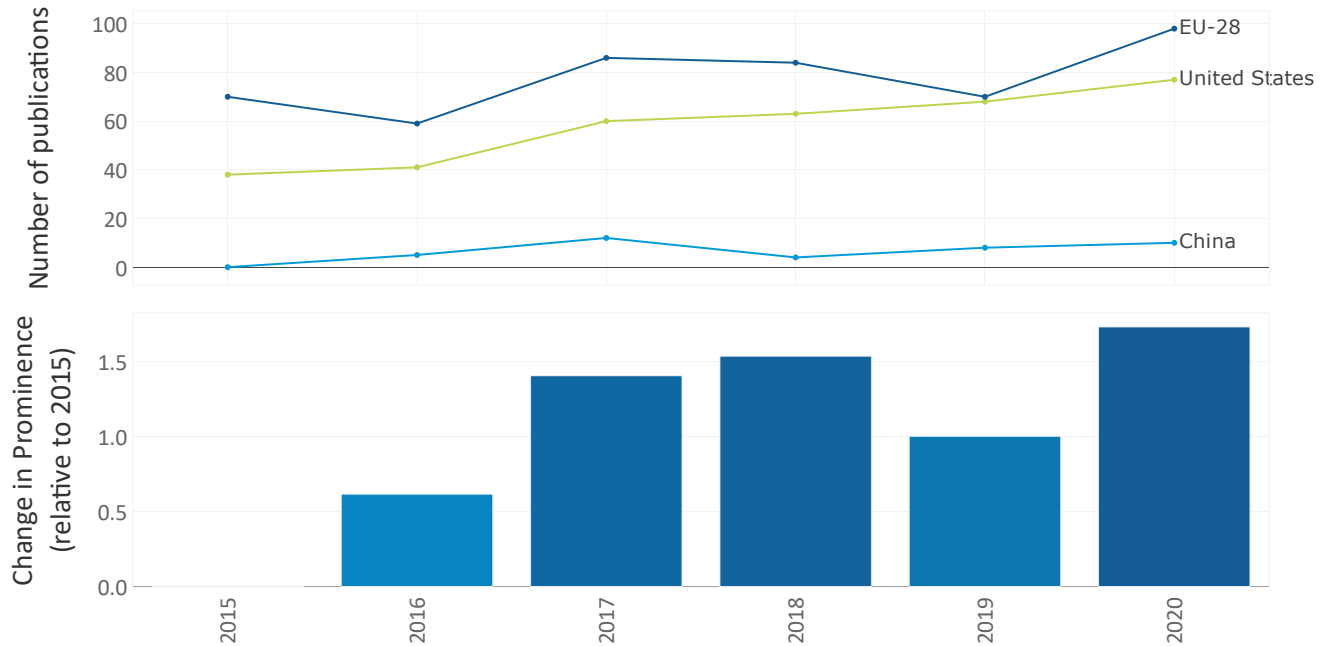
*Micronesia*

Topic keywords *Decision to Migrate*

*Small Islands*

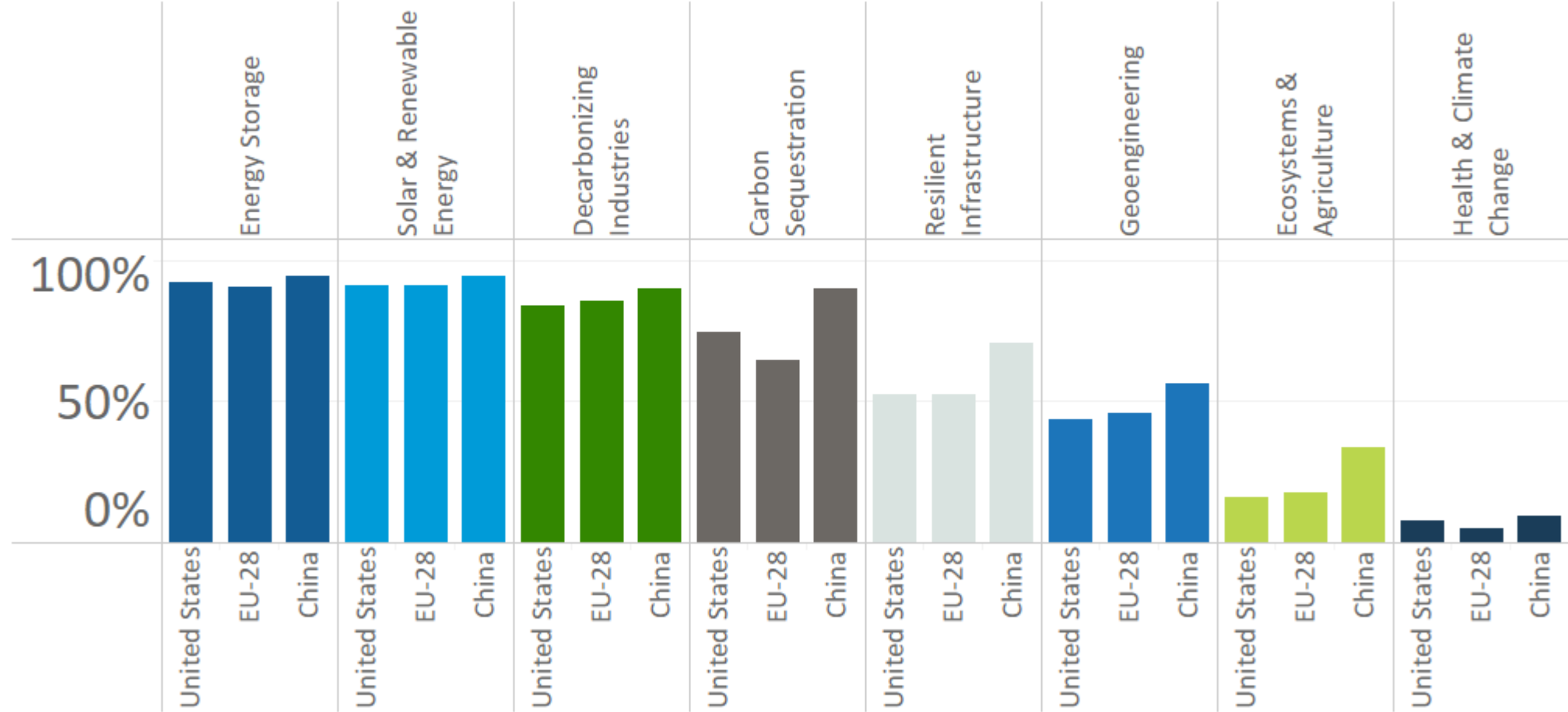
Currently in the **97.6th prominence percentile**

Relevant for the **Health & Climate Change** topic



# Representation of Engineering in Research Across Climate Change Issues

## Engineering Publications



# Q&A / Discussion

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