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2021 Patent and Patent Application Analysis for the U.S. Department of Energy Hydrogen and Fuel Cell Technologies Office

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PNNL- 33465

U.S. DEPARTMENT OF ENERGY BATTELLE

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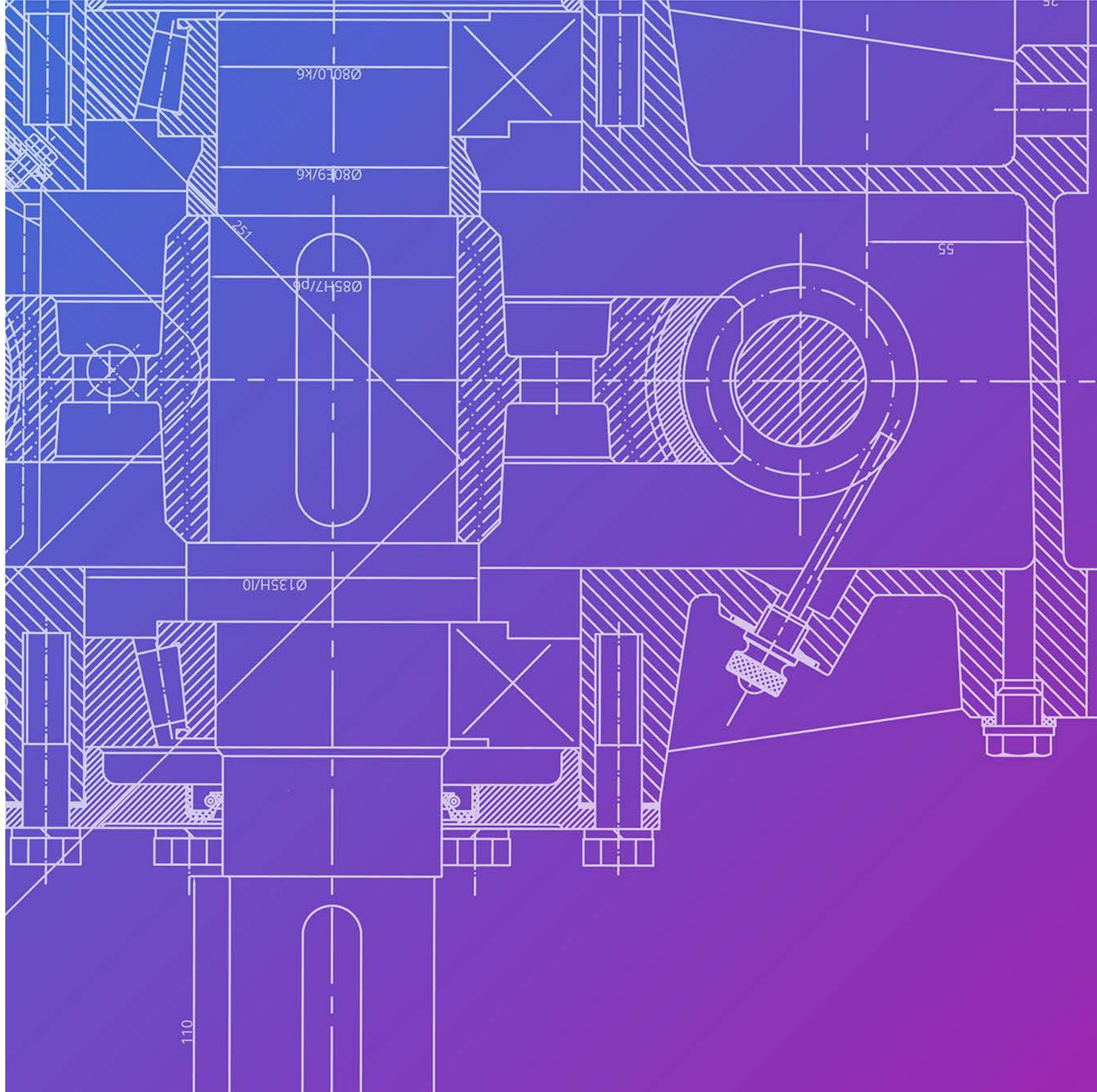

HFTO Patent Tracking – Purpose

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 U.S. patent applications and patent awards
- PNNL patent tracking and analysis identifies, analyzes, and characterizes U.S. patent applications and U.S. patent awards related to HFTO-funded R&D
  - Patent applications and patent awards filed with United States Patent and Trademark Office (USPTO)
  - 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
  - U.S. Patent data has been tracked from the inception of DOE activities in 1977
  - U.S. 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

1,193 U.S. patent applications and 1,256 U.S. patent awards related to HFTO-funded R&D through 2021

- **1,256 U.S. patent awards resulting from HFTO-funded R&D (1977–2021)**
  - 653 fuel cell patents (52%)
  - 434 hydrogen production and delivery patents (35%)
  - 169 hydrogen storage patents (13%)
  - 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% overall) lead in hydrogen storage R&D
  - Universities (19%) research activities primarily in fuel cell and hydrogen and production R&D
  - Private companies (46%) lead in fuel cell and hydrogen production and delivery R&D
- **1,193 U.S. patent applications resulting from HFTO-funded R&D (2001–2021)***
  - 628 fuel cell patent applications (53%)
  - 388 hydrogen production and delivery patent applications (32%)
  - 177 hydrogen storage patents (15%)
  - 78% 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 U.S. 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

All patent applications and patent awards used in this report are filed with the USPTO

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

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/netahtml/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/

** All patent applications and patent awards used in this report are filed with the USPTO*

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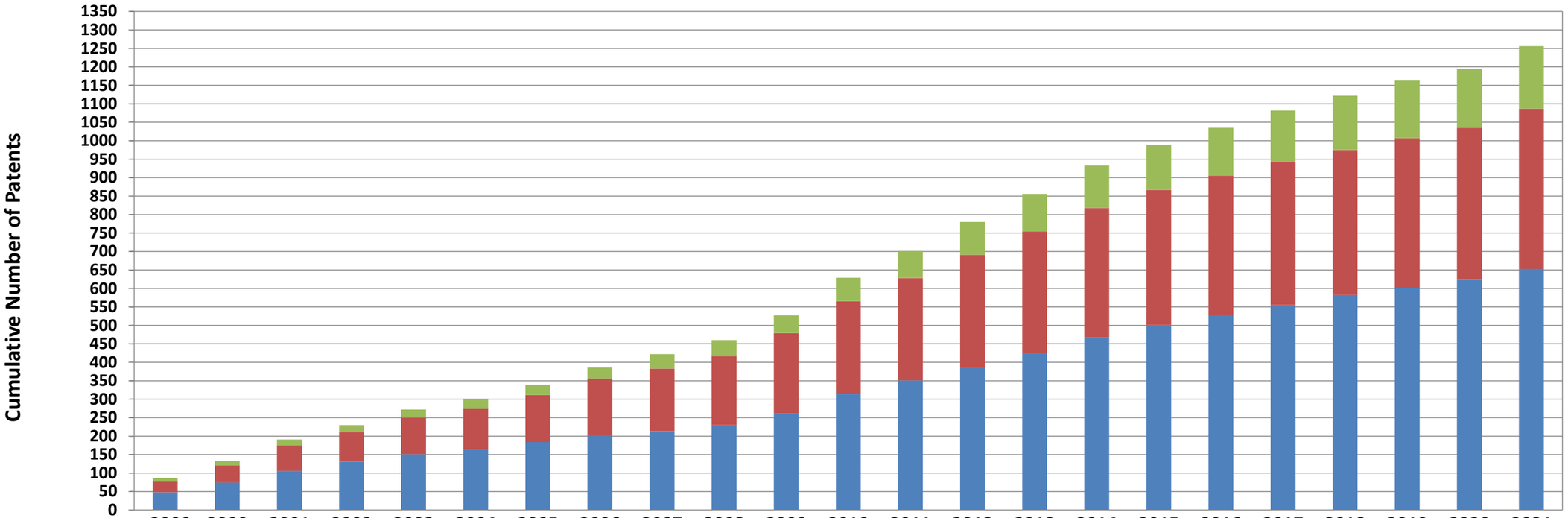
Patent Results

Cumulative Number of Patents Awarded Over Time (≤2000–2021)

1,256 patent awards, 61 issued in 2021

- 653 fuel cell
- 434 hydrogen production and delivery
- 169 hydrogen storage



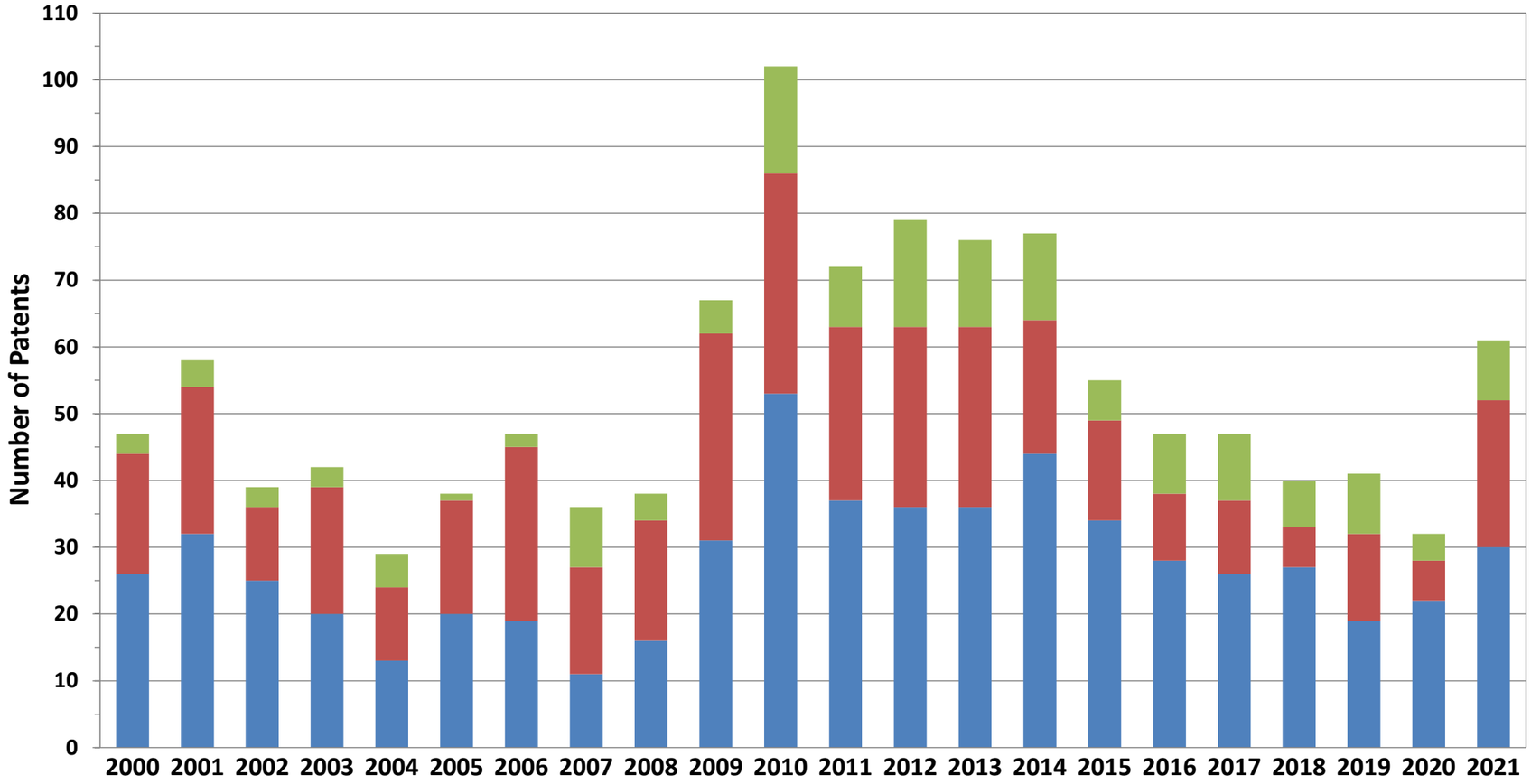
	<2000	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Storage	9	12	16	19	22	27	28	30	39	43	48	64	73	89	102	115	121	130	140	147	156	160	169
Production/Delivery	29	47	69	80	99	110	127	153	169	187	218	251	277	304	331	351	366	376	387	393	406	412	434
Fuel Cell	48	74	106	131	151	164	184	203	214	230	261	314	351	387	423	467	501	529	555	582	601	623	653
Total	86	133	191	230	272	301	339	386	422	460	527	629	701	780	856	933	988	1035	1082	1122	1163	1195	1256

Note: Calendar years

Number of Patents Awarded Per Year (2000–2021)

Average 53 patents per year since 2000

- 28 fuel cell
- 18 hydrogen production and delivery
- 8 hydrogen storage

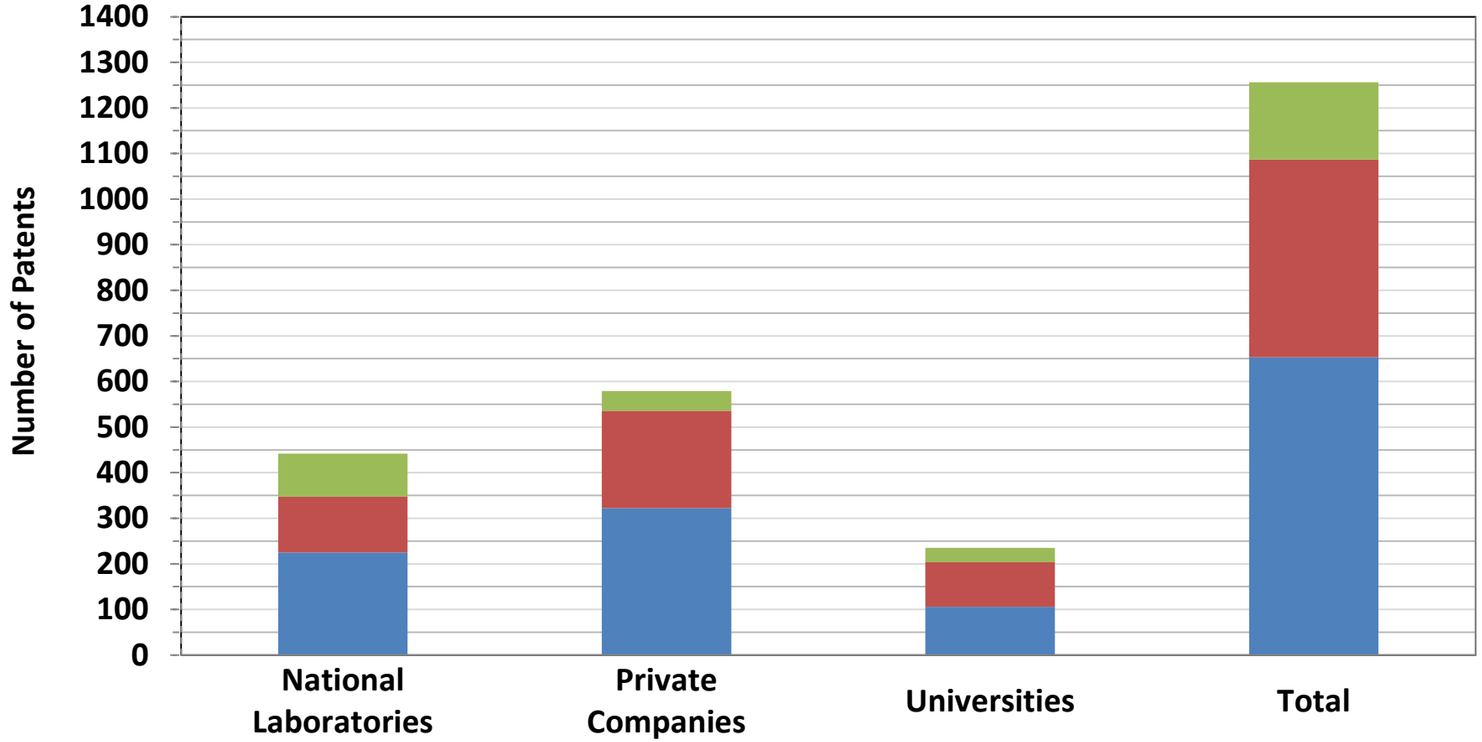


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Storage	3	4	3	3	5	1	2	9	4	5	16	9	16	13	13	6	9	10	7	9	4	9
Production/Delivery	18	22	11	19	11	17	26	16	18	31	33	26	27	27	20	15	10	11	6	13	6	22
Fuel Cell	26	32	25	20	13	20	19	11	16	31	53	37	36	36	44	34	28	26	27	19	22	30
Total	47	58	39	42	29	38	47	36	38	67	102	72	79	76	77	55	47	47	40	41	32	61

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 (R&D is mainly fuel cells and production/delivery)



	National Laboratories	Private Companies	Universities	Total
Storage	95	43	31	169
Production/Delivery	122	214	98	434
Fuel Cell	225	322	106	653
Total	442	579	235	1256

Patent Distribution by Organization Type

158 organizations receiving patent awards

- 113 private companies have 46% of patent awards
- 14 national laboratories have 35% of patent awards
- 32 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	113 (62%)	322	214	42	578	5	46.0%
National Laboratory	14 (8%)	225	122	95	442	32	35.2%
University	45 (30%)	106	98	32	236	4	18.8%
Total	182	653	434	169	1256	7	

298 patents associated with 80 technologies

- 35 fuel cell technologies (139 patents)
- 29 production and delivery technologies (88 patents)
- 6 safety technologies (28 patents)
- 10 storage technologies (43 patents)

Patents Related to Available Hydrogen and Fuel Cell Technologies*

298 patents associated with 80 technologies

- 139 patents (35 fuel cell technologies)
- 88 patents (29 production and delivery technologies)
- 28 patents (6 safety technologies)
- 43 patents (10 storage technologies)

Type of Organization	No. of Fuel Cell Patents (Technologies)	No. of Production/ Delivery Patents (Technologies)	No. of Storage Patents (Technologies)	No. of Safety Patents (Technologies)	Total Number of Patents (Technologies)
Private	105 (26)	80 (24)	13 (4)	22 (4)	220 (58)
National Laboratory	23 (5)	3 (3)	29 (5)	6 (2)	61 (15)
University	11 (4)	5 (2)	1 (1)	0 (0)	17 (7)
Total	139 (35)	88 (29)	43 (10)	28 (6)	298 (80)

** Available technology implies that the technology has either been commercialized, in-use or adopted by the organization or industry, available for commercial sale or will be available in less then 3 years.*

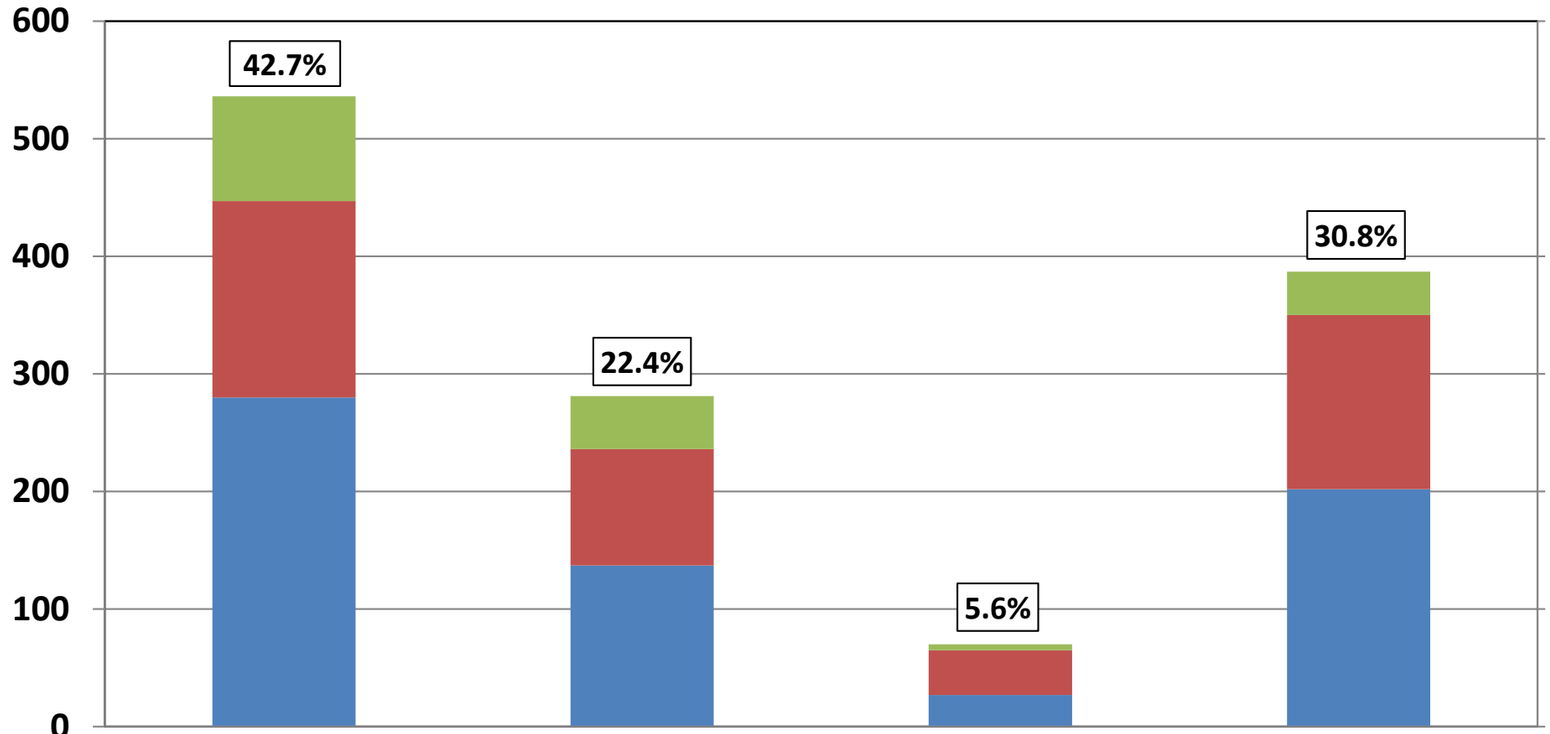
These technologies are a direct result of HFTO R&D project funding

These technologies are a direct result of HFTO R&D project funding

Status of Awarded Patents by Type

43% of patents relevant to current research

28% of patents are licensed or available for license



	Still Used in Research	Seeking to License	Licensed	No Longer Being Pursued
Storage	89	45	5	37
Production/Delivery	167	99	38	148
Fuel Cell	280	137	27	202
Total	536	281	70	387

Note: Patents can be in more than one category, sum of percentages ≠ 100%

Percentages are fractions of total number of patents in portfolio (1256)

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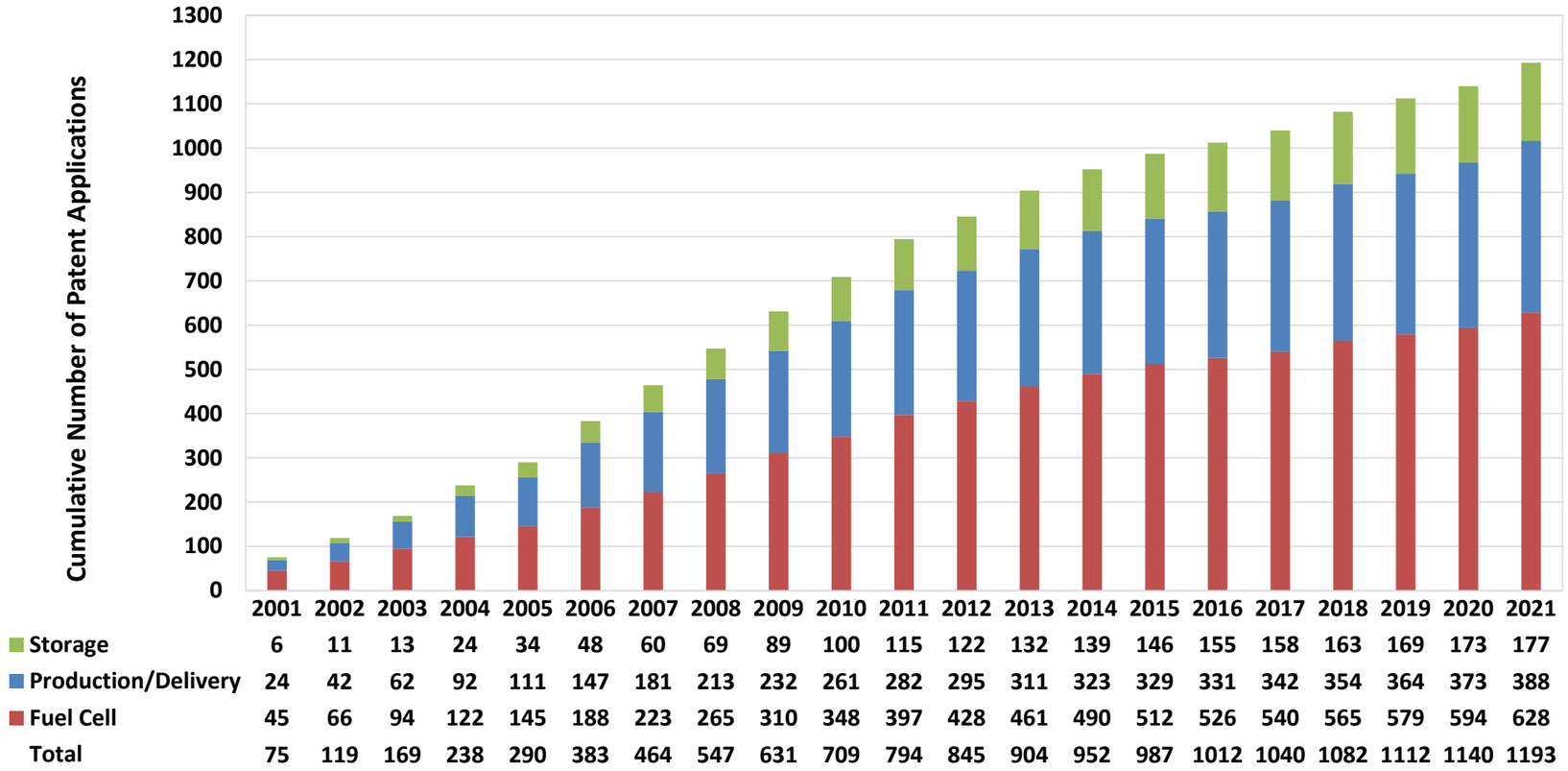
Patent Application Results

Cumulative HFTO-Funded Patent Applications by Subprogram (2001–2021)

1,193 patent applications
- 53% fuel cells
- 32% production delivery
- 15% storage

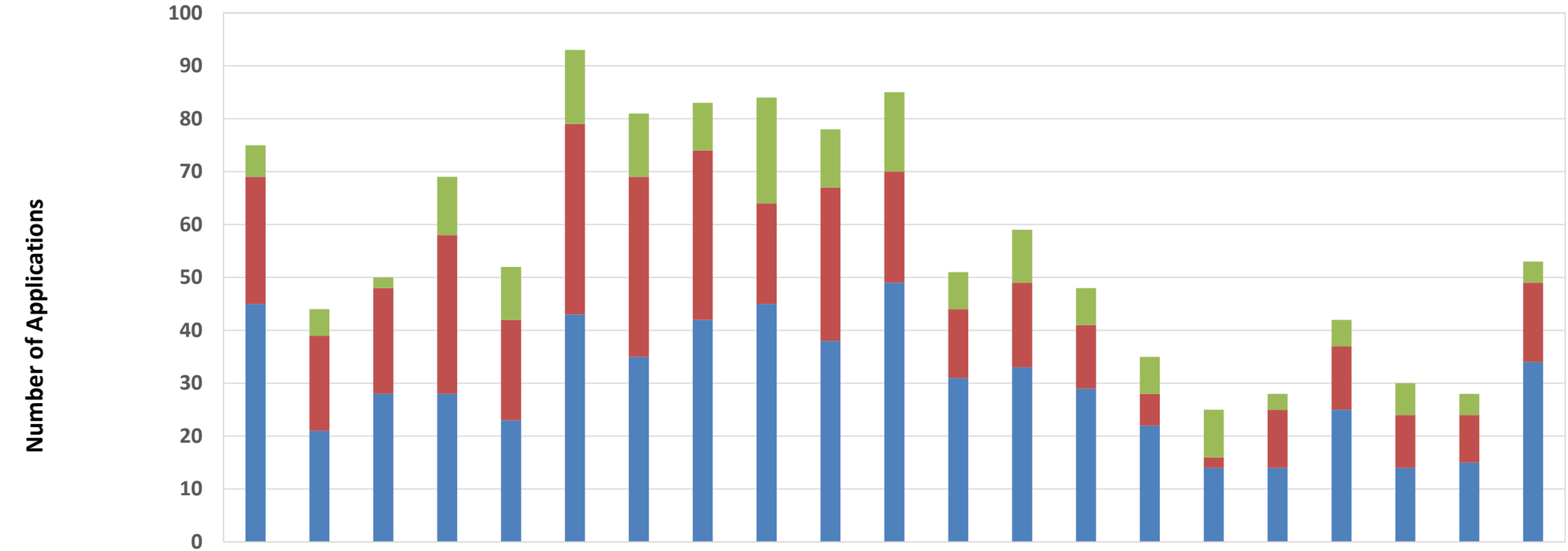


	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Storage	6	11	13	24	34	48	60	69	89	100	115	122	132	139	146	155	158	163	169	173	177
Production/Delivery	24	42	62	92	111	147	181	213	232	261	282	295	311	323	329	331	342	354	364	373	388
Fuel Cell	45	66	94	122	145	188	223	265	310	348	397	428	461	490	512	526	540	565	579	594	628
Total	75	119	169	238	290	383	464	547	631	709	794	845	904	952	987	1012	1040	1082	1112	1140	1193

- Patent application search for 2021 found 1,800 hydrogen and fuel cell-related applications
- Identified 1,193 HFTO-funded R&D-related hydrogen and fuel cell-related applications through 2021
- Rechecked previously identified hydrogen and fuel cell-related patent applications 2001–2020 for new patent awards

Patent Applications by Type (2001–2021)

53 patent applications in 2021
Average 57 patent applications per year since 2001

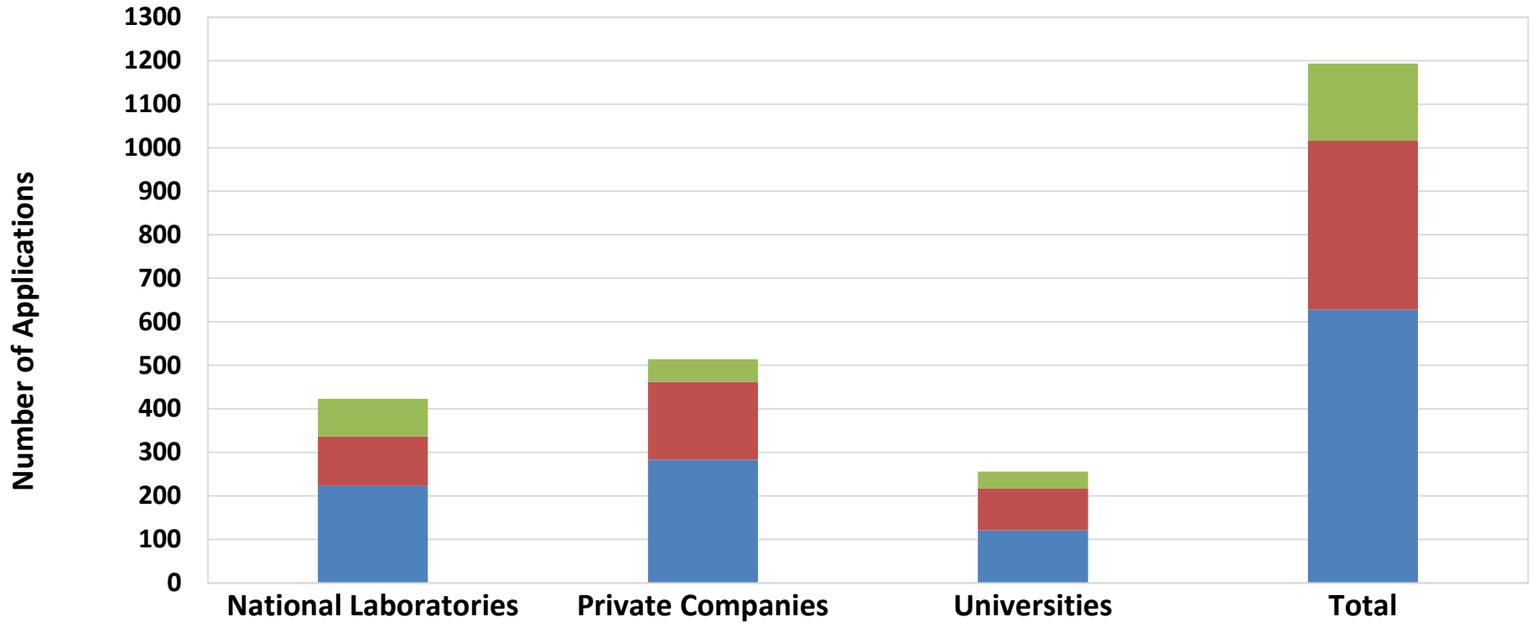


	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Storage	6	5	2	11	10	14	12	9	20	11	15	7	10	7	7	9	3	5	6	4	4
Production/Delivery	24	18	20	30	19	36	34	32	19	29	21	13	16	12	6	2	11	12	10	9	15
Fuel Cell	45	21	28	28	23	43	35	42	45	38	49	31	33	29	22	14	14	25	14	15	34
Total	75	44	50	69	52	93	81	83	84	78	85	51	59	48	35	25	28	42	30	28	53

- Number of patent applications has increased in 2021 – post pandemic application backlog processing
- 2020–2021 data is possibly affected by the 18-month pre-application publication period and legal litigation process

Patent Applications by Organization Type (2001–2021)

43% private companies
36% national laboratories
21% universities



	National Laboratories	Private Companies	Universities	Total
Storage	86	52	39	177
Production/Delivery	113	179	96	388
Fuel Cell	224	283	121	628
Total	423	514	256	1193

- 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

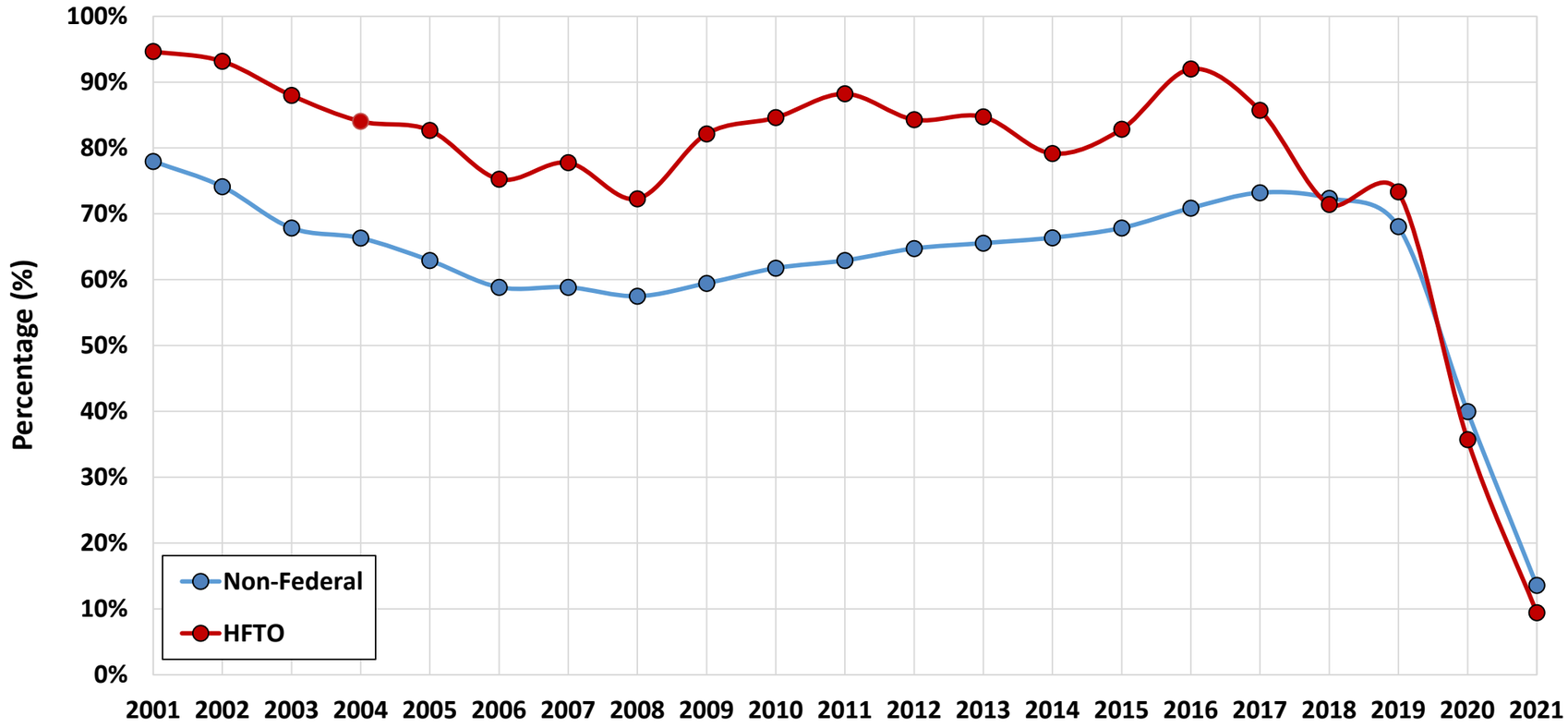
178 organizations receiving patent applications

- Private companies 60%
- Universities 33%
- National laboratories 7%
- 30 applications per national laboratory
- 4 applications per private company
- 4 applications per university

Type of Organization	Number of Organizations	Fuel Cell Applications (53%)	Production/ Delivery Applications (33%)	Storage Applications (14%)	Total	Applications per Organization	Percentage of Applications
Private	127 (60%)	283	179	52	514	4	43%
National Laboratory	14 (7%)	224	113	86	423	30	36%
University	69 (33%)	121	96	39	256	4	21%
Total	210	628	388	177	1193	6	

Percentage Non-Federal* and HFTO-Funded Patent Applications Awarded Patents (2001–2021)

78% HFTO-funded R&D-related applications are awarded patents
64% non-federal funded-related applications are awarded patents

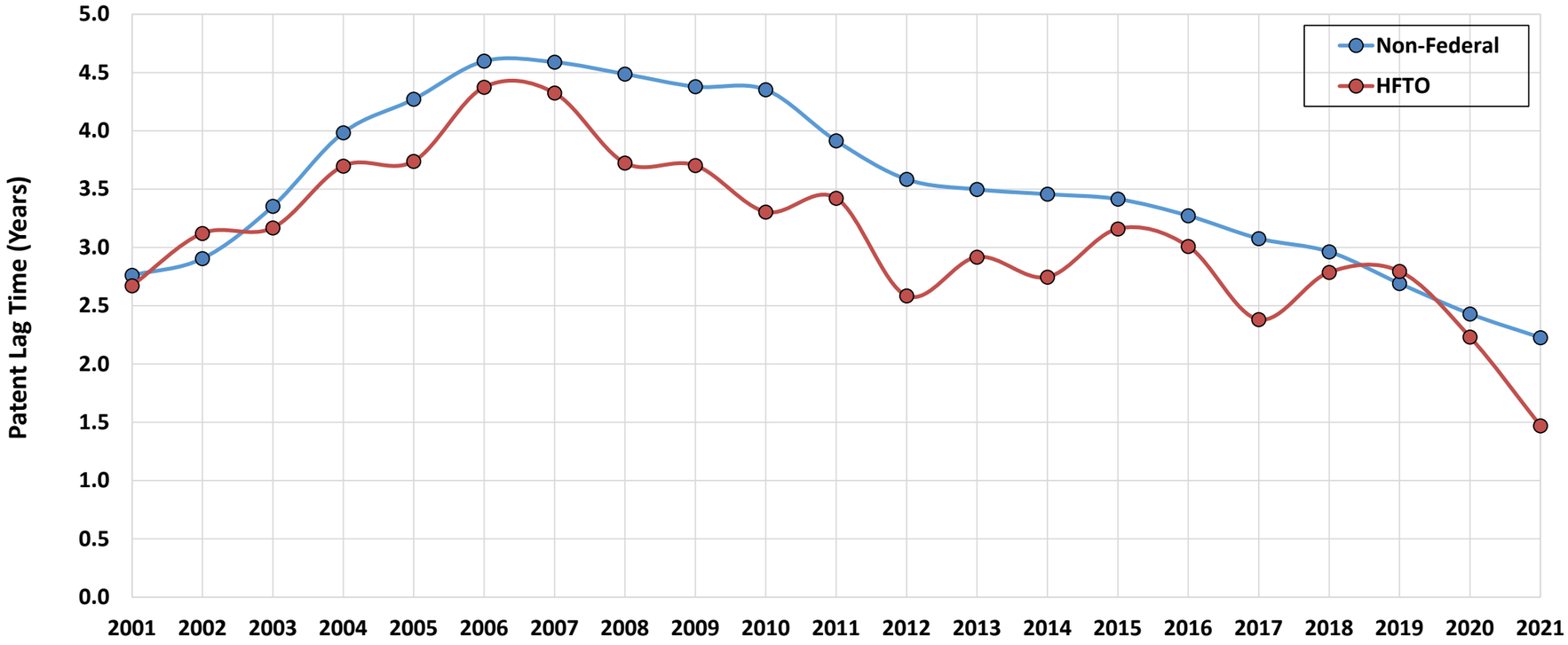


- 2020 and 2021 data is possibly affected by the 18-month pre-application publication period and legal litigation process

** 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 (2001–2021)

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 3.1 years compared to 3.5 years for non-federal patent lag times
- 2020 and 2021 data is possibly affected by the 18-month pre-application publication period and legal litigation process

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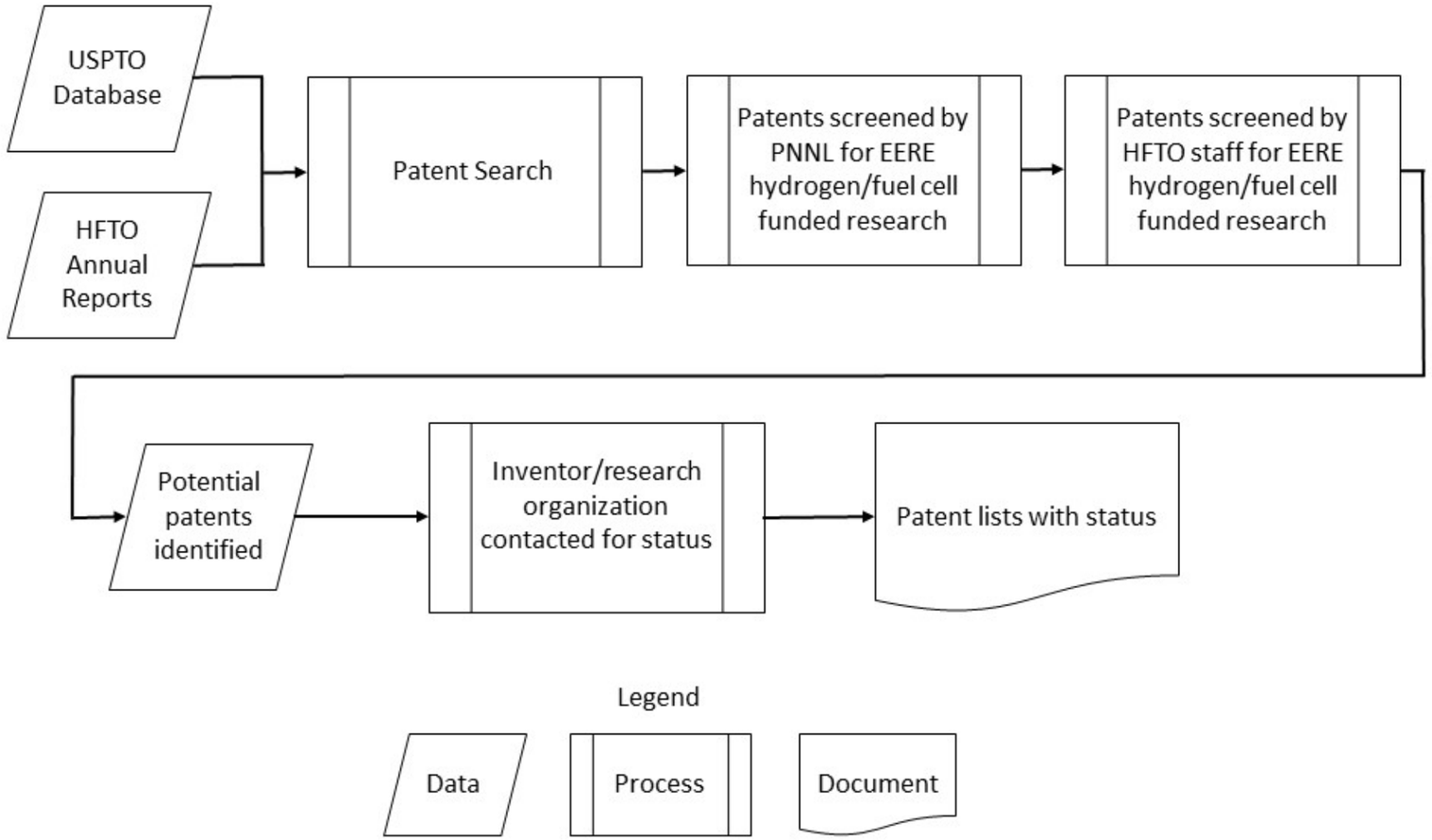
Back Up Slides

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

** Hydrogen and 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



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]

16 CPC Code Search from HFTO Patent Portfolio

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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

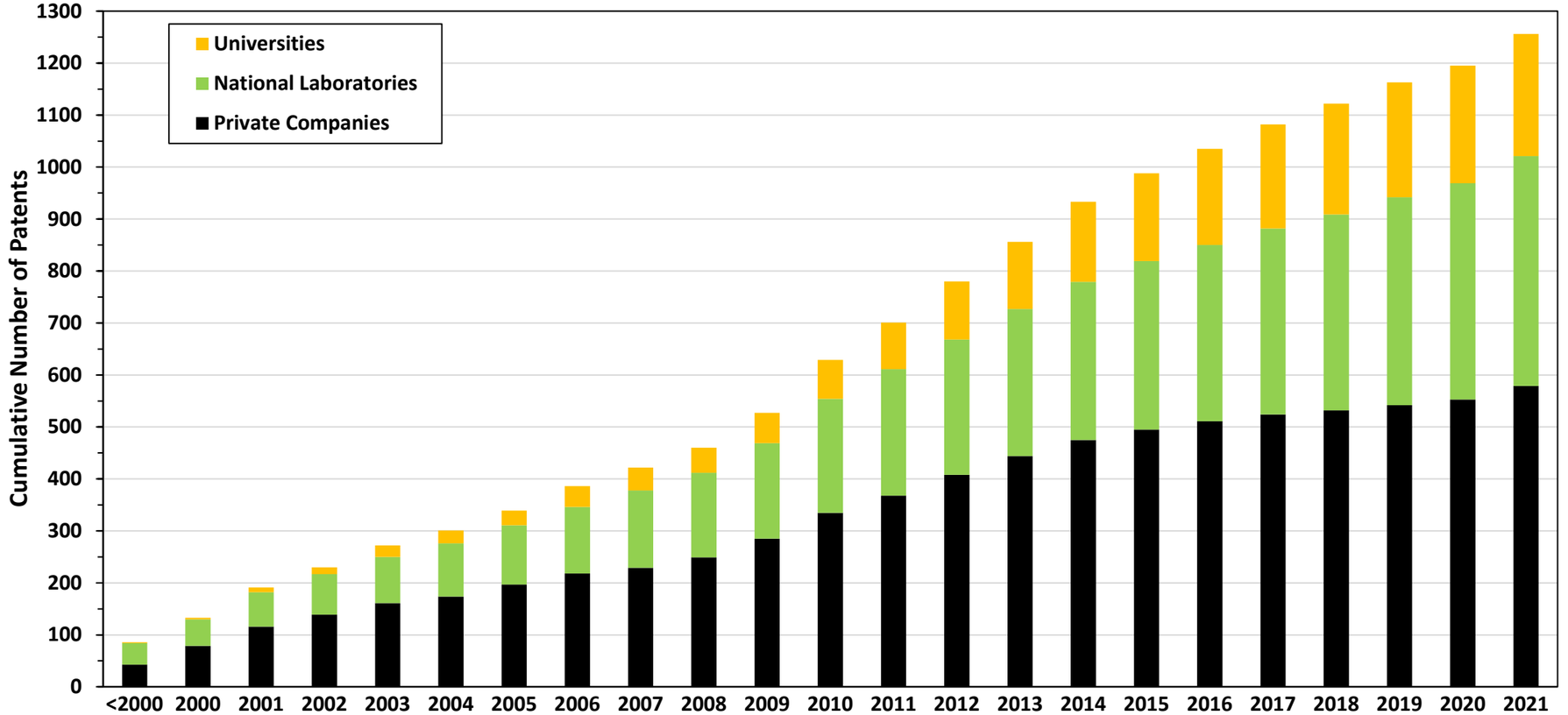
5-combos				
B01B	B01D	B01J	C01B	F28D
B01D	B01J	C01B	F28D	H01M
B01D	C08G	C08J	H01B	H01M
B01D	C08J	H01B	H01M	Y02E
B01J	B60K	B60L	C01B	H01M
B01J	B82Y	C01B	H01M	Y02E
B01J	B82Y	H01M	Y02E	Y10S
B01J	C01B	C07C	H01M	Y02E
B01J	C08G	C08J	H01M	Y02E
B82Y	C01B	H01G	H01M	Y02E
B82Y	C01B	H01M	Y02E	Y10S
C01B	C08G	C08J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

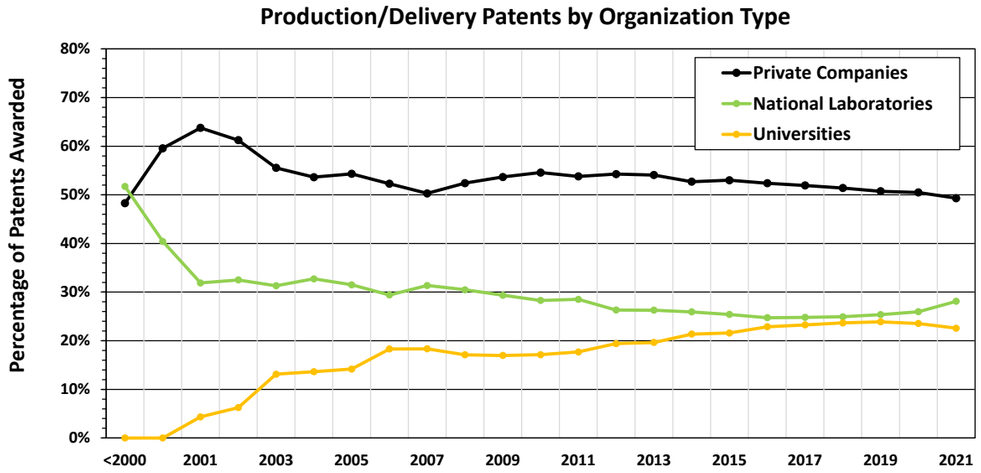
Patents Awarded Over Time by Organization Type

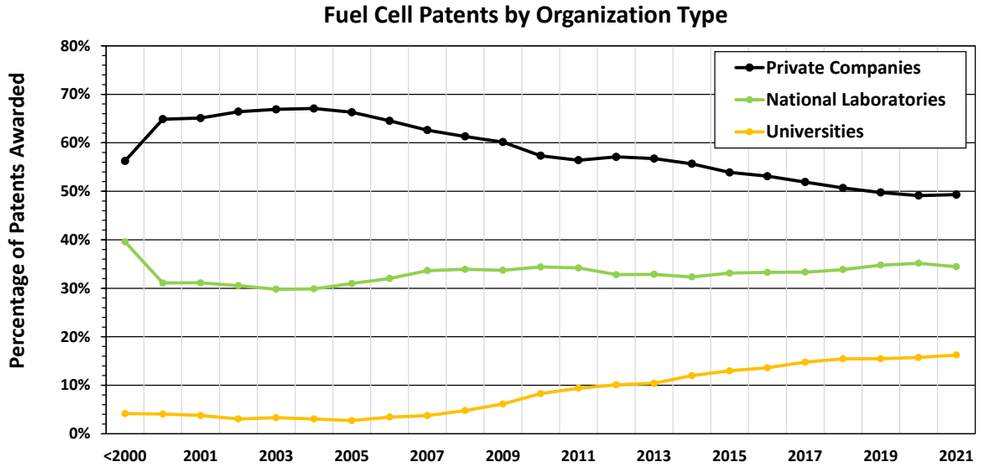


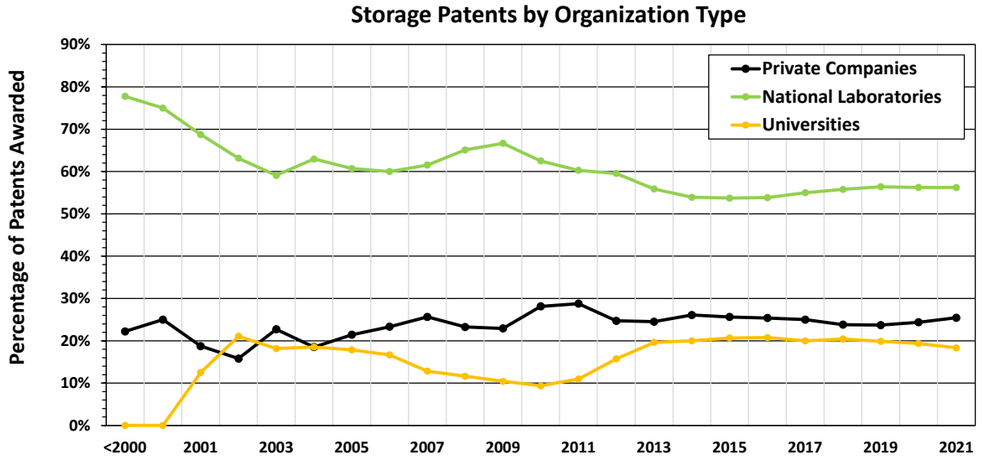
	<2000	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Universities	2	3	9	13	22	25	28	40	44	48	58	75	90	112	129	154	169	185	200	213	221	226	235
National Laboratories	41	51	66	78	89	102	114	128	149	163	184	219	243	260	283	304	324	339	358	377	400	416	442
Private Companies	43	79	116	139	161	174	197	218	229	249	285	335	368	408	444	475	495	511	524	532	542	553	579
Total	86	133	191	230	272	301	339	386	422	460	527	629	701	780	856	933	988	1035	1082	1122	1163	1195	1256

- Private companies awarded 46% patents, national laboratories 35%, and universities 19%
- Private companies awarded 24 patents per year since 2000 (national laboratories 18, universities 10)
- Patent activity increasing for universities and national laboratories
- Private company patent activity decreasing

Patent Type Over Time by Organization Type

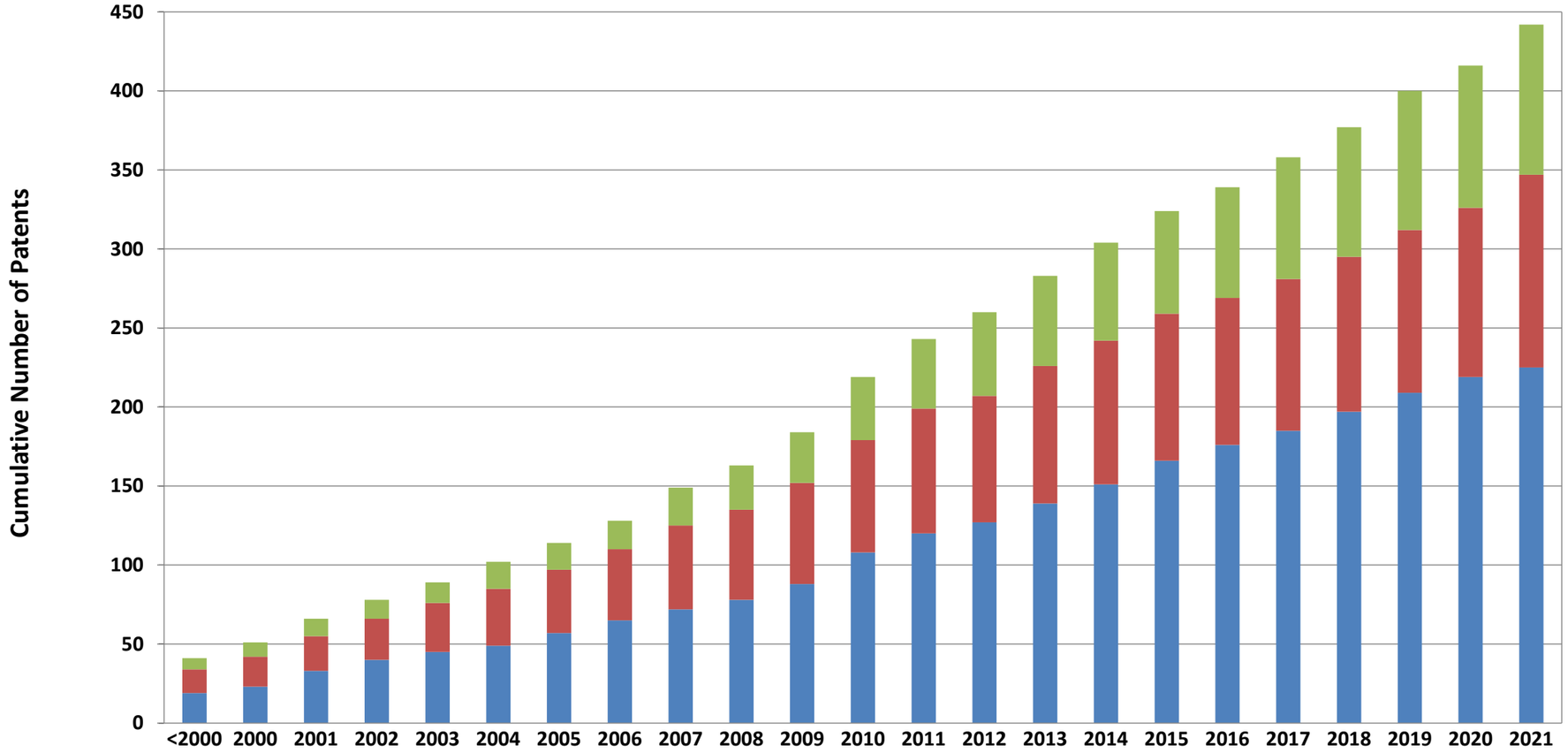






- National laboratory and university fuel cell activity increasing
- Overall production/delivery activity constant
- National laboratory storage activity constant

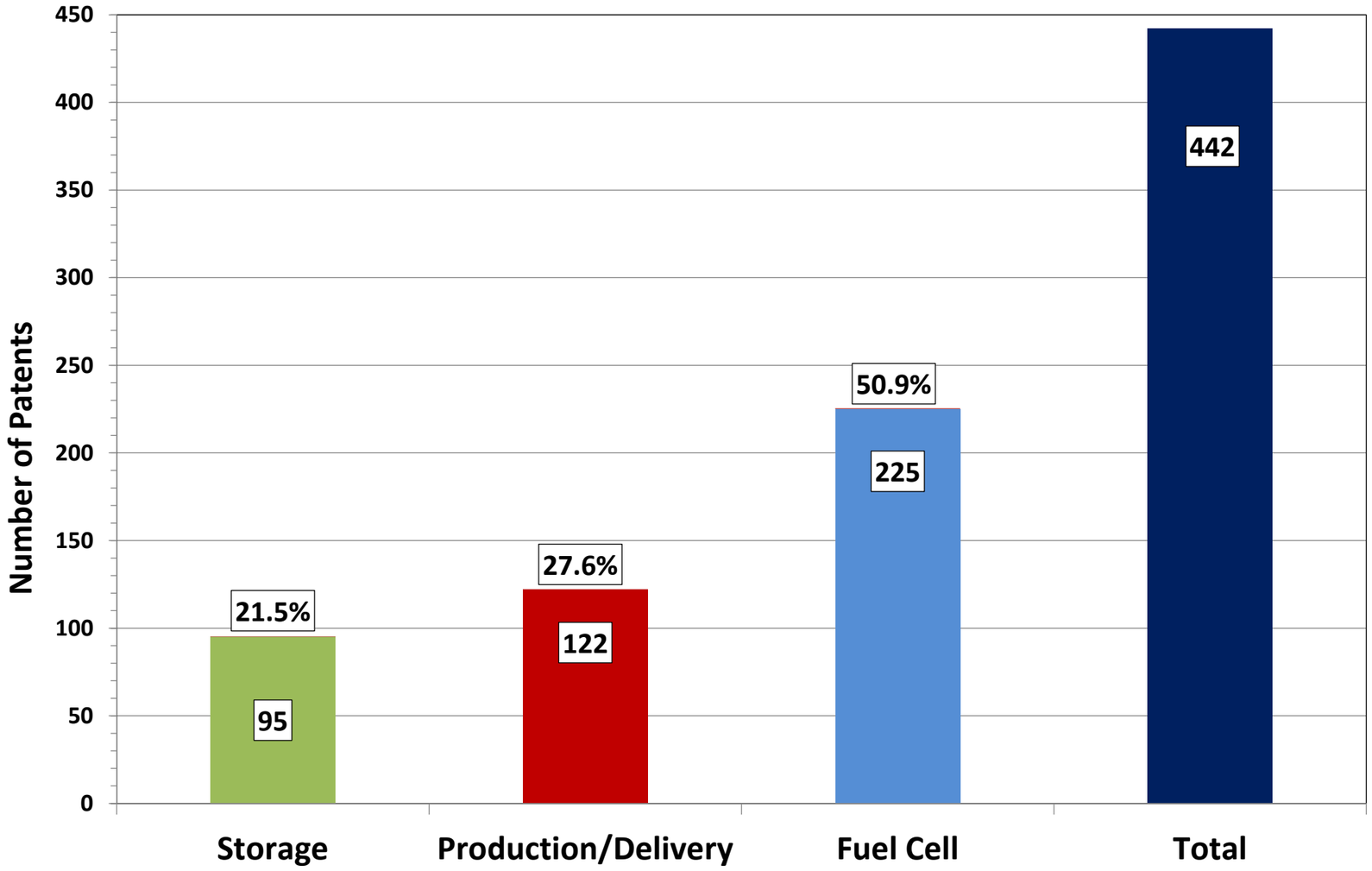
National Laboratory Patent Analysis
Cumulative Number of Patents Awarded Over Time



	<2000	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Storage	7	9	11	12	13	17	17	18	24	28	32	40	44	53	57	62	65	70	77	82	88	90	95
Production/Delivery	15	19	22	26	31	36	40	45	53	57	64	71	79	80	87	91	93	93	96	98	103	107	122
Fuel Cell	19	23	33	40	45	49	57	65	72	78	88	108	120	127	139	151	166	176	185	197	209	219	225
Total	41	51	66	78	89	102	114	128	149	163	184	219	243	260	283	304	324	339	358	377	400	416	442

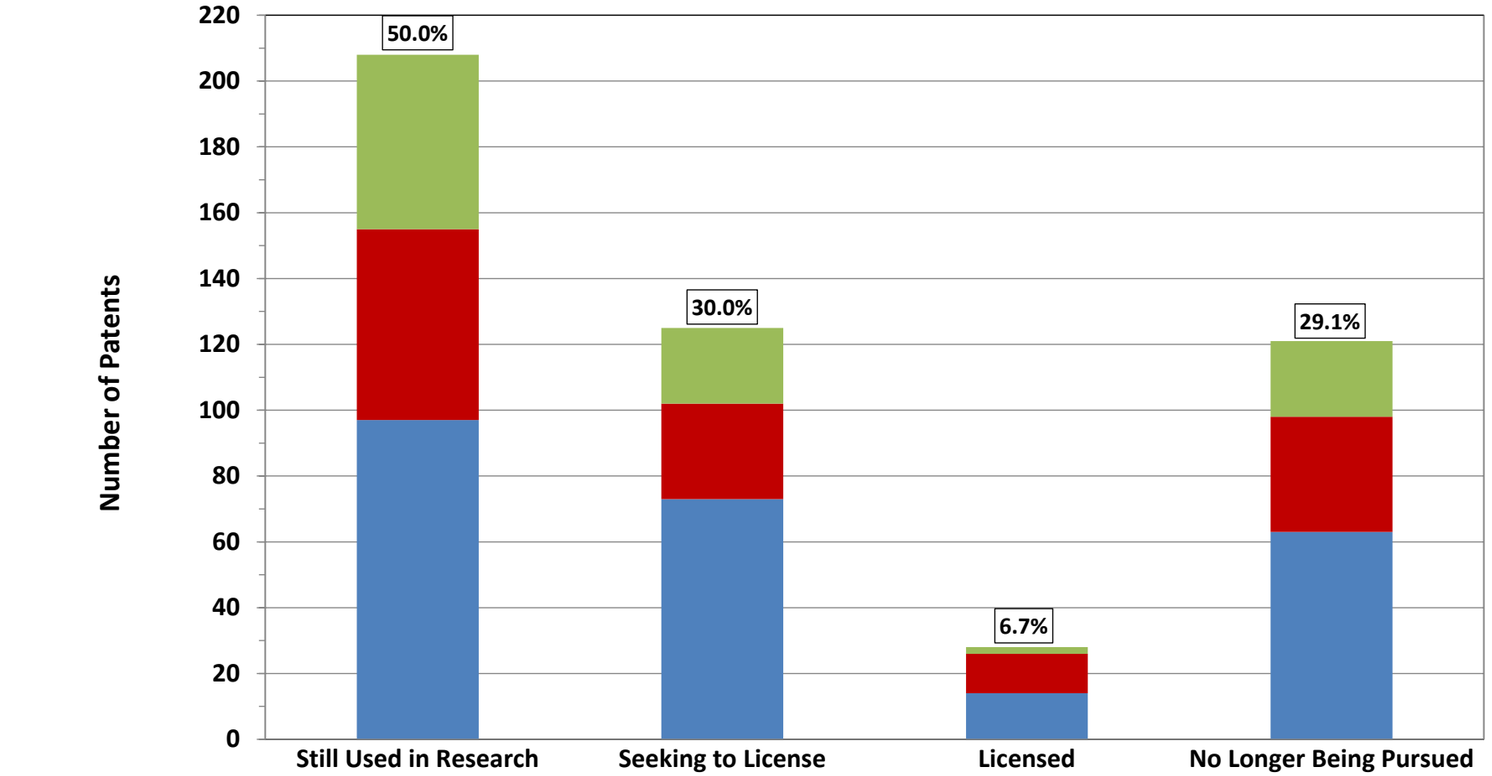
- 442 national laboratory patents
- National laboratory activity primarily in fuel cells

National Laboratory Patent Analysis: Patents by Type



- 51% of national laboratory patents in fuel cells
- National laboratory research activity in production/delivery and storage approximately equal

National Laboratory Patent Analysis: Patent Status



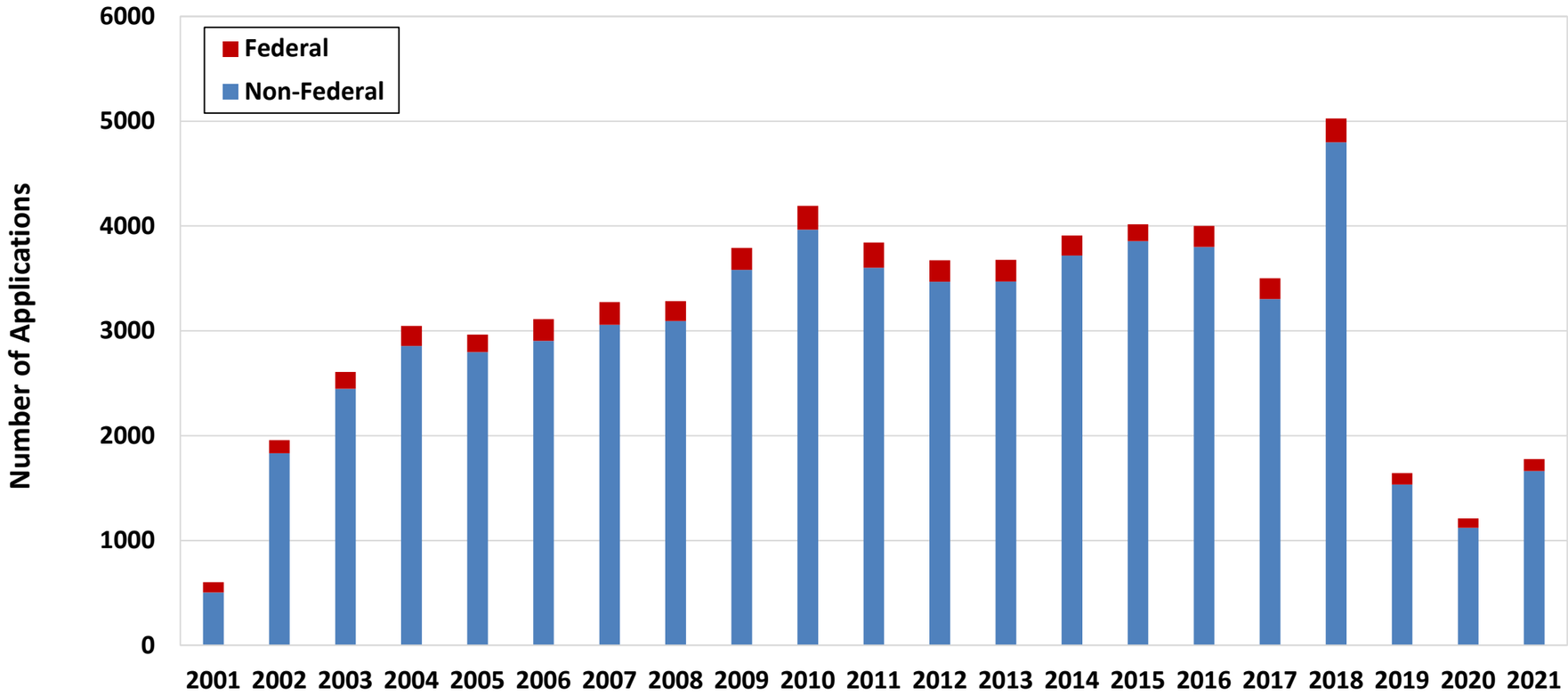
	Still Used in Research	Seeking to License	Licensed	No Longer Being Pursued
Storage	53	23	2	23
Production/Delivery	58	29	12	35
Fuel Cell	97	73	14	63
Total	208	125	28	121

- 47% of national laboratory patents still relevant to current research activities
- Approximately 36% 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 (442)

All Hydrogen and Fuel Cell-Related Patent Applications* (2001–2021)

Number of patent applications increased in 2021 (1,778)



** Federal and Non-Federal funded. 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 non-U.S. Government agencies.*

Non-Federal Funded Patent Applications by Organization Type (2001–2021)

Type of Organization	Fuel Cell Applications	Production/ Delivery Applications	Storage Applications	Total	Percentage of Applications
Private Companies	35,446 (92.2%)	17,240 (91.2%)	2,184 (92.4%)	54,870	91.9%
Foreign National Laboratories	1,006 (2.5%)	477 (2.5%)	56 (2.4%)	1,539	2.6%
National Laboratories	63 (0.2%)	62 (0.3%)	2 (0.1%)	127	0.2%
Universities	1,944 (5.1%)	1,117 (6.0%)	121 (5.1%)	3,182	5.3%
Total	38,459 (64.4%)	18,896 (31.6%)	2,363 (4.0%)	59,939	