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NATIONAL LABORATORY

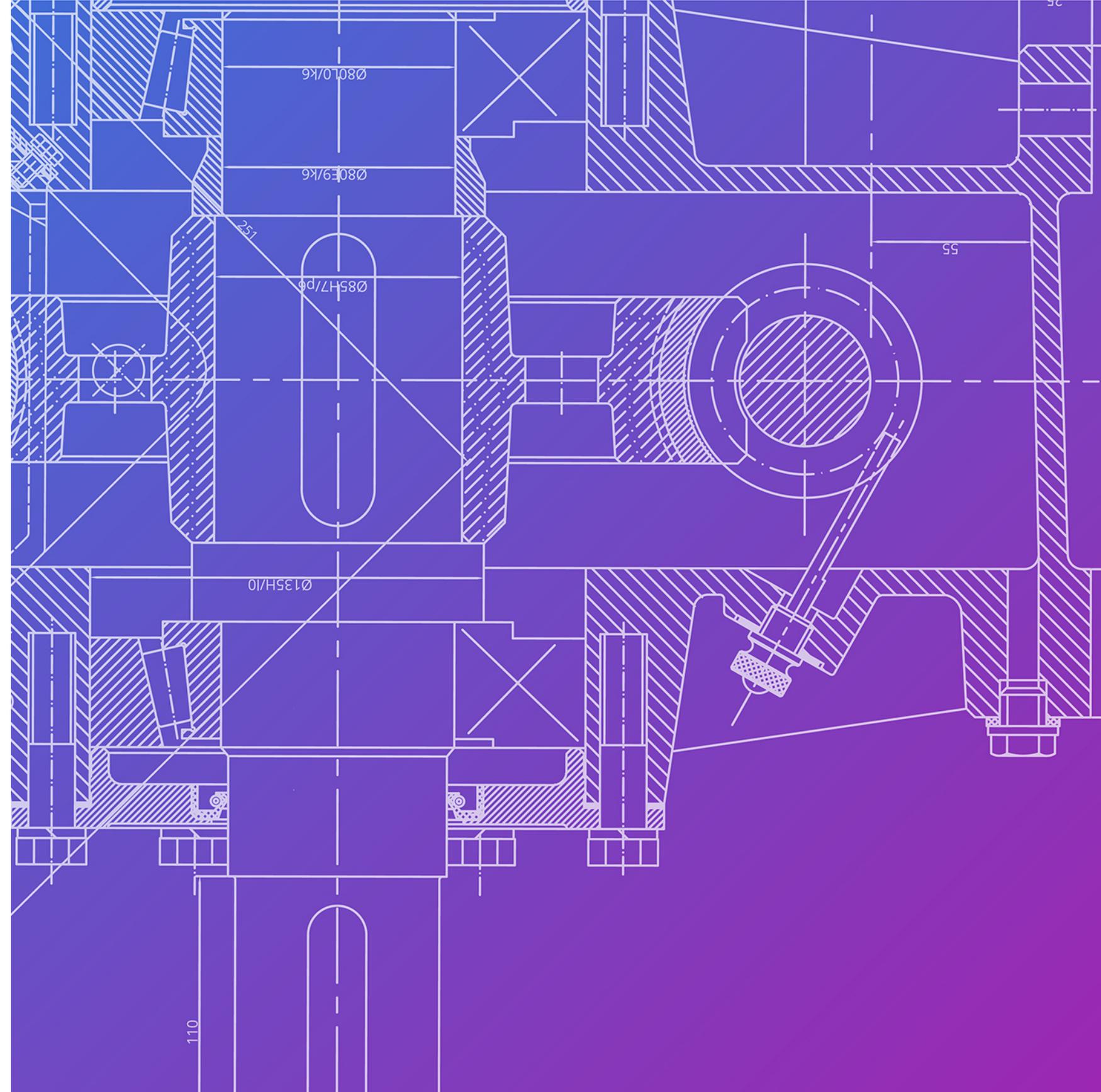
2019 Patent Analysis for the U.S. Department of Energy Hydrogen and Fuel Cell Technologies Office

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PNNL-SA-156721

U.S. DEPARTMENT OF
ENERGY **BATTELLE**

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HFTO Patent Tracking – Purpose

Identify and document research and development (R&D) innovations and intellectual property resulting from Hydrogen and Fuel Cell Technologies Office (HFTO) support as an indicator of R&D program impact

- HFTO-funded project led by PNNL to track patent applications and patent awards
- PNNL patent tracking and analysis identifies, analyzes, and characterizes U.S. patent applications and patent awards related to HFTO-funded R&D
 - Patent applications and patent awards
 - Distribution (organization type, subprogram; e.g., fuel cells)
 - Trends over time
 - Patent status (active, licensed, no longer pursued)

HFTO Patent Tracking – Approach

- Beginning in FY2008, PNNL has conducted an annual review of patents related to fuel cells, hydrogen production, delivery, and storage resulting from HFTO R&D funding*
- In FY2017 the scope was expanded to include analysis of patent applications resulting from HFTO-funded R&D
 - Patent data has been tracked from the inception of DOE activities in 1977
 - Patent application has been tracked since 2001 (1st year available online)
- Until FY2016 this project also tracked commercial technologies resulting from HFTO R&D funding

* Reports available at <https://www.energy.gov/eere/fuelcells/market-analysis-reports#mkt-pathways>. HFTO funding includes funding through the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs.

HFTO Patent Tracking – Results Summary

**1,023 patent applications and 1113 patent awards
related to HFTO-funded R&D through 2019**

- **1113 patent awards resulting from HFTO-funded R&D (1977–2019)**
 - 582 fuel cell patents (52%)
 - 397 hydrogen production and delivery patents (36%)
 - 134 hydrogen storage patents (12%)
 - 28% of all patents are available for license or licensed
 - 43% are actively being used in R&D
- **Three types of organizations received patents**
 - National laboratories (35%) lead in hydrogen storage R&D
 - Universities (18%) research activities primarily in fuel cells, hydrogen and production R&D
 - Private companies (47%) lead in fuel cell and hydrogen production and delivery R&D
- **1,023 patent applications resulting from HFTO-funded R&D (2001–2019)***
 - 559 fuel cell patent applications (55%)
 - 332 hydrogen production and delivery patent applications (32%)
 - 132 hydrogen storage patents (13%)
 - 86% of HFTO-funded R&D-related patent applications receive patent awards
 - Average time elapsed between filing and receiving patent award (patent lag time) 37 months

* Note: Published patent application data is only available from March 2001

Patent Tracking - Process

- Gather patent application and award information from HFTO Annual Progress Reports and from HFTO project points of contact (POC)
- Compile patent lists by organization, year, subprogram
- Contact organization or POCs for patent application/award status verification
- Compile patent application/award details from online patent databases

Patent Tracking – Patent Information Sources

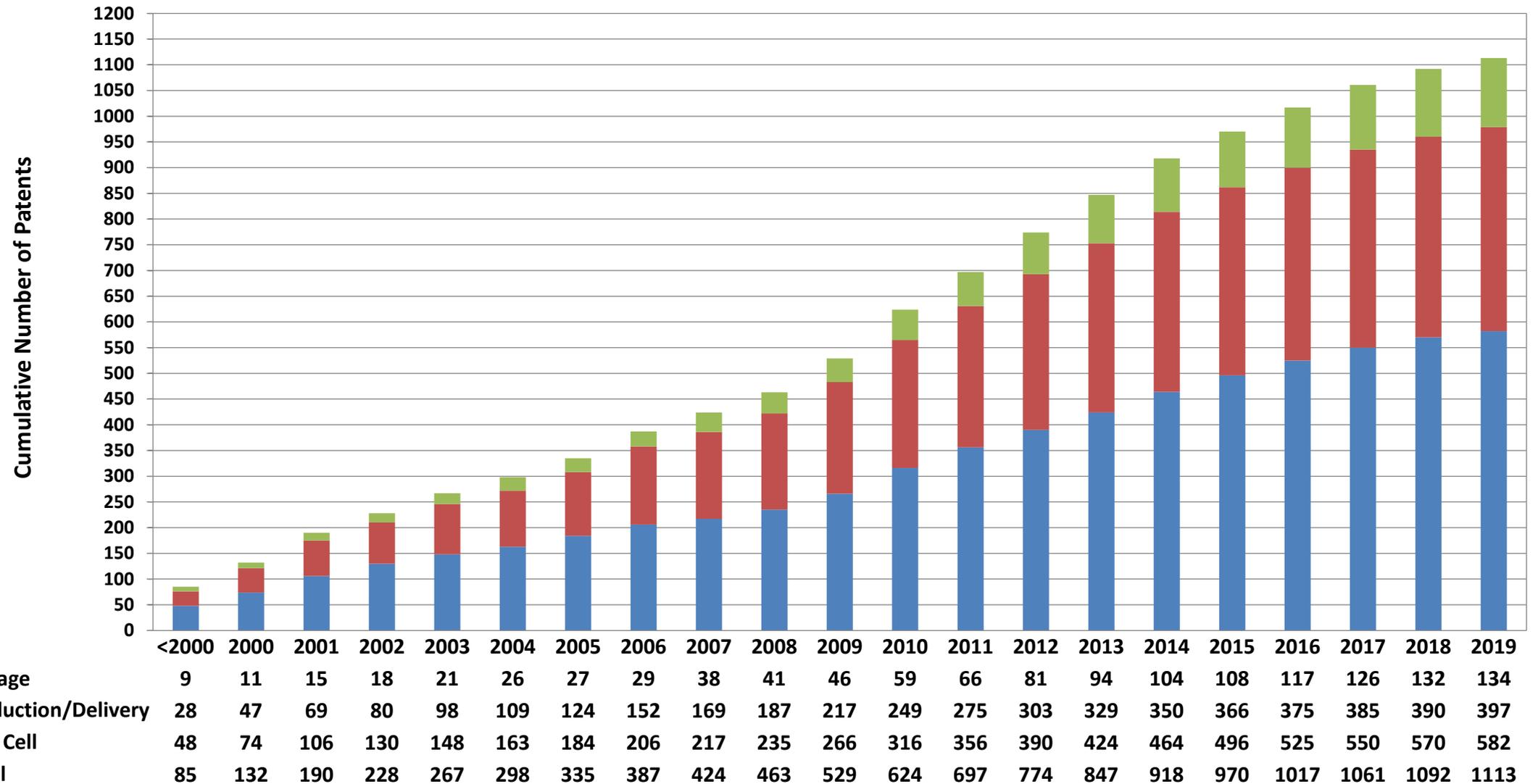
- **HFTO Annual Progress Reports 1995–2019**
 - Organizations awarded HFTO R&D funding (over 1,300 organizations and 2,300 projects)
 - Organizations report patent applications and patent awards
 - https://www.hydrogen.energy.gov/annual_progress.html
- **United States Patent and Trademark Office (USPTO) patent application and patent full-text databases PatFT and AppFT**
 - <http://appft.uspto.gov/netathtml/PTO/index.html>
- **European Patent Office website**
 - <https://worldwide.espacenet.com/>
- **World Intellectual Property Organization website**
 - <https://www.wipo.int/pct/en/>
- **Google Patents website**
 - <https://patents.google.com/>

Patent Results

Cumulative Number of Patents Awarded Over Time (≤2000–2019)

1113 patent awards, 12 issued in 2019

- 582 fuel cell
- 134 hydrogen storage
- 397 hydrogen production and delivery

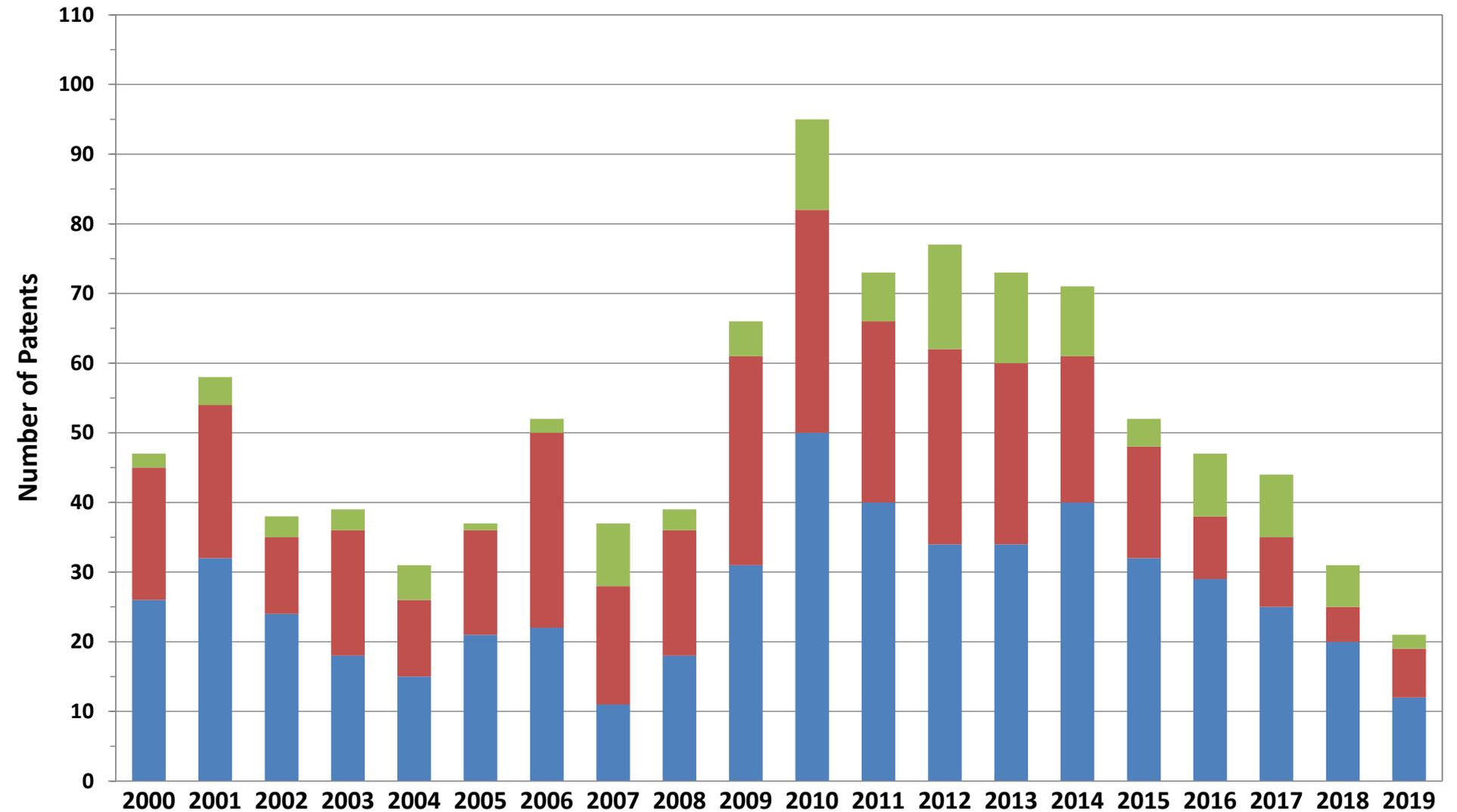


Note: Calendar years

Number of Patents Awarded Per Year (2000–2019)

Average 51 patents per year since 2000

- 27 fuel cell
- 18 hydrogen production and delivery
- 6 hydrogen storage

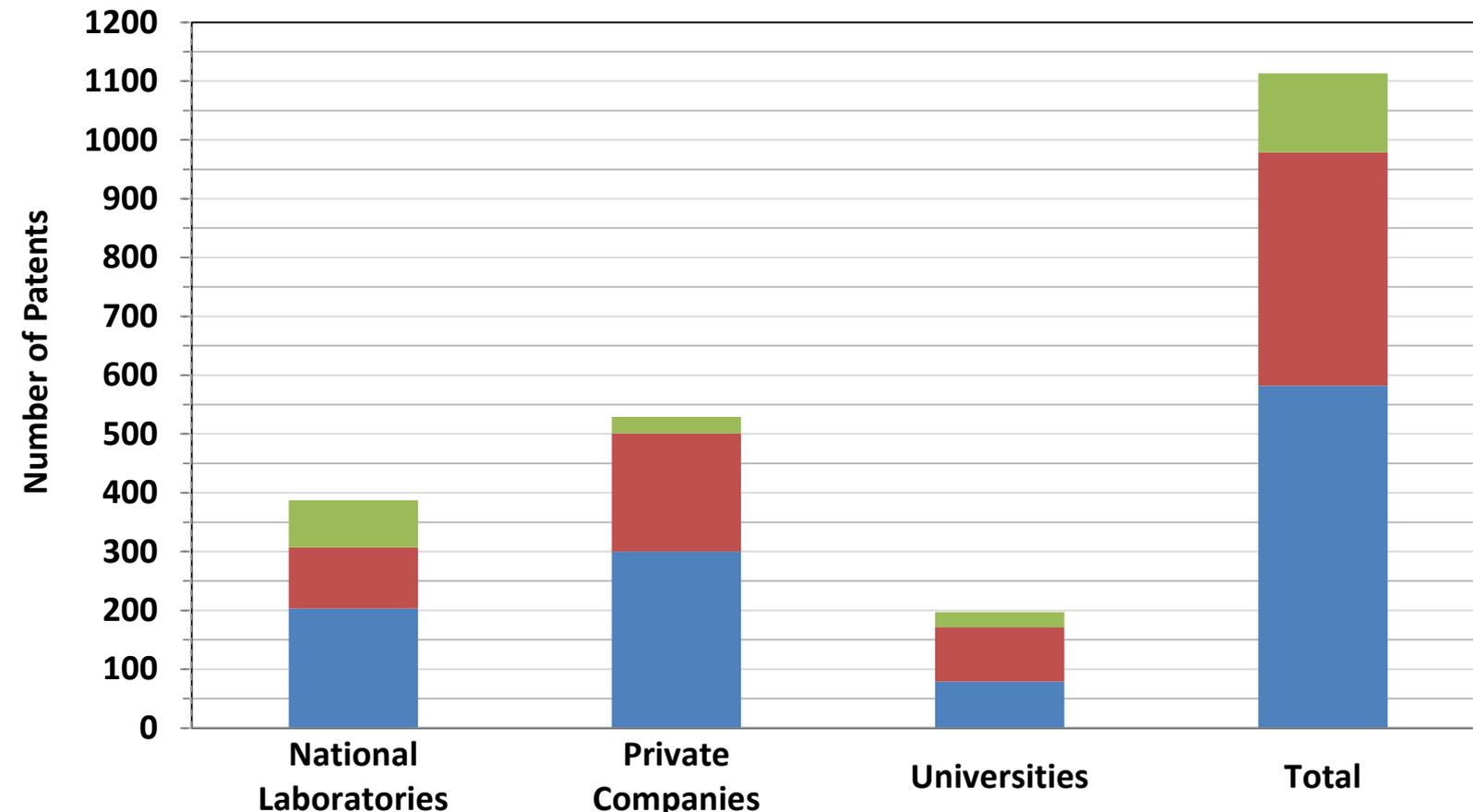


Storage	2	4	3	3	5	1	2	9	3	5	13	7	15	13	10	4	9	9	6	2
Production/Delivery	19	22	11	18	11	15	28	17	18	30	32	26	28	26	21	16	9	10	5	7
Fuel Cell	26	32	24	18	15	21	22	11	18	31	50	40	34	34	40	32	29	25	20	12
Total	47	58	38	39	31	37	52	37	39	66	95	73	77	73	71	52	47	44	31	21

Types of Organization Receiving Patent Awards

Most number of patent awards:

1. Private companies (lead in fuel cells and production/delivery)
2. National laboratories (lead in storage)
3. Universities (mainly fuel cells and production/delivery)



	National Laboratories	Private Companies	Universities	Total
Storage	80	28	26	134
Production/Delivery	104	201	92	397
Fuel Cell	203	300	79	582
Total	387	529	197	1113

Patent Distribution by Organization Type

158 organizations receiving patent awards

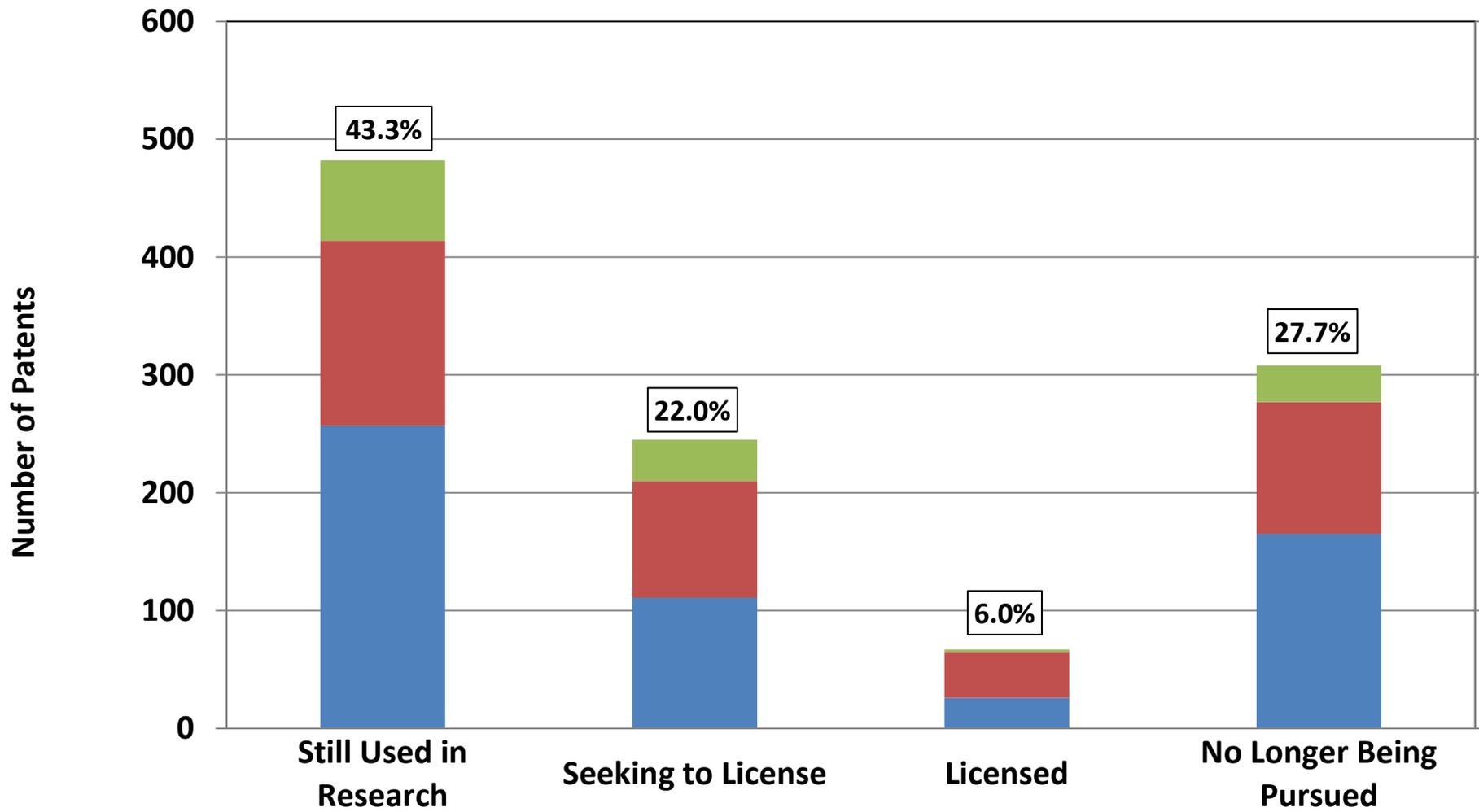
- 98 private companies have 47% of patent awards
- 13 national laboratories have 35% of patent awards
- 30 patents per national laboratory
- 5 patents per private company
- 4 patents per university

Type of Organization	Number of Organizations	Fuel Cell Patents	Production/Delivery Patents	Storage Patents	Total	Patents per Organization	Percent Patent Awards
Private	98 (62%)	301	201	28	530	5	47.6%
National Laboratory	13 (8%)	203	104	80	387	30	34.8%
University	47 (30%)	78	92	26	196	4	17.6%
Total	158	582	397	134	1113	7	

Status of Awarded Patents by Type

43% of patents relevant to current research

28% of patents are licensed or available for license



Storage	68	35	2	31
Production/Delivery	157	99	39	112
Fuel Cell	257	111	26	165
Total	482	245	67	308

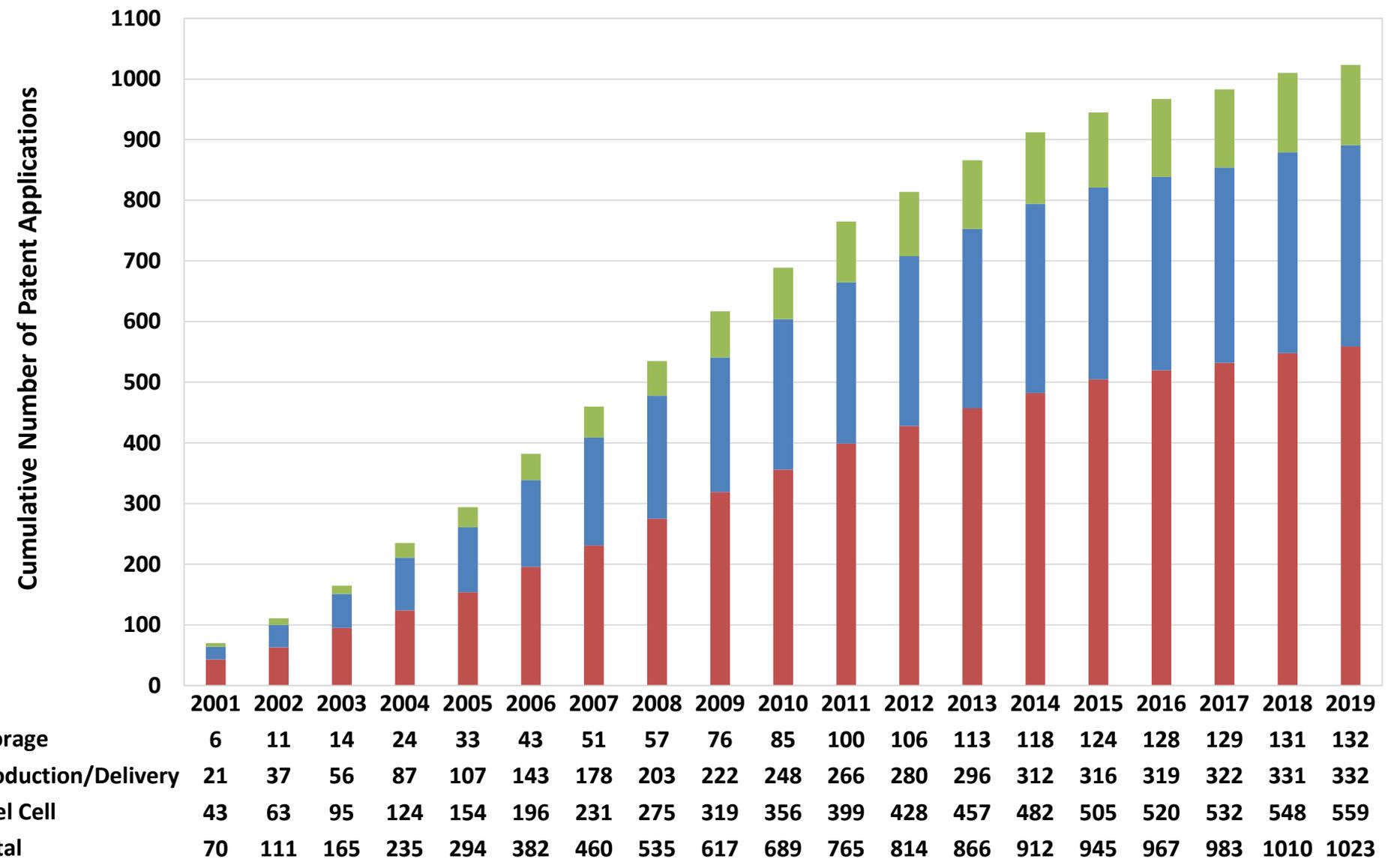
Note: Patents can be in more than one category, sum of percentages ≠ 100%
Percentages are fractions of total number of patents in portfolio (1113)

Patent Application Results

Cumulative HFTO-Funded Patent Applications by Subprogram (2001–2019)

1,023 patent applications

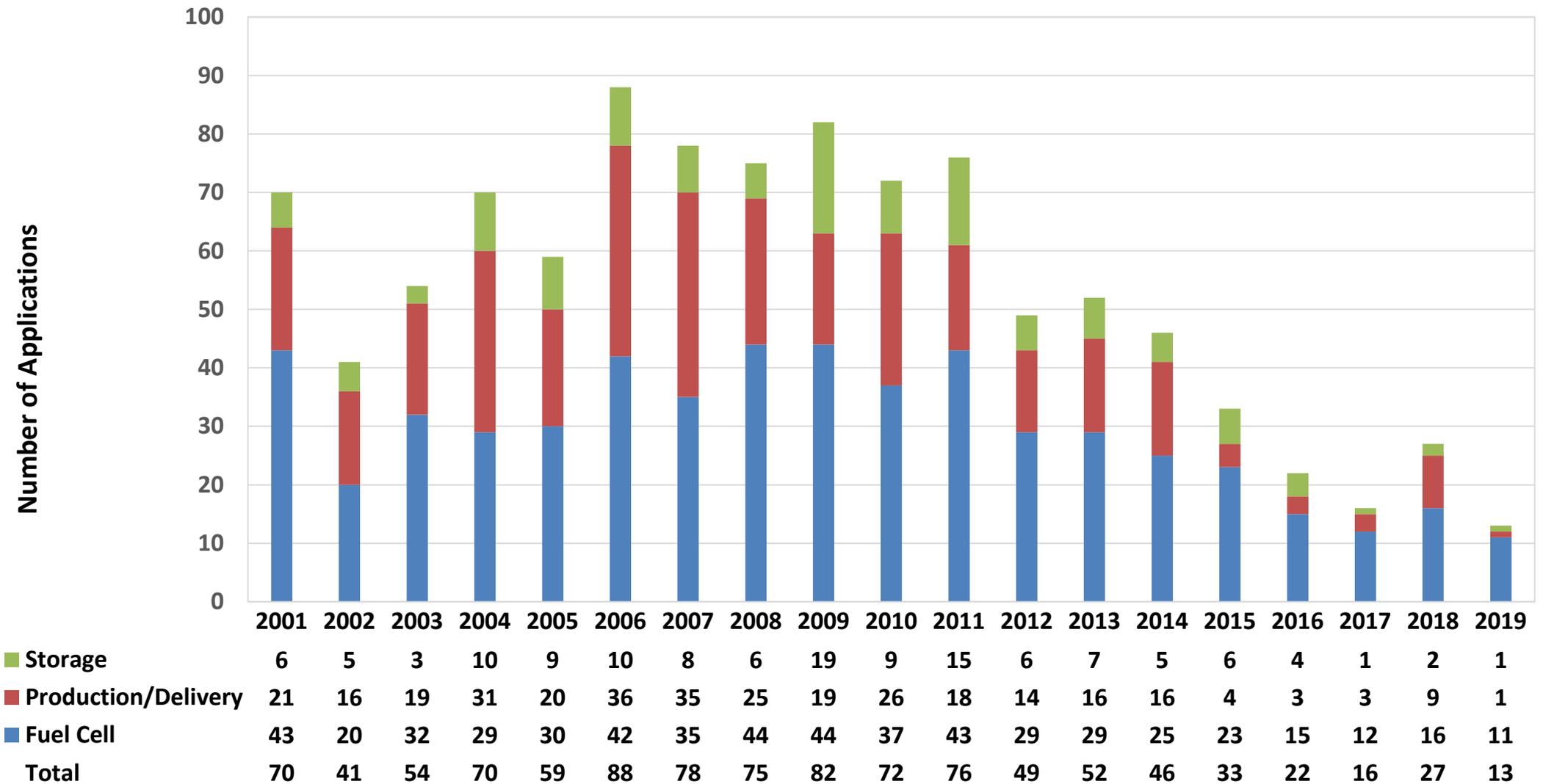
- 55% fuel cells
- 32% production delivery
- 13% storage



- Patent application search for 2019 found over 1,600 hydrogen and fuel cell-related applications
- Identified 1,023 HFTO-funded R&D-related hydrogen and fuel cell-related applications through 2019
- Rechecked previously identified hydrogen and fuel cell-related patent applications 2001–2018 for new patent awards

Patent Applications by Type (2001–2019)

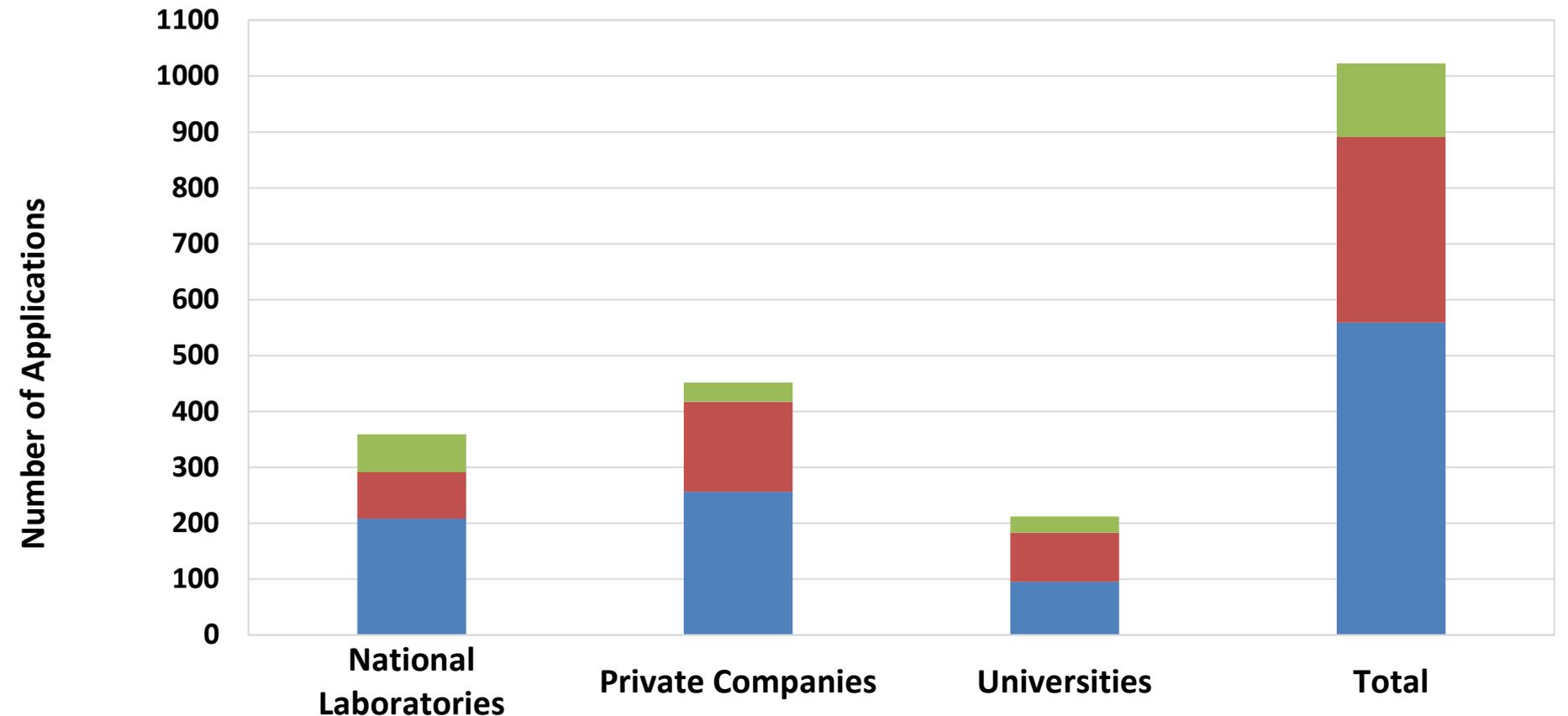
13 patent applications in 2019
Average 54 patent applications per year since 2001



- Number of patent applications has decreased in 2019
- 2017–2019 data is possibly affected by the 18-month pre-application publication period and legal litigation process

Patent Applications by Organization Type (2001–2019)

44% private companies
35% national laboratories
21% universities



	National Laboratories	Private Companies	Universities	Total
Storage	68	35	29	132
Production/Delivery	83	161	88	332
Fuel Cell	208	256	95	559
Total	359	452	212	1023

- Private companies have the most applications overall, leading in fuel cell and production & delivery applications
- National laboratories have the most storage patents (equal to private companies and universities combined)

Patent Applications Distribution by Organization Type

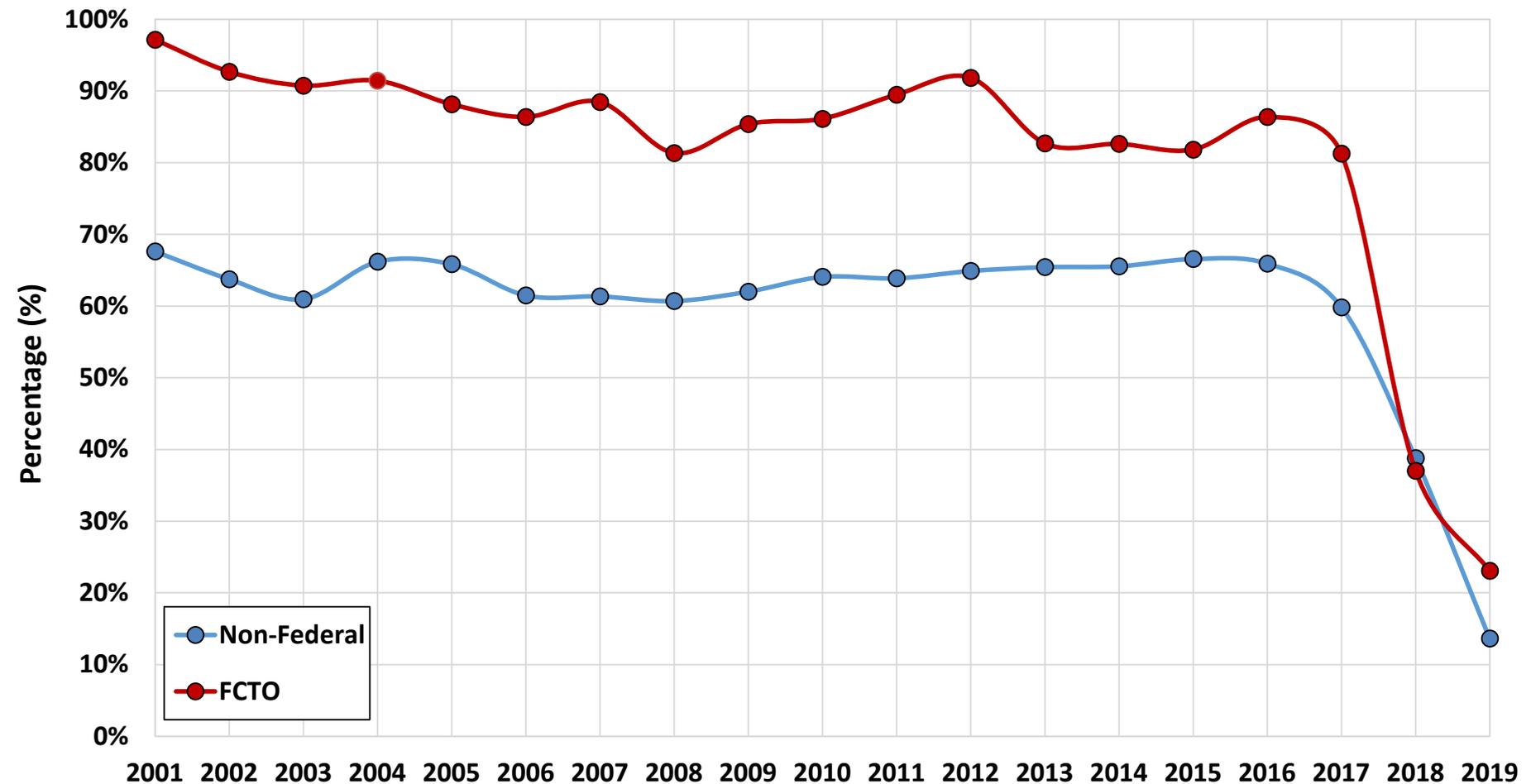
167 organizations receiving patent applications

- Private companies 57%
- Universities 35%
- National laboratories 8%
- 26 applications per national laboratory
- 5 applications per private company
- 4 applications per university

Type of Organization	Number of Organizations	Fuel Cell Applications	Production/Delivery Applications	Storage Applications	Total	Applications per Organization	Percentage of Applications
Private	95 (57%)	256	161	35	452	5	44.2%
National Laboratory	13 (8%)	208	83	68	359	28	35.1%
University	58 (35%)	95	88	29	212	4	20.7%
Total	166	559	332	132	1023	6	

Percentage Non-Federal* and HFTO-Funded Patent Applications Awarded Patents (2001–2019)

86% HFTO-funded R&D-related applications are awarded patents
60% non-federal funded-related applications are awarded patents

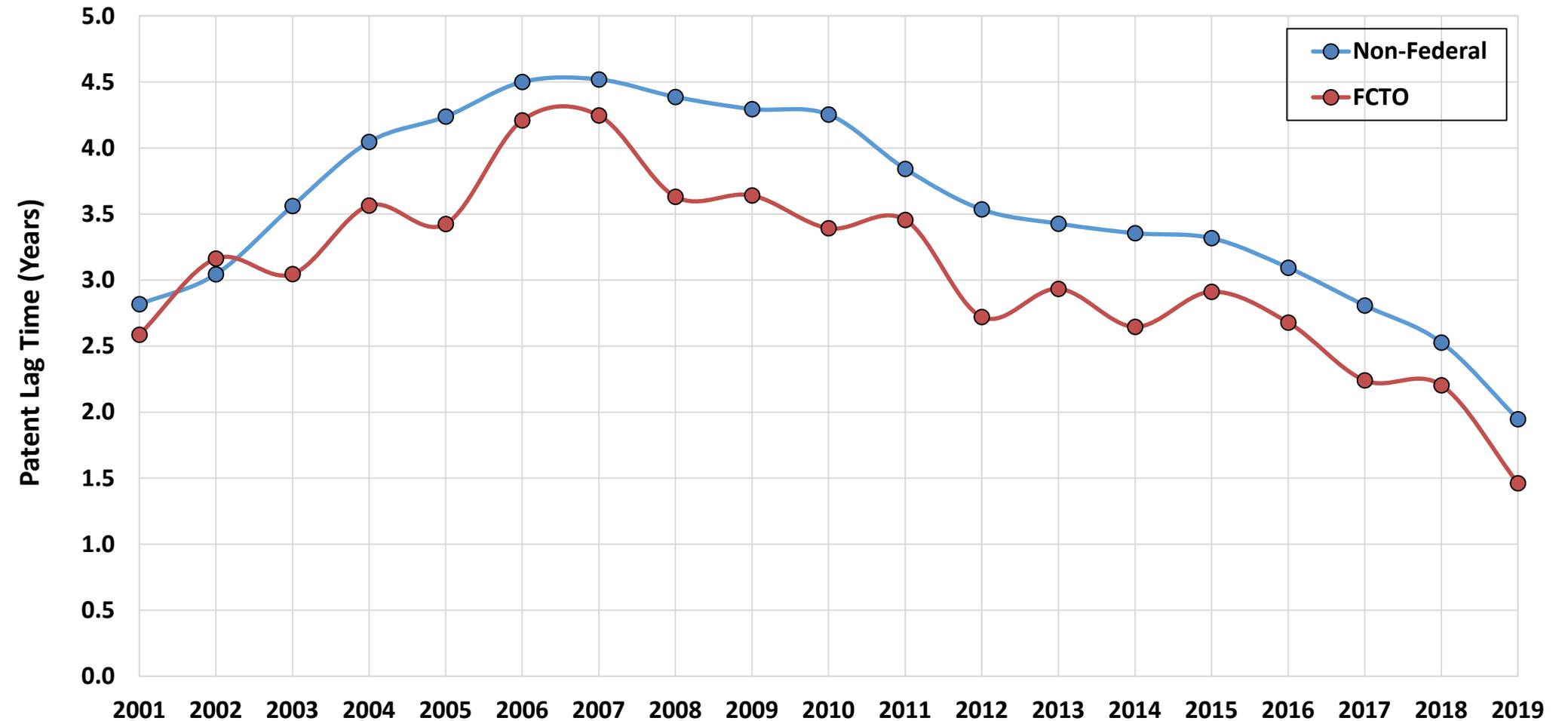


- 2018 and 2019 data is possibly affected by the 18-month pre-application publication period and legal litigation process

* Non-federal funding is defined as research funding from any source, private, state or foreign, and not from any U.S. Government agencies

Non-Federal and HFTO Patent Award Lag Time (2001–2019)

HFTO-funded R&D related applications are awarded patents in less time



- Overall the patent lag time has decreased (elapsed time between patent application file date and patent award date)
- Average HFTO-funded R&D related patent lag time is 3.0 years compared to 3.5 years for non-federal patent lag times
- 2018 and 2019 data is possibly affected by the 18-month pre-application publication period and legal litigation process

* Non-federal funding is defined as research funding from any source, private, state or foreign, and not from any U.S. Government agencies

Future Work for FY2021

- Patent application and patent award analysis for 2020
- Continue improvements to patent data processing (data management – access database and patent filtering code)
- Continue to develop Access database will unify and centralize AMR data, patent, and patent application portfolio data compiled by PNNL
- Explore commercial patent search software (2 packages available at PNNL, 3rd package under investigation)

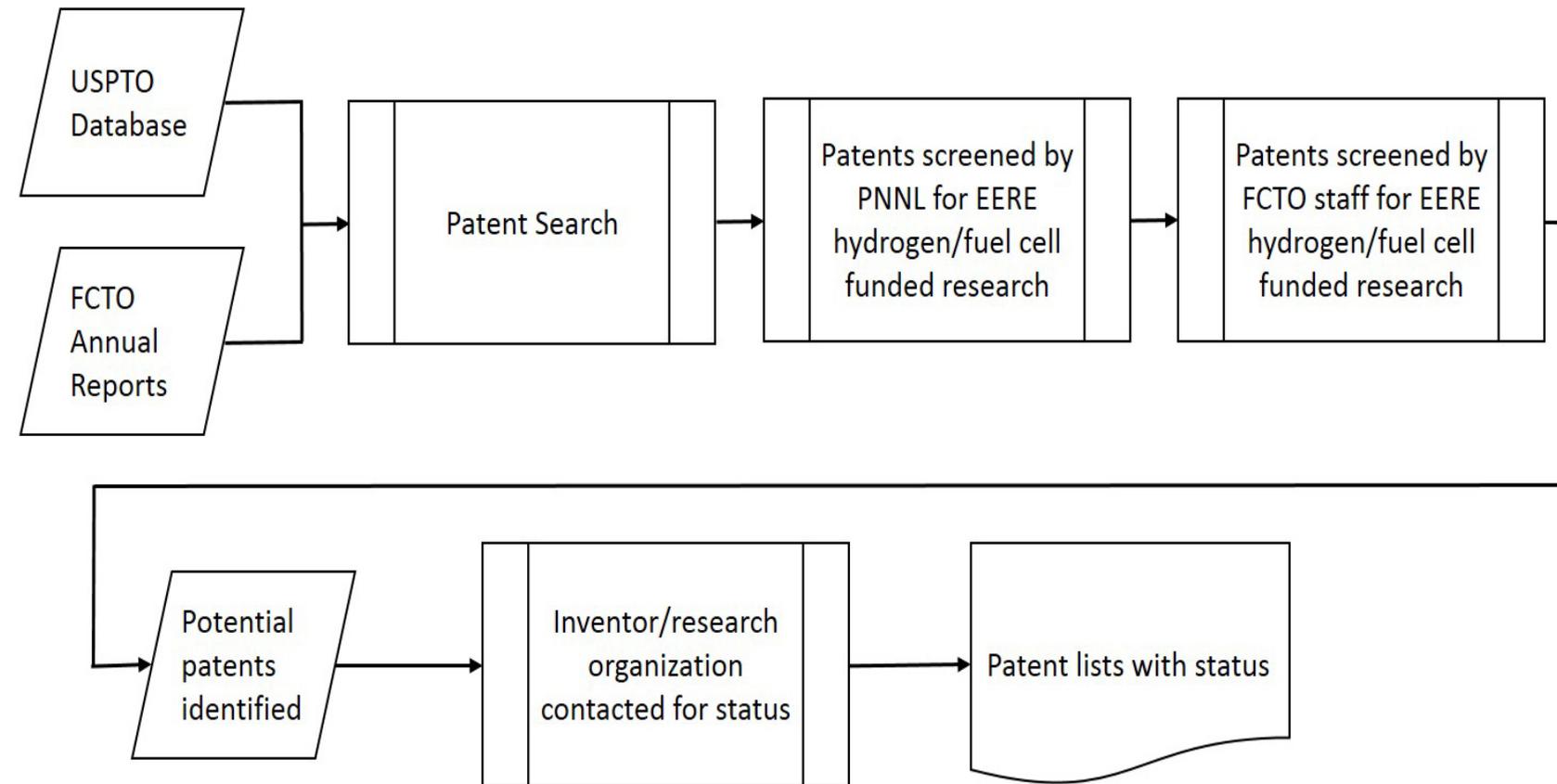
Back Up Slides

Patent Tracking - Process

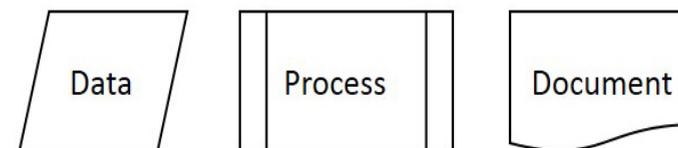
- **Gather patent information from HFTO Annual Progress Reports and from HFTO project points of contact (POC)**
 - Conduct patent searches using applications and issued patent numbers from annual progress reports*
 - Conduct searches on organization (assignee) and POC and project team members (inventors)
 - Conduct keyword searches e.g., hydrogen, fuel cell, PEM (Proton Exchange Membrane)
 - Conduct search on government interest
- **Compile patent lists by organization, year, subprogram**
- **Contact organization or POCs for patent status verification**
- **HFTO-funded related patent application tracking includes all of the above with additional data processing and filtering**
 - Examine HFTO patent portfolio for common Cooperative Patent Classification (CPC) codes
 - Gather patent application 2001–2019 information using subclass-level CPC code searches
 - Filter only hydrogen and hydrogen fuel cell-related applications using subgroup CPC codes
 - Identify government interest funding information
 - Identify any unpublished patent applications from patent awards

* Fuel Cell Technology Office Annual Progress Reports can be found here: https://www.hydrogen.energy.gov/annual_progress.html

Patent Analysis Process Flow Diagram for Hydrogen and Fuel Cell Technologies



Legend



Patent and Patent Application CPC Code

- PNNL’s patent application analysis involved searching applications using the CPC code scheme used to categorize patent applications
- PNNL derived 16 CPC codes (at the subclass level) for the patent application search to capture technologies in the existing HFTO-funded R&D patent portfolio
- Applications were further filtered using a list of hydrogen and fuel cell related CPC codes (at the subgroup level)
- Online patent resources USPTO, WIPO, and Espacenet were used to develop the subgroup level CPC code list filter

EXAMPLE: “Proton Exchange Membrane Fuel Cell” CPC code = Y02E 60/521		
Section	Y	General Tagging of New Technological Developments; General Tagging of Cross-over technologies spanning over several sections of the IPC; technical subjects covered by former USPC cross reference art collections and digest
Class	02	Technologies or Applications for Mitigation or Adaptation against Climate
Subclass	E	Reduction of Greenhouse Gas [GHG] Emissions related to Energy Generation, Transmission or Distribution
Main Group (00)	60/00	Enabling technologies or technologies with a potential or indirect contribution to GHG emissions mitigation
Subgroup	60/521	Proton Exchange Membrane Fuel Cells [PEMFC]



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16 CPC Code Search from HFTO Patent Portfolio

No. CPC Classes	# Patents	%
1	226	30.7%
2	235	31.8%
3	172	23.3%
4	74	10.1%
5	22	3.0%
6	6	0.8%
7	2	0.3%
Total	738	100.0%

Single CPC
B01D
B01J
B60K
B82Y
C01B
C04B
C08G
C08J
C12N
C25B
F17C
G01N
H01B
H01M
Y02E
Y10S

2 -Combos	
B01D	B01J
B01D	C01B
B01D	C04B
B01D	C08G
B01D	H01M
B01J	B82Y
B01J	C01B
B01J	C10G
B01J	F28D
B01J	H01M
B82Y	H01M
B82Y	Y02E
B82Y	Y10S
C01B	C10G
C01B	H01M
C01B	Y02E
C04B	H01B
C04B	H01M
C08G	C08J
C08J	H01M
C12N	Y10S
C25B	H01M
C25B	Y02E
F17C	Y02E
F28D	H01M
G01N	H01M
H01B	H01M
H01M	Y02E
H01M	Y10S
H01M	Y10S

3-combos		
B01D	B01J	C01B
B01D	B01J	G01N
B01D	B01J	Y10S
B01D	C01B	C04B
B01D	C01B	H01M
B01D	C01B	Y02E
B01D	C04B	Y10S
B01D	C08G	C08J
B01D	C08J	H01M
B01D	F28D	H01M
B01J	B82Y	Y10S
B01J	C01B	C07C
B01J	C01B	F28D
B01J	C01B	H01M
B01J	C01B	Y02E
B01J	C01B	Y10S
B01J	F28D	H01M
B01J	H01B	H01M
B01J	H01M	Y02E
B60K	F17C	Y02E
B82Y	C01B	Y02E
B82Y	C01B	Y10S
B82Y	C04B	H01M
B82Y	C12N	H01M
B82Y	H01M	Y02E
C01B	C10G	Y02E
C01B	F17C	Y02E
C01B	F28D	Y02E
C01B	F28D	Y02E
C01B	H01M	Y02E
C01B	H01M	Y10S
C01B	Y02E	Y10S
C08G	C08J	H01M
C08G	H01B	H01M
C08J	H01M	Y02E
C25B	H01B	H01M
C25B	H01G	Y02E
C25B	H01M	Y02E
F17C	H01M	Y02E
F17C	Y02E	Y10S
F28D	H01M	Y02E
H01B	H01M	Y02E

4-combos			
B01B	B01J	C01B	F28D
B01B	B60L	C01B	H01M
B01D	B01J	C01B	C04B
B01D	C01B	C10G	Y02E
B01D	C01B	H01B	H01M
B01D	C01B	H01M	Y02E
B01J	B60L	C01B	H01M
B01J	B82Y	C01B	H01M
B01J	B82Y	H01M	Y02E
B01J	C01B	C04B	H01M
B01J	C01B	C07C	C10G
B01J	C01B	C25B	Y02E
B01J	C01B	F17C	Y02E
B01J	C01B	F28D	H01M
B01J	C01B	F28D	Y02E
B01J	C01B	H01M	Y02E
B82Y	C01B	C25B	Y10S
B82Y	C01B	F17C	Y02E
C01B	C08G	H01M	Y02E
C01B	F17C	F28D	Y02E
C01B	F17C	H01M	Y02E
C04B	H01M	Y02E	Y10S
C08G	C08J	H01B	H01M
C08J	H01B	H01M	Y02E
C25B	H01G	H01M	Y02E
G01N	H01G	H01M	Y02E
H01B	H01G	H01M	Y02E

5-combos				
B01B	B01D	B01J	C01B	F28D
B01D	B01J	C01B	F28D	H01M
B01D	C08G	C08J	H01B	H01M
B01D	C08J	H01B	H01M	Y02E
B01J	B60K	B60L	C01B	H01M
B01J	B82Y	C01B	H01M	Y02E
B01J	B82Y	H01M	Y02E	Y10S
B01J	C01B	C07C	H01M	Y02E
B01J	C08G	C08J	H01M	Y02E
B82Y	C01B	H01G	H01M	Y02E
B82Y	C01B	H01M	Y02E	Y10S
C01B	C08G	C08J	H01M	Y02E
C01B	F17C	H01M	Y02E	Y10S

6-combos					
B01B	B01D	B01J	C01B	F28D	F28D
B01J	B82Y	C01B	H01G	H01M	H01M
B01J	C01B	F17C	H01M	Y02E	Y02E
B82Y	C01B	C25B	H01M	Y02E	Y02E

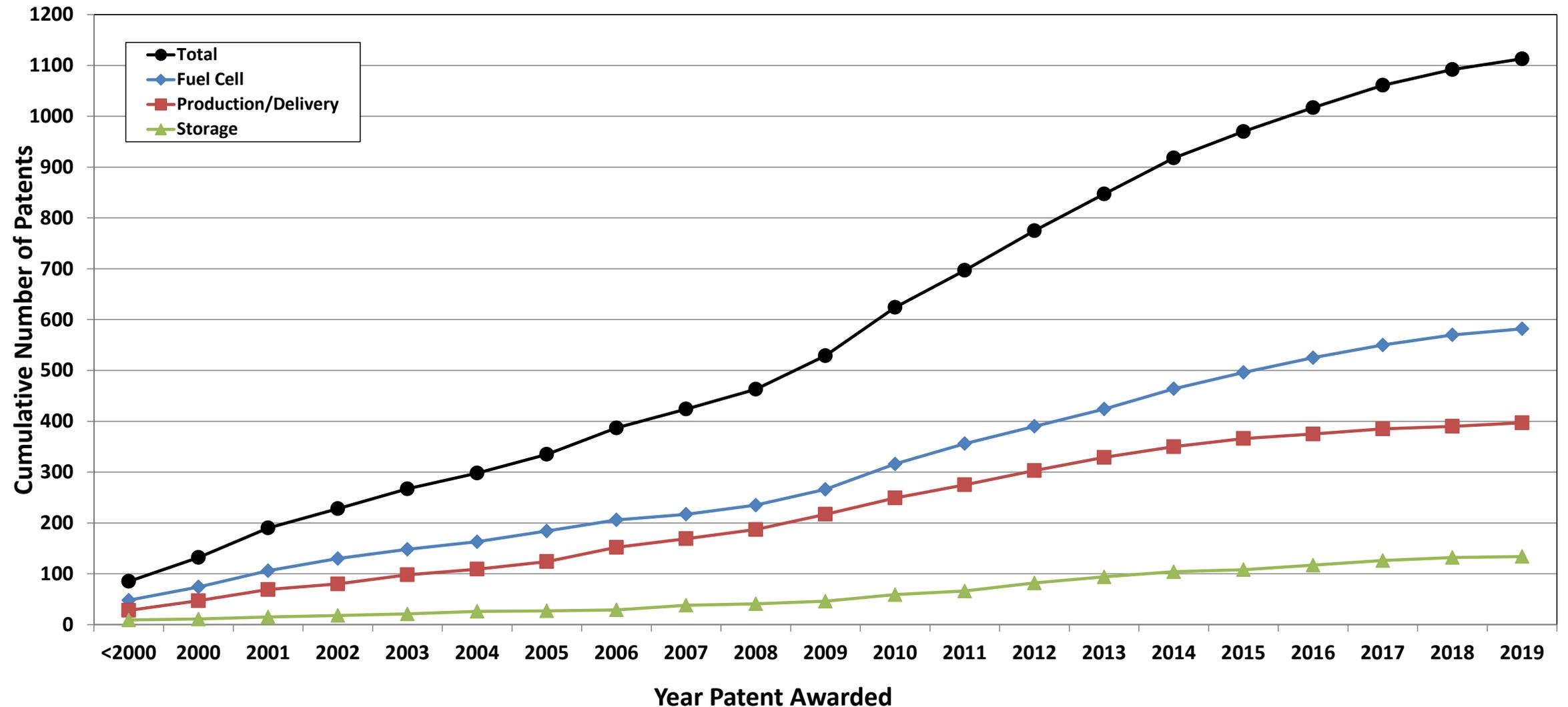
7-combos						
B01B	B01D	B01J	C01B	F28D	F28D	G01N
B01J	B82Y	C01B	F17C	H01M	H01M	Y02E

- Derived 16 CPC subclass codes from HFTO R&D-funded patent portfolio
- 16 CPC codes capture all possible patent applications combinations found in HFTO portfolio
- Search at subclass level reduces possibility of excluding relevant patent applications

Cumulative Number of Patents Awarded Over Time (≤2000–2019)

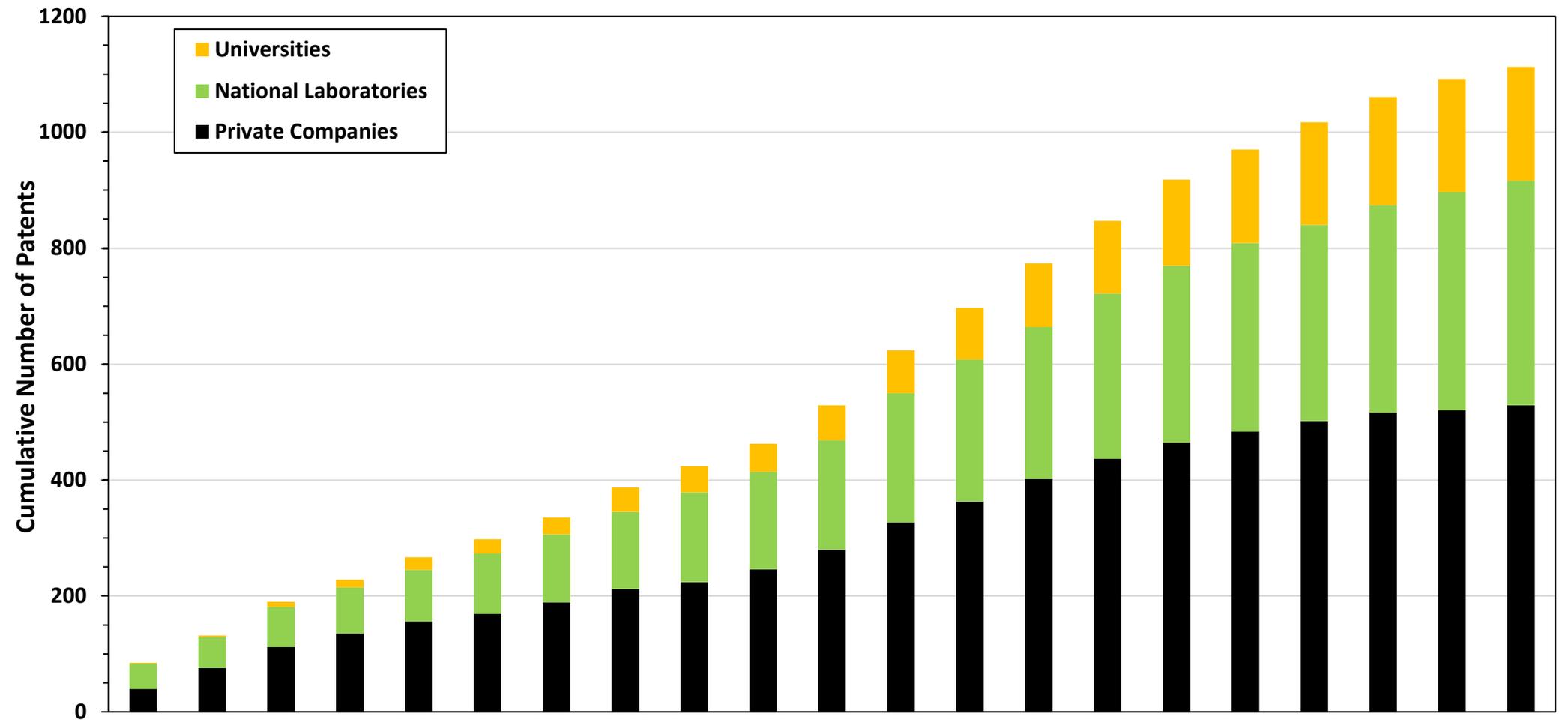
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Note: Calendar years

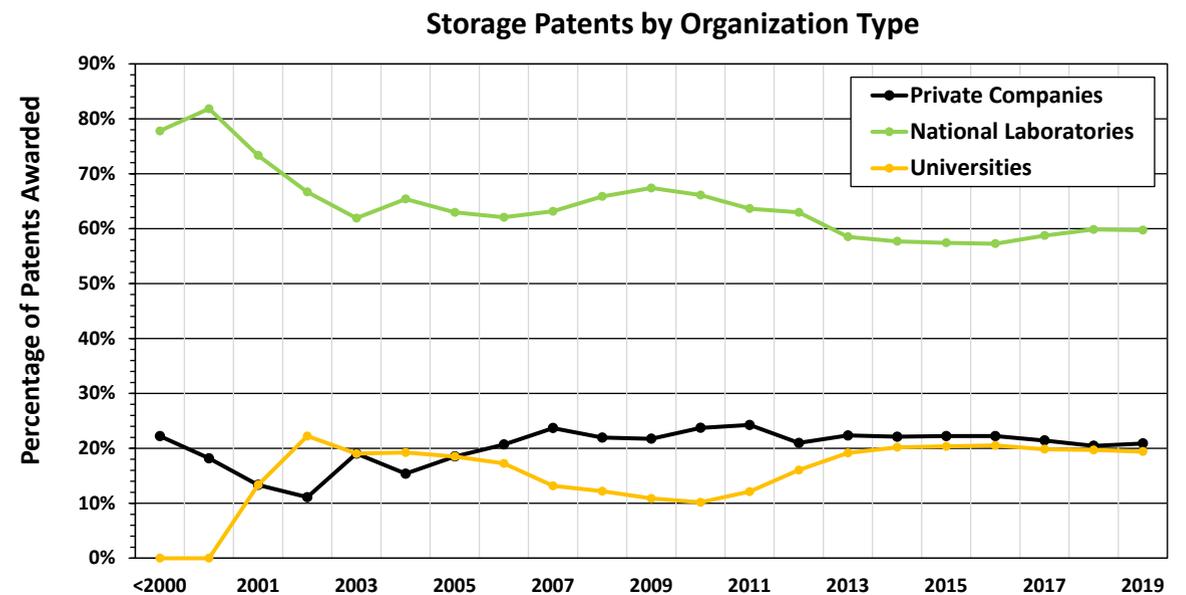
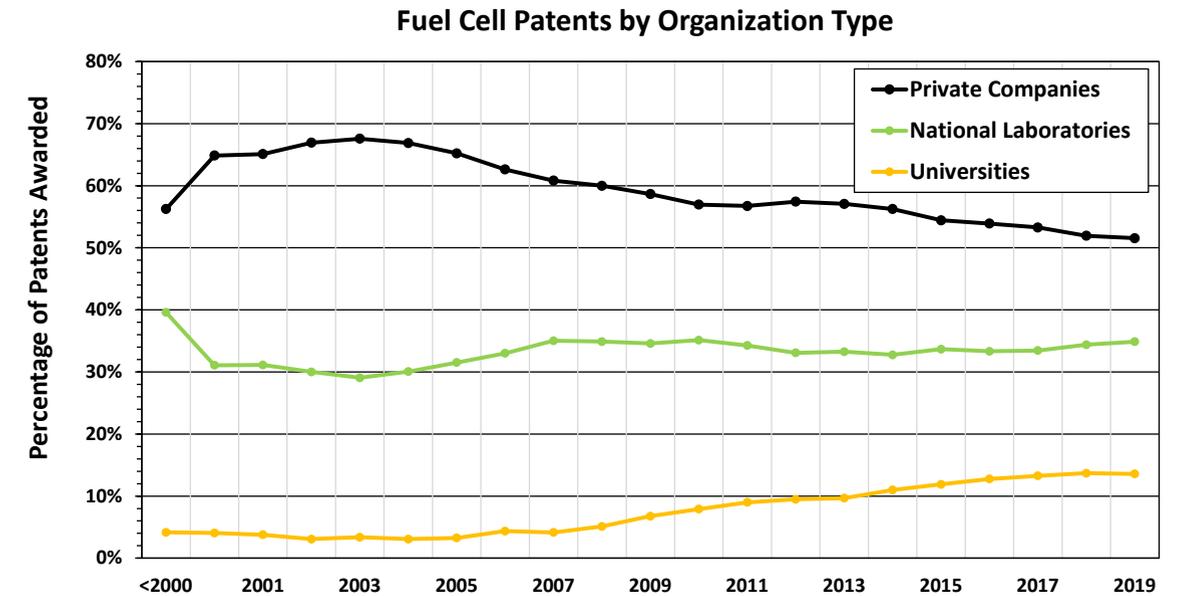
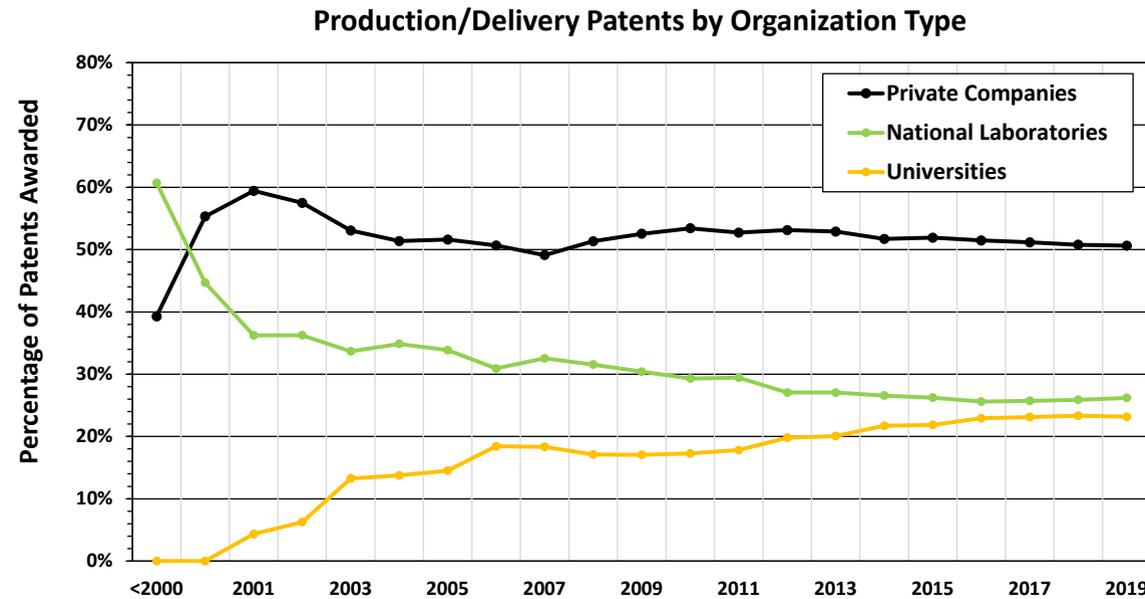
Patents Awarded Over Time by Organization Type



	<2000	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Universities	2	3	9	13	22	25	29	42	45	49	60	74	89	110	125	148	161	177	187	195	197
National Laboratories	43	53	69	80	89	104	117	133	155	168	189	223	245	262	285	305	325	338	357	376	387
Private Companies	40	76	112	135	156	169	189	212	224	246	280	327	363	402	437	465	484	502	517	521	529
Total	85	132	190	228	267	298	335	387	424	463	529	624	697	774	847	918	970	1017	1061	1092	1113

- Private companies awarded 48% patents, national laboratories 34%, and universities 18%
- Private companies awarded 24 patents per year since 2000 (national laboratories 17, universities 10)
- Patent activity increasing for universities and national laboratories
- Private company patent activity decreasing

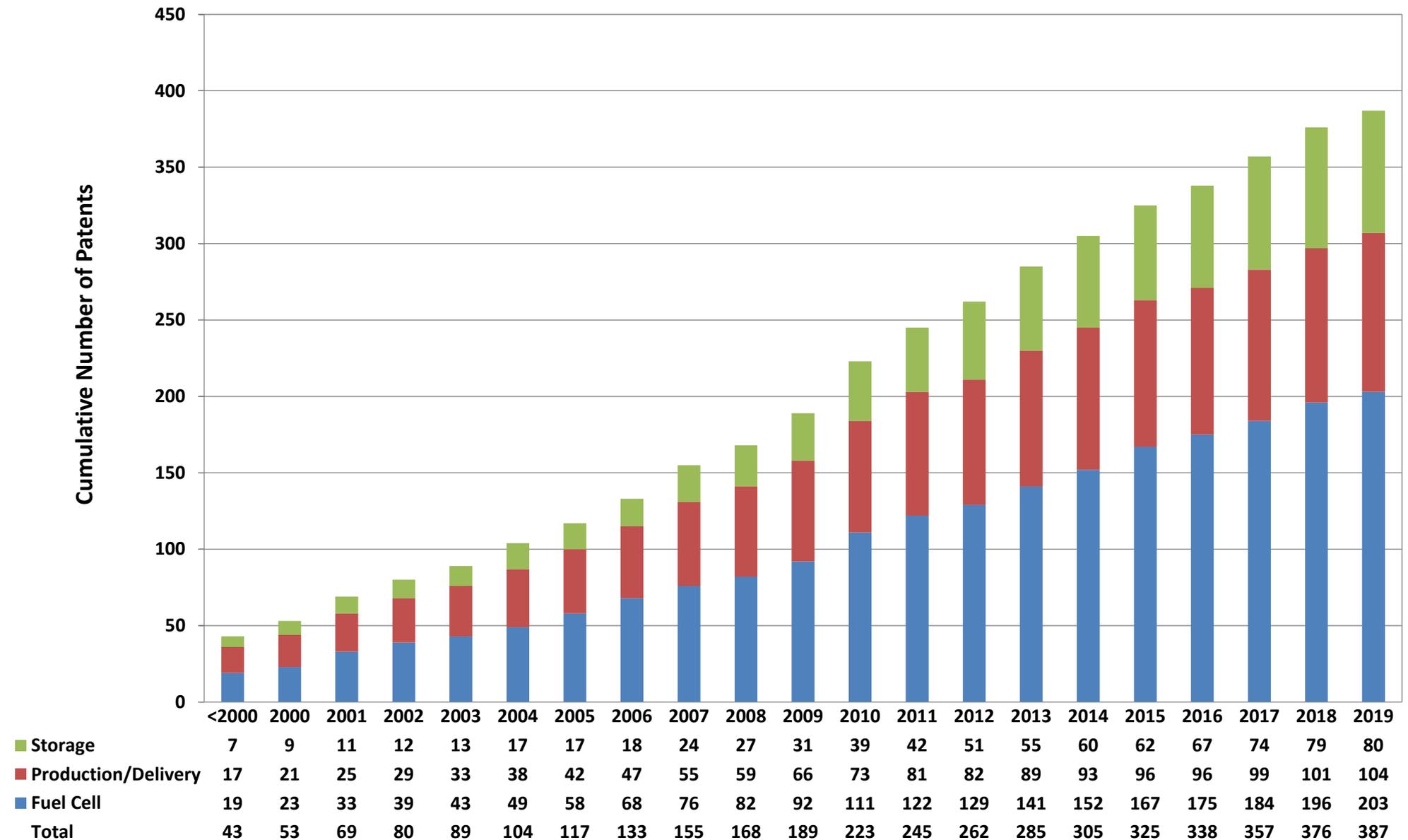
Patent Type Over Time by Organization Type



- National laboratory and university fuel cell activity increasing
- Overall production/delivery activity constant
- National laboratory storage activity increasing

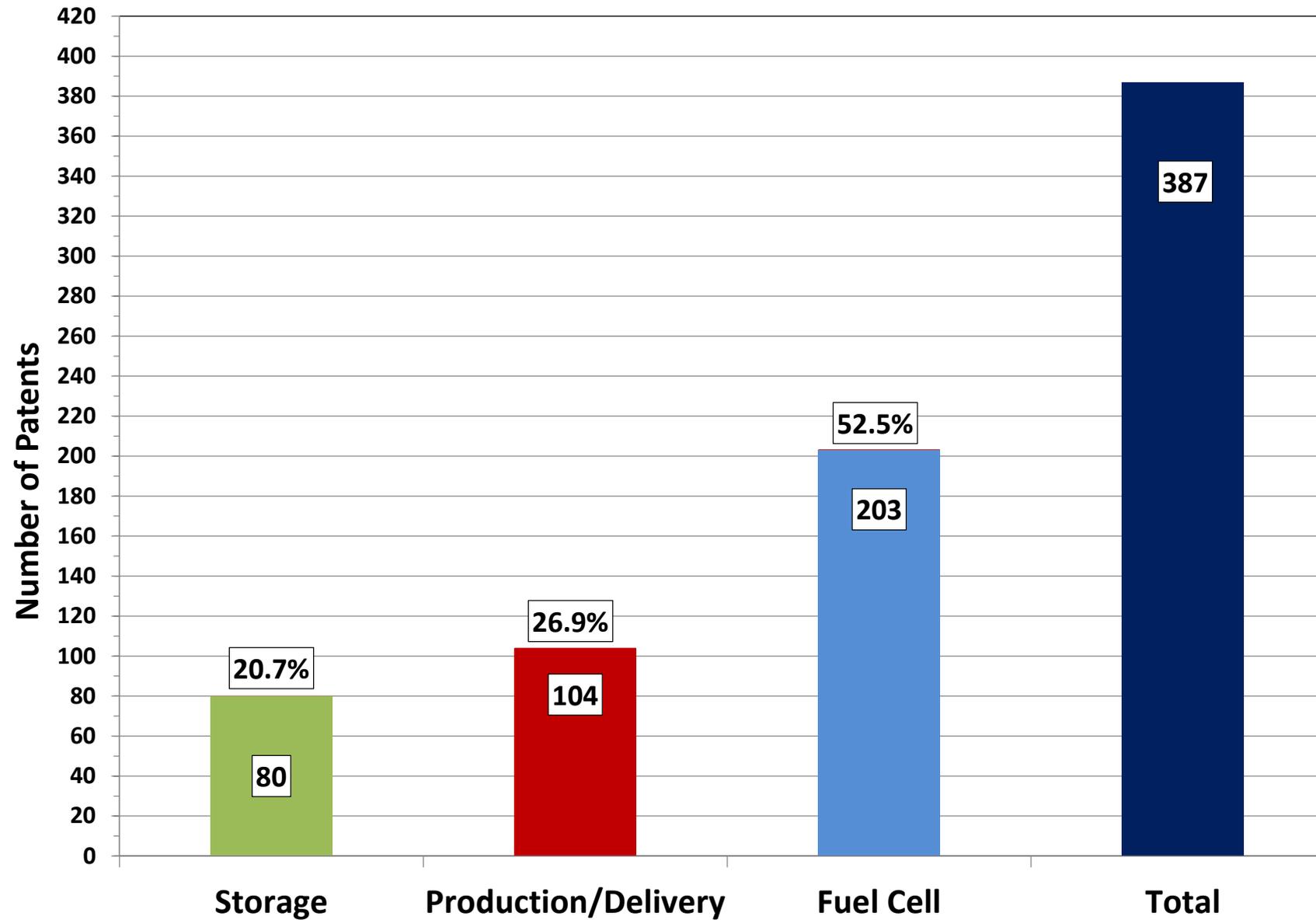
National Laboratory Patent Analysis

Cumulative Number of Patents Awarded Over Time



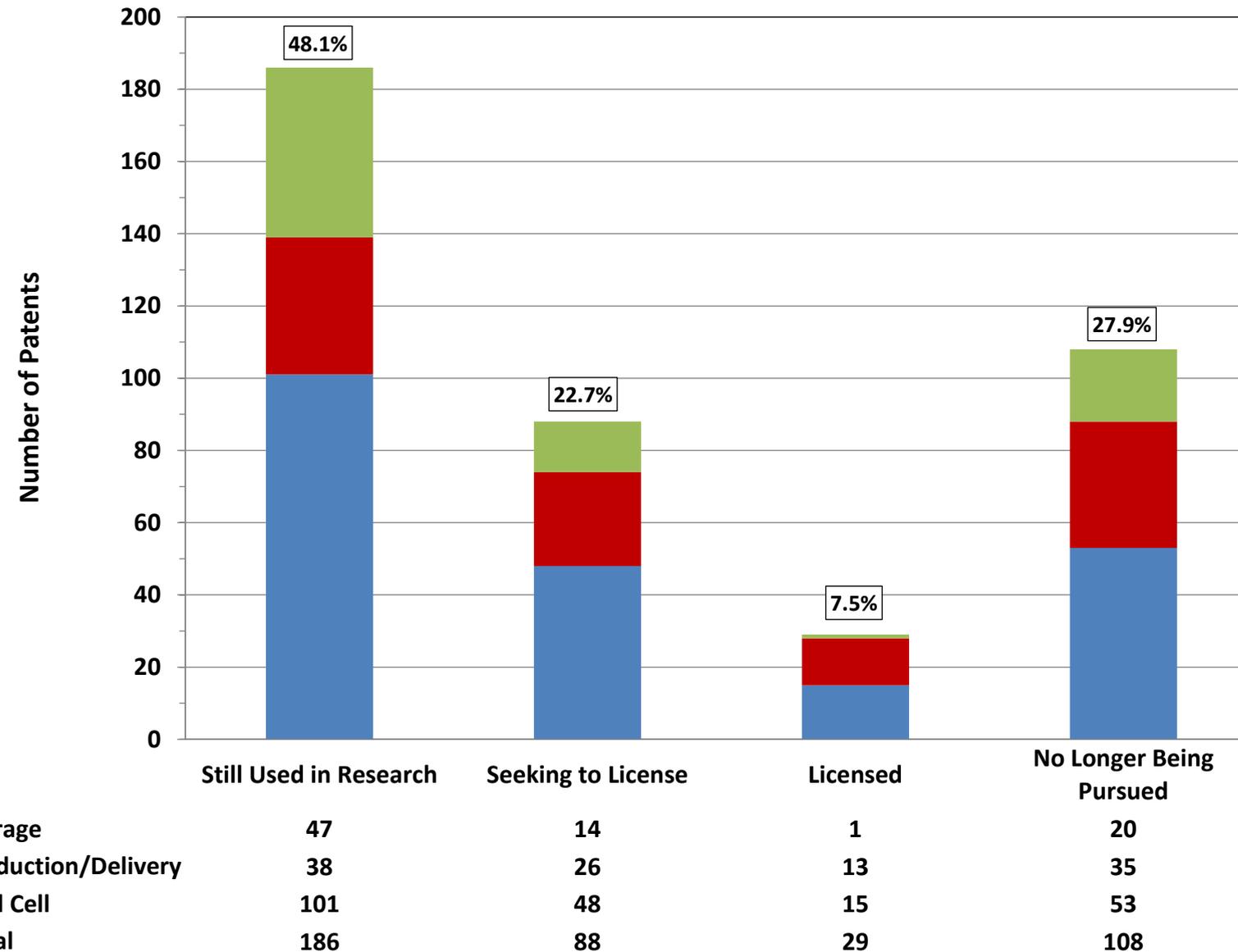
- 387 national laboratory patents
- National laboratory activity primarily in fuel cells

National Laboratory Patent Analysis: Patents by Type



- 53% of national laboratory patents in fuel cells
- National laboratory research activity in production/delivery and storage approximately equal

National Laboratory Patent Analysis: Patent Status

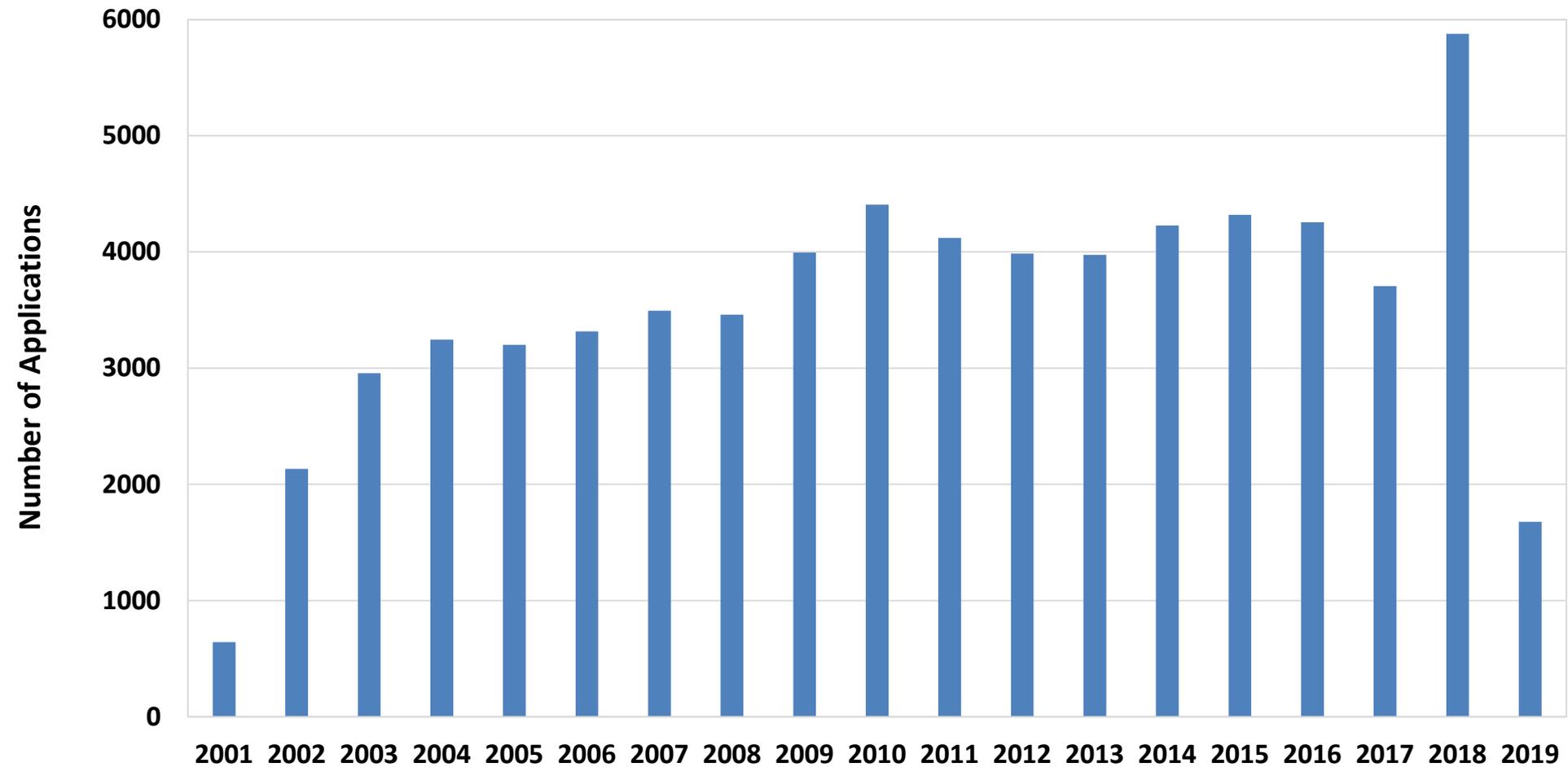


- 48% of national laboratory patents still relevant to current research activities
- Approximately 30% of national laboratory patents licensed or available for licensing

*Note: Patents can be in more than one category, sum of percentages ≠ 100%
Percentages are fraction of total number of patents in national laboratory portfolio (354)*

All Hydrogen and Fuel Cell-Related Patent Applications* (2001–2019)

Number of patent applications decreased in 2019 (1,585)



* Federal funding is defined as research funding from any U.S. Government agency.
Non-federal funding is defined as research funding from any source, private, state or foreign, and not U.S. Government agencies.