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2020 Patent and Patent Application Analysis for the U.S. Department of Energy Hydrogen and Fuel Cell Technologies Office

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PNNL-31850

U.S. DEPARTMENT OF ENERGY BATTELLE

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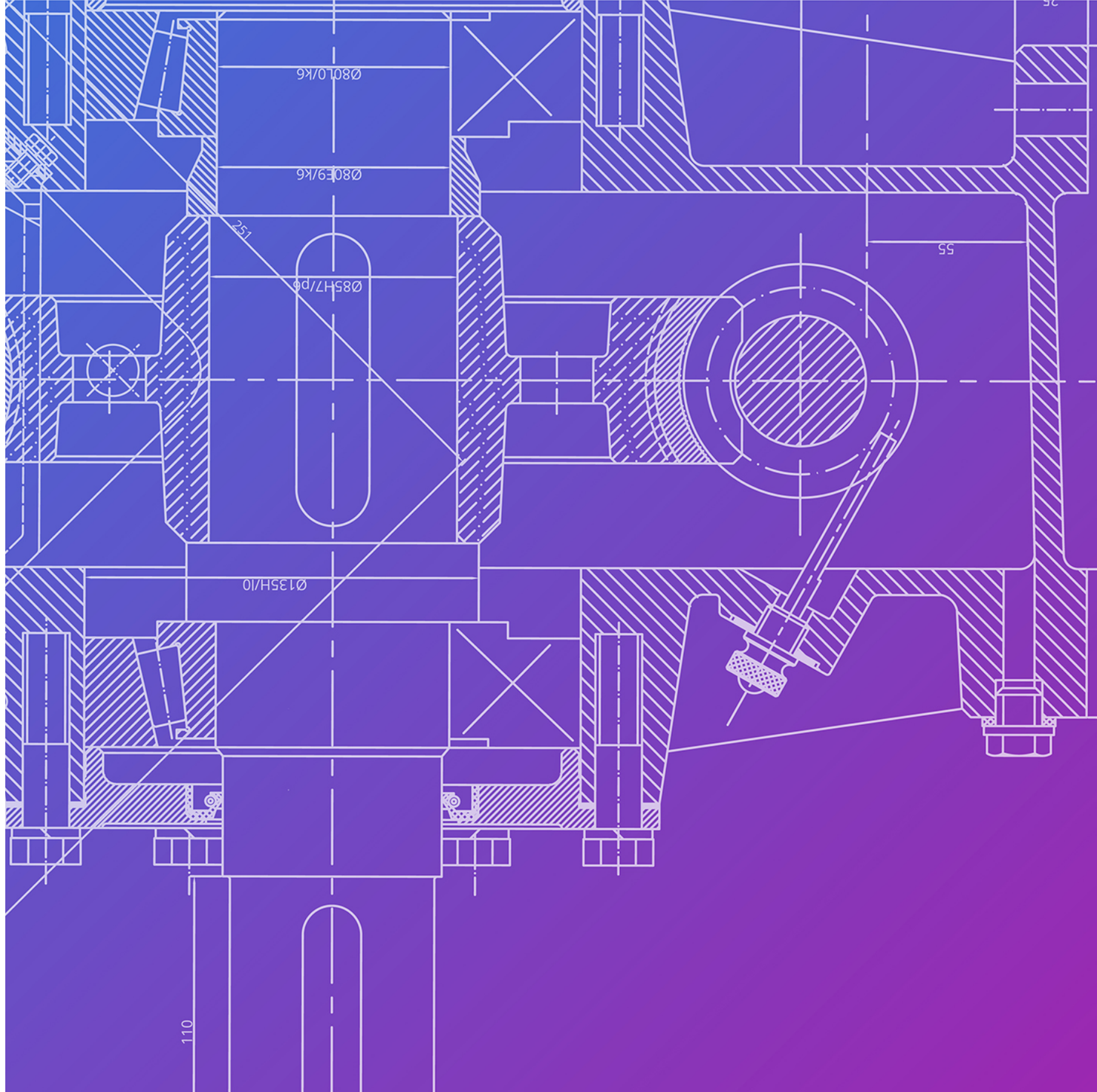

HFTO Patent Tracking – Purpose

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

1,117 U.S. patent applications and 1,137 U.S. patent awards related to HFTO-funded R&D through 2020

- **1,137 U.S. patent awards resulting from HFTO-funded R&D (1977–2020)**
  - 589 fuel cell patents (52%)
  - 398 hydrogen production and delivery patents (35%)
  - 150 hydrogen storage patents (13%)
  - 29% of all patents are available for license or licensed
  - 41% are actively being used in R&D
- **Three types of organizations received patents**
  - National laboratories (35% overall) 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
- **1,117 U.S. patent applications resulting from HFTO-funded R&D (2001–2020)***
  - 612 fuel cell patent applications (55%)
  - 349 hydrogen production and delivery patent applications (31%)
  - 156 hydrogen storage patents (14%)
  - 83% 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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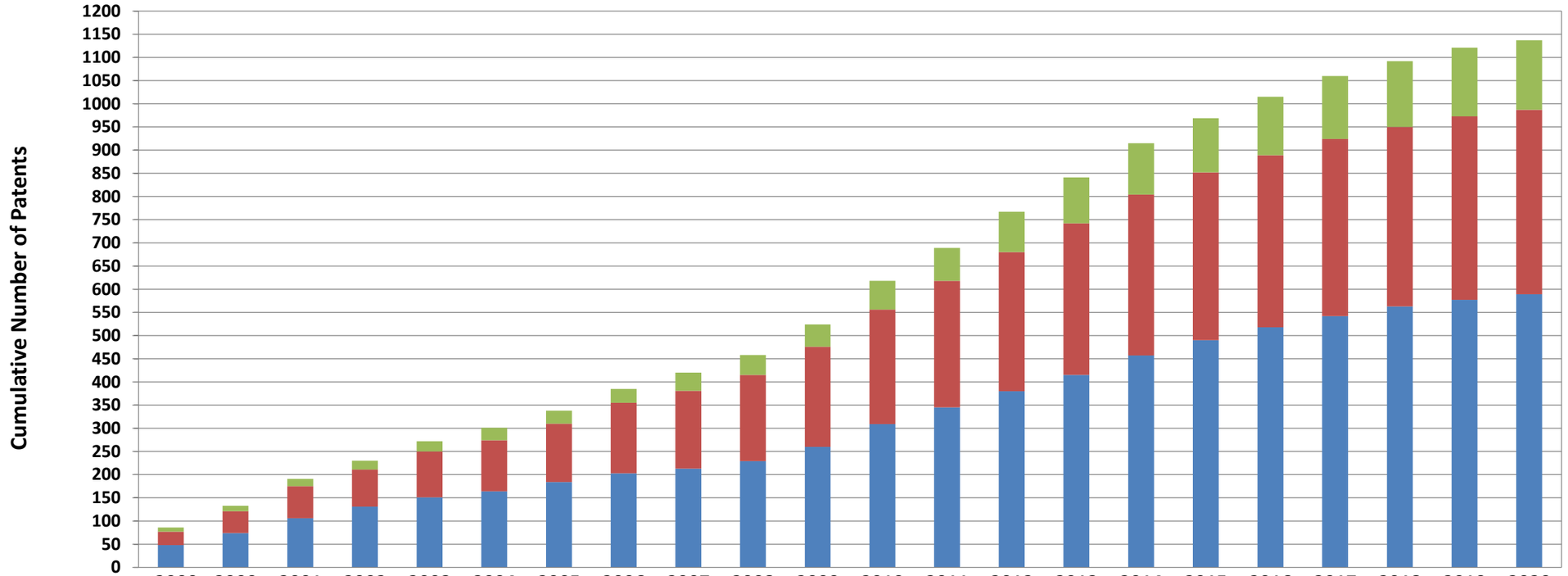
Patent Results

Cumulative Number of Patents Awarded Over Time (≤2000–2020)

1,137 patent awards, 16 issued in 2020

- 589 fuel cell
- 150 hydrogen storage
- 398 hydrogen production and delivery



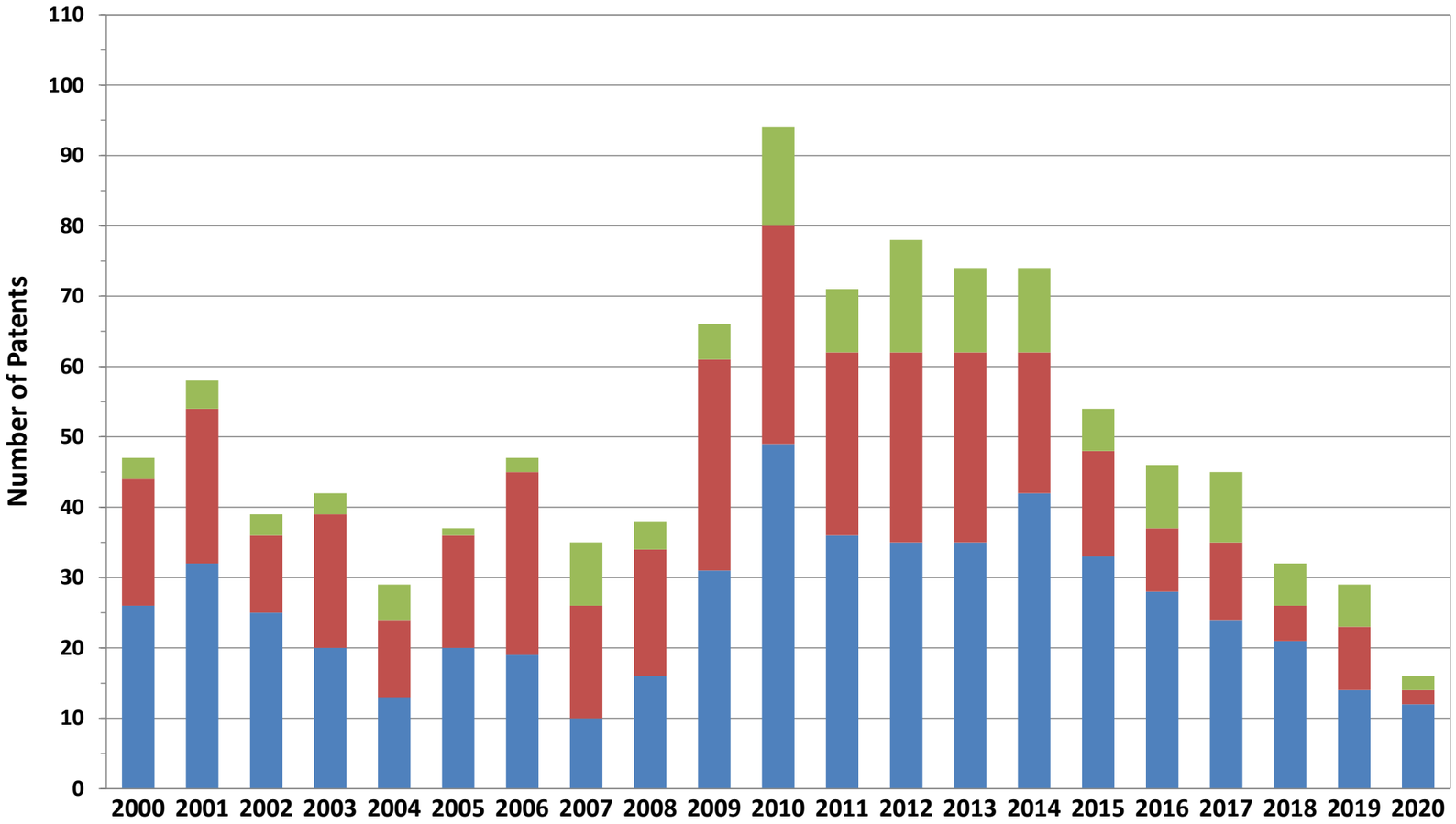
	<2000	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Storage	9	12	16	19	22	27	28	30	39	43	48	62	71	87	99	111	117	126	136	142	148	150
Production/Delivery	29	47	69	80	99	110	126	152	168	186	216	247	273	300	327	347	362	371	382	387	396	398
Fuel Cell	48	74	106	131	151	164	184	203	213	229	260	309	345	380	415	457	490	518	542	563	577	589
Total	86	133	191	230	272	301	338	385	420	458	524	618	689	767	841	915	969	1015	1060	1092	1121	1137

Note: Calendar years

Number of Patents Awarded Per Year (2000–2020)

Average 50 patents per year since 2000

- 26 fuel cell
- 18 hydrogen production and delivery
- 7 hydrogen storage

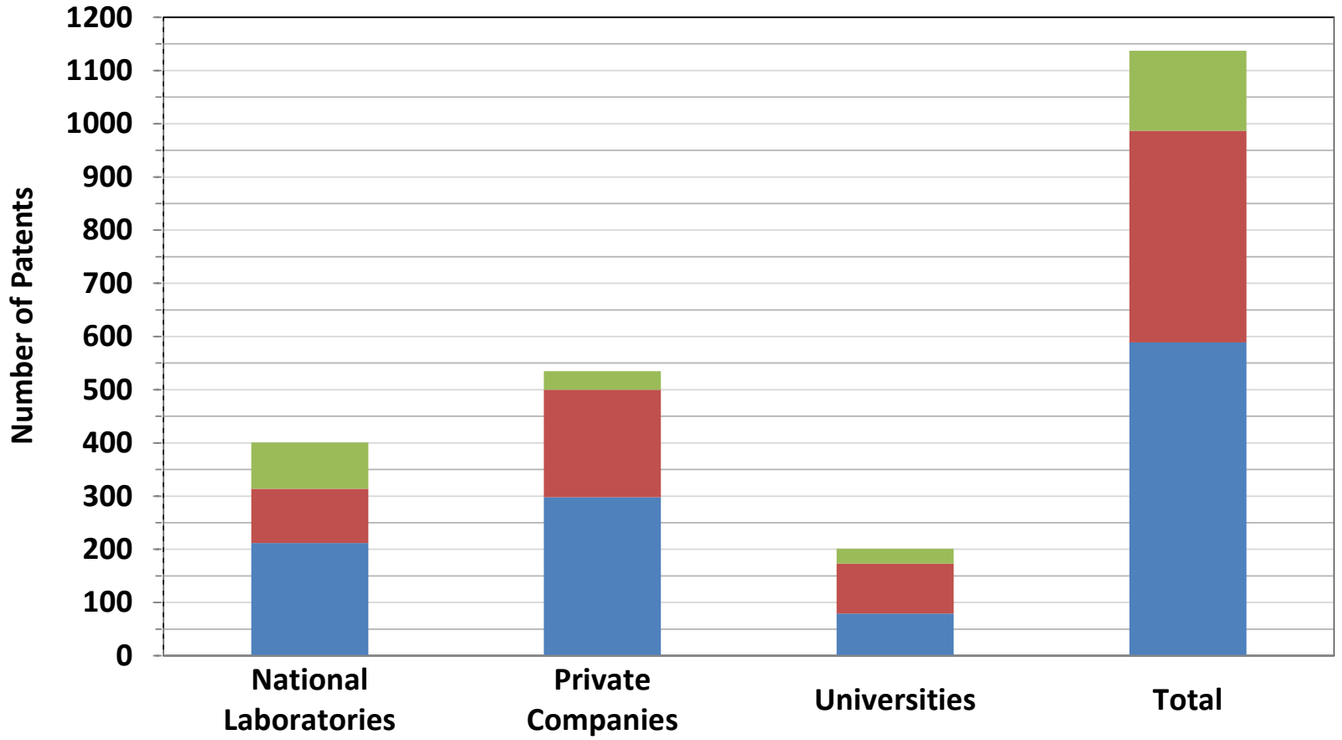


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Storage	3	4	3	3	5	1	2	9	4	5	14	9	16	12	12	6	9	10	6	6	2
Production/Delivery	18	22	11	19	11	16	26	16	18	30	31	26	27	27	20	15	9	11	5	9	2
Fuel Cell	26	32	25	20	13	20	19	10	16	31	49	36	35	35	42	33	28	24	21	14	12
Total	47	58	39	42	29	37	47	35	38	66	94	71	78	74	74	54	46	45	32	29	16

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	87	35	28	150
Production/Delivery	102	202	94	398
Fuel Cell	212	298	79	589
Total	401	535	201	1137

Patent Distribution by Organization Type

158 organizations receiving patent awards

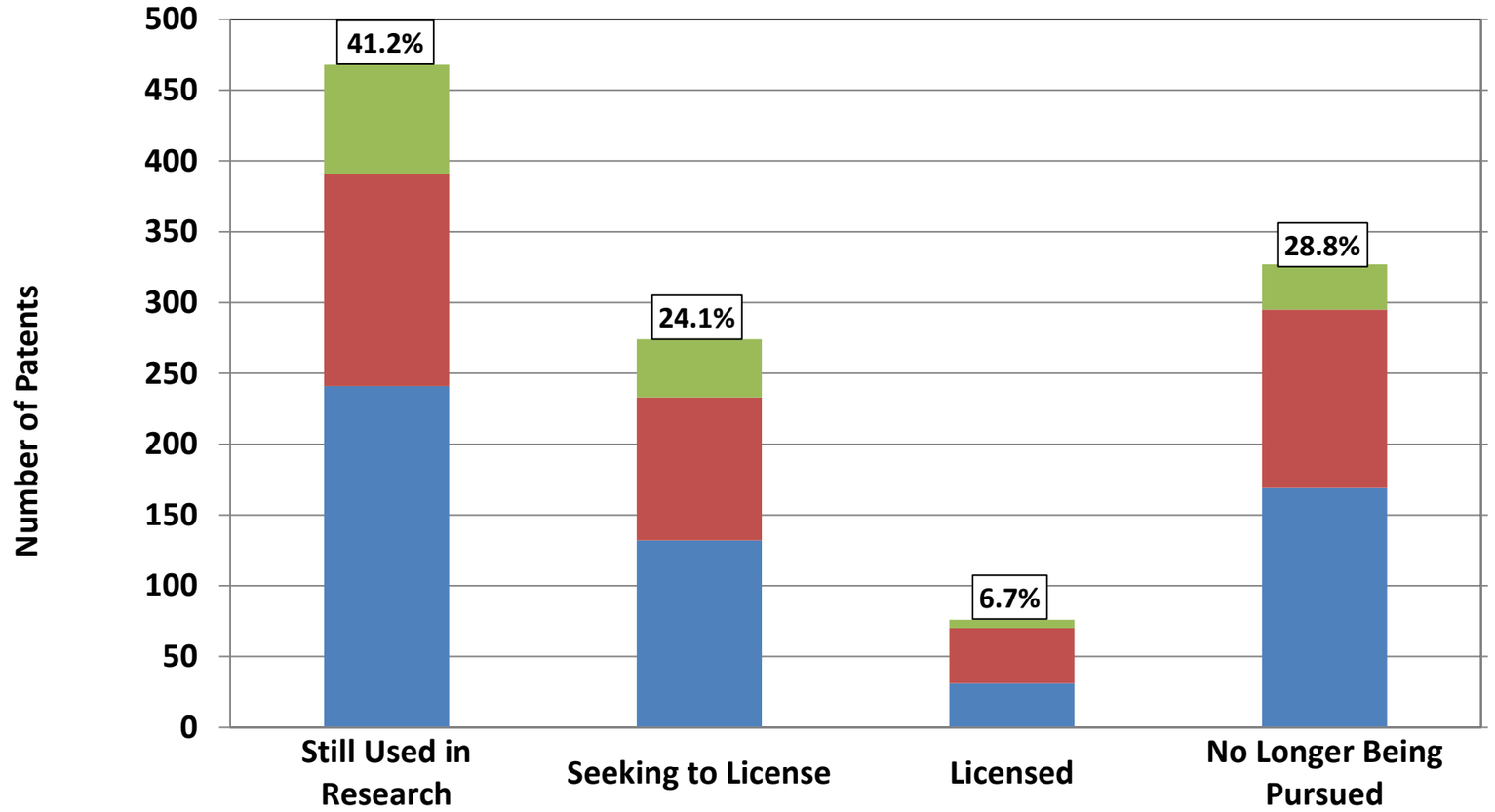
- 98 private companies have 47% of patent awards
- 13 national laboratories have 35% of patent awards
- 31 patents per national laboratory
- 4 patents per private company
- 7 patents per university

Type of Organization	Number of Organizations	Fuel Cell Patents	Production/ Delivery Patents	Storage Patents	Total	Patents per Organization	Percent Patent Awards
Private	98 (63%)	299	202	35	536	5	47.1%
National Laboratory	13 (8%)	212	102	87	401	31	35.3%
University	45 (29%)	78	94	28	200	4	17.6%
Total	158	589	398	150	1137	7	

Status of Awarded Patents by Type

41% of patents relevant to current research

31% of patents are licensed or available for license



	Still Used in Research	Seeking to License	Licensed	No Longer Being Pursued
Storage	77	41	6	32
Production/Delivery	150	101	39	126
Fuel Cell	241	132	31	169
Total	468	274	76	327

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

Percentages are fractions of total number of patents in portfolio (1113)

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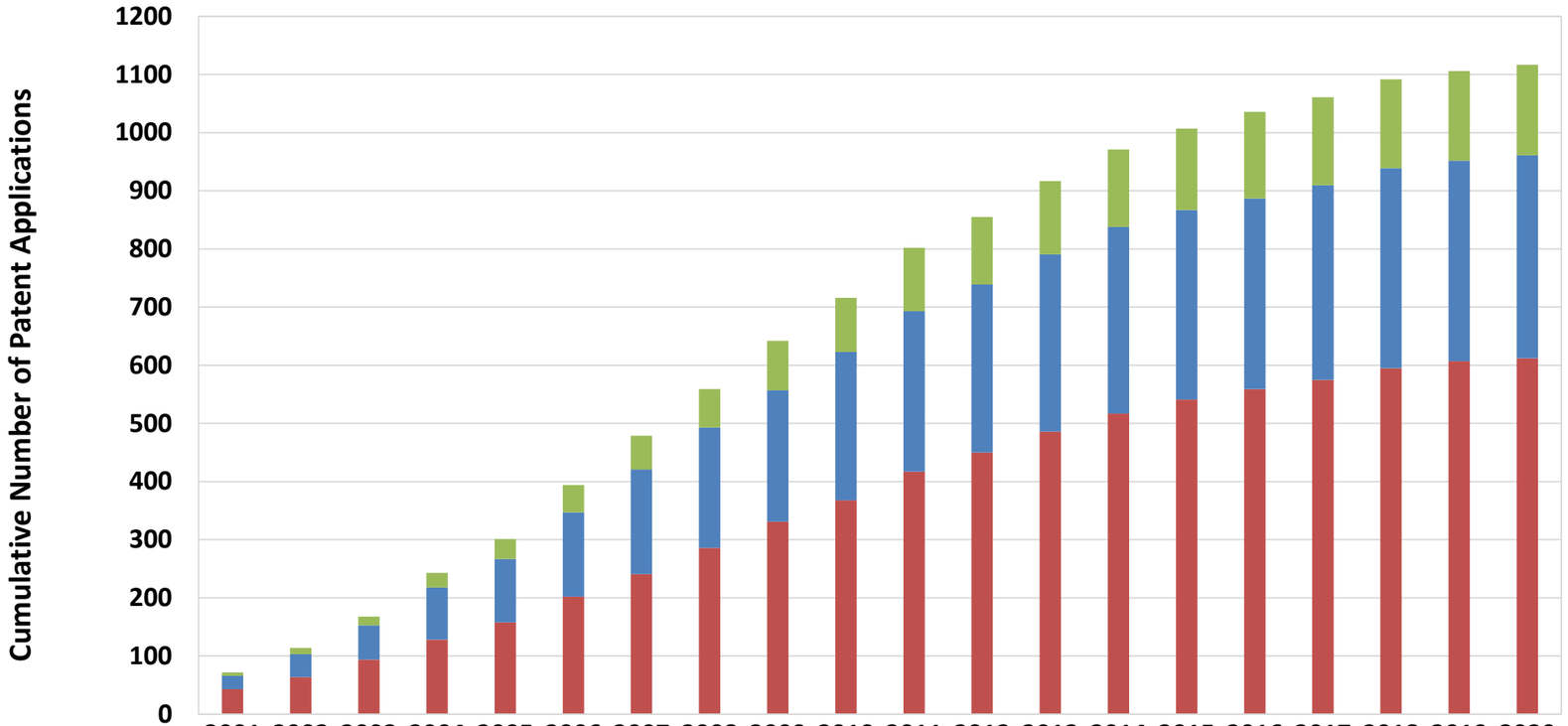
Patent Application Results

Cumulative HFTO-Funded Patent Applications by Subprogram (2001–2020)

1,117 patent applications
- 55% fuel cells
- 31% production delivery
- 14% storage

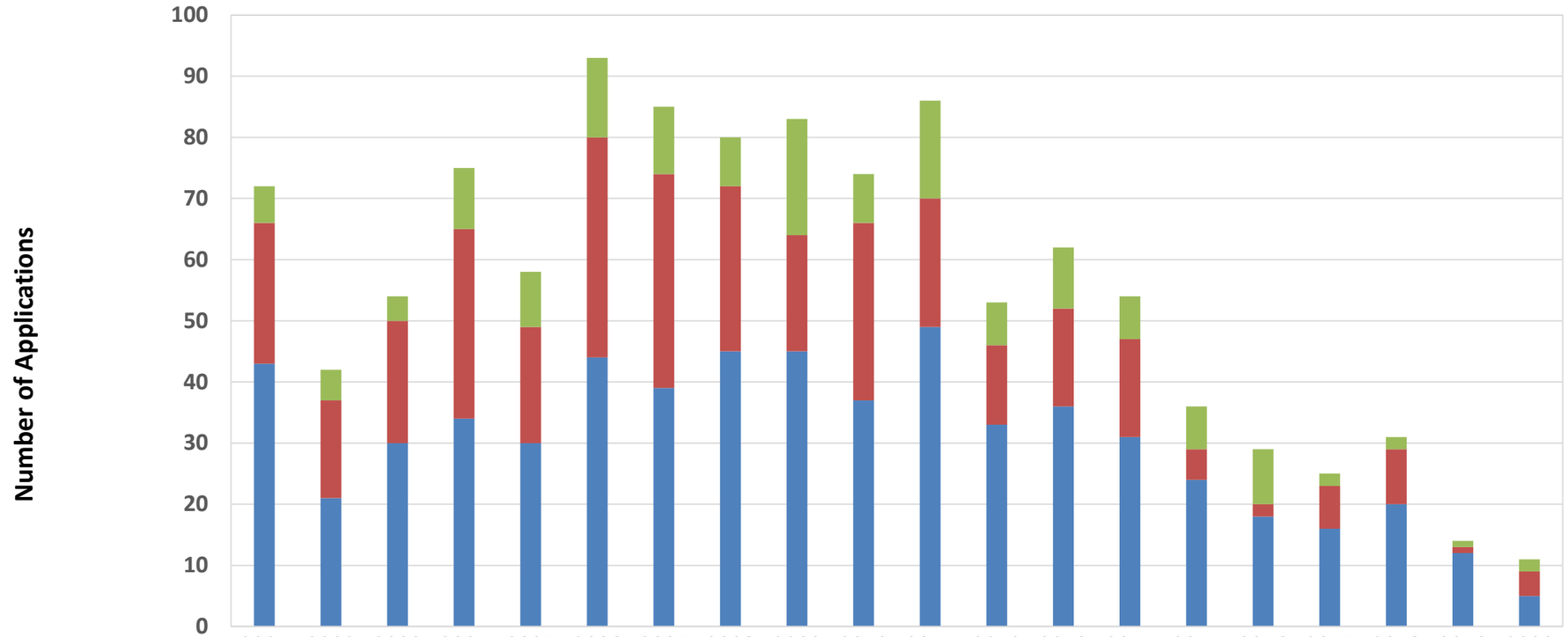


	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Storage	6	11	15	25	34	47	58	66	85	93	109	116	126	133	140	149	151	153	154	156
Production/Delivery	23	39	59	90	109	145	180	207	226	255	276	289	305	321	326	328	335	344	345	349
Fuel Cell	43	64	94	128	158	202	241	286	331	368	417	450	486	517	541	559	575	595	607	612
Total	72	114	168	243	301	394	479	559	642	716	802	855	917	971	1007	1036	1061	1092	1106	1117

- Patent application search for 2020 found 1,200 hydrogen and fuel cell-related applications
- Identified 1,117 HFTO-funded R&D-related hydrogen and fuel cell-related applications through 2020
- Rechecked previously identified hydrogen and fuel cell-related patent applications 2001–2019 for new patent awards

Patent Applications by Type (2001–2020)

11 patent applications in 2020
Average 56 patent applications per year since 2001

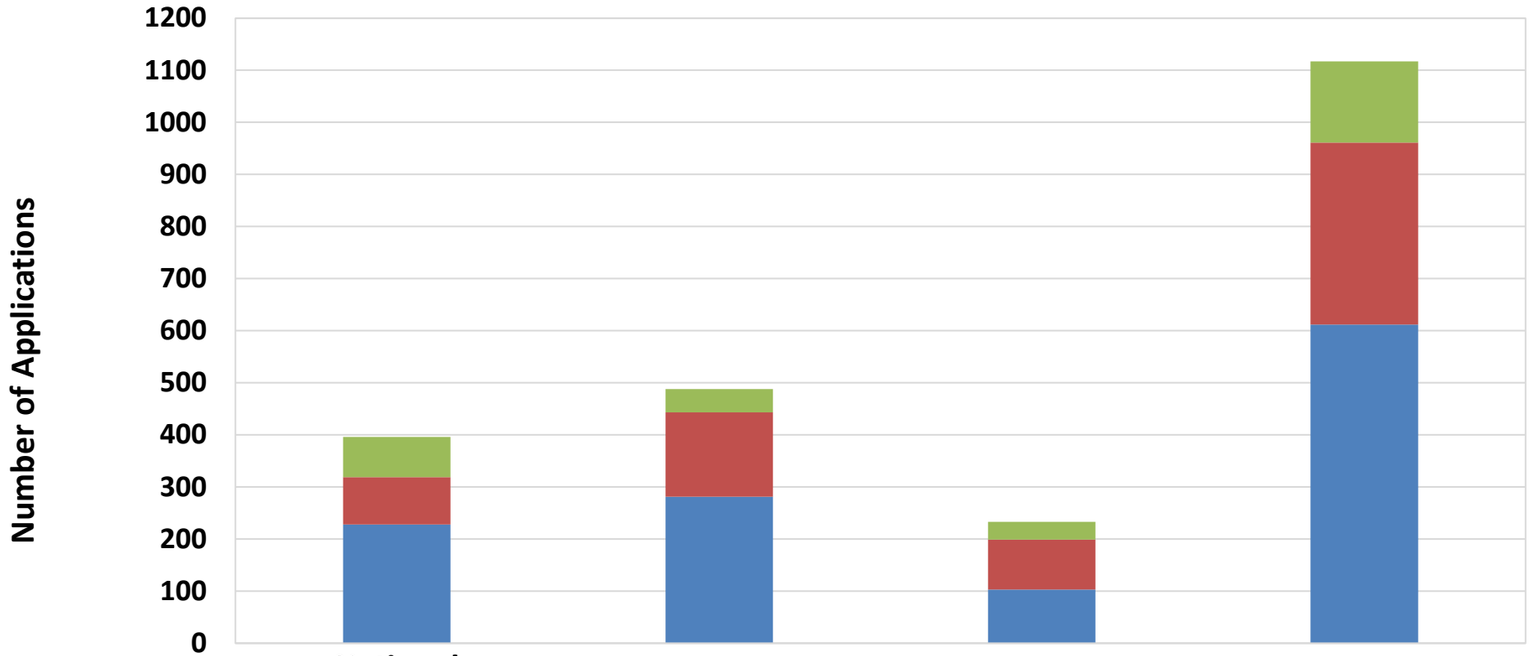


	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Storage	6	5	4	10	9	13	11	8	19	8	16	7	10	7	7	9	2	2	1	2
Production/Delivery	23	16	20	31	19	36	35	27	19	29	21	13	16	16	5	2	7	9	1	4
Fuel Cell	43	21	30	34	30	44	39	45	45	37	49	33	36	31	24	18	16	20	12	5
Total	72	42	54	75	58	93	85	80	83	74	86	53	62	54	36	29	25	31	14	11

- Number of patent applications has remained approximately the same in 2019 and 2020
- 2019–2020 data is possibly affected by the 18-month pre-application publication period and legal litigation process

Patent Applications by Organization Type (2001–2020)

44% private companies
35% national laboratories
21% universities



	National Laboratories	Private Companies	Universities	Total
Storage	77	45	34	156
Production/Delivery	91	162	96	349
Fuel Cell	228	281	103	612
Total	396	488	233	1117

- 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

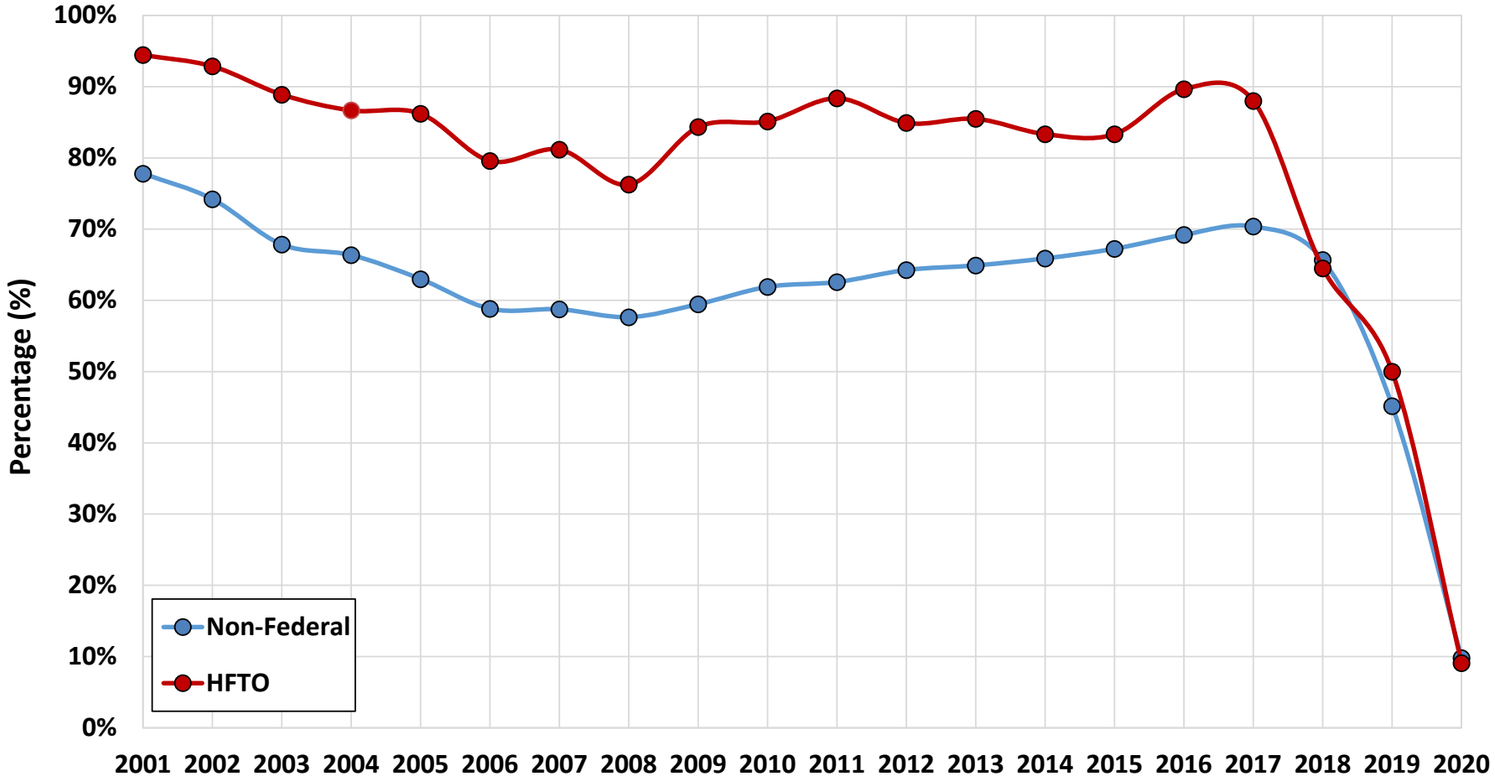
178 organizations receiving patent applications

- Private companies 57%
- Universities 35%
- National laboratories 8%
- 30 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	108 (61%)	281	162	45	488	5	44%
National Laboratory	13 (7%)	228	91	77	396	30	35%
University	57 (32%)	103	96	34	233	4	21%
Total	178	612 (55%)	349 (31%_	156 (14%)	1117	6	

Percentage Non-Federal* and HFTO-Funded Patent Applications Awarded Patents (2001–2020)

83% HFTO-funded R&D-related applications are awarded patents
63% non-federal funded-related applications are awarded patents

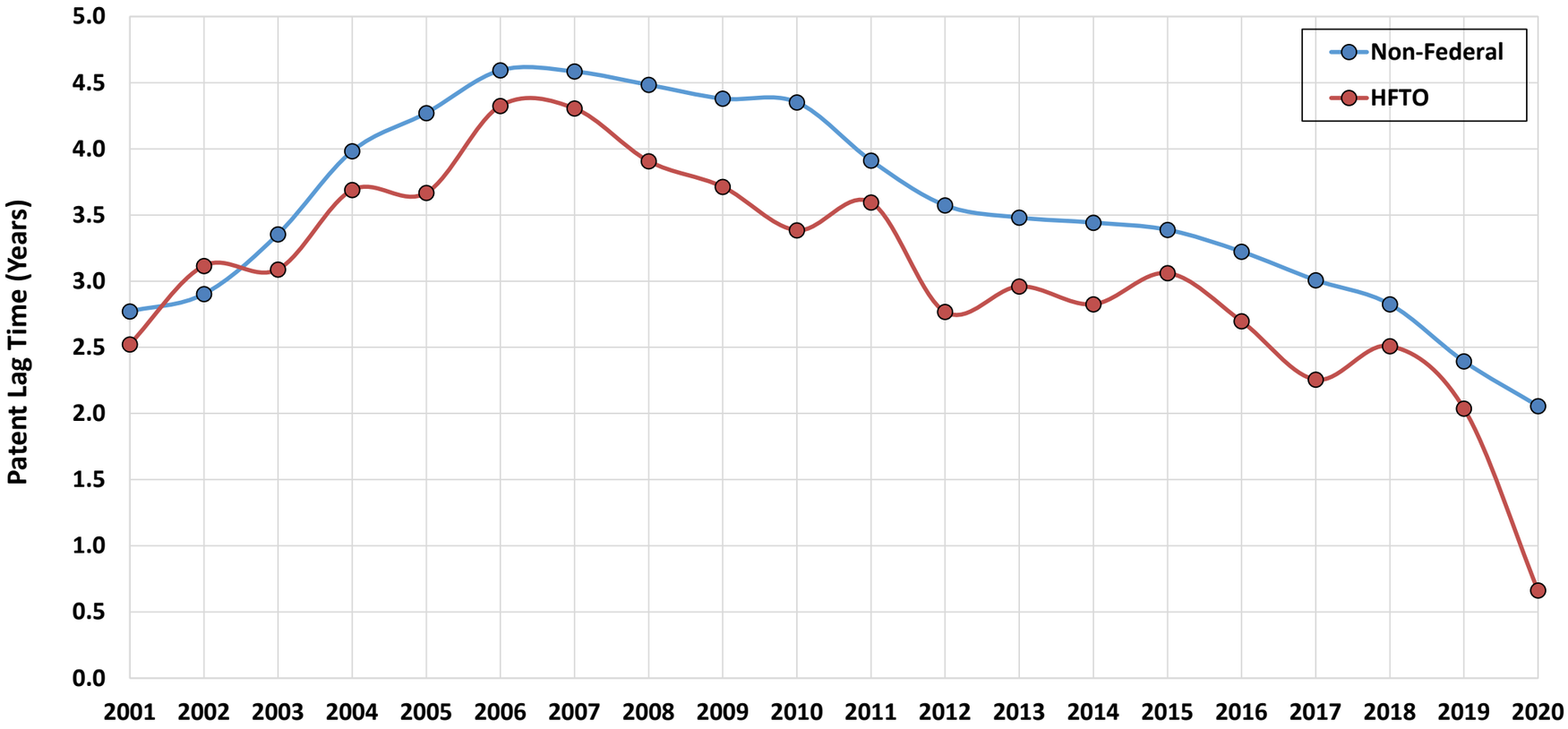


- 2019 and 2020 data is possibly affected by the 18-month pre-application publication period and legal litigation process

** 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 (2001–2020)

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

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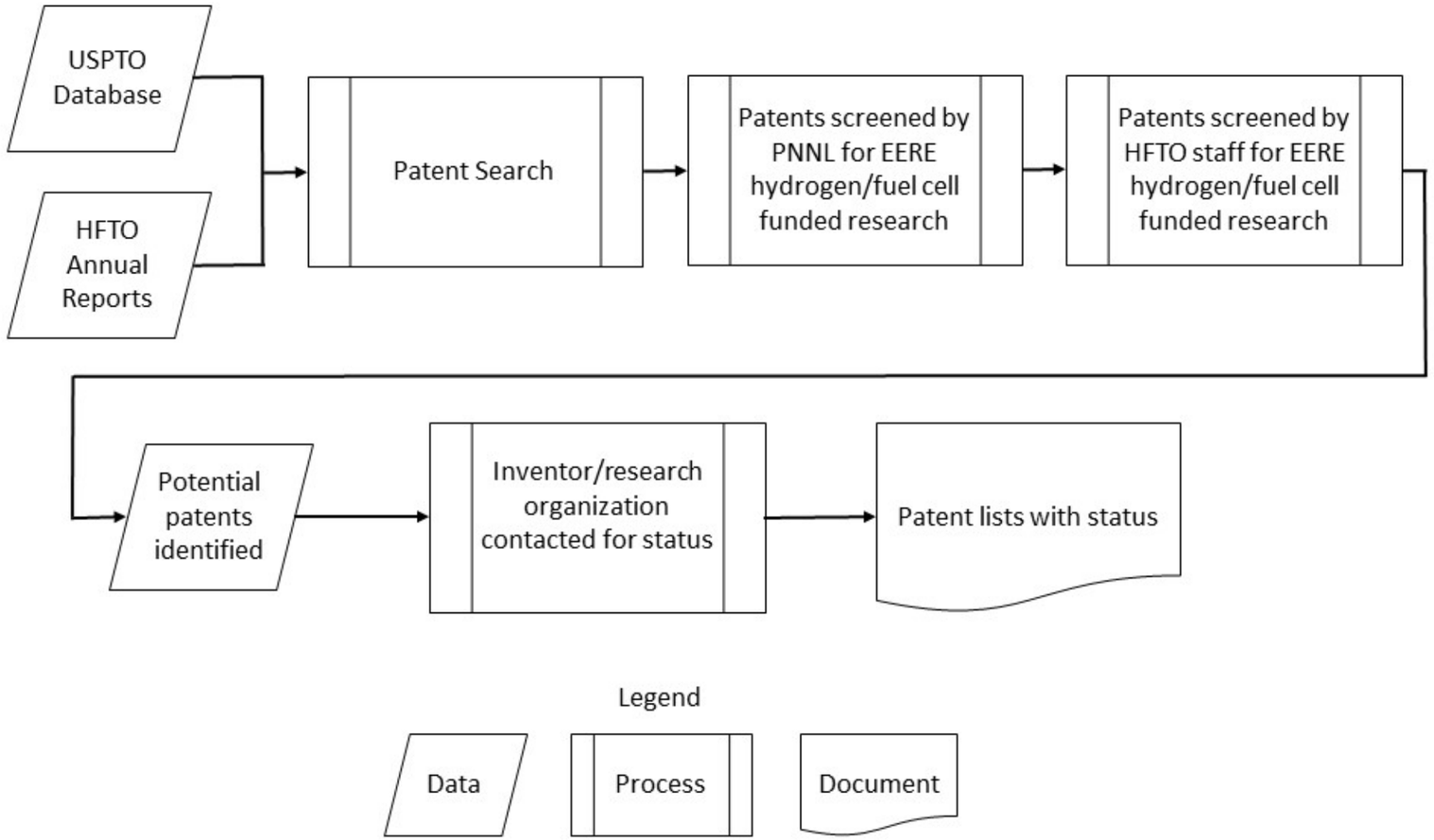
Back Up Slides

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

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

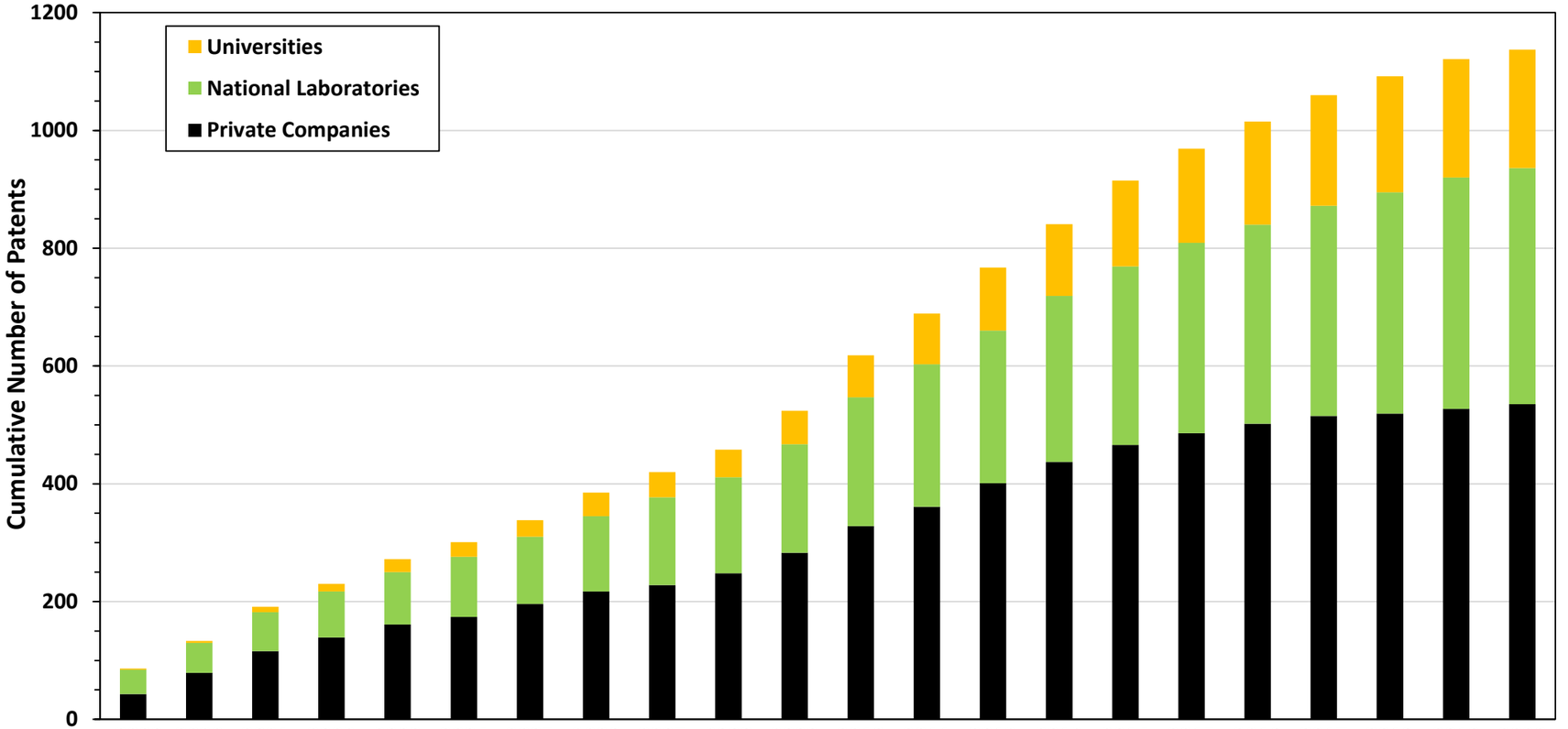
5-combos				
B01B	B01D	B01J	C01B	F28D
B01D	B01J	C01B	F28D	H01M
B01D	C08G	C08J	H01B	H01M
B01D	C08J	H01B	H01M	Y02E
B01J	B60K	B60L	C01B	H01M
B01J	B82Y	C01B	H01M	Y02E
B01J	B82Y	H01M	Y02E	Y10S
B01J	C01B	C07C	H01M	Y02E
B01J	C08G	C08J	H01M	Y02E
B82Y	C01B	H01G	H01M	Y02E
B82Y	C01B	H01M	Y02E	Y10S
C01B	C08G	C08J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

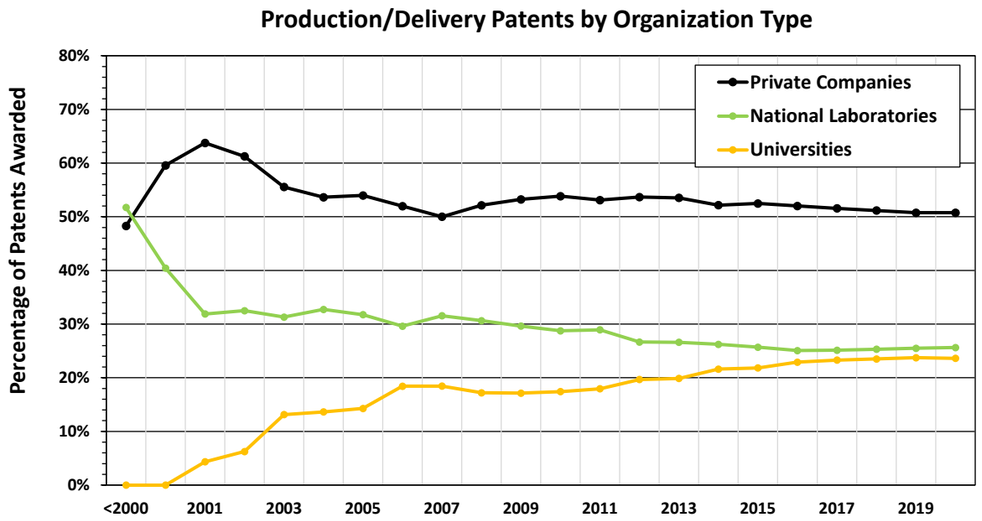
Patents Awarded Over Time by Organization Type

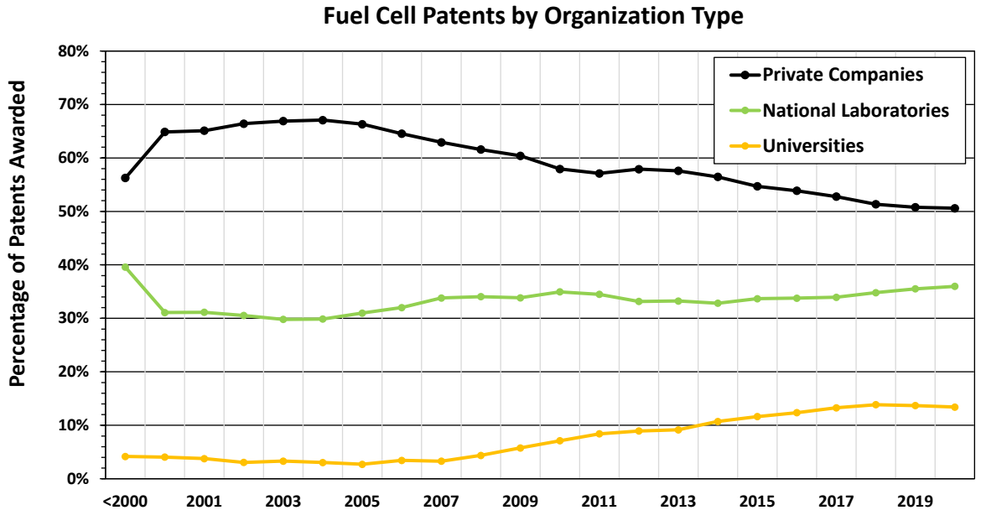


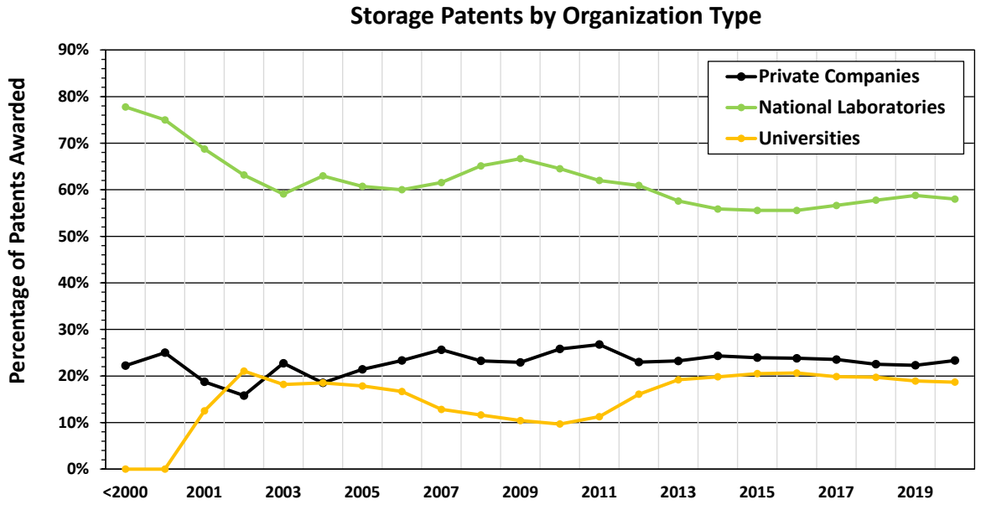
	<2000	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Universities	2	3	9	13	22	25	28	40	43	47	57	71	86	107	122	146	160	175	188	197	201	201
National Laboratories	41	51	66	78	89	102	114	128	149	163	184	219	242	259	282	303	323	338	357	376	393	401
Private Companies	43	79	116	139	161	174	196	217	228	248	283	328	361	401	437	466	486	502	515	519	527	535
Total	86	133	191	230	272	301	338	385	420	458	524	618	689	767	841	915	969	1015	1060	1092	1121	1137

- Private companies awarded 47% patents, national laboratories 35%, 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

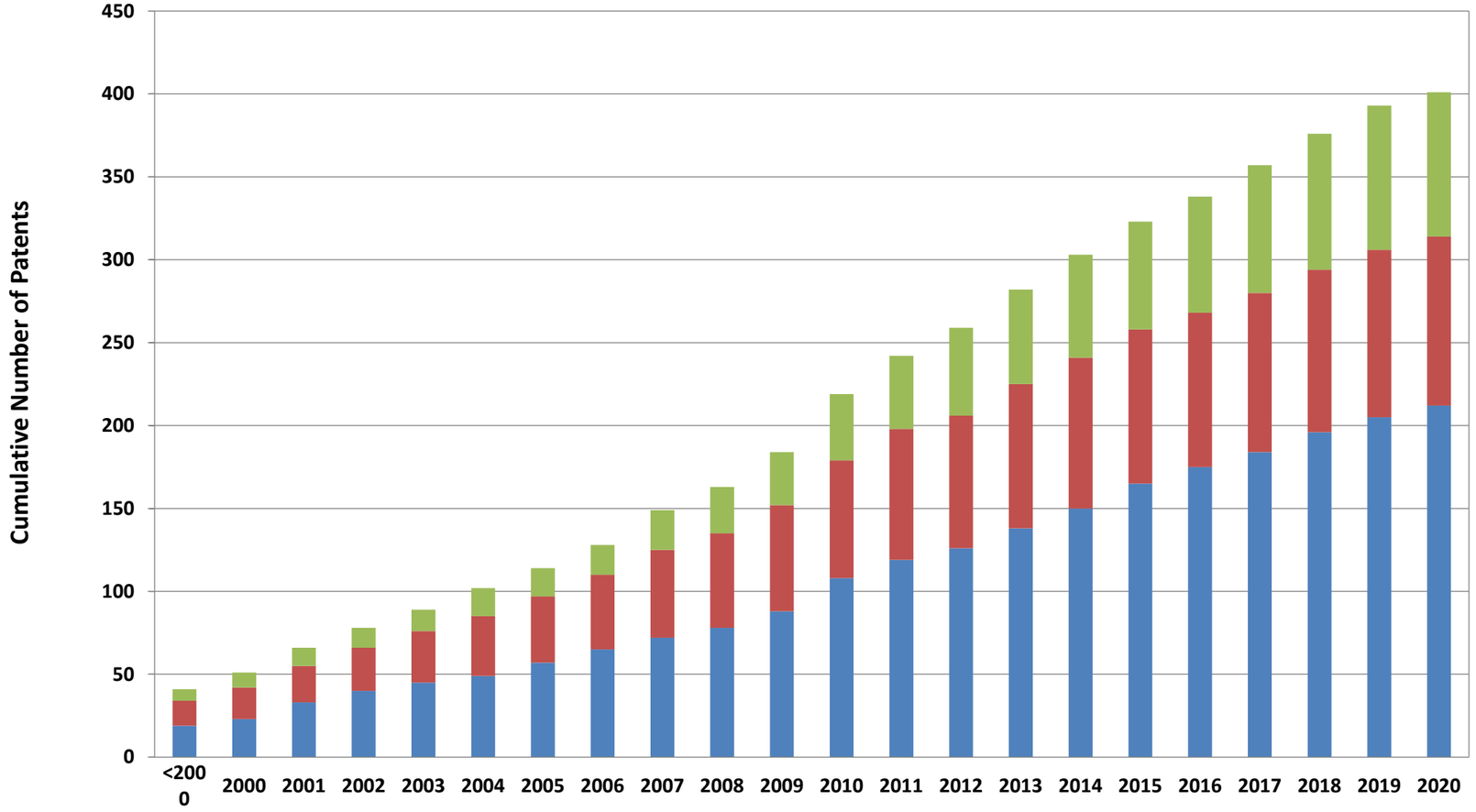






- National laboratory and university fuel cell activity increasing
- Overall production/delivery activity constant
- National laboratory storage activity constant

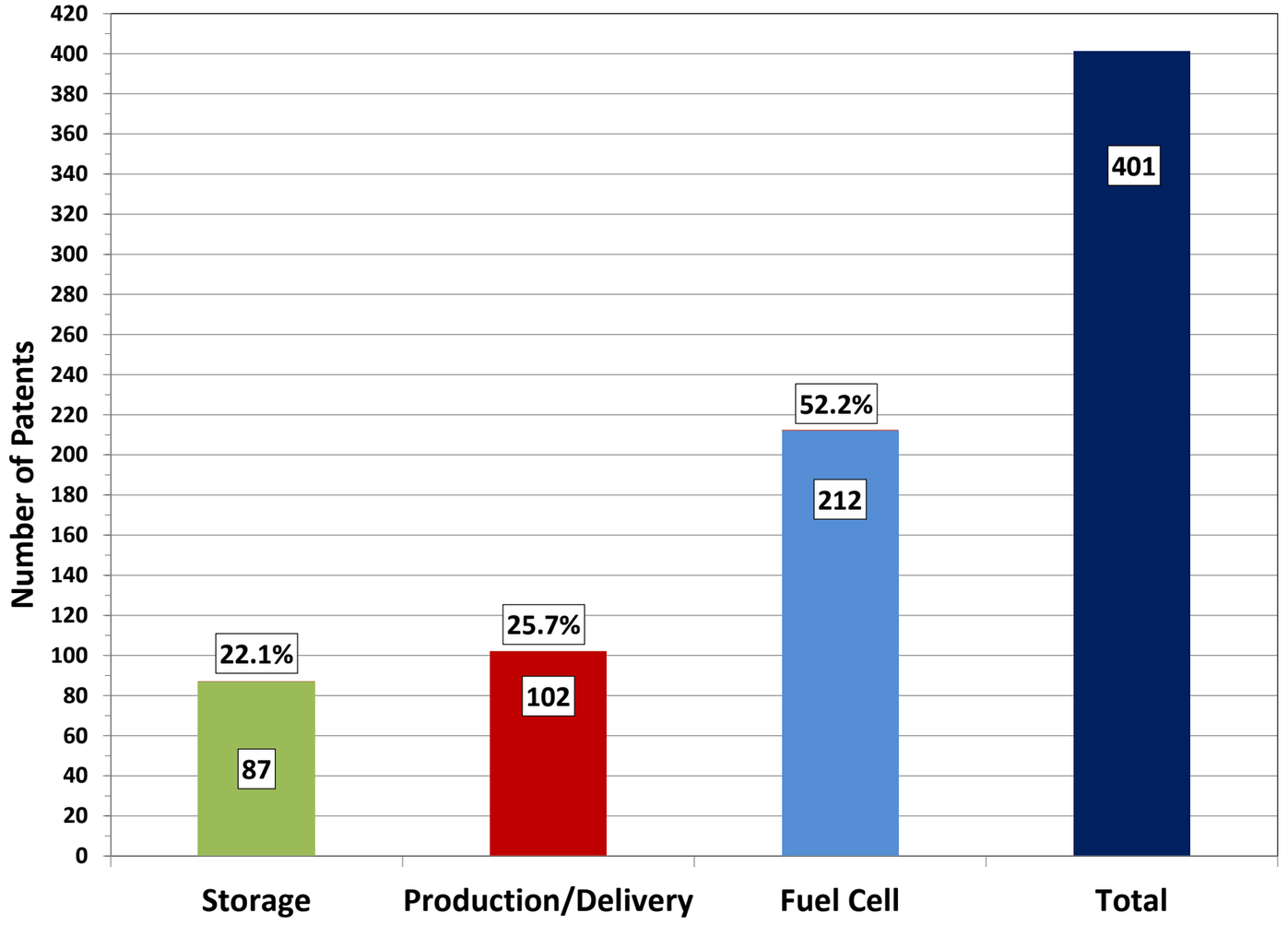
National Laboratory Patent Analysis
Cumulative Number of Patents Awarded Over Time



	<2000	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Storage	7	9	11	12	13	17	17	18	24	28	32	40	44	53	57	62	65	70	77	82	87	87
Production/Delivery	15	19	22	26	31	36	40	45	53	57	64	71	79	80	87	91	93	93	96	98	101	102
Fuel Cell	19	23	33	40	45	49	57	65	72	78	88	108	119	126	138	150	165	175	184	196	205	212
Total	41	51	66	78	89	102	114	128	149	163	184	219	242	259	282	303	323	338	357	376	393	401

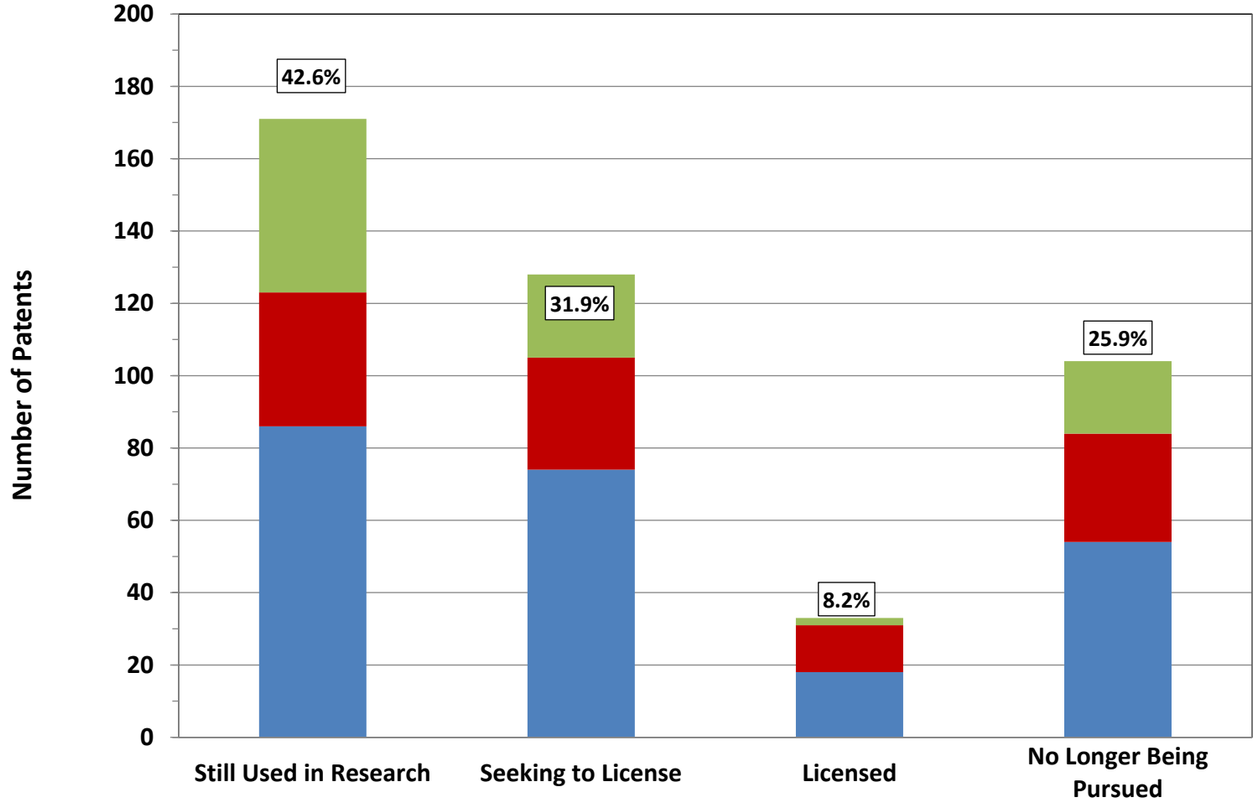
- 401 national laboratory patents
- National laboratory activity primarily in fuel cells

National Laboratory Patent Analysis: Patents by Type



- 52% of national laboratory patents in fuel cells
- National laboratory research activity in production/delivery and storage approximately equal

National Laboratory Patent Analysis: Patent Status



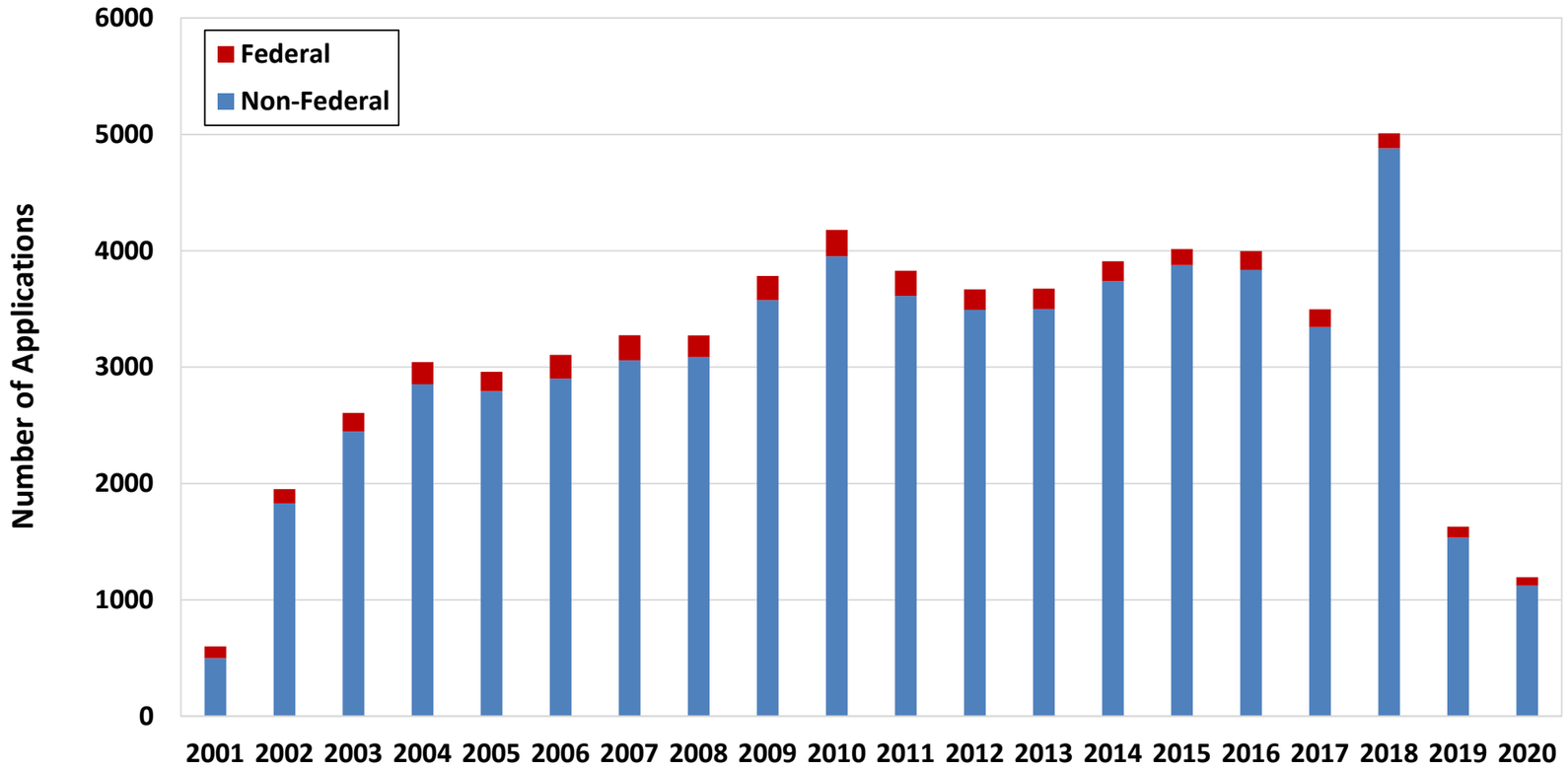
	Still Used in Research	Seeking to License	Licensed	No Longer Being Pursued
Storage	48	23	2	20
Production/Delivery	37	31	13	30
Fuel Cell	86	74	18	54
Total	171	128	33	104

- 43% of national laboratory patents still relevant to current research activities
- Approximately 40% 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 (401)

All Hydrogen and Fuel Cell-Related Patent Applications* (2001–2020)

Number of patent applications decreased again in 2020 (1,194)



** 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 (2001–2020)

Type of Organization	Fuel Cell Applications	Production/ Delivery Applications	Storage Applications	Total	Percentage Of Applications
Private Companies	35,471 (91.9%)	17253 (91.0%)	2182 (92.1%)	54,906	91.6%
Foreign National Laboratories	1,004 (2.6%)	476 (2.5%)	55 (2.3%)	1,535	2.6%
U.S. National Laboratories	71 (0.2%)	70 (0.4%)	4 (0.2%)	145	0.2%
Universities	2,063 (5.3%)	1,163 (6.1%)	127 (5.4%)	3,353	5.6%
Total	38,609 (64.4%)	18,962 (31.6%)	2,368 (4.0%)	59,939	