> CHAPTER 5

A global map of technological inventions

Mapping and characterizing SDG-related patenting activity across the world

AUTHORS

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OVERVIEW

This chapter maps inventions that are of potential relevance for specific SDGs.

Key findings include:

- Only a tiny share (1.9%) of patented inventions between 2001 and 2017 were related to the SDGs
- SDG-related inventions mainly focus on SDG 3, SDG 7 and SDG 6, and include market solutions such as drugs and solar panels
- Most inventions are generated in high-income countries and in upper-middle income countries
- Inventions filed in low-income countries often originate in higher-income countries
- Most SDG-related inventions focus on a single SDG, with only a tiny fraction addressing synergies and trade-offs between SDGs
- The use of patents can prevent others from using a particular innovation to address sustainability challenges

Footnotes for this chapter are on page 71. A full list of references can be found on page 140.

Introduction

This chapter maps SDG-related inventions between 2001 and 2017. It analyses the countries and technology fields involved, and the connections between SDGs.

Inventions and patent authorities play a central role in contributing to SDG 9 (Industry, innovation and infrastructure) by building new technologies.[1,2] Inventions contribute to the other SDGs in various ways: not only through new products and services based on patented inventions, but also by increasing the pool of technical knowledge available to society. In this chapter, we look beyond countries' overall rates of innovation, (number of patents) and focus on the direction of innovative activity (content of patents).

Which SDGs attract the most inventions?

Using the method developed in this study, we found that 369,253 unique inventions produced from 2001 to 2017 were related to SDGs. This represents just 2% of all inventions produced worldwide in that timeframe.

Three SDGs accounted for the vast majority of SDG-related inventions, as follows:

- SDG 3: Good health and well-being (229,529; 62%)
- SDG 7: Affordable and clean energy (58,230; 16%)
- SDG 6: Clean water and sanitation (39,443; 11%)

Only a small proportion of SDG-related inventions were related to the other SDGs: SDG 12 (7% of all SDG-related inventions); SDG 11 (3%); SDG 2 (2%); SDG 15 (2%); SDG 13 (1%); SDG 14 (0.6%); and SDG 4 (0.1%).

Figure 5.1 shows how the proportion of inventions related to SDG 3 has decreased since reaching a peak in 2010-2011, while the proportions relating to other SDGs have increased, especially since 2005.

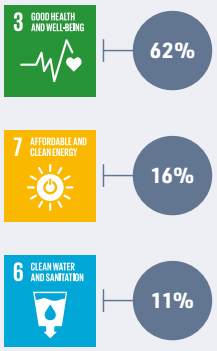
Which countries focus most on SDG-related inventions?

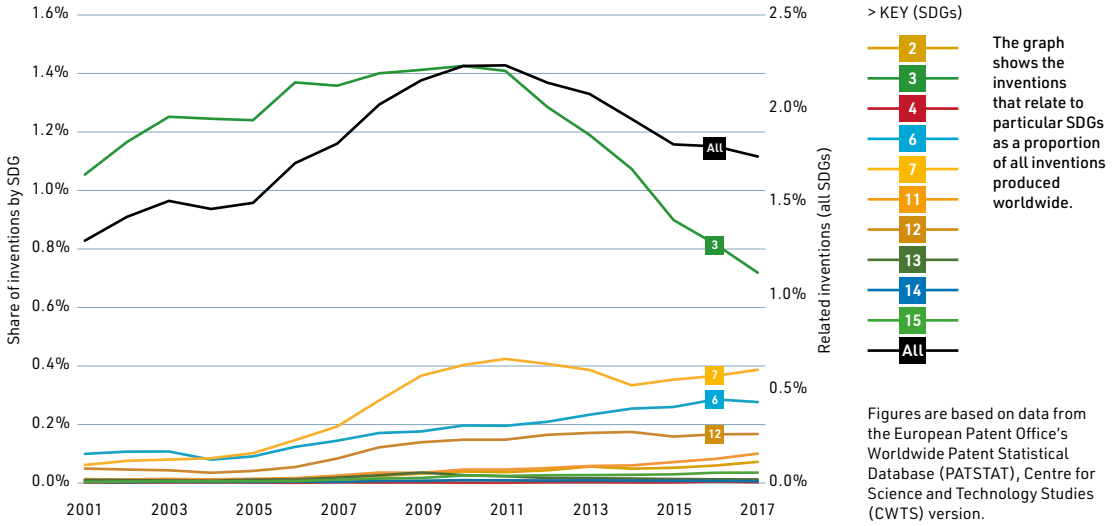
Inventions in low income countries (LICs) are more likely to relate to SDGs than those in other country groups, as shown in Figure 5.2. When we consider all patents for which we have information about the country of the inventor, approximately 9% of LIC inventions are SDG-related, compared with 6% of inventions in lower-middle income countries (LMICs), 3% in high-income countries (HICs) and 2% in upper-middle income countries (UMICs). However, the absolute number of inventions in LICs is just 60, compared with 224,019 in HICs.

These differences between country groups remain when we consider the country in which the patent was filed, rather than the country of the inventor.[3] The African Regional Intellectual Property Organization (ARIPO) is the patent authority with the highest percentage of inventions related to any of the SDGs (24%).[4]

Figure 5.1 / Share of inventions related to different SDGs (2001-2017)

Three SDGs accounted for the vast majority of SDG-related inventions:





The graph shows the inventions that relate to particular SDGs as a proportion of all inventions produced worldwide.

Figures are based on data from the European Patent Office's Worldwide Patent Statistical Database (PATSTAT), Centre for Science and Technology Studies (CWTS) version.

The World Intellectual Property Organization (WIPO) and European Patent Office (EPO) have a higher share of SDG-related inventions (6%) than other authorities in HICs, such as the United States Patent and Trademark Office (USPTO) and the Japan Patent Office (JPO) (3% and 2%, respectively). At the China National Intellectual Property Administration (CNIPA), which dominates patenting activities among UMICs, around 2% of inventions are related to the SDGs.

Despite ARIPO's relatively high percentage of SDG-related inventions, the absolute number of inventions filed at ARIPO represents a tiny fraction of worldwide SDG-related inventions: just 1,673, compared with more than 180,000 at CNIPA or USPTO[5] in the same period.

Across country groups, the share of SDG-related inventions began to increase in 2005 and then declined after 2011. The number of SDG-related inventions produced in LICs has fluctuated over time, while numbers in the other three country groups have been much more stable.

SDG focus within country groups

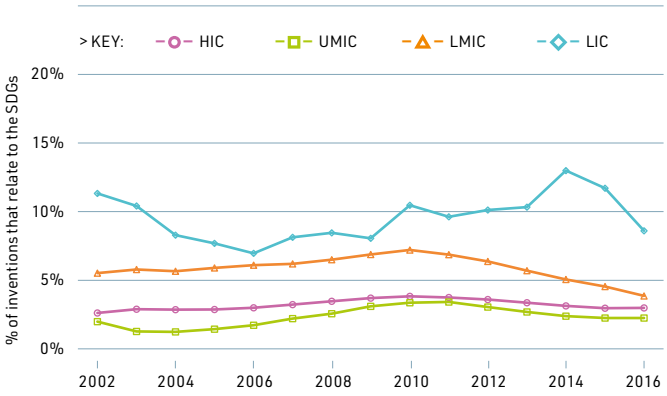
SDG 3 accounts for the highest share of SDG-related inventions in all country groups, as shown in Figure 5.3. However, compared with other country groups, UMICs produce a lower proportion of SDG 3-related inventions and a higher proportion of inventions related to SDG 7. This pattern is driven by the role of China in developing renewable technologies.

The SDG with the second-highest percentage of inventions is SDG 7 in HICs, UMICs and LMICs, and SDG 6 in LICs. SDG 6 has also been the focus of a relatively high share of inventions in HICs, UMICs and LMICs.

This pattern is confirmed when considering the patent authority, rather than the country of the inventor.[6] SDG 3 accounts for the highest share of SDG-related inventions in all patent authorities, ranging from 47% in CNIPA to 86% at the EPO. SDG 7 accounts for the second-highest percentage of SDG-related inventions across patent authorities. CNIPA has a substantially higher proportion of inventions related to SDG 7 (20%) and SDG 6 (13%) than all other patent authorities (less than 10% for both SDGs).

The other SDGs account for a much lower share of inventions across all income groups and patent authorities. In particular, LICs did not file any patents related to SDG 2, SDG 4, SDG 13 or SDG 14.

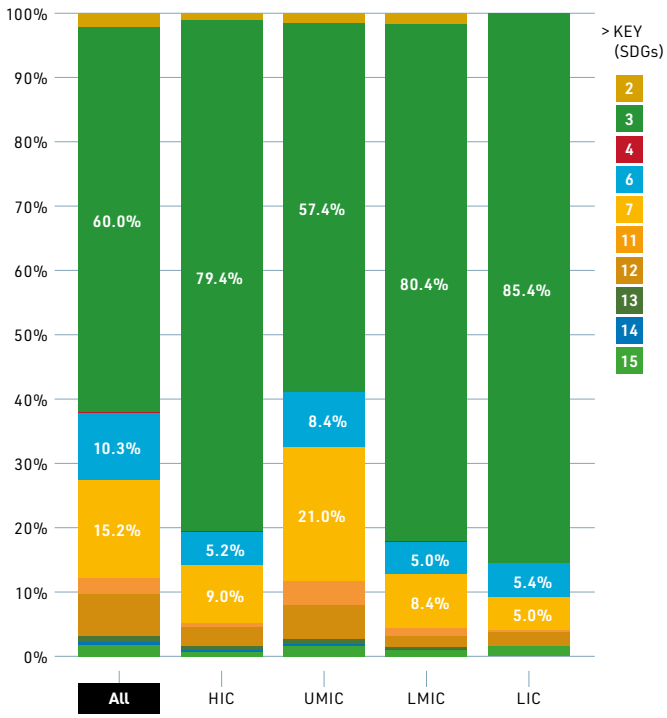
Figure 5.2 / SDG-related inventions in different income groups (2001-2017)



The graph shows the proportion of inventions that relate to any of the SDGs in the study. For each year, we show the average over a three-year period (for example, for 2002, we show inventions from 2001-2003). Figures are based on the total number of inventions in countries in each of the four World Bank income groups (2021 definition): high-income countries (HIC); upper-middle income countries (UMIC); lower-middle income countries (LMIC); low-income countries (LIC).

Figures based on PATSTAT data (CWTS version).

Figure 5.3 / Inventions related to the SDGs by country group (2001-2017)



The chart (right) shows the proportion of SDG-related inventions that relate to each SDG for each country group. Data is shown for each group of countries, defined according to World Bank income group classifications: high-income countries (HIC); upper-middle income countries (UMIC); lower-middle income countries (LMIC); and low-income countries (LIC).

Figures based on PATSTAT data (CWTS version).

Identification of SDG-related inventions: our methods

Our strategy to identify SDG-related patents builds on the methodology we used to identify SDG-related scientific publications (chapter 4).

We first retrieved all patent applications filed between 2001 and 2017 in one or more of the most important national and regional patent authorities worldwide.[7]

- African Regional Intellectual Property Organization (ARIPO)
- China National Intellectual Property Administration (CNIPA)
- European Patent Office (EPO)
- Japan Patent Office (JPO)
- Korean Intellectual Property Office (KIPO)
- United States Patent and Trademark Office (USPTO)
- World Intellectual Property Organization (WIPO)

By selecting several authorities, we minimized the possibility of bias due to the propensity of inventors to file patents in their own country. The rationale for looking beyond some of the largest patent authorities (USPTO, EPO and JPO) was to increase the chances of capturing the inventive activity of at least some lower-middle income countries (LMICs) and low-income countries (LICs).

We then identified which of these patents cited at least one SDG-related scientific publication (see chapter 4).

We also searched the titles and abstracts of patents (when an English version was available) with the same keywords used to identify SDG-related publications.[8]

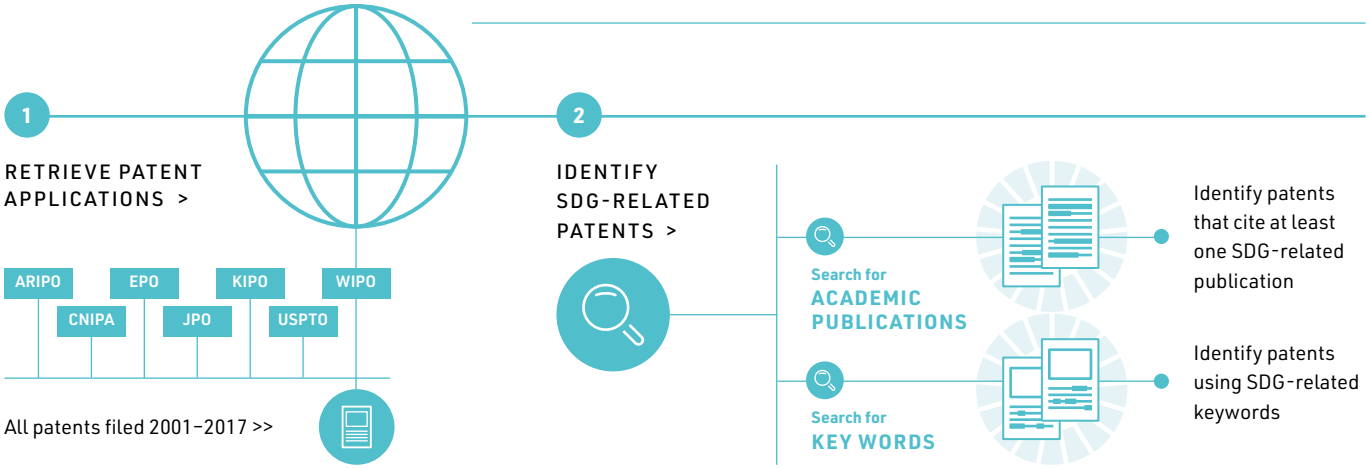
This method is purposefully restrictive. Not all patents that are relevant to SDGs will cite SDG-related publications (the number of patents citing any publications is very low, as discussed in chapter 4). Moreover, patents use technical language to describe inventions thus, even where inventions are potentially relevant for achieving the SDGs, they might not include keywords that relate directly to the goals. The results in this chapter are therefore based on a conservative interpretation of which inventions are related to SDGs. Because our study compares shares of inventions across SDGs, countries and technology fields, we believe a conservative interpretation produces a more accurate analysis than a method that privileges coverage over precision.

To avoid double-counting, we grouped SDG-related patent applications into simple 'patent families'. Each family represented a unique invention, whose protection may have been sought in multiple patent authorities. We then performed our analyses at the level of these patent families.[9]

SDGs included in the analysis

Because patented technologies are less likely to be directly relevant for the SDGs that address social and political issues – such as poverty, gender and economic inequalities, economic growth, and violent conflict – we included only the following SDGs in this analysis: 2, 3, 4, 6, 7, 11, 12, 13, 14 and 15.

This was based on our initial manual assessment of the relevance of International Patent Classification codes for each SDG.[10]



Changes in focus over time

In LICs, the main focus on SDG 3 has remained relatively stable over time. However, efforts to develop inventions related to other SDGs seem to have taken off since 2008, as shown in Figure 5.4, with some fluctuations over time due to the small number of inventions.

In LMICs, inventions related to SDG 6 and SDG 3 steadily increased up to 2012, when they started to decline. Inventions related to most other SDGs increased from around 2006/2007. Figures for LMICs are mainly driven by India, which files most of the LMIC patents.

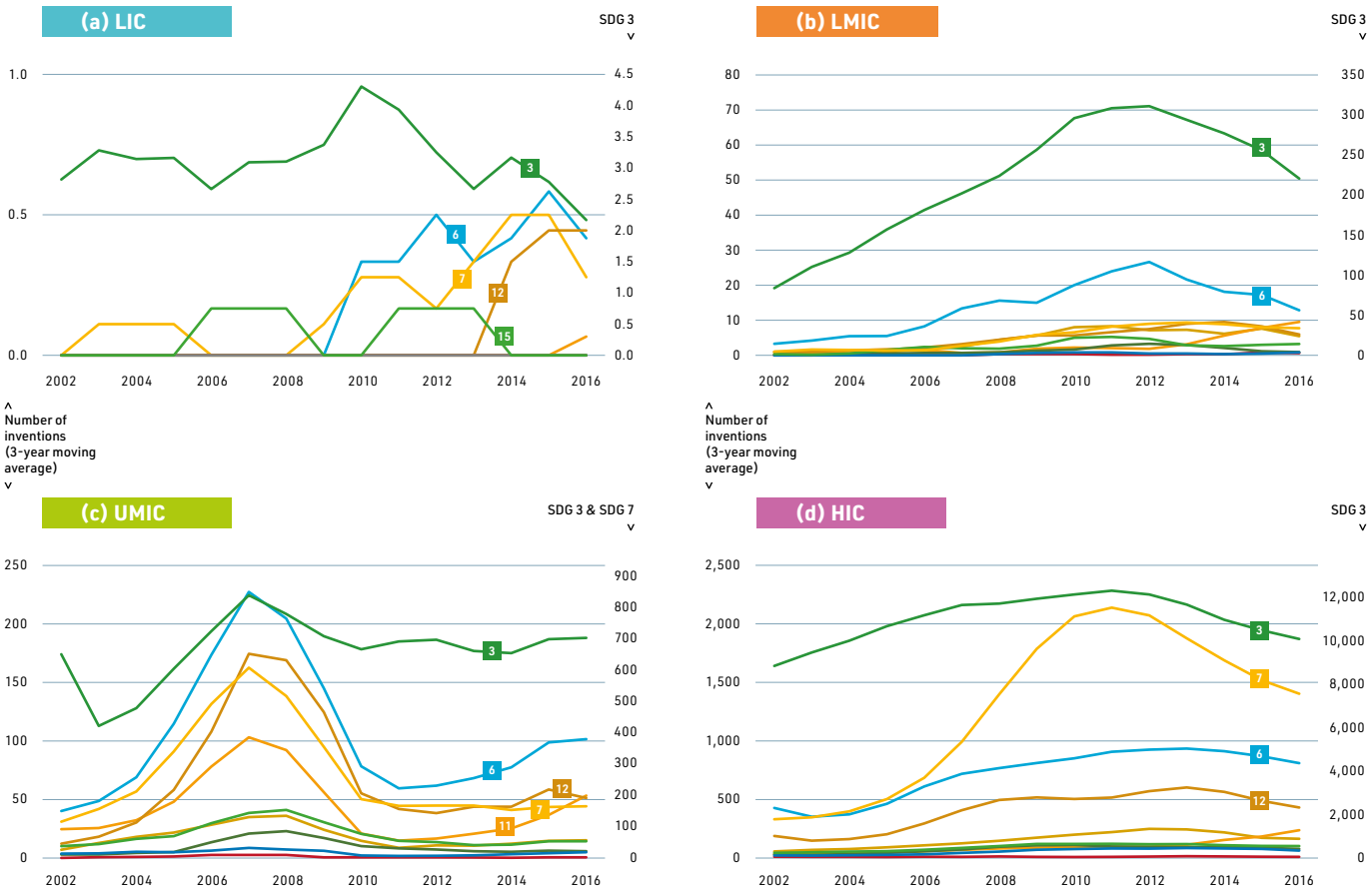
In UMICs, inventions related to many of the SDGs increased rapidly until 2006/2007, when they began to fall before rising again in recent years. These trends are clearly influenced by China,[11] which develops roughly 80% of all UMIC inventions.

Inventions in HICs are characterized by relatively stable and continuous growth until 2012. Inventions related to several SDGs have stagnated since 2014, with some (including SDGs 3, 7 and 12) declining. A notable exception is SDG 11 (Sustainable cities and communities), which has experienced sustained growth since 2013.

Countries' technological capabilities

Roughly 90% of all SDG-related inventions worldwide have been developed by inventors in HICs, while 8% were developed by inventors in UMICs. A similar concentration of inventive activity also exists within income groups. For example, 80% of SDG-related inventions in HICs were developed by just 6 of the 73 HICs, and the United States alone developed 47% of all HIC SDG-related inventions.

Figure 5.4 / Number of SDG-related inventions by income group (2002-2016)



The charts show the number of SDG-related inventions by year for each SDG. For each year we considered the average over a three-year period (for example, for 2002, we considered inventions from 2001-2003). Each panel refers to one of the four World Bank income groups: high-income countries (HIC); upper-middle income countries (UMIC); lower-middle income countries (LMIC);and low-income countries (LIC). Figures based on PATSTAT (CWTS version).

> KEY: **Sustainable Development Goals**
SDG 2 Zero hunger
SDG 3 Good health and well-being
SDG 4 Quality education
SDG 6 Clean water and sanitation
SDG 7 Affordable and clean energy
SDG 11 Sustainable cities and communities
SDG 12 Responsible consumption and production
SDG 13 Climate action
SDG 14 Life below water
SDG 15 Life on land

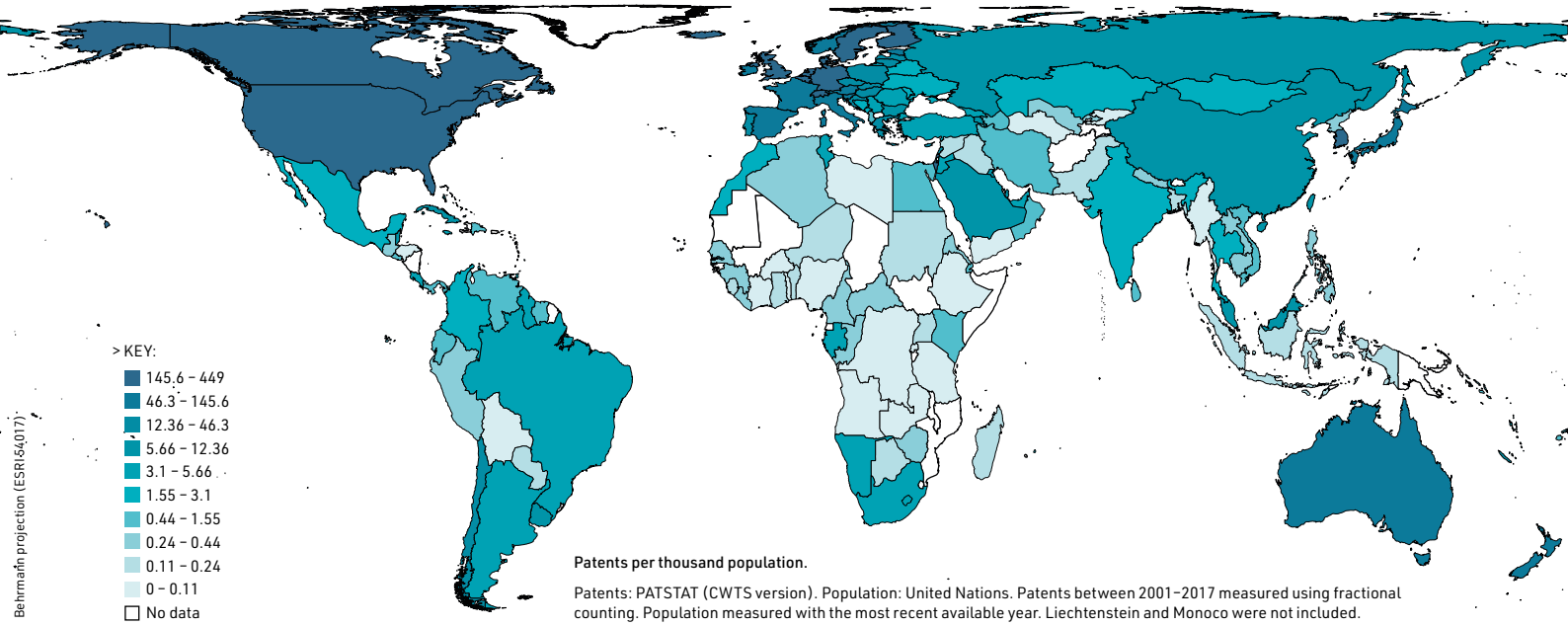
The disparity between countries is even more extreme in middle-income countries. China alone, for example, developed around 80% of the SDG-related inventions in UMICs, while India accounts for roughly 85% of the SDG-related inventions from LMICs. Details of SDG-related inventions by country can be found in Appendix 3.

When we consider inventions per capita (see Figure 5), smaller countries such as Switzerland, Denmark, Singapore, Israel and Sweden stand out in terms of their SDG-related inventive activity. However, the most scientifically and technologically advanced countries, including the United States, Canada, Germany, France, United Kingdom, Australia, Japan and South Korea, also produce a high number of inventions per capita.

Collaborations between countries

Collaborations between two or more countries account for only 13% of all those SDG-related inventions for which we have information about the inventor's country. As shown in Table 5.1a, roughly 91% of all collaborations involve HICs and/or UMICs, while 83.1% are exclusively between HICs. The

Figure 5.5 / SDG-related inventions per capita (2001-2017)



Patents per thousand population.

Patents: PATSTAT (CWTS version). Population: United Nations. Patents between 2001–2017 measured using fractional counting. Population measured with the most recent available year. Liechtenstein and Monoco were not included.

Do patents and the patent system contribute to or prevent the achievement of SDGs?

Patented inventions can contribute to achieving the SDGs in two key ways:

- Through the use of knowledge embodied in patents to commercialize products or services
- By disseminating technical information through patent documents, thus inspiring subsequent inventions (technical information is freely available for most patent applications and granted patents)

On the other hand, the patent system can prevent the use of inventions by anyone who does not have patent rights. This potentially prevents many people from benefiting from protected inventions. Such barriers became prominent, for example, during the AIDS crisis in South Africa in the 1990s and during the contemporary COVID-19 pandemic.[12, 13]

Moreover, patents do not necessarily equate to innovation. Many inventions protected by patents have not yet been translated into new products or services. Instead, many patented inventions represent, at best, promising technologies in an embryonic status, which may take a long time to develop. Development often requires substantial financial investment, usually by private firms whose objectives do not always align with SDGs.

In the rare cases that products or services based on SDG-related inventions are brought to market, there remains the serious challenge of making these products available in countries that currently lack basic infrastructures.

Table 5.1a / Collaborative SDG-related inventions within and between each country group (as a percentage of all collaborative inventions), 2001-2017

COUNTRY GROUPS	HIC	UMIC	LMIC	LIC
HIC	83.1%			
UMIC	7.9%	3.7%		
LMIC	3.3%	0.3%	1.5%	
LIC	0.1%	0%	0%	0%
TOTAL	29,609.3 (84.6%)	3,731.6 (10.7%)	1,602.9 (4.6%)	47.8 (0.1%)

Table 5.1b / Collaborative SDG-related inventions within and between each country group (as a percentage of collaborative inventions within each income group), 2001-2017

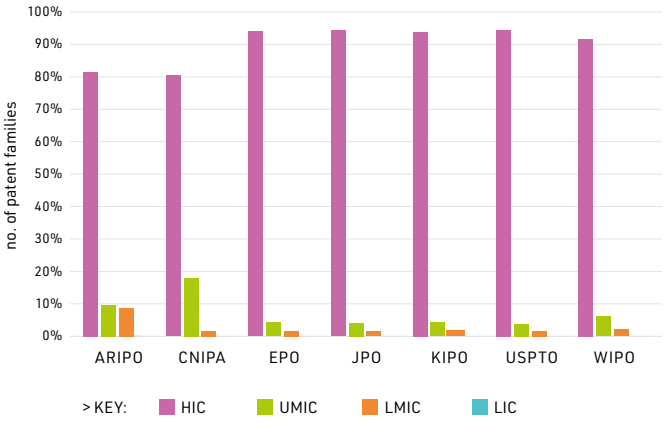
COUNTRY GROUPS	HIC	UMIC	LMIC	LIC
HIC	88.0%	8.4%	3.5%	0.1%
UMIC	66.7%	31.0%	2.2%	0.1%
LMIC	65.2%	5.1%	29.6%	0.0%
LIC	65.2%	7.7%	0.6%	30.0%

1a: This shows what proportion of all collaborative inventions occurred within (diagonal) and between (off the diagonal) country groups. For example, an invention co-developed by authors in the USA and the UK (both HICs) would contribute to the percentage in the top left cell. An invention co-developed by inventors in the USA and Brazil (between HIC and UMIC) would contribute to the second row of the first column. The sum of all cells equals 100%, that is, all the inventions co-developed by two or more countries (based on the country of the inventor).

1b: This shows what proportion of the collaborations within each country group occurred within and between country groups. For example, the first row shows the country groups involved in all collaborative inventions undertaken by HIC. Each row total adds up to 100%.

Figures are based on PATSTAT data (CWTS version), 2001-17.

Figure 5.6 / SDG-related inventions by income level of the country of the inventors



The chart shows, for each of the patent authorities considered in the study, the percentage of SDG-related inventions filed by each of the country groups: HICs in blue, UMICs in orange, LMICs in grey and LICs in yellow.

Figures are based on PATSTAT data (CWTS version), 2001-17.

most frequent collaborations between different income groups involve HICs and UMICs (7.9%), followed by those involving HICs and LMICs (3.3%). These collaboration patterns indicate that the less scientifically and technologically developed countries rarely participate in developing joint inventions.

Table 1b shows that HICs are involved in most collaborative inventions produced in all other country groups. The majority (more than 60%) of collaborations in UMICs, LMICs and LICs involve HICs, with very few collaborations between LICs, LMICs or UMICs. As noted, these collaborations represent a low number of inventions as SDG-related inventive activity is highly concentrated in HICs and UMICs.

LICs and LMICs may gain knowledge and technological capabilities through their collaborations with HICs. However, such collaborations may also indicate a dependence on the focus and priorities of HICs, which may make it less likely that the inventions and related knowledge will address LICs' needs.

Inventions by country group across patent authorities

Dominance by richer nations is confirmed by the evidence that HICs generate more than 80% of SDG-related inventions in most patent authorities, including ARIPO (Figure 5.6). CNIPA is the only exception, in part due to the large percentage of inventions at this office for which the inventor's country is not available (58%).[14] UMIC inventive activity is more modest. UMICs generated around 18% of the SDG-related inventions at CNIPA, and between 4% and 10% in other authorities.[15, 16]

The inventive activity of LICs is hardly visible in any patent authority. These countries were involved in developing just 0.1% of the inventions registered at ARIPO, and their activity is even lower in the other patent authorities.

Technologies underpinning SDG-related inventions

Our analysis of the technologies that underpin SDG-related inventions (Figure 5.8) is based on the technology classification developed by Ulrich Schmoch,[17] which maps the International Patent Classification in 35 technology fields. The predominant technical fields relating to each of the SDGs are shown in Figure 5.7. In the next subsection we investigate the extent to which technology fields are related to different SDGs.

Figure 5.7 / Some of the main technology fields associated with each SDG

SDG 2: Other special machines (inc. food productionand harvesting) and **Basic materials chemistry** (inc. fertilizers, pesticides and herbicides)

SDG 3: Pharmaceuticals (preparations for medical purposes) and **Biotechnology**

SDG 4: Control (inc. appliances and devices designed for education, teaching and training)

SDG 6: Environmental technology (inc. filters, waste disposal, water cleaning, waste combustion or noise-absorption walls)

SDG 7: Electrical machinery, apparatus, energy (including non-electronic) and **Thermal processes and apparatus**

SDG 11: Civil engineering (inc. locks, plumbing etc); **Environmental technology**; **Control**; and **Digital communication**

SDG 12: Environmental technology and **Materials, metallurgy** (including metals, ceramics, glass)

SDG 13: Basic materials chemistry: engines, pumps, turbines (including non-electrical engines); and **Other special machines**

SDG 14: Other special machines and **Environmental technology**

SDG 15: Other special machines and **Basic materials chemistry**.

Figure 5.8 / Breakdown of inventions by technology field in each SDG

Technology field	SDG 2	SDG 3	SDG 4	SDG 6	SDG7	SDG11	SDG 12	SDG 13	SDG 14	SDG 15
Analysis of biological materials										
Audiovisual technology										
Basic communication processes										
Basic materials chemistry										
Biotechnology										
Chemical engineering										
Civil engineering										
Computer technology										
Control										
Digital communication										
Electrical machinery, apparatus, energy										
Engines, pumps, turbines										
Environmental technology										
Food chemistry										
Furniture, games										
Handling										
IT methods for management										
Machine tools										
Macromolecular chemistry, polymers										
Materials, metallurgy										
Measurement										
Mechanical elements										
Medical technology										
Micro-structural and nano-technology										
Optics										
Organic fine chemistry										
Other consumer goods										
Other special machines										
Pharmaceuticals										
Semiconductors										
Surface technology, coating										
Telecommunications										
Textile and paper machines										
Thermal processes and apparatus										
Transport										

The figure shows the relative relevance of each of the 35 technology fields for each of the SDGs, based on the number of patent families within each SDG that relate to that technology. In darker blue are the technology areas that are most relevant for the SDG. For instance, for SDG3, the most relevant technology areas are pharmaceuticals and biotechnology. In pale blue are those technology areas which appear less relevant for each of the SDGs. **Colours are not comparable between SDGs.** Figures are based on PATSTAT data (CWTS version), 2001-17. The correspondence between the International Patent Classification and the 35 technology fields is fully integrated in PATSTAT.

> KEY:
: Most relevant
Least relevant :

Synergies across SDGs in inventive activities

We investigated the connections between the different SDG-related inventions in two ways. First, we analysed how many inventions relate to more than one technology field (Figure 5.9) and, second, how many inventions relate to more than one SDG.

Inventions related to more than one technology field

We identified three main clusters of technology fields, based on co-occurrences of inventions in different technologies. The clusters are as follows:

1. **Biotech** (including all pharmaceutical production)
2. **Chemistry** (food and basic)
3. **Engineering** (from machines to computers, including medical and environmental technologies)

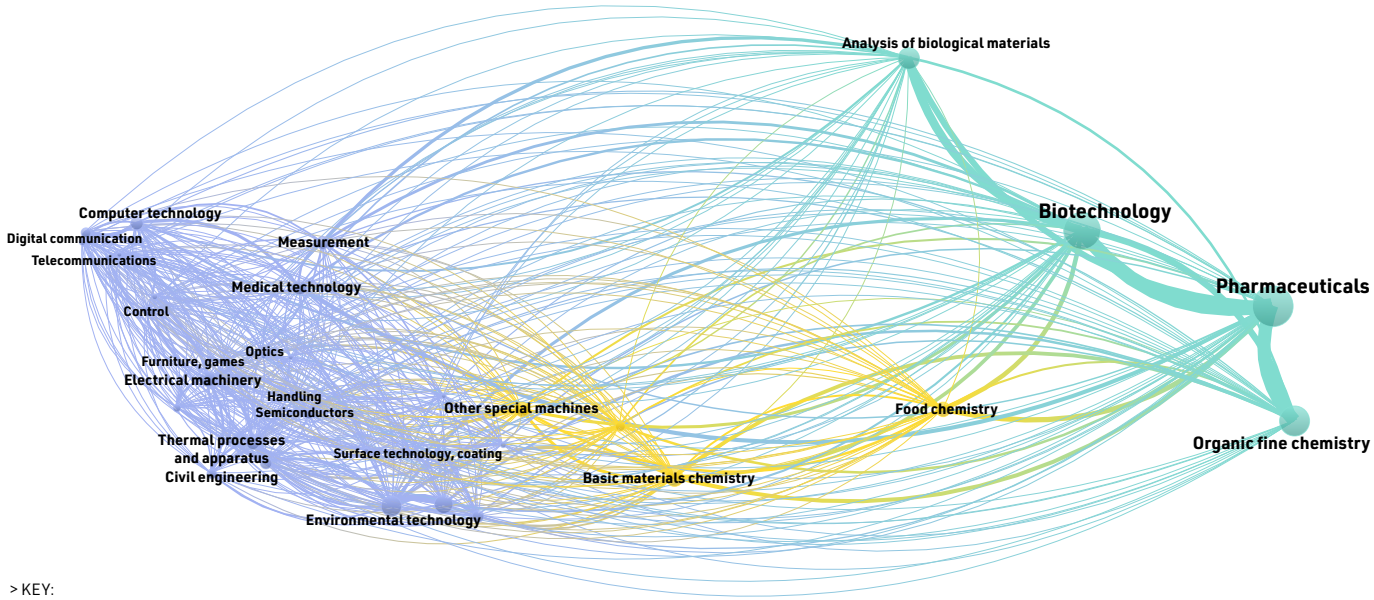
Due to the high number of inventions related to SDG 3 (Good health and well-being), many SDG-related inventions involve pharmaceuticals and biotechnology, analysis of biological materials and organic fine chemistry. Inventions related to SDG 3 often combine all three of these technologies. Far fewer SDG 3-related inventions involve the other technology fields such as medical technologies and food chemistry.[18]

Inventions related to other SDGs also combine different technology fields. For instance, inventions linked to SDG 2 (Zero hunger) tend to combine food chemistry and basic material chemistry for soil productivity, as well as special machines for agriculture and biotechnology for seed breeding. Inventions related to SDG 11 (Sustainable cities and communities) tend to combine even more technologies, including civil engineering, transport, telecommunications, environmental technologies, information technologies and control systems for smart cities.[19]

Inventions related to more than one SDG

We also studied the few inventions (3%) that are related to more than one SDG (see Figure 5.10). Developing inventions that relate to more than one SDG may help inventors to consider synergies and tensions between the goals. Figure 5.10 shows the strength of the relationships between SDGs: for example, SDG 4 appears isolated from other SDGs (except for weak connections with SDG 3, SDG 7 and SDG 15), while inventions related to SDG 3 are more likely to be connected with many other SDGs.

Figure 5.9 / Co-occurrence of technology fields across inventions



> KEY:

- **Biotech** (includes all pharmaceutical production)
- **Chemistry** (food and basic)
- **Engineering** (from machines to computers, including medical and environmental technologies)

The figure shows the co-occurrence of the 35 technology fields across SDG-related inventions. The size of each node is proportional to the number of inventions related to that technology. The thickness of the lines is proportional to the number of inventions related to two technology fields simultaneously. Technology fields of the same colour are more similar than technology fields of a different colour. This clustering has been created with the Leiden cluster algorithm implemented in VoSviewer. Appendix 3 includes figures for each co-occurrence network, showing how inventions related to each of the SDGs are linked to the 35 technology fields.

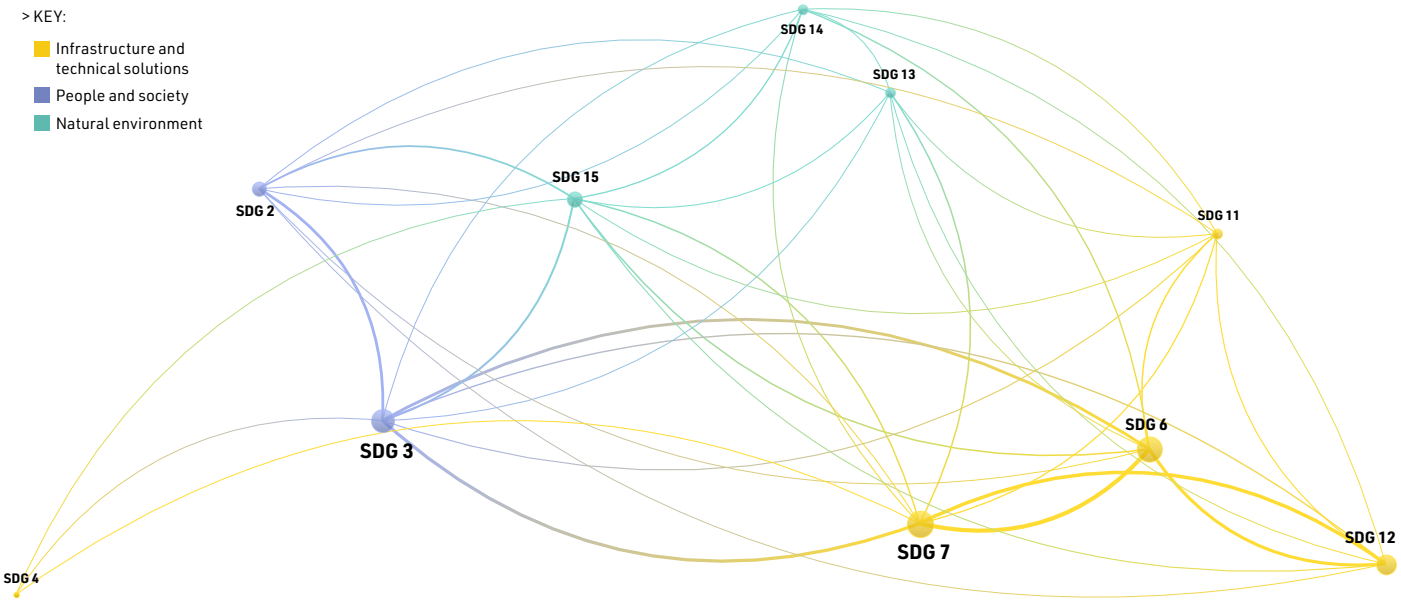
The figure is based on PATSTATdata (CWTS version), 2001-17. The correspondence between the International Patent Classification and the 35 technology fields is fully integrated in PATSTAT.

The analysis reveals three small clusters of related SDGs, similar to those found for research publications (chapter 4).

- The first cluster focuses on infrastructures and technical solutions. It contains inventions related to SDG 7 (Affordable and clean energy), SDG 6 (Clean water and sanitation), SDG12 (Responsible consumption and production) and SDG 11 (Sustainable cities and communities).
- The second cluster connects inventions related to people and society, linked to SDG 3 (good health and well-being) and SDG 2 (zero hunger).
- The third cluster contains inventions related to the natural environment, which link SDG 13 (Climate action), SDG 14 (Life below water) and SDG 15 (Life on land).

Despite these interconnections between SDGs, only a very small number of patents are related to more than one SDG. This casts doubt on the ability of inventions to tackle the complexity of synergies and tensions between the SDGs.

Figure 5.10 / Co-occurrence of SDGs among inventions



The figure shows the co-occurrences of SDGs among inventions. Each node identifies one SDG. The size of the node is proportional to the total number of inventions related to that SDG which are also related to at least one other SDG.

The thicker the line between two SDG nodes, the more inventions are related to both SDGs. SDGs of the same colour are more similar than SDGs of a different colour. This clustering has been created with the Leiden clustering algorithm, implemented in VoSviewer.

Figures are based on PATSTAT data (CWTS version), 2001-17.

Notes

1. European Union, 2021.
2. https://www.wipo.int/sdgs/en/story.html
3. Appendix 3, Table A.3.1.
4. Appendix 3, Figure A.3.1.
5. Appendix 3, Table A.3.1.
6. Appendix 3, Figure A.3.2.
7. We used the 2020 Autumn Edition of PATSTAT.
8. Chapter 4 and related Appendix 2.
9. Patent families are sets of patents that are filed in more than one country/office, to protect a single invention in several countries.
10. Appendix 3, section 3.1 details the procedure used to select SDG-related inventions.
11. There is a similar pattern when all inventions (not only those relating to SDGs) are considered, with a peak in 2007 and a decrease until 2010. However, this trend most likely reflects a lack of data about the inventor for a large percentage of patent families at the CNIPA.
12. https://www.bloomberg.com/news/articles/2021-05-11/aids-drugs-in-south-africa-shows-precedent-for-overriding-patents-on-medications
13. https://www.nature.com/articles/d41586-021-01242-1
14. Appendix 3, section 3.4.
15. The activity of UMICs at CNIPA is most likely underrepresented in this study , due to the large percentage of inventions at this office for which the country of the inventor is not available. Chinese inventors are much more active in their domestic patent office.
16. de Rassenfosse, G., & Seliger, F., 2021.
17. Schmoch, U., 2008.
18. Appendix 3, Figure A.3.4.
19. Appendix 3, Figure A.3.8.