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2018 Patent Analysis for the U.S. Department of Energy Fuel Cell Technologies Office

Prepared by Pacific Northwest National Laboratory
PNNL-SA-147049

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U.S. DEPARTMENT OF ENERGY BATTELLE

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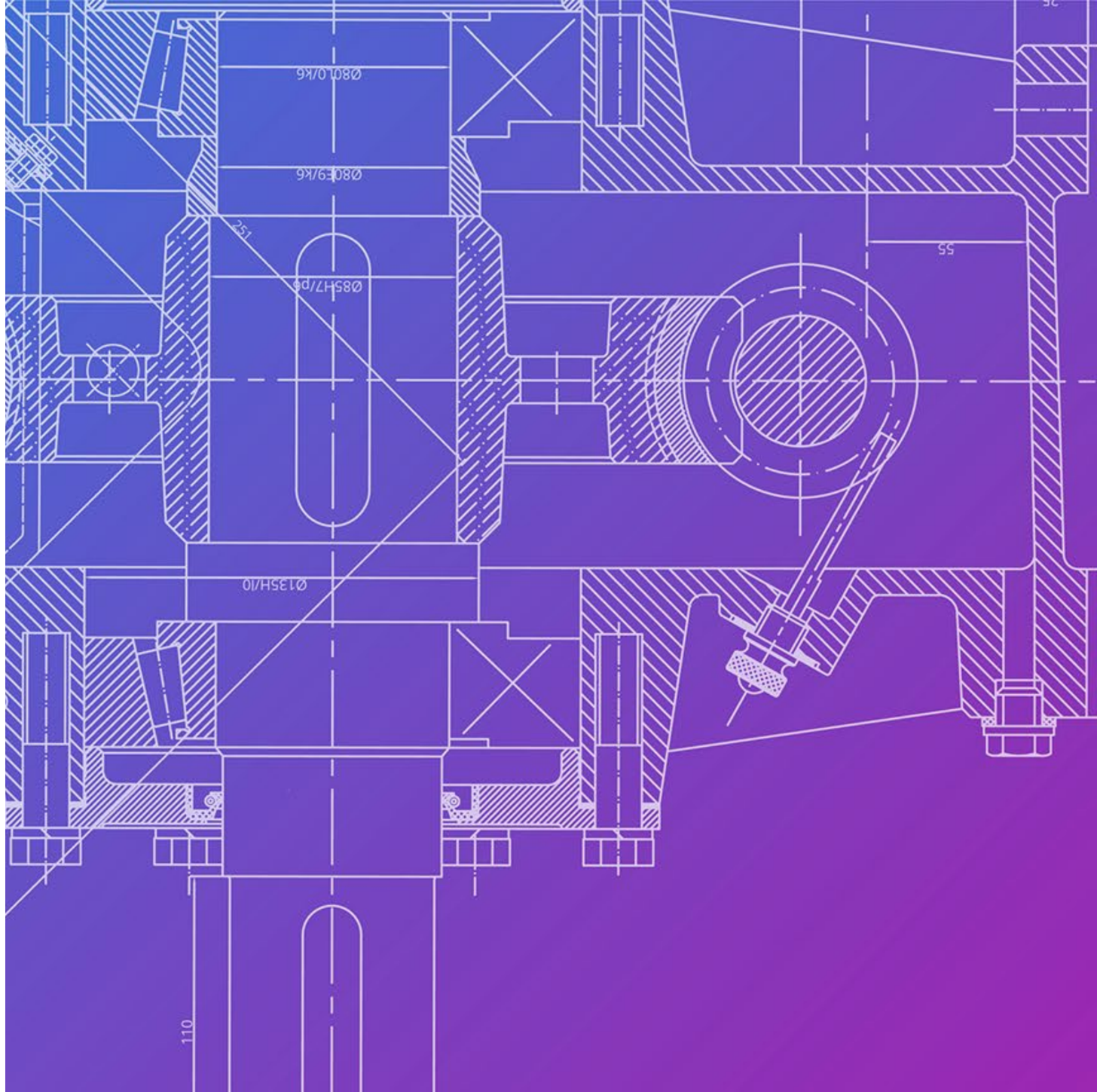

FCTO Patent Tracking – Purpose

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

- FCTO-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 FCTO-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)

FCTO Patent Tracking – Approach

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

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

FCTO Patent Tracking – Results Summary

1,009 patent applications and 962 patent awards related to FCTO-funded R&D through 2018

- **962 patent awards resulting from FCTO-funded R&D (1977–2018)**
  - 497 fuel cell patents (52%)
  - 347 hydrogen production and delivery patents (36%)
  - 118 hydrogen storage patents (12%)
  - 25% of all patents are available for license or licensed
  - 47% are actively being used in R&D
- **Three types of organizations received patents**
  - National laboratories (37%) lead in hydrogen storage R&D
  - Universities (16%) 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
- **1,009 patent applications resulting from FCTO-funded R&D (2001–2018)***
  - 548 fuel cell patent applications (54%)
  - 330 hydrogen production and delivery patent applications (33%)
  - 131 hydrogen storage patents (13%)
  - 82% of FCTO-funded R&D-related patent applications receive patent awards
  - Average time elapsed between filing and receiving patent award (patent lag time) 38 months

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

Patent Tracking - Process

- Gather patent application and award information from FCTO *Annual Progress Reports* and from FCTO 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

- **FCTO *Annual Progress Reports* 1995–2018**
  - Organizations awarded FCTO 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/

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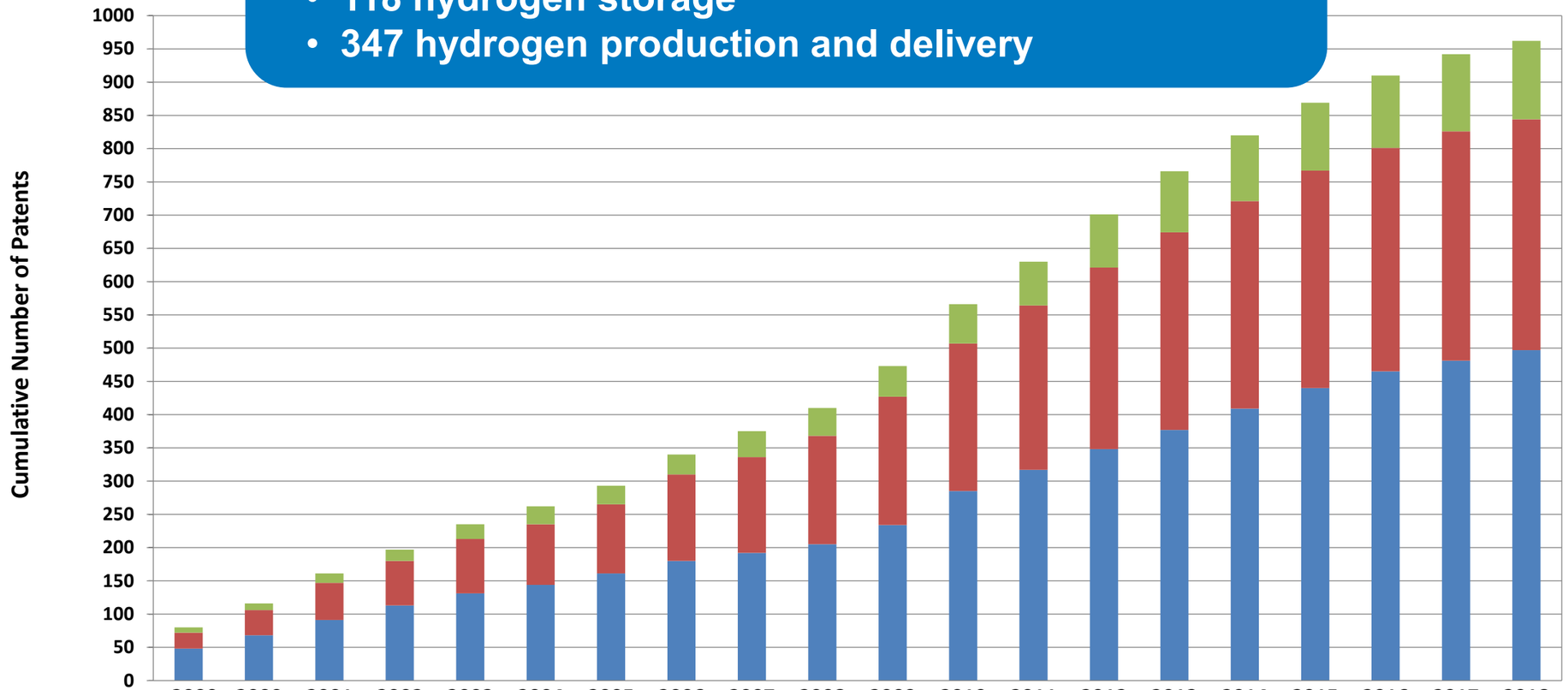
Patent Analysis Results

Cumulative Number of Patents Awarded Over Time (≤2000–2018)

962 patent awards, 20 issued in 2018

- 497 fuel cell
- 118 hydrogen storage
- 347 hydrogen production and delivery



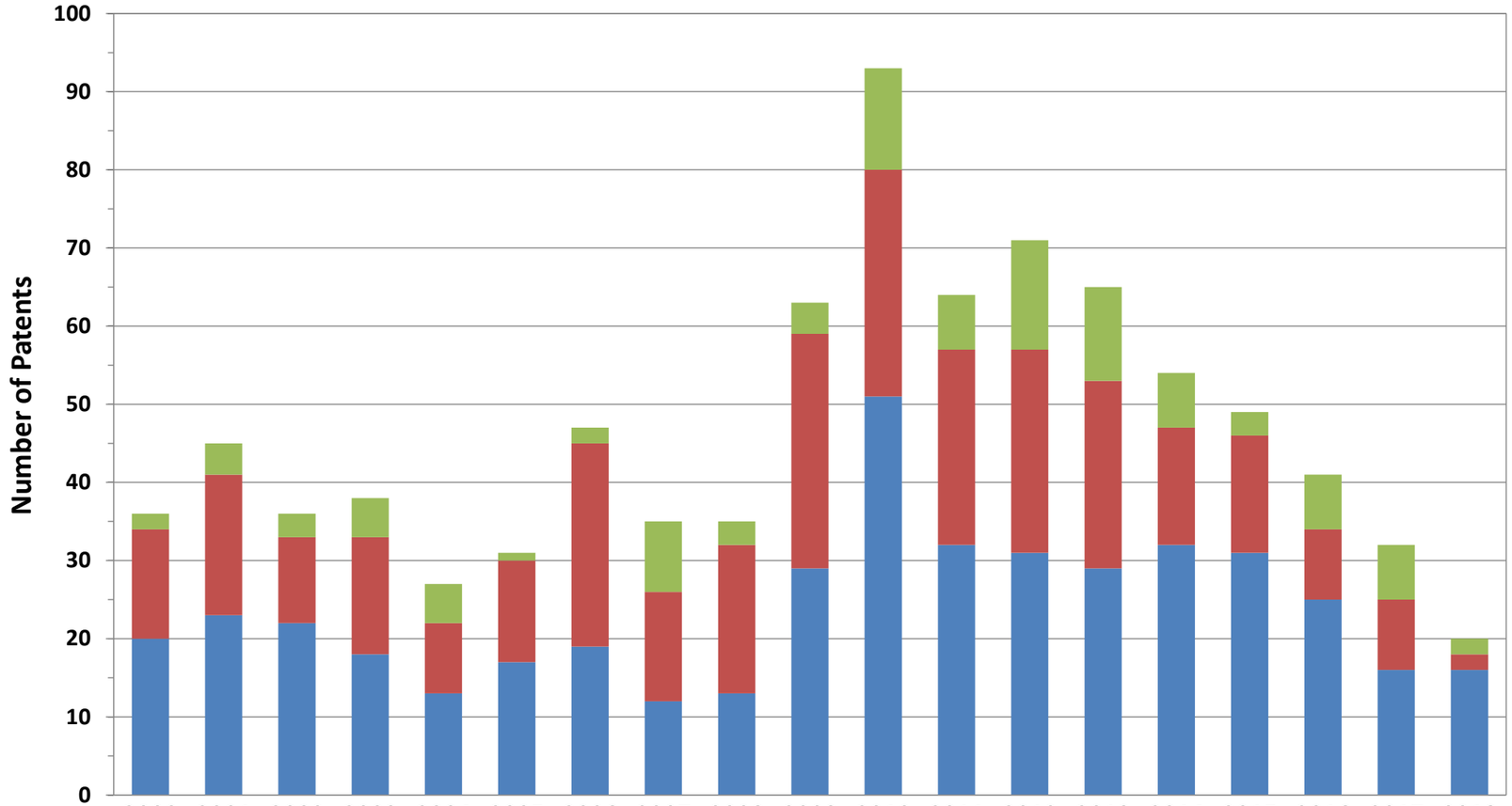
	<2000	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Storage	8	10	14	17	22	27	28	30	39	42	46	59	66	80	92	99	102	109	116	118
Production/Delivery	24	38	56	67	82	91	104	130	144	163	193	222	247	273	297	312	327	336	345	347
Fuel Cell	48	68	91	113	131	144	161	180	192	205	234	285	317	348	377	409	440	465	481	497
Total	80	116	161	197	235	262	293	340	375	410	473	566	630	701	766	820	869	910	942	962

Note: Calendar years

Number of Patents Awarded Per Year (2000–2018)

Average 46 patents per year since 2000

- 23 fuel cell
- 17 hydrogen production and delivery
- 6 hydrogen storage

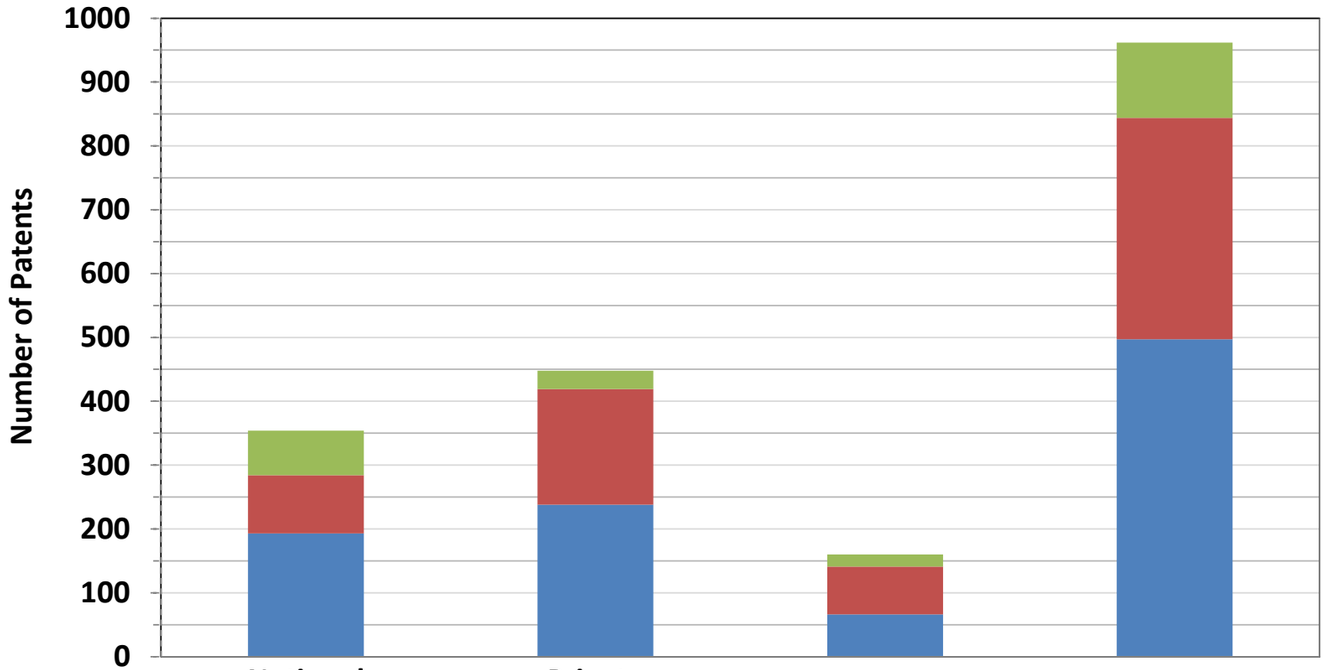


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Storage	2	4	3	5	5	1	2	9	3	4	13	7	14	12	7	3	7	7	2
Production/Delivery	14	18	11	15	9	13	26	14	19	30	29	25	26	24	15	15	9	9	2
Fuel Cell	20	23	22	18	13	17	19	12	13	29	51	32	31	29	32	31	25	16	16
Total	36	45	36	38	27	31	47	35	35	63	93	64	71	65	54	49	41	32	20

Types of Organizations 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	70	29	19	118
Production/Delivery	91	181	75	347
Fuel Cell	193	238	66	497
Total	354	448	160	962

Patent Distribution by Organization Type

129 organizations receiving patent awards

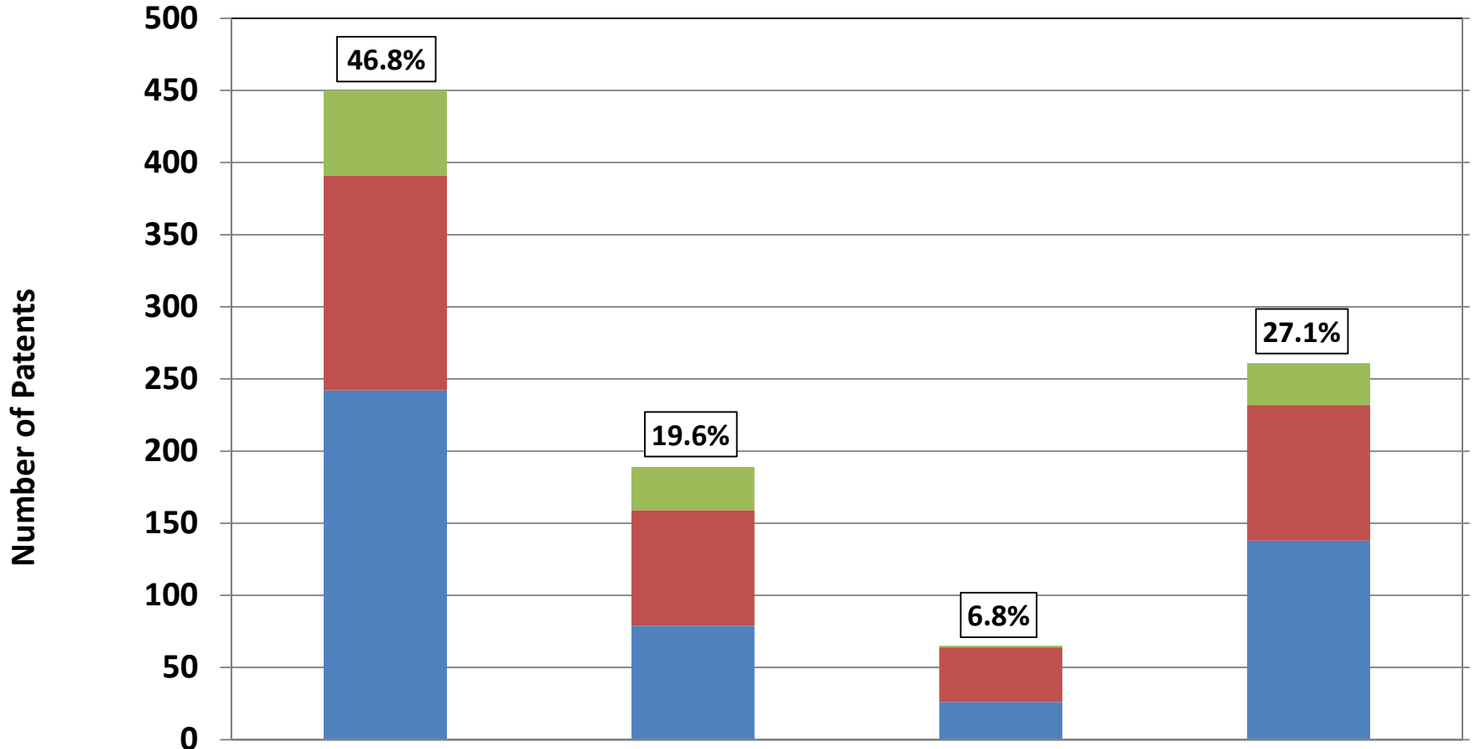
- 80 private companies have 47% of patent awards
- 12 national laboratories have 37% of patent awards
- 29 patents per national laboratory
- 6 patents per private company
- 4 patents per university

Type of Organization	Number of Organizations	Fuel Cell Patents	Production/ Delivery Patents	Storage Patents	Total	Patents per Organization	Percent Patent Awards
Private	80 (62%)	248	181	29	458	6	47.6%
National Laboratory	12 (9%)	192	91	70	353	29	36.7%
University	37 (29%)	57	75	19	151	4	15.7%
Total	129	497	347	118	962	8	

Status of Awarded Patents by Type

47% of patents relevant to current research

25% of patents are licensed or available for license



	Still Used in Research	Seeking to License	Licensed	No Longer Being Pursued
Storage	59	30	1	29
Production/Delivery	149	80	38	94
Fuel Cell	242	79	26	138
Total	450	189	65	261

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

Percentages are fractions of total number of patents in portfolio (962)

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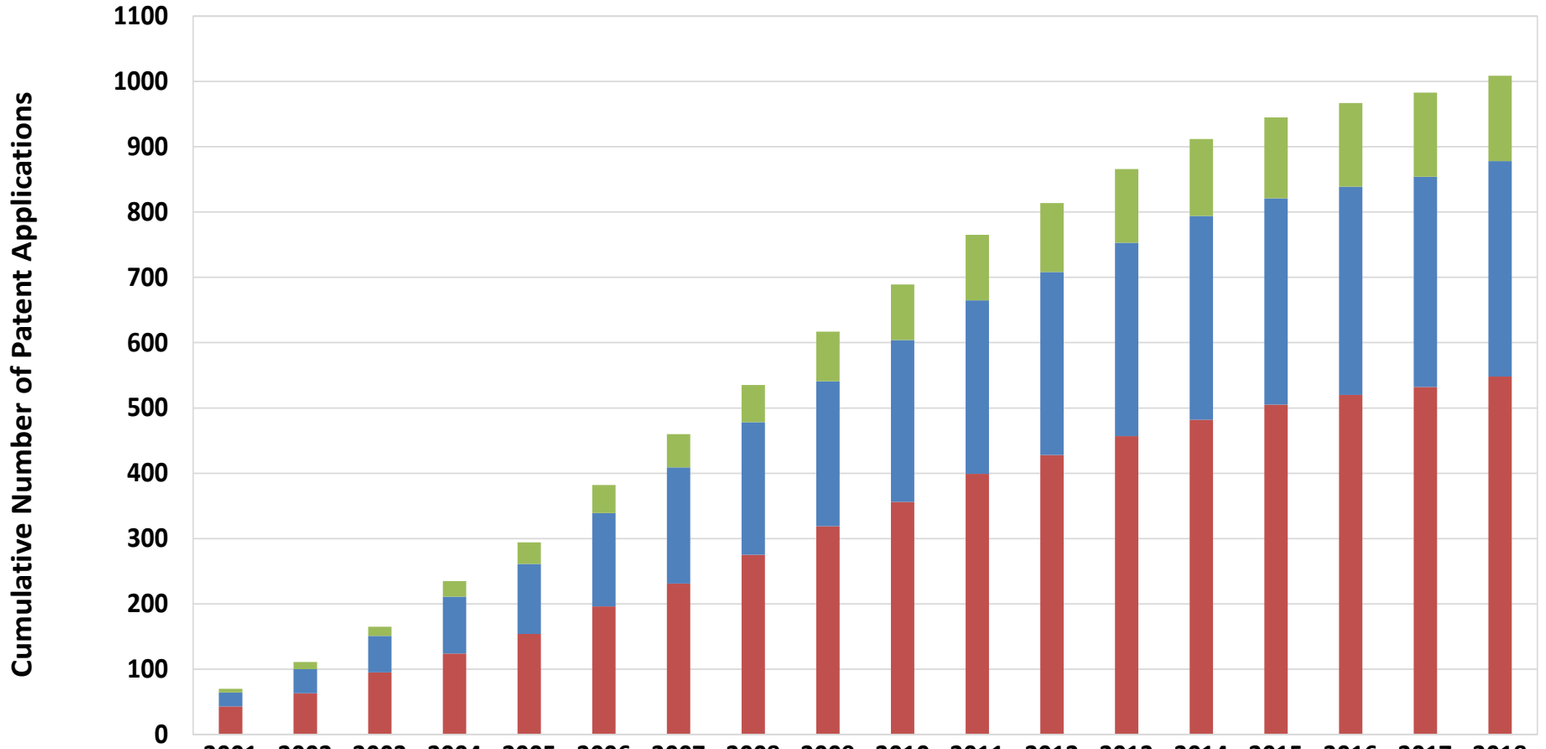
Patent Application Results

Cumulative FCTO-Funded Patent Applications by Subprogram (2001–2018)

1,009 patent applications
- 50% fuel cells
- 33% production delivery
- 17% storage

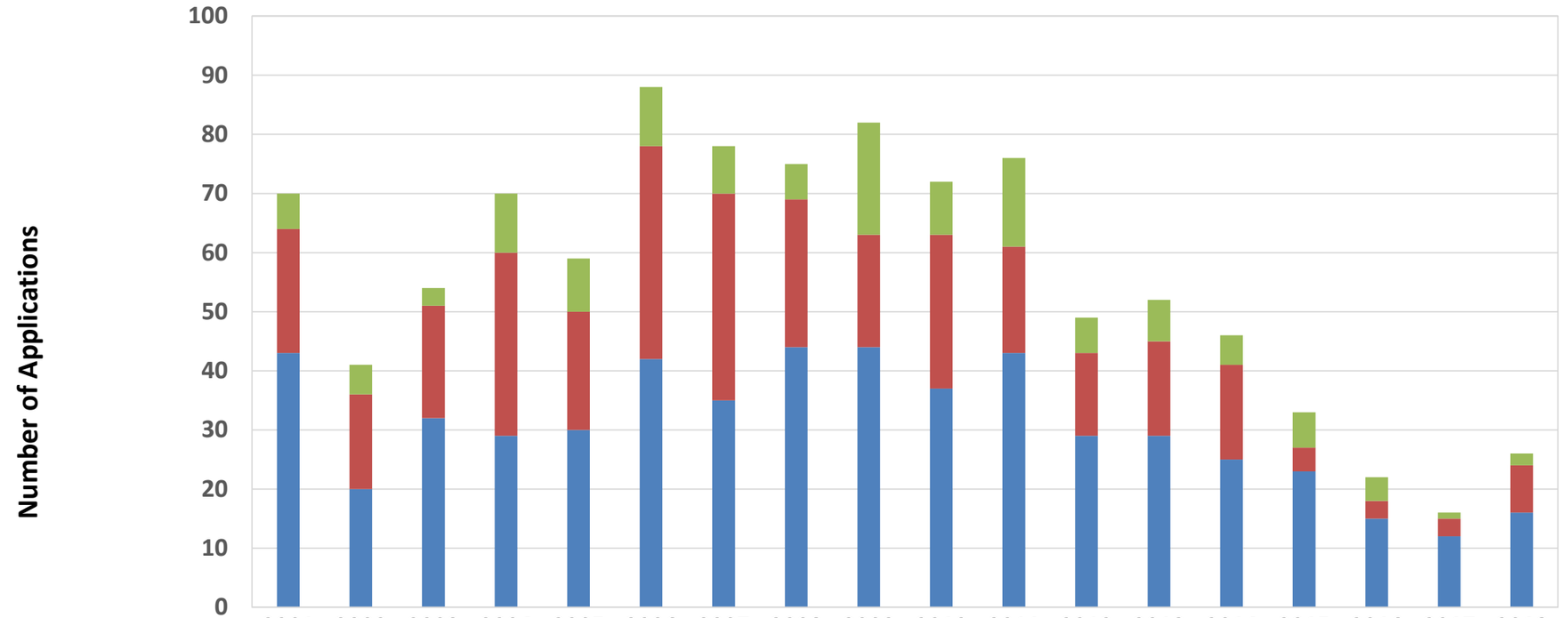


	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Storage	6	11	14	24	33	43	51	57	76	85	100	106	113	118	124	128	129	131
Production/Delivery	21	37	56	87	107	143	178	203	222	248	266	280	296	312	316	319	322	330
Fuel Cell	43	63	95	124	154	196	231	275	319	356	399	428	457	482	505	520	532	548
Total	70	111	165	235	294	382	460	535	617	689	765	814	866	912	945	967	983	1009

- Patent application search for 2018 found over 5,800 hydrogen and fuel cell-related applications
- Identified 1,009 FCTO-funded R&D-related hydrogen and fuel cell-related applications through 2018
- Rechecked previously identified hydrogen and fuel cell-related patent applications 2001–2017 for new patent awards

Patent Applications by Type (2001–2017)

26 patent applications in 2018
Average of 56 patent applications per year since 2001

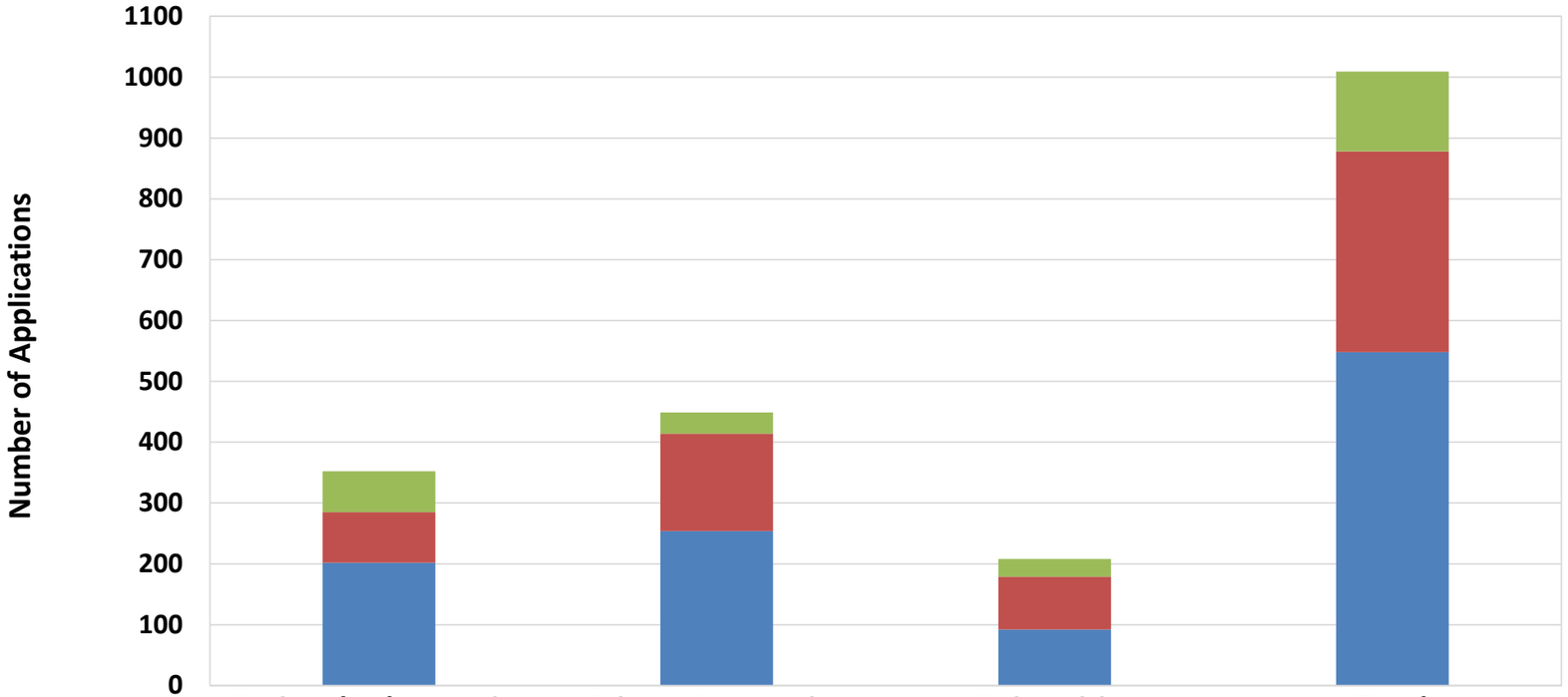


	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Storage	6	5	3	10	9	10	8	6	19	9	15	6	7	5	6	4	1	2
Production/Delivery	21	16	19	31	20	36	35	25	19	26	18	14	16	16	4	3	3	8
Fuel Cell	43	20	32	29	30	42	35	44	44	37	43	29	29	25	23	15	12	16
Total	70	41	54	70	59	88	78	75	82	72	76	49	52	46	33	22	16	26

- Number of patent applications has increased in 2018
- 2016–2018 data is possibly affected by the 18-month pre-application publication period and legal litigation process

Patent Applications by Organization Type (2001–2017)

44% private companies
35% national laboratories
21% universities



	National Laboratories	Private Companies	Universities	Total
Storage	67	35	29	131
Production/Delivery	83	160	87	330
Fuel Cell	202	254	92	548
Total	352	449	208	1009

- 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

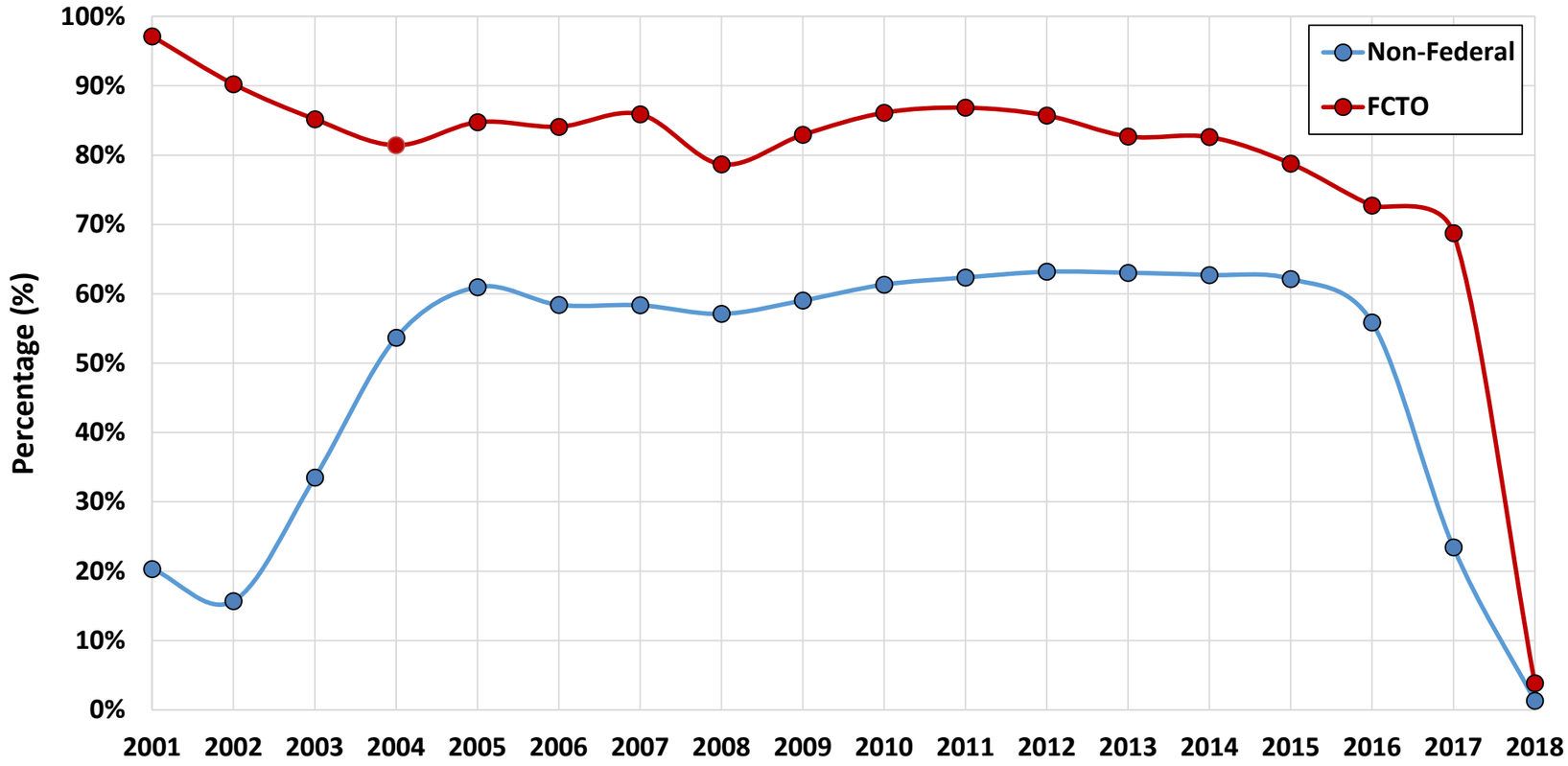
145 organizations receiving patent applications

- Private companies 57%
- Universities 35%
- National laboratories 8%
- 29 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	83 (57%)	254	160	35	449	5	44.5%
National Laboratory	12 (8%)	202	83	67	352	29	34.9%
University	50 (35%)	92	87	29	208	4	20.6%
Total	145	548	330	131	1009	7	

Percentage Non-Federal* and FCTO-Funded Patent Applications Awarded Patents (2001–2018)

80% FCTO-funded R&D-related applications are awarded patents
60% non-federal funded-related applications are awarded patents

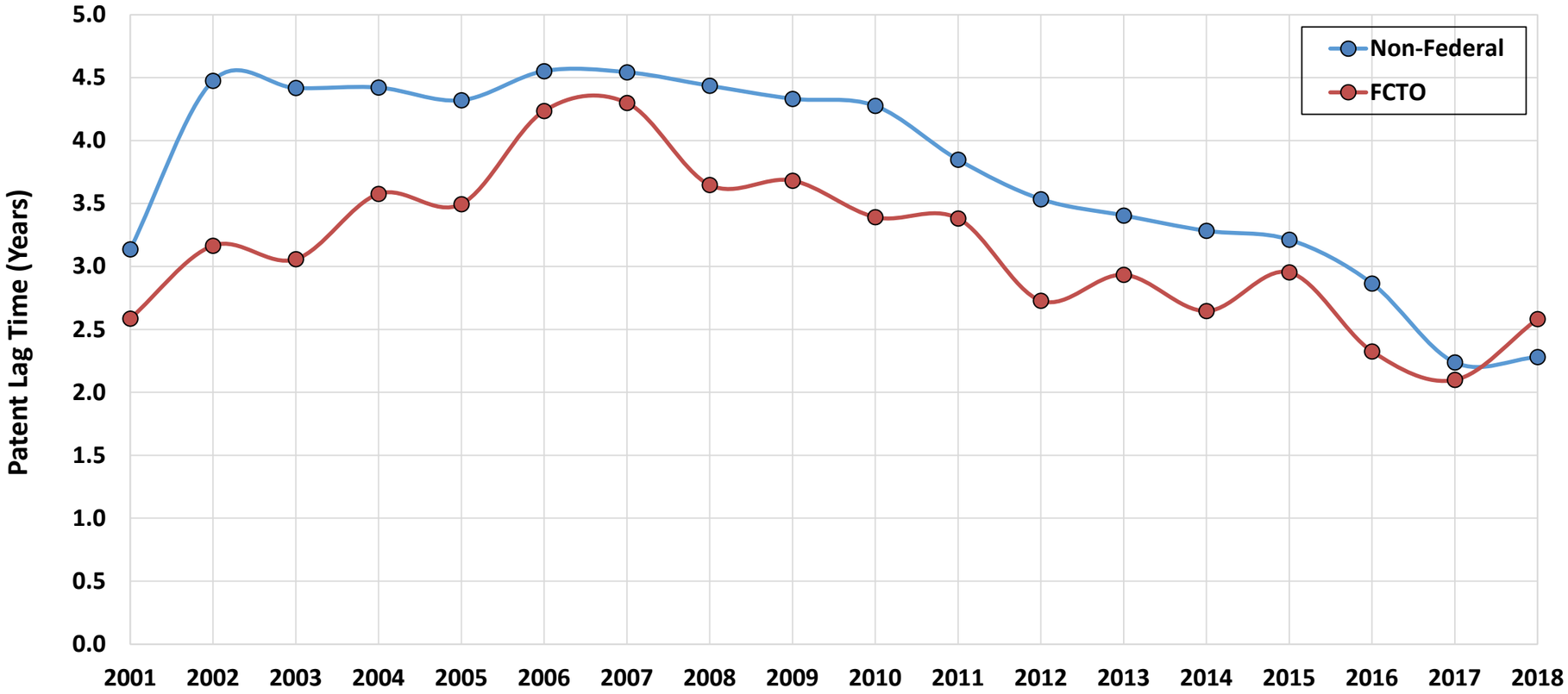


- 2017 and 2018 data is possibly affected by the 18-month pre-application publication period and legal litigation process

** 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 FCTO Patent Award Lag Time (2001–2018)

FCTO-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 FCTO-funded R&D related patent lag time is 3.16 years compared to 3.75 years for non-federal patent lag times
- 2017 and 2018 data is possibly affected by the 18-month pre-application publication period and legal litigation process

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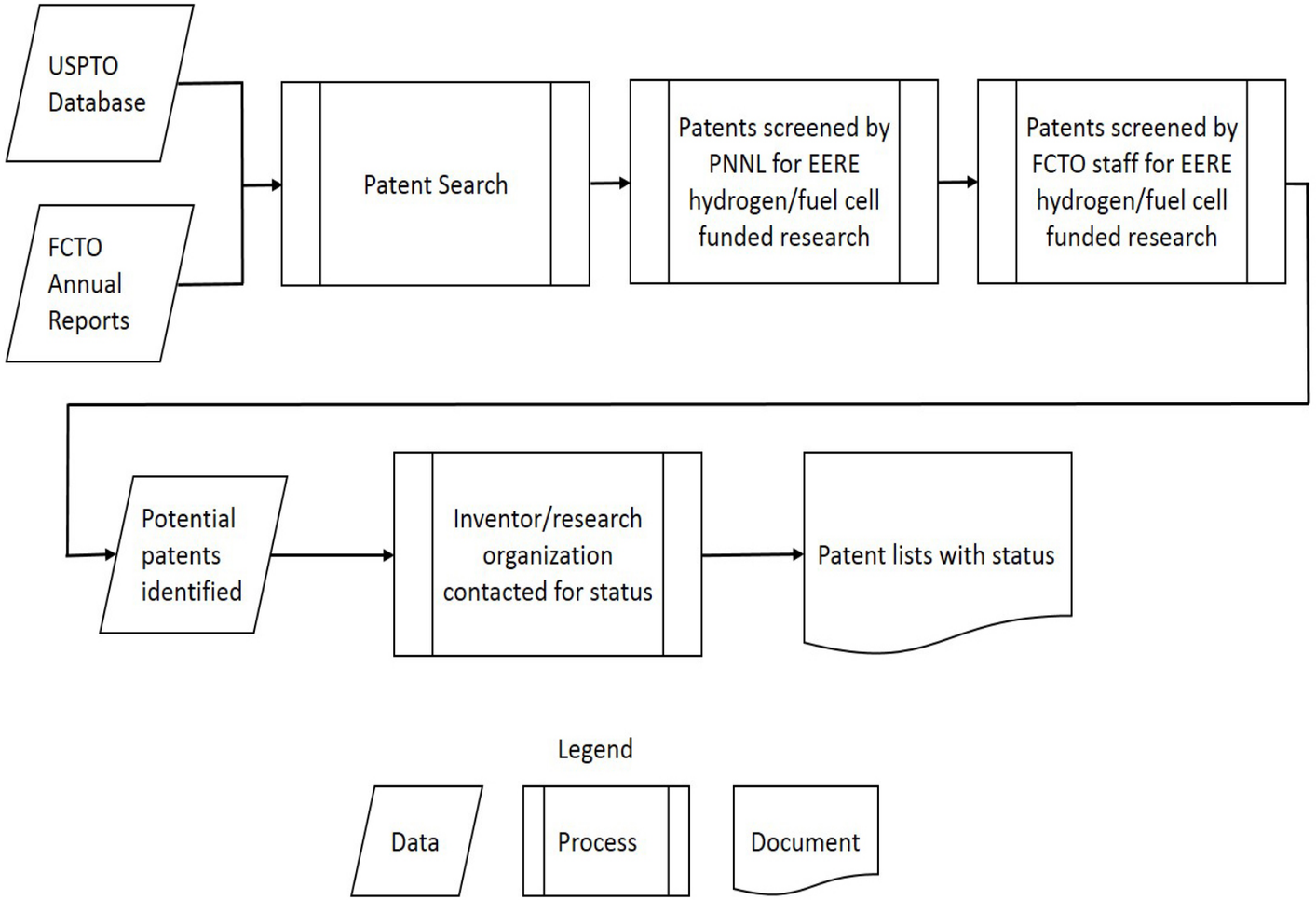
Back Up Slides

Patent Tracking - Process

- **Gather patent information from FCTO Annual Progress Reports and from FCTO 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**
- **FCTO-funded related patent application tracking includes all of the above with additional data processing and filtering**
  - Examine FCTO patent portfolio for common Cooperative Patent Classification (CPC) codes
  - Gather patent application 2001–2018 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



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 FCTO-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 FCTO 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

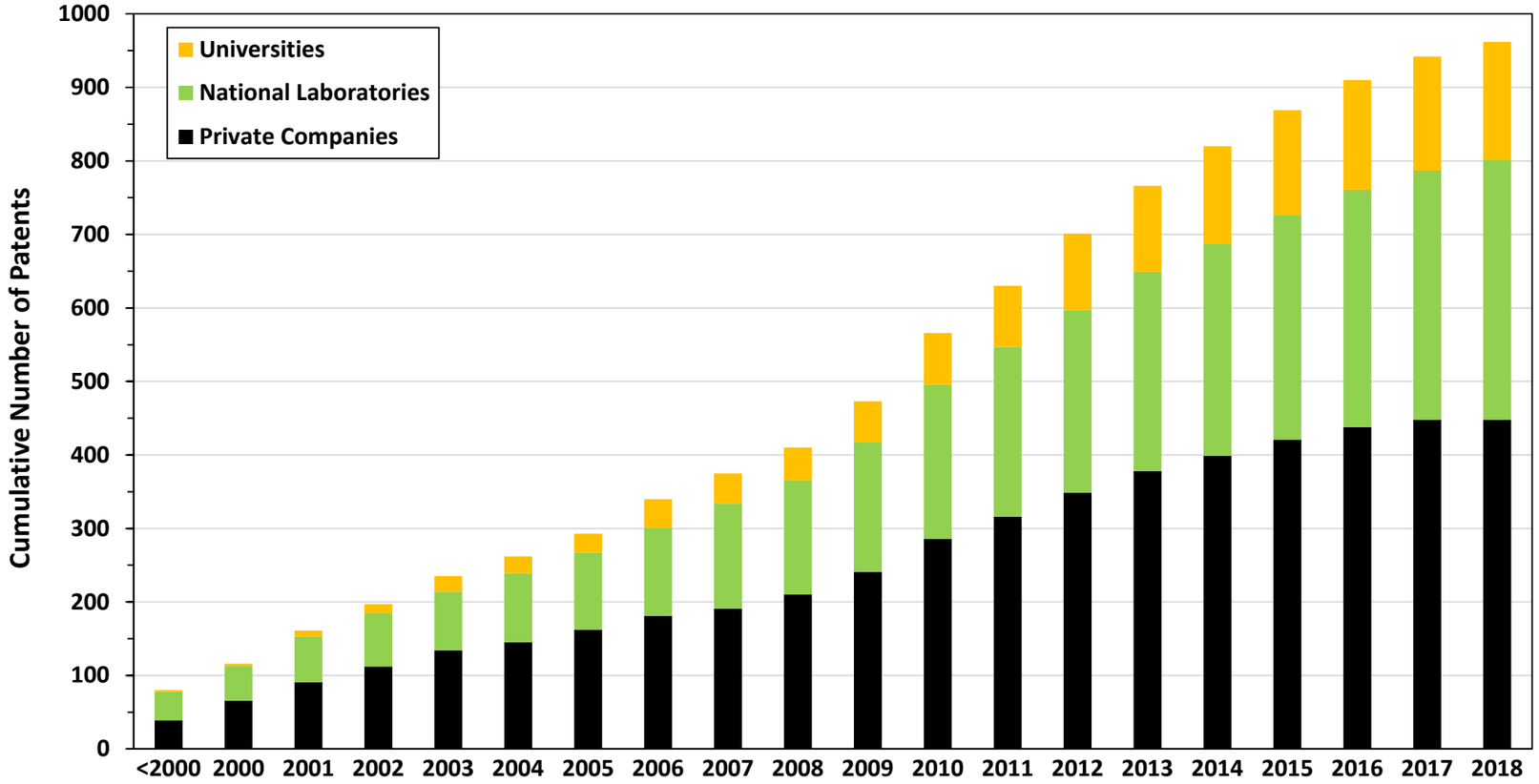
5-combos				
B01B	B01D	B01J	C01B	F28D
B01D	B01J	C01B	F28D	H01M
B01D	C08G	C08J	H01B	H01M
B01D	C08J	H01B	H01M	Y02E
B01J	B60K	B60L	C01B	H01M
B01J	B82Y	C01B	H01M	Y02E
B01J	B82Y	H01M	Y02E	Y10S
B01J	C01B	C07C	H01M	Y02E
B01J	C08G	C08J	H01M	Y02E
B82Y	C01B	H01G	H01M	Y02E
B82Y	C01B	H01M	Y02E	Y10S
C01B	C08G	C08J	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 FCTO R&D-funded patent portfolio
- 16 CPC codes capture all possible patent applications combinations found in FCTO portfolio
- Search at subclass level reduces possibility of excluding relevant patent applications

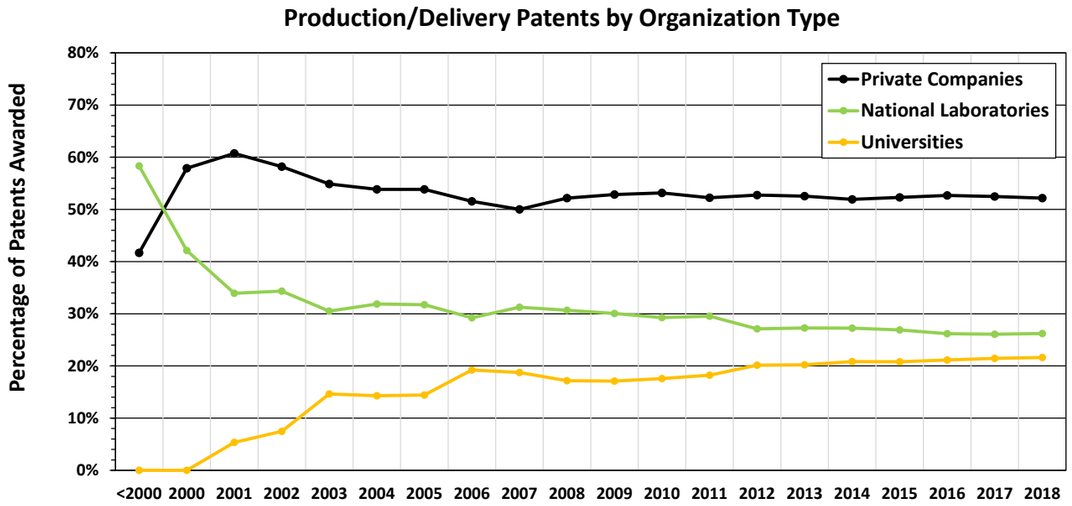
Patents Awarded Over Time by Organization Type

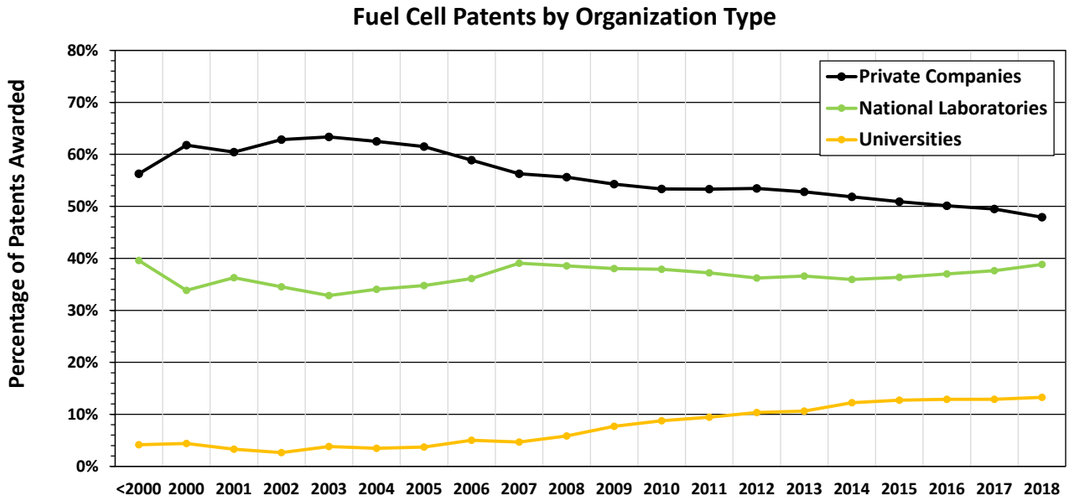


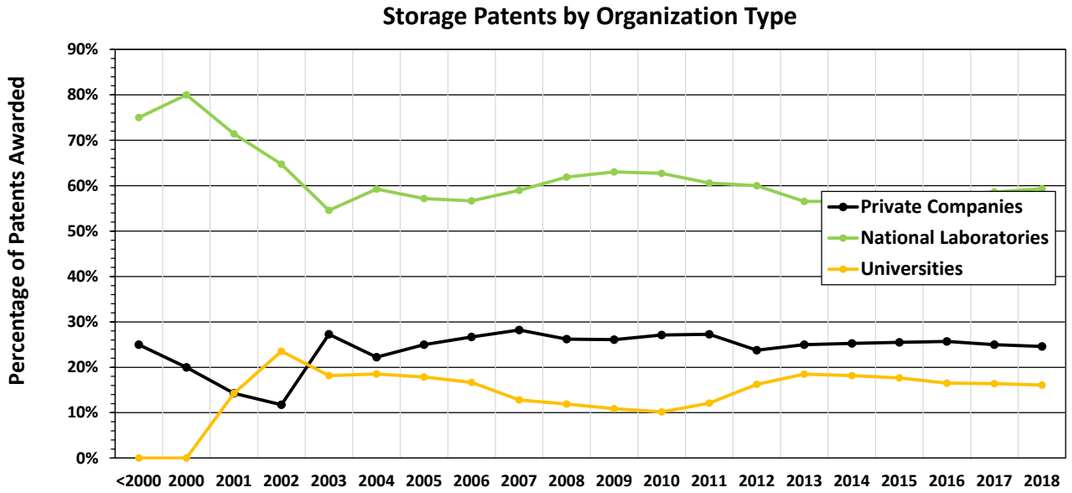
	<2000	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Universities	2	3	8	12	21	23	26	39	41	45	56	70	83	104	117	133	142	149	155	160
National Laboratories	39	47	62	73	80	94	105	120	143	155	176	210	231	248	271	288	306	323	339	354
Private Companies	39	66	91	112	134	145	162	181	191	210	241	286	316	349	378	399	421	438	448	448
Total	80	116	161	197	235	262	293	340	375	410	473	566	630	701	766	820	869	910	942	962

- Private companies awarded 47% patents, national laboratories 37%, and universities 16%
- Private companies awarded 21 patents per year since 2000 (national laboratories 17, universities 9)
- Patent activity increasing for universities and national laboratories
- Private company patent activity decreasing

Patent Type Over Time by Organization Type

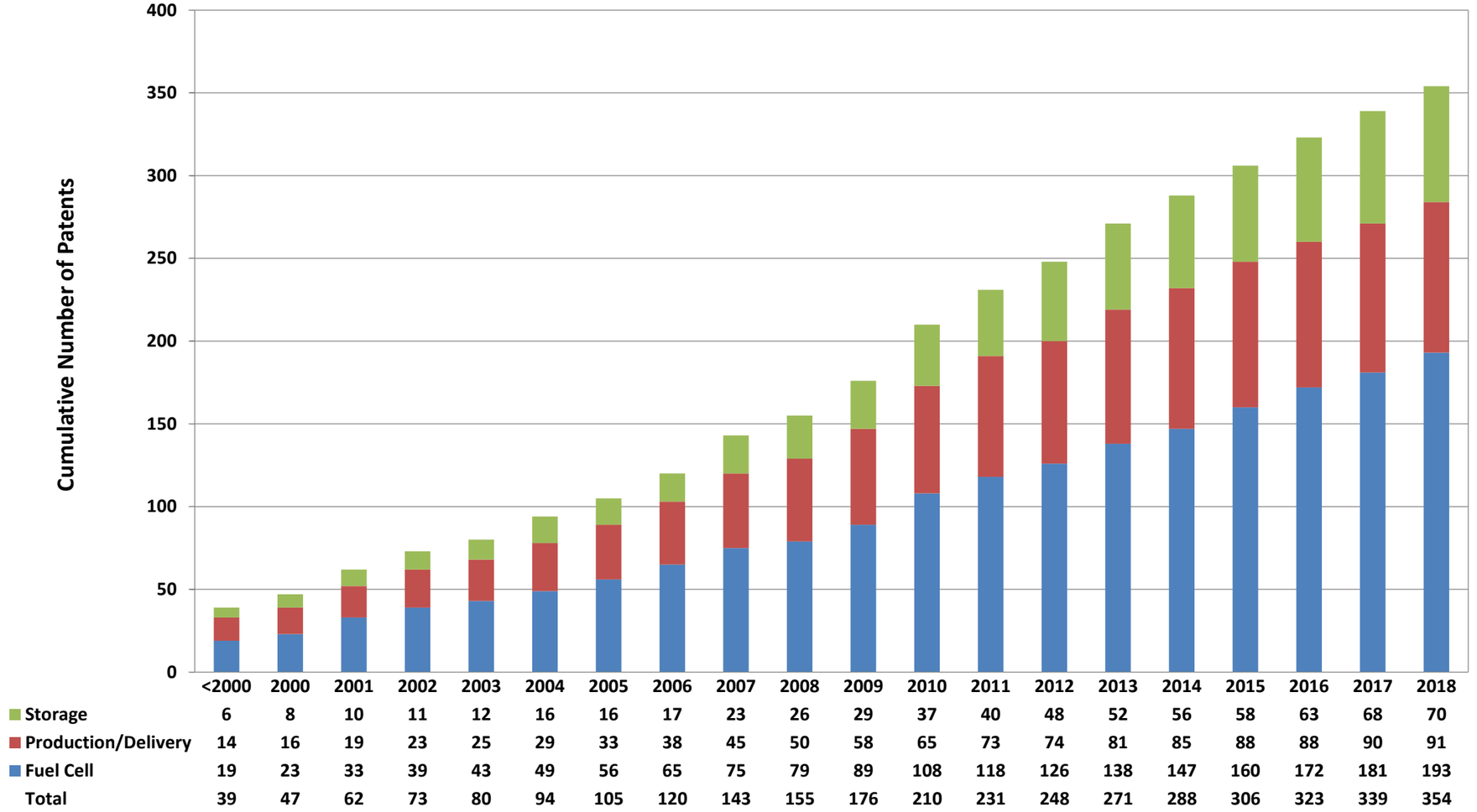






- National laboratory and university fuel cell activity increasing
- Overall production/delivery activity constant
- National laboratory storage activity increasing

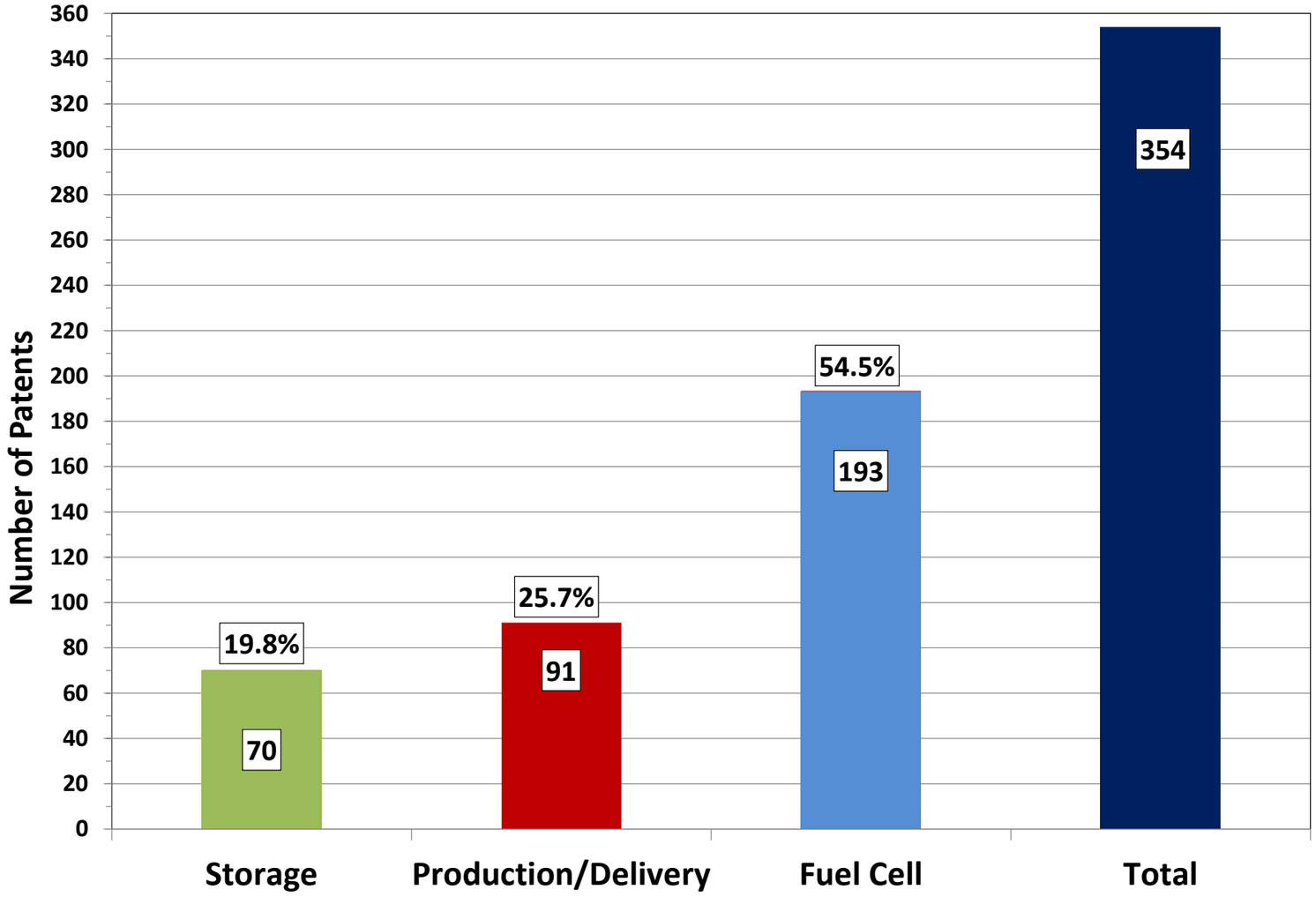
National Laboratory Patent Analysis
Cumulative Number of Patents Awarded Over Time



	<2000	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Storage	6	8	10	11	12	16	16	17	23	26	29	37	40	48	52	56	58	63	68	70
Production/Delivery	14	16	19	23	25	29	33	38	45	50	58	65	73	74	81	85	88	88	90	91
Fuel Cell	19	23	33	39	43	49	56	65	75	79	89	108	118	126	138	147	160	172	181	193
Total	39	47	62	73	80	94	105	120	143	155	176	210	231	248	271	288	306	323	339	354

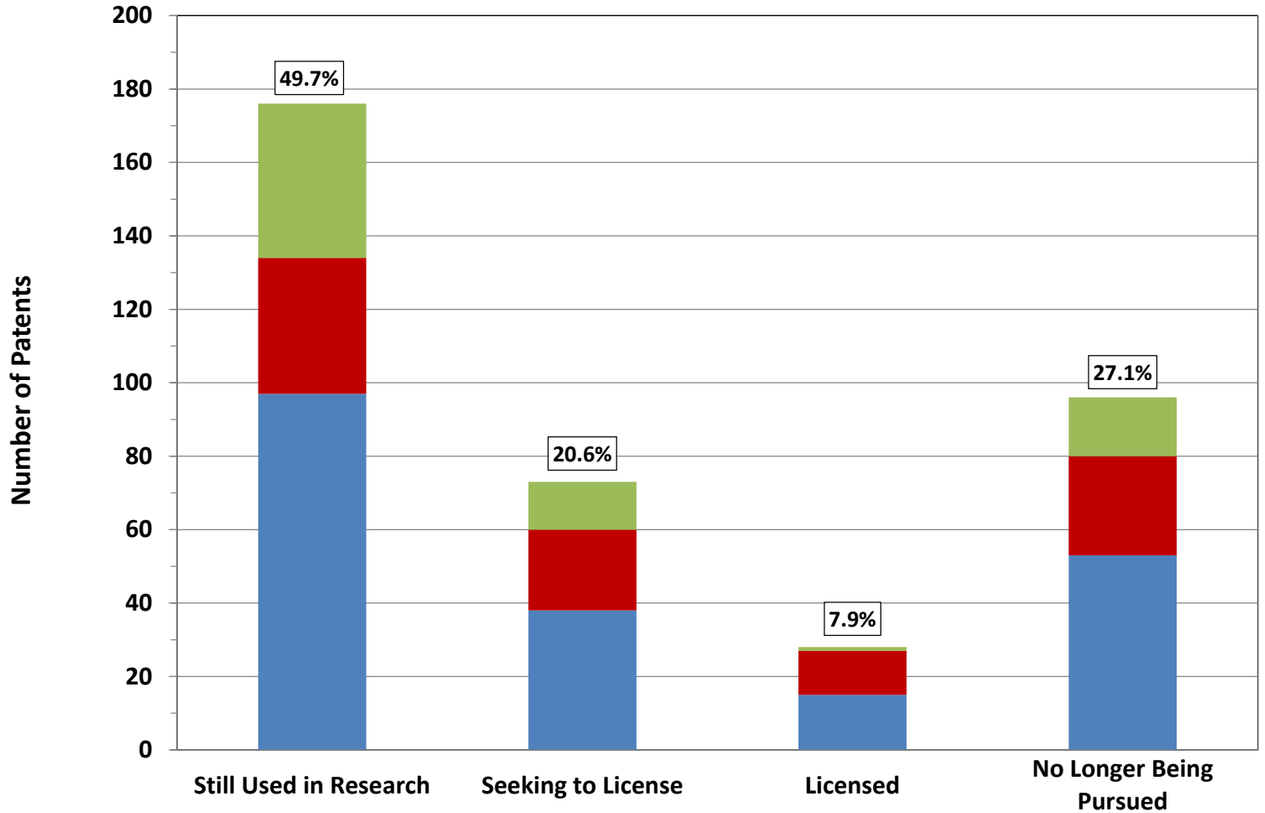
- 354 national laboratory patents
- National laboratory activity primarily in fuel cells

National Laboratory Patent Analysis: Patents by Type



- 55% of national laboratory patents in fuel cells
- National laboratory research activity in production/delivery and storage approximately equal

National Laboratory Patent Analysis: Patent Status



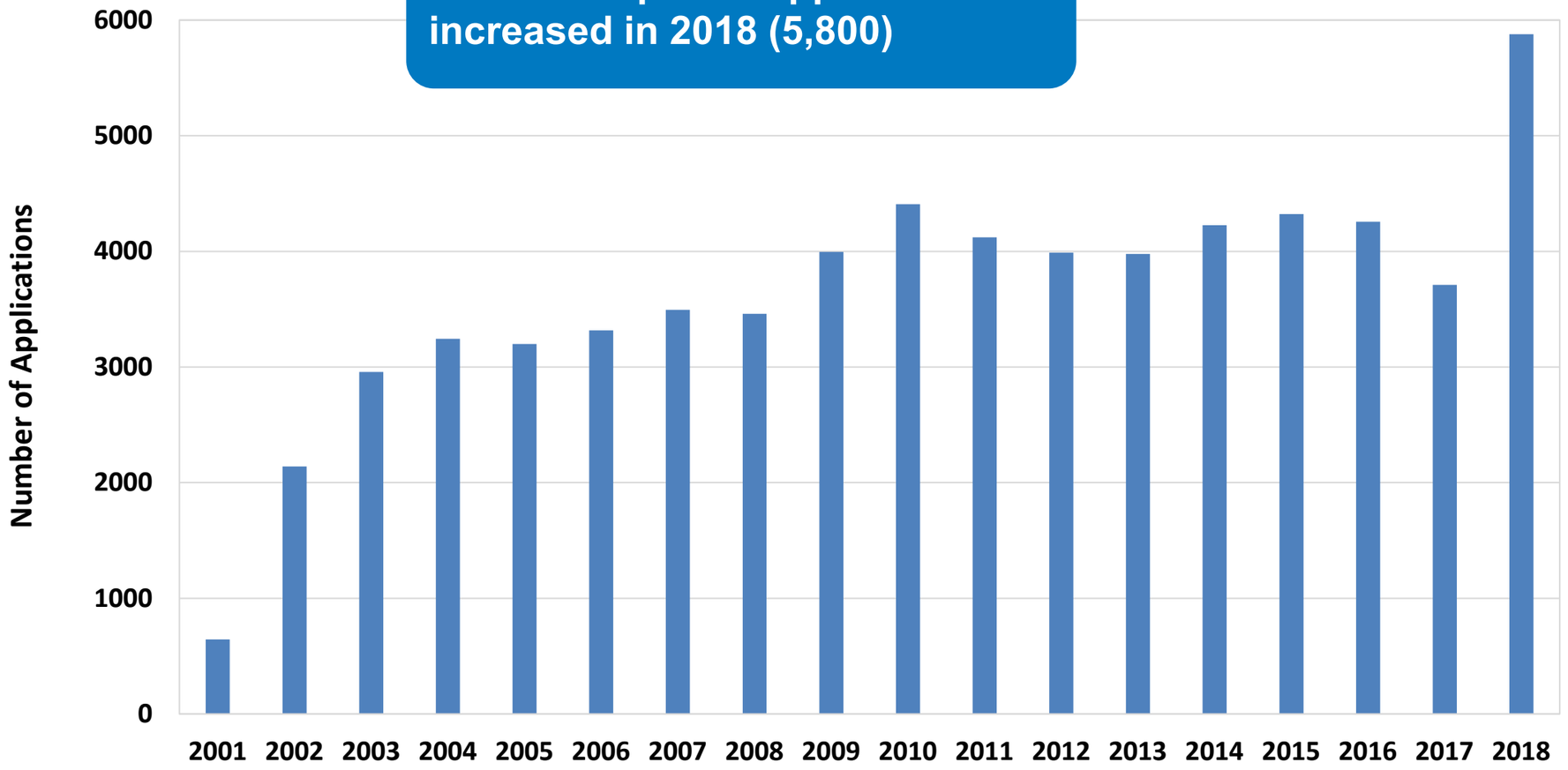
	Still Used in Research	Seeking to License	Licensed	No Longer Being Pursued
Storage	42	13	1	16
Production/Delivery	37	22	12	27
Fuel Cell	97	38	15	53
Total	176	73	28	96

- 50% 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* (2001–2018)

Number of patent applications increased in 2018 (5,800)



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