CAS Chemistry Research Report

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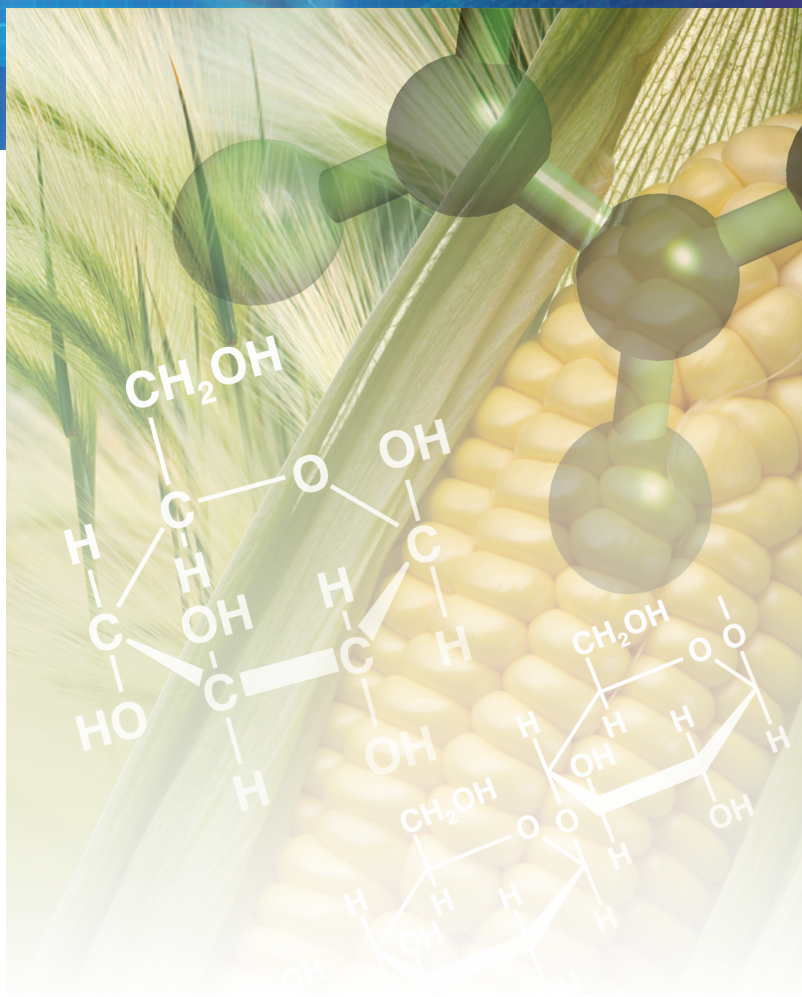
China Takes Lead in the Commercialization of Bioethanol



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Summary

In 2009, the United Nations Environment Programme (UNEP) reported that global ethanol production for transport fuel had tripled between 2000 and 2007, from 17 billion to more than 52 billion liters.[1] During the same timeframe, published scientific research pertaining to bioethanol more than doubled. Together, these trends demonstrate an increasing interest in the commercialization of biofuels around the world.

In the first CAS Chemistry Research Report, researchers from CAS, a division of the American Chemical Society and the world's authority for chemical information, analyzed major trends in published research related to bioethanol production and found that scientific research on second-generation biofuels—fuels derived from non-food sources—has grown more than any other category of biofuel research throughout the last 40 years.

Furthermore, while the United States leads all other nations in the publication of scientific journal literature regarding bioethanol, China is the global leader in the patenting of bioethanol discoveries, demonstrating an emerging leadership position in the commercialization of bioethanol.

Background

UNEP defines biofuels as "combustible materials directly or indirectly derived from biomass, commonly produced from plants, animals and micro-organisms but also from organic wastes."[1]

Bioethanol is perhaps the earliest example of biofuel technology used in transportation. In 1908, Henry Ford introduced the Ford Model T, an automobile originally designed to run on corn-derived ethanol. As the auto industry adopted fossil fuels, interest in bioethanol and other biofuels for transportation diminished and nearly disappeared until the last quarter of the 20th century.

New technologies have since improved and increased bioethanol production. According to UNEP, not only did bioethanol production triple from 2000 to 2007, but "global use of bioethanol and biodiesel will nearly double from 2005-2007 to 2017. Most of this increase will probably be due to biofuel use in the USA, the EU, Brazil and China." [1]

While the dramatic increase in global production of bioethanol is attributable, in part, to new processing technology, it also reflects a diversification of the starting material—or feedstock—used to derive bioethanol. In addition to corn, today's bioethanol is derived from such feedstock as sugar cane, lignocellulosic biomass, and algae.

Biofuels, including bioethanol, are commonly grouped into first-, second-, and third-generations according to the source of the feedstock and the technology required to process the feedstock into fuel.[1] These biofuel generations are defined by UNEP as follows:

- **First-generation biofuels – Derived from food sources (e.g., corn, sugar cane, cereals, sugar beets)**
- **Second-generation biofuels – Derived from non-food sources (e.g., stalks of wheat, corn stover, wood)**
- **Third-generation biofuels – Derived from algae**

Using these definitions, CAS analysts examined overall trends in global scientific research regarding bioethanol production from 1969 to 2009 in the CAS databases, the world's most authoritative and comprehensive collection of chemistry-related information.

The following report examines the growth of first-, second-, and third-generation bioethanol research over the last four decades and identifies the nations leading the world in the exploration and commercialization of renewable fuels.

Second-generation bioethanol research soars nearly 600 percent in a decade.

Analysis of the world's bioethanol research published between 1969 and 2009 indicates that second-generation bioethanol was the most frequently studied category of bioethanol throughout the last 40 years. While published research related to all types of bioethanol has increased during the last four decades, and particularly over the last 10 years, publication of research pertaining to second-generation bioethanol grew 586 percent between 2000 and 2009 (Figure 1).

This growth demonstrates a surge of interest in the production of biofuels derived from non-food sources, which is widely considered more sustainable, affordable, and environmentally friendly compared to biofuels derived from food sources such as corn, sugar beets, or cereals.

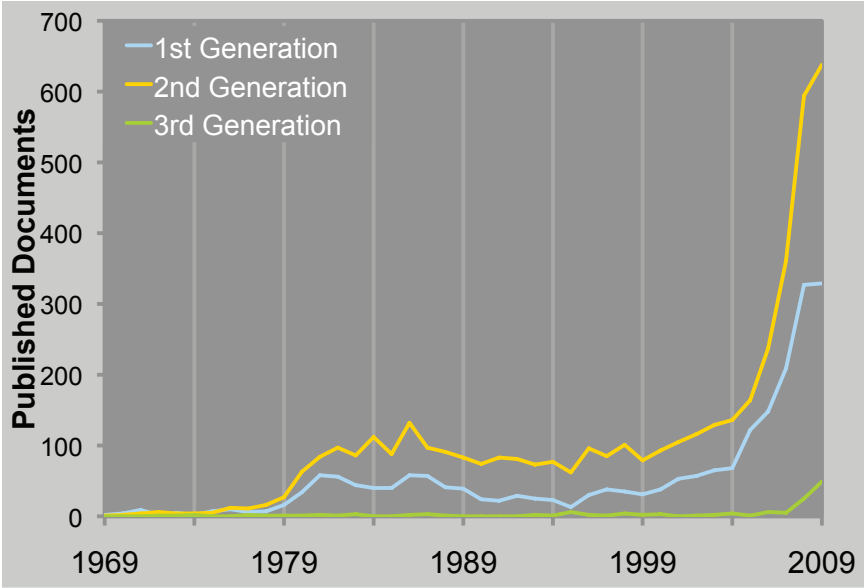
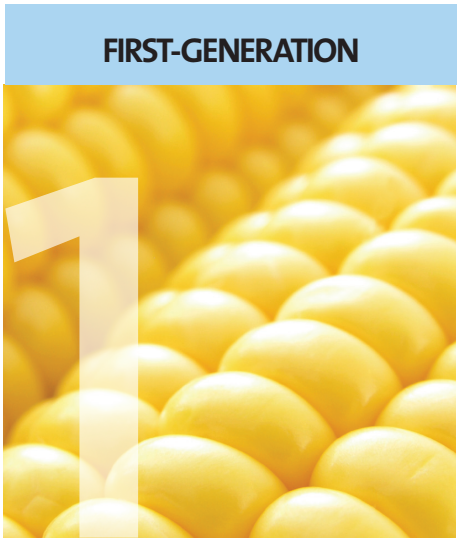
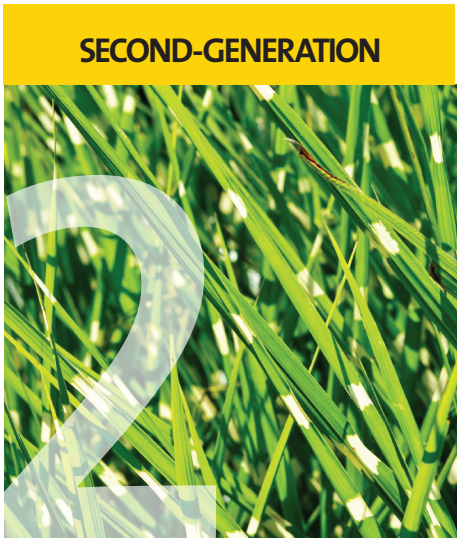
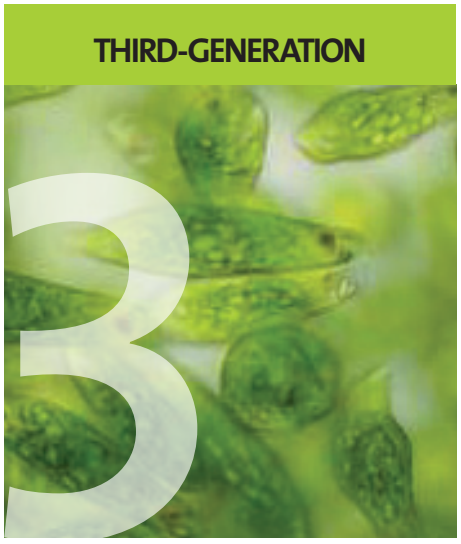


Figure 1 - Patent and journal literature pertaining to second-generation bioethanol research was published most frequently from 1969 to 2009.







Patenting of bioethanol research accelerates as countries began to commercialize research.

When journal articles (Figure 2) and patent documents (Figure 3) are analyzed separately and normalized over time as a percentage of all ethanol production-related research, it is apparent that while bioethanol research was more commonly published in journal articles during the last 40 years, the patenting of research has accelerated in the last decade.

Patent documents pertaining to second-generation bioethanol rose more dramatically than the other categories over the last decade, increasing 2,341 percent between 2000 and 2009.

This shift in publication methods indicates that research organizations are increasingly choosing to stake claim on intellectual property regarding second-generation bioethanol research by patenting their discoveries, rather than disseminating research information via journal articles. The move toward patenting bioethanol research indicates an increasing global tendency for researchers to monetize and commercialize their discoveries.

According to the International Energy Agency, "second-generation biofuels are not yet produced commercially, but a considerable number of pilot and demonstration plants have been announced or set up in recent years, with research activities taking place mainly in North America, Europe and a few emerging countries (e.g. Brazil, China, India and Thailand)."[2]

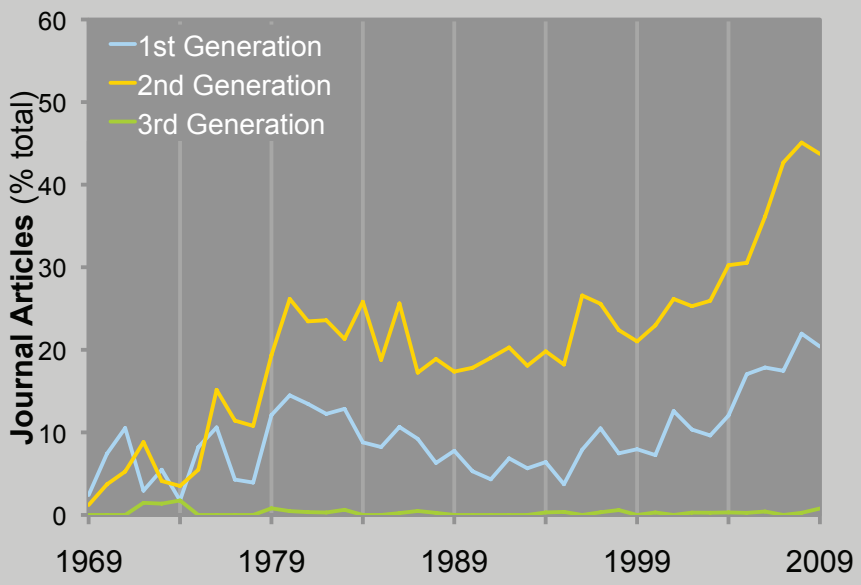


Figure 2 - Second-generation bioethanol journal articles accounted for a quarter of all journal articles related to ethanol production in the past 40 years.

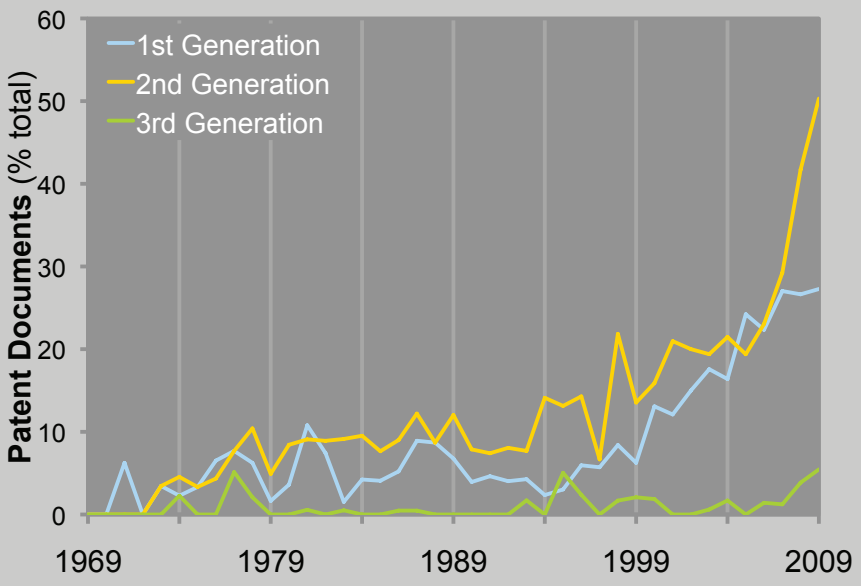


Figure 3 - Patenting of second-generation bioethanol research has accelerated rapidly since 2005.

While the United States is the primary publisher of bioethanol journal articles, China has emerged as the world's leader in commercializing bioethanol research.

In 2009, researchers from the United States led all nations in the publication of journal articles about both first- and second-generation bioethanol research (Figures 4 and 5). Yet in the same year, the State Intellectual Property Office (SIPO) of the People's Republic of China ranked well ahead of the United States Patent and Trademark Office (USPTO) in the publication of patent documents related to first- and second- generation bioethanol (Figures 6 and 7), despite the U.S. preeminence in journal articles during the same year.

The 2009 patent and journal rankings represent a distinct shift from 2003, when the U.S. ranked first in patents and second in journal articles.

This shift in patent publication most reflects China's greater interest in the commercialization of bioethanol research.

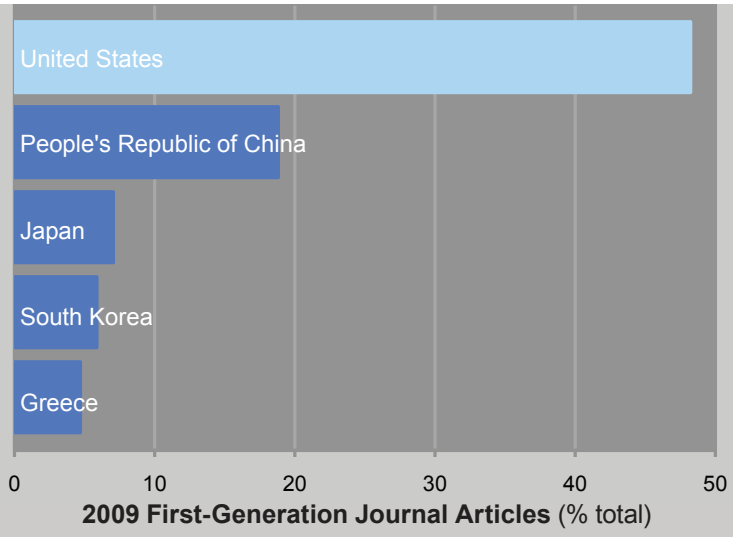


Figure 4 - Researchers from the United States and the People's Republic of China were the top two contributors of first-generation bioethanol journal articles in 2009.

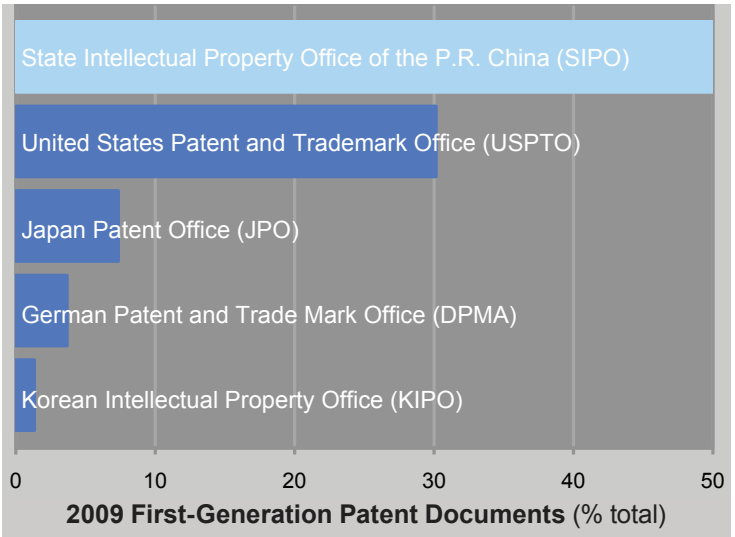


Figure 6 - SIPO and the USPTO were the top two publishers of first-generation bioethanol patent documents in 2009.

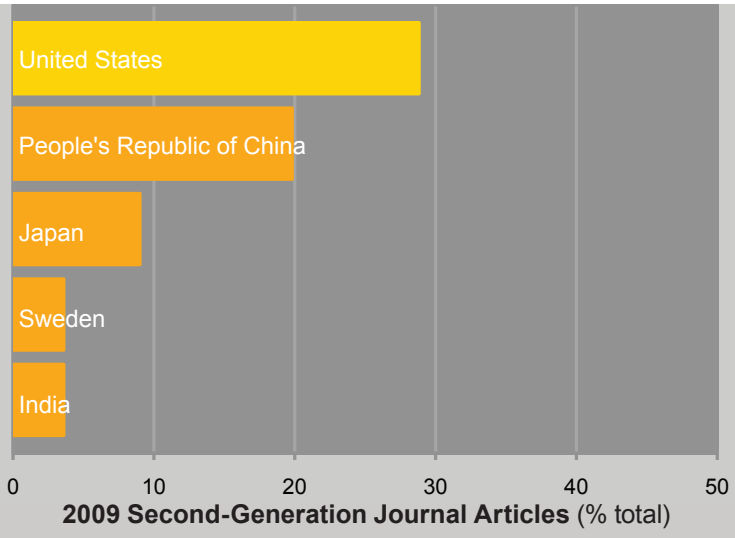


Figure 5 - Researchers from the United States and the People's Republic of China were the top two contributors of second-generation bioethanol journal articles in 2009.

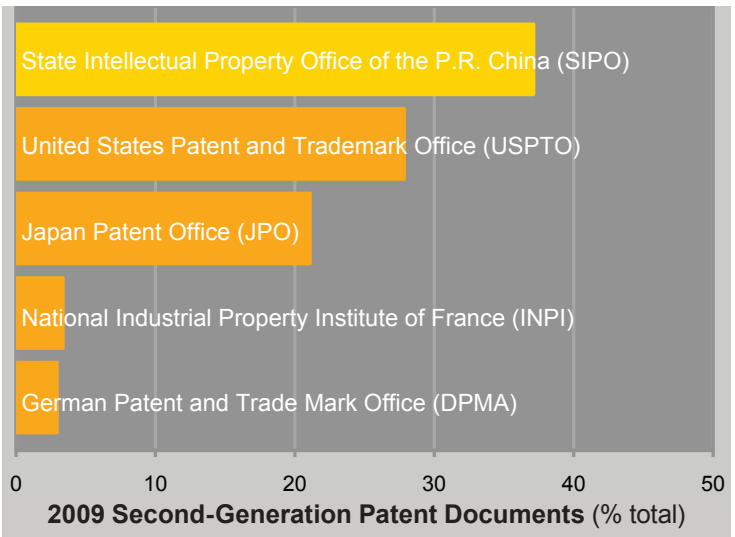


Figure 7 - SIPO and the USPTO were the top two publishers of second-generation bioethanol patent documents in 2009.

While comparatively limited, third-generation bioethanol research has increased rapidly since 2007, with the United States and Japan leading discovery.

Research into algae-based bioethanol remains limited compared to first- and second-generation fuels. However, the total number of published patent documents and journal articles related to third-generation bioethanol increased substantially in 2008 and 2009, with patent documents accounting for most of the growth. The total number of published research documents examining third-generation bioethanol grew from just two documents in 1999 to 49 in 2009 (Figure 8).

Given the relatively small number of documents involved, CAS considered the last 40 years as a group in analyzing geographic research output about third-generation bioethanol. During this timeframe, the United States led the world in both journal and patent literature pertaining to third-generation bioethanol, with Japan also emerging as a strong player in this research space (Figures 9 and 10).

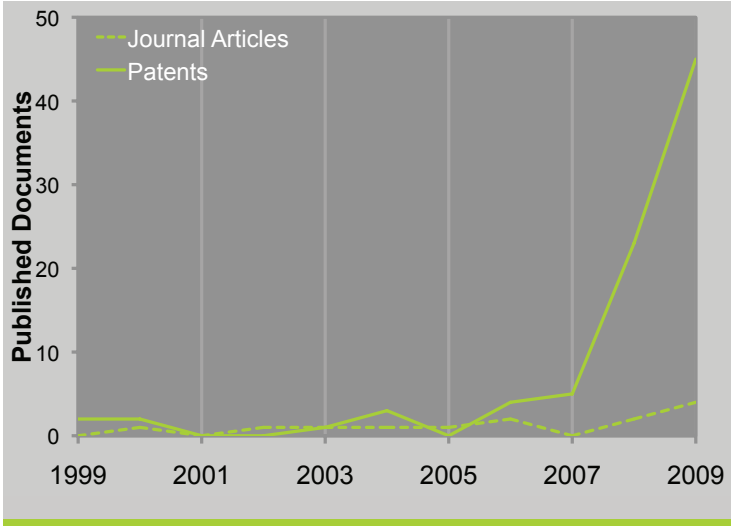


Figure 8 - Published research documents regarding third-generation bioethanol increased dramatically from 2007 to 2009.

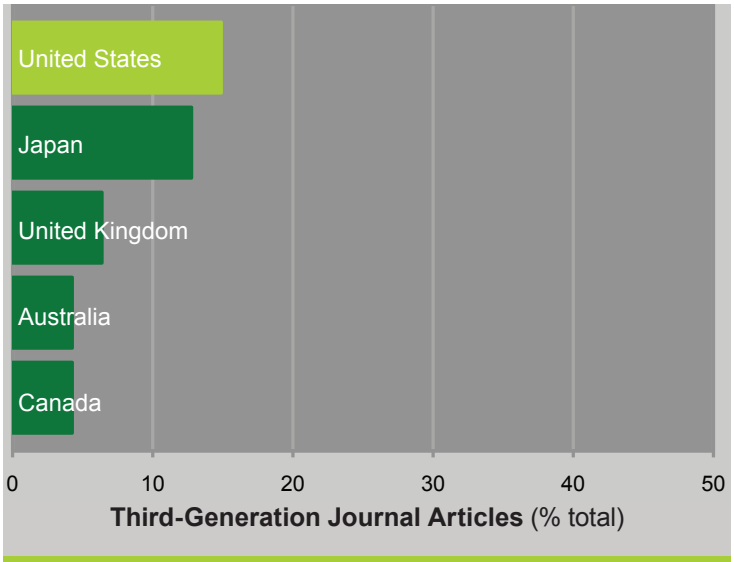


Figure 9 - Chinese researchers were not among the top five contributors of third-generation bioethanol journal articles published from 1969-2009.

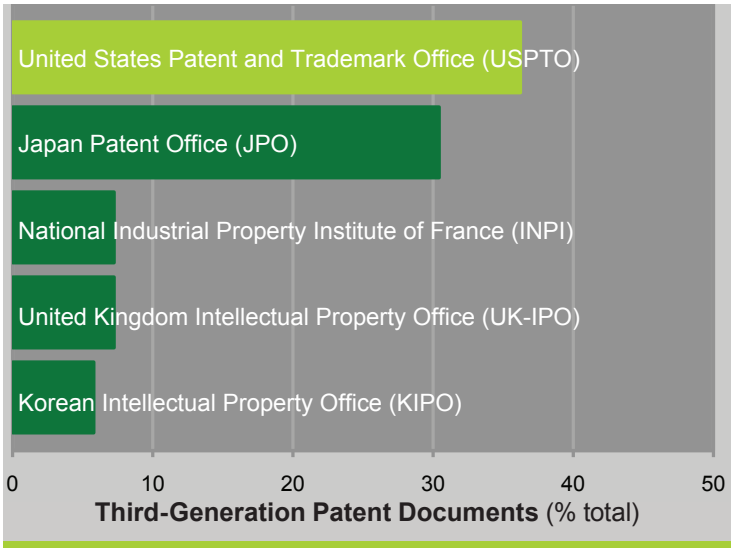


Figure 10 - The USPTO led in third-generation bioethanol patent documents published from 1969-2009.

References

1. International Panel for Sustainable Resource Management, *Towards Sustainable Production and Use of Resources: Assessing Biofuels.* UNEP, 2009.
2. International Energy Agency, *Sustainable Production of Second Generation Bio-Fuels: Potential and Perspectives in Major Economies and Developing Countries.* 2010.

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