Pacific Northwest
NATIONAL LABORATORY

Patent and Technology Portfolios Resulting from HFTO R&D Funding

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U.S. DEPARTMENT OF ENERGY BATTELLE

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)

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*

HFTO Patent Tracking

- PNNL updates the hydrogen patent portfolio annually (by calendar year)
- Since 2008, PNNL has searched and recorded over 7,000 patents and 60,000 patent applications related to hydrogen and fuel cell technologies
- PNNL links IP to technologies resulting from HFTO R&D funding
- Over 160 organizations are currently developing hydrogen-related technologies
- Patents and patent applications investigated covered by 421 group level patent cooperative classification codes (CPC)
- Over 50% of patents and patent applications within H01M8 CPC group
- Patent and patent application data collection
  - Python web-scraping tool pulls patent and patent application information from the USPTO website

HFTO Patent Tracking – Results Summary

1,193 U.S. patent applications and 1,306 U.S. patent awards related to HFTO-funded R&D through 2022

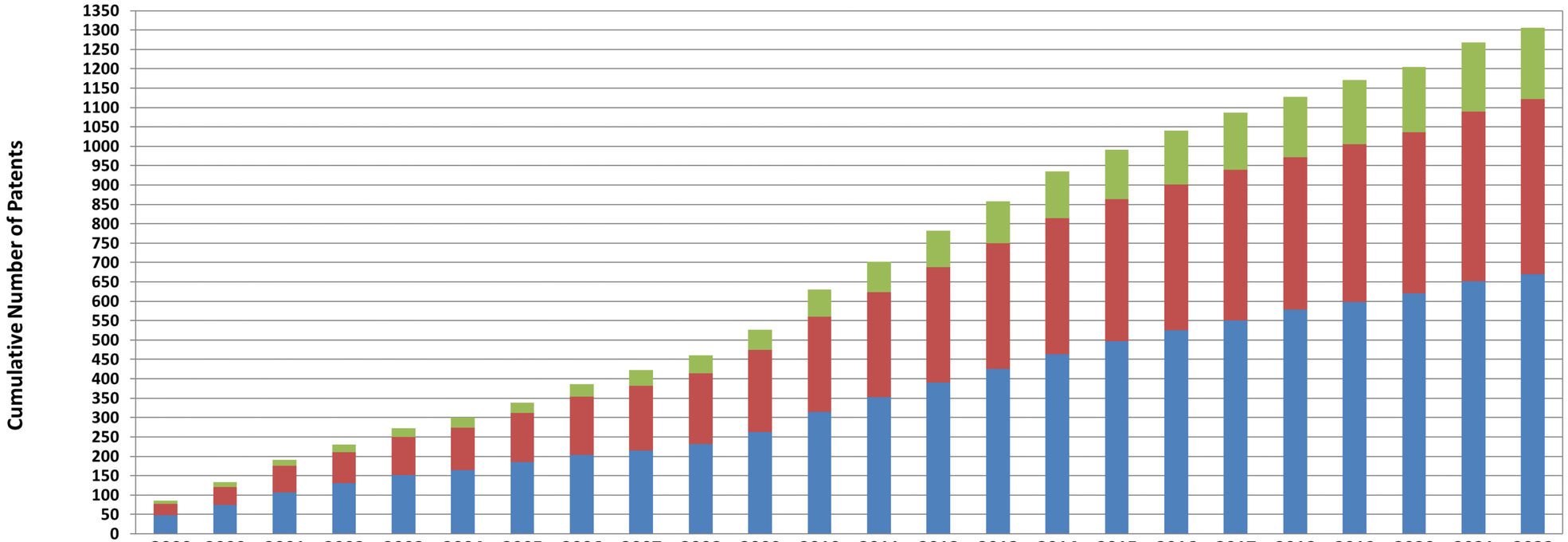
- **1,306 U.S. patent awards resulting from HFTO-funded R&D (1977–2022)**
  - 670 fuel cell patents (51.3%)
  - 452 hydrogen production and delivery patents (34.6%)
  - 184 hydrogen storage patents (14.1%)
  - 32% of all patents are available for license or licensed
  - 43% are actively being used in R&D
- **Three types of organizations received patents**
  - National laboratories (35.7% overall) lead in hydrogen storage R&D
  - Universities (18.6%) research activities primarily in fuel cell and hydrogen production R&D
  - Private companies (45.7%) 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*

Cumulative Number of Patents Awarded Over Time (≤2000–2022)

1,306 patent awards, 38 issued in 2022

- 670 fuel cell
- 452 hydrogen production and delivery
- 184 hydrogen storage



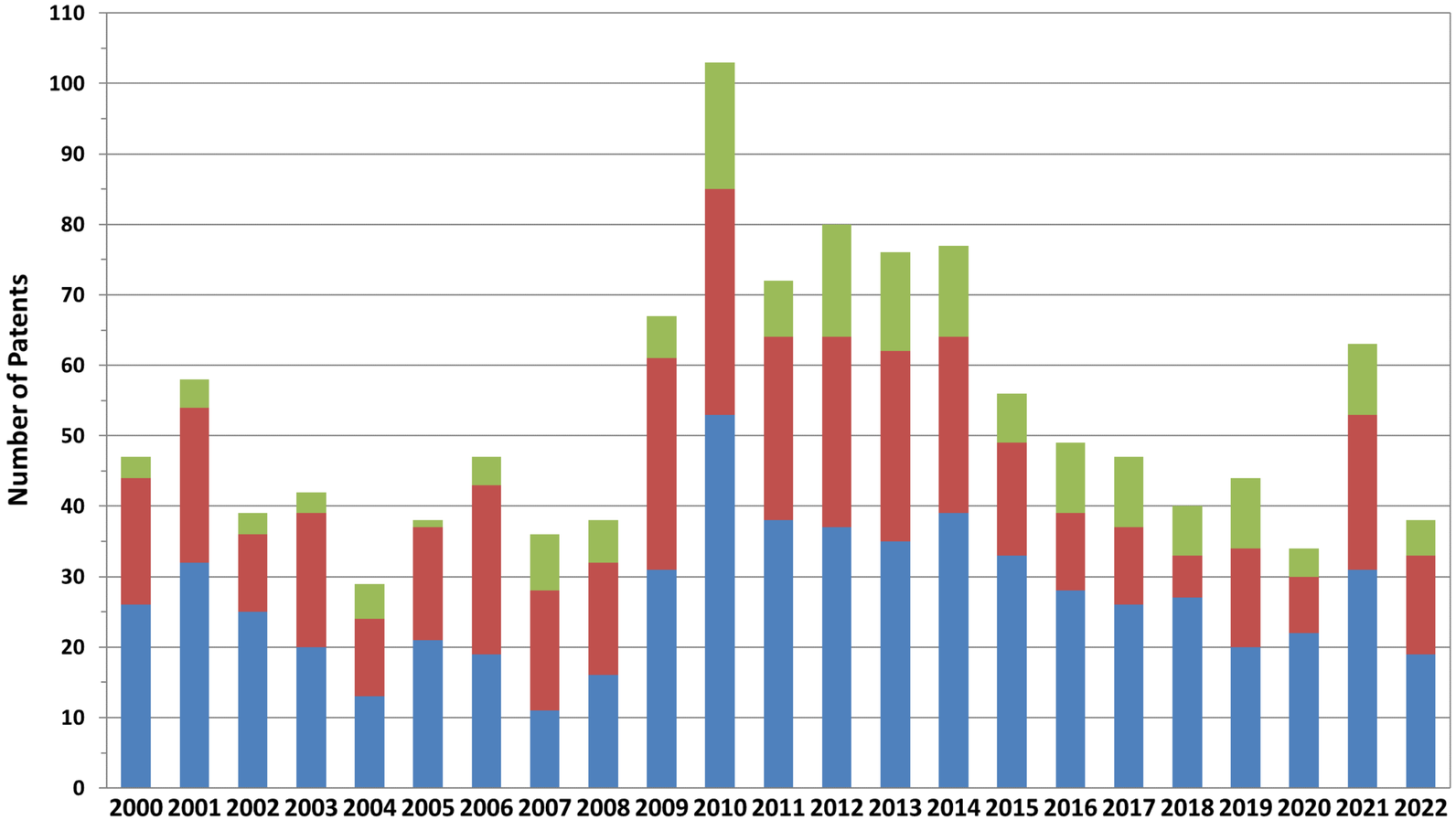
	<2000	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Storage	9	12	16	19	22	27	28	32	40	46	52	70	78	94	108	121	128	138	148	155	165	169	179	184
Production/Delivery	29	47	69	80	99	110	126	150	167	183	213	245	271	298	325	350	366	377	388	394	408	416	438	452
Fuel Cell	48	74	106	131	151	164	185	204	215	231	262	315	353	390	425	464	497	525	551	578	598	620	651	670
Total	86	133	191	230	272	301	339	386	422	460	527	630	702	782	858	935	991	1040	1087	1127	1171	1205	1268	1306

Note: Calendar years

Number of Patents Awarded Per Year (2000–2022)

Average 53 patents per year since 2000

- 27 fuel cell
- 19 hydrogen production and delivery
- 8 hydrogen storage

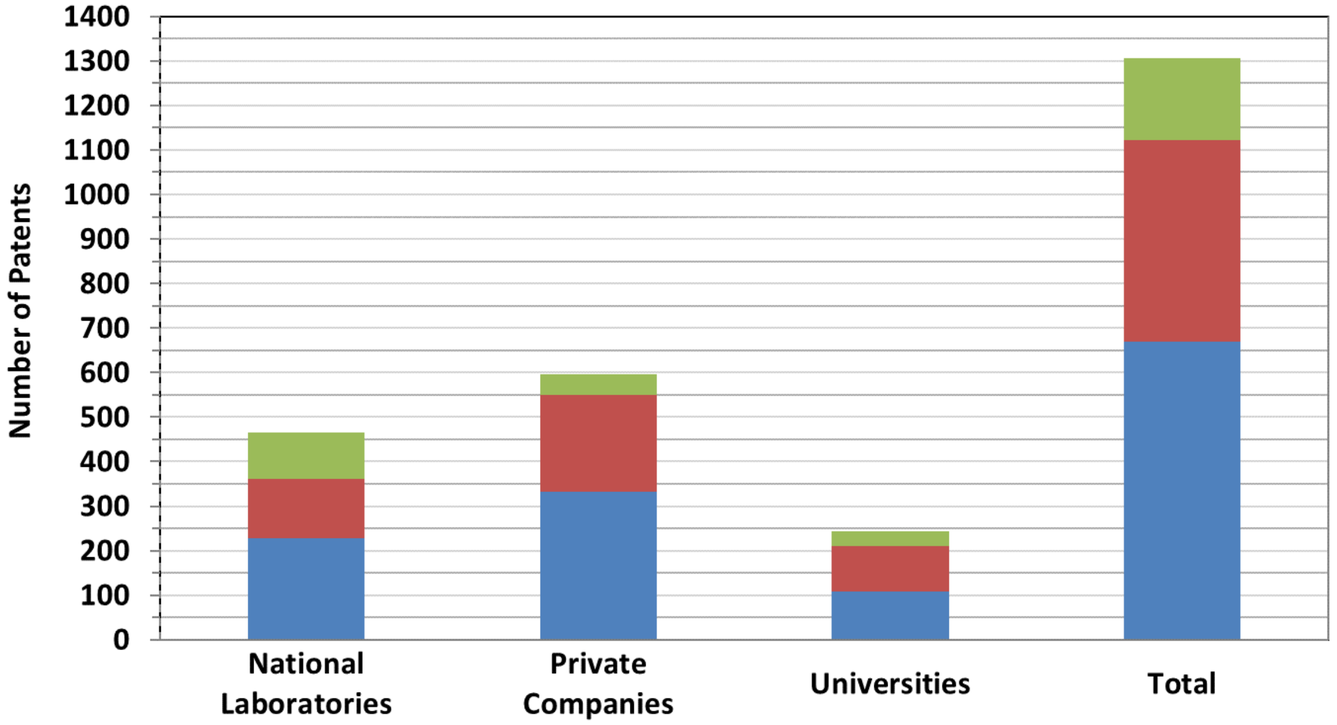


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Storage	3	4	3	3	5	1	4	8	6	6	18	8	16	14	13	7	10	10	7	10	4	10	5
Production/Delivery	18	22	11	19	11	16	24	17	16	30	32	26	27	27	25	16	11	11	6	14	8	22	14
Fuel Cell	26	32	25	20	13	21	19	11	16	31	53	38	37	35	39	33	28	26	27	20	22	31	19
Total	47	58	39	42	29	38	47	36	38	67	103	72	80	76	77	56	49	47	40	44	34	63	38

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	104	47	33	184
Production/Delivery	133	218	101	452
Fuel Cell	229	332	109	670
Total	466	597	243	1306

Patent Distribution by Organization Type

211 organizations receiving patent awards

- 129 private companies have 45.7% of patent awards
- 14 national laboratories have 35.7% of patent awards
- 33 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	129 (61.1%)	336	216	45	597	5	45.7%
National Laboratory	14 (6.6%)	232	134	100	466	33	35.7%
University	68 (32.2%)	111	99	33	243	4	18.6%
Total	211	679	449	178	1306	6	100%

- *PNNL determines patent funding status via communication with inventors, project researchers and patenting organization IP representatives*
- *PNNL determines patent active and licensing status via communication with patenting organization IP or Technology Transfer Offices*

Patents resulted from R&D funding or R&D funding in part by HFTO

Patents Related to Available Hydrogen and Fuel Cell Technologies

316 patents associated with 83 technologies

- 136 patents (35 fuel cell technologies)
- 114 patents (31 production and delivery technologies)
- 26 patents (6 safety technologies)
- 40 patents (11 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	99 (26)	107 (26)	15 (5)	20 (4)	242 (61)
National Laboratory	26 (5)	3 (3)	24 (5)	6 (2)	59 (15)
University	11 (4)	4 (2)	1 (1)	0 (0)	16 (7)
Total	136 (35)	114 (31)	40 (11)	26 (6)	316 (83)

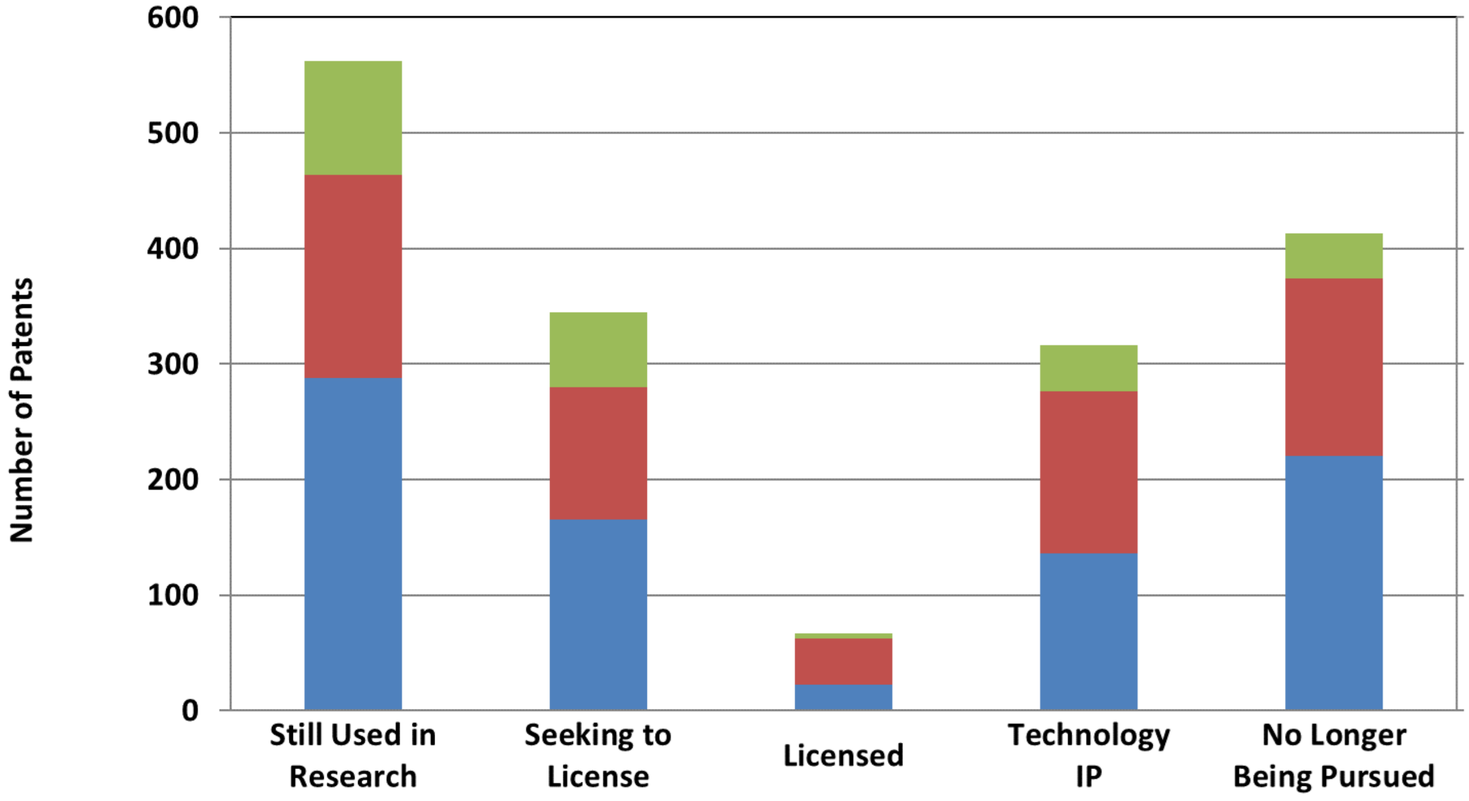
- *Available technology implies that the technology has either been commercialized, in-use or adopted by the organization or industry, available for commercial sale or will be available in less then 3 years.*
- *PNNL determines technology status via communication with the technology developers.*

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

32% of patents are licensed or available for license



	Still Used in Research	Seeking to License	Licensed	Technology IP	No Longer Being Pursued
Storage	98	65	5	40	39
Production/Delivery	176	115	40	140	154
Fuel Cell	288	165	22	136	220
Total	562	345	67	316	413

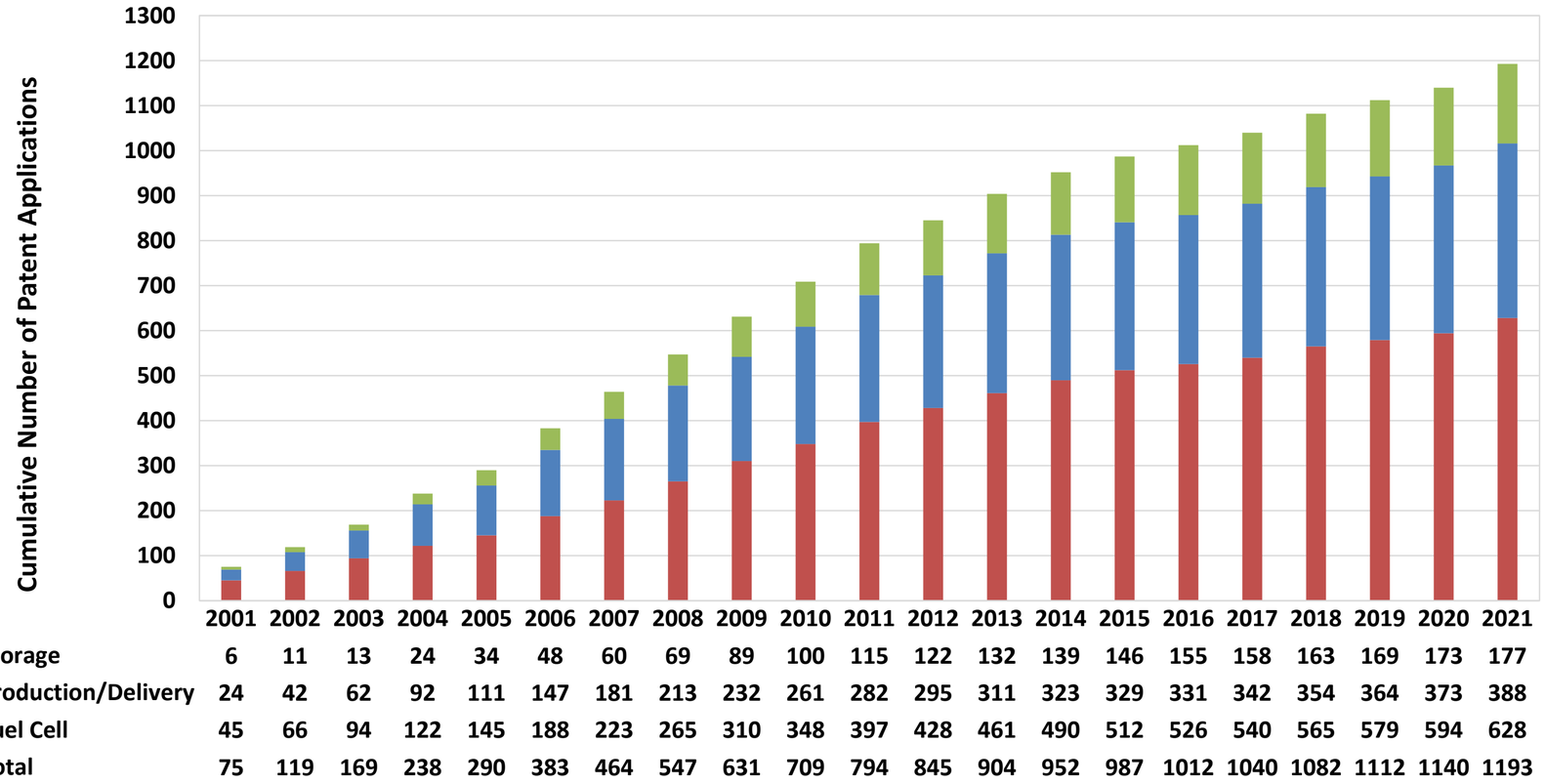
Note: Patents can be in more than one category, sum of percentages ≠ 100%

Percentages are fractions of total number of patents in portfolio (1306)

Technology IP are patents related to commercial or near market-ready technologies (determined by PNNL) resulting from HFTO R&D funding

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

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

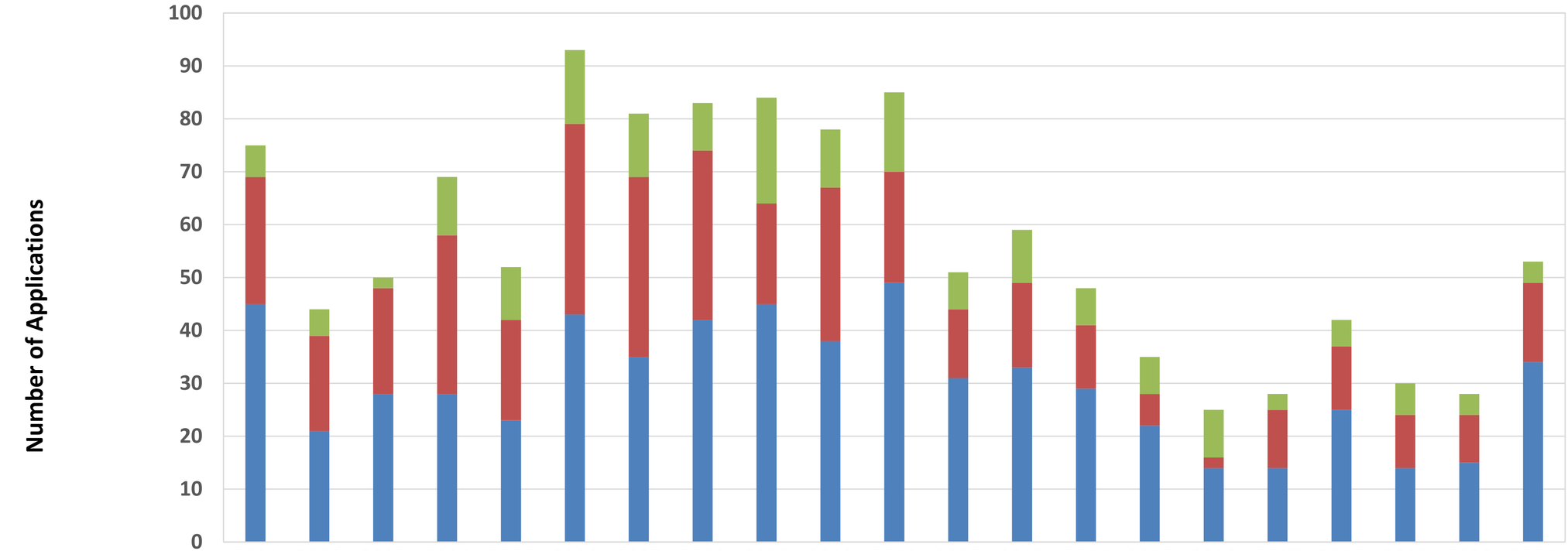


	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Storage	6	11	13	24	34	48	60	69	89	100	115	122	132	139	146	155	158	163	169	173	177
Production/Delivery	24	42	62	92	111	147	181	213	232	261	282	295	311	323	329	331	342	354	364	373	388
Fuel Cell	45	66	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

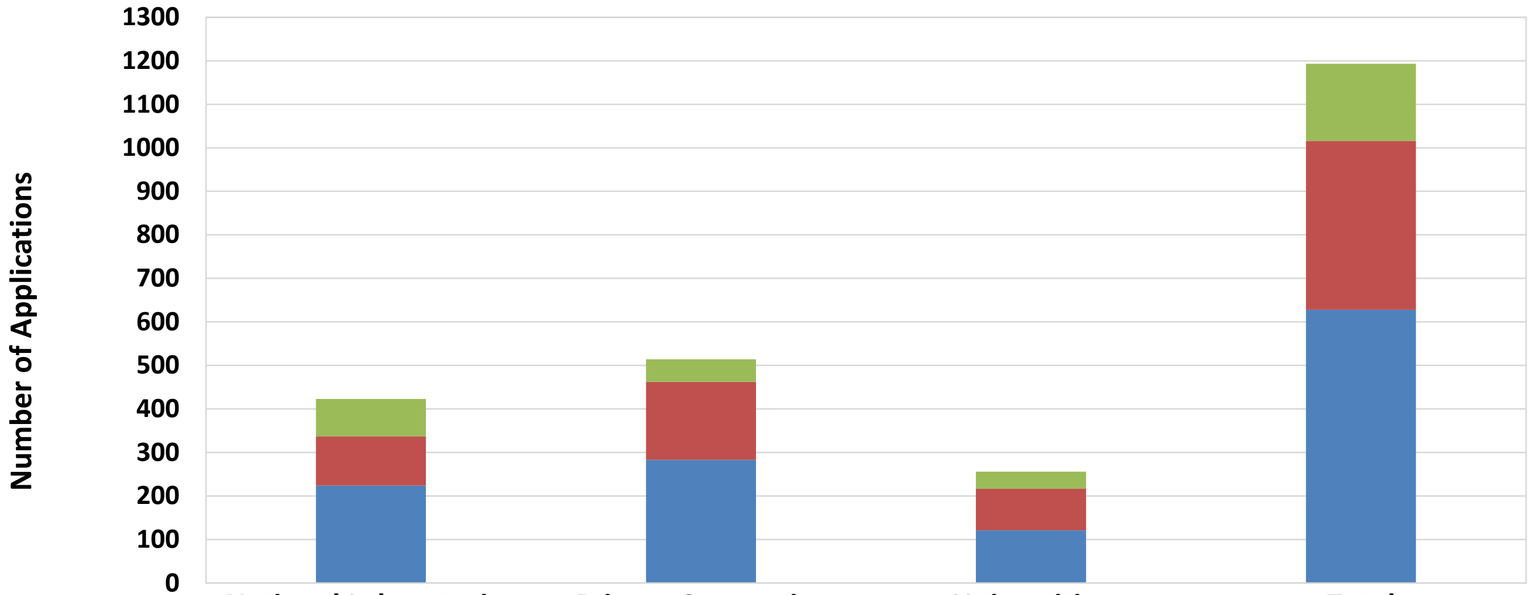


	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Storage	6	5	2	11	10	14	12	9	20	11	15	7	10	7	7	9	3	5	6	4	4
Production/Delivery	24	18	20	30	19	36	34	32	19	29	21	13	16	12	6	2	11	12	10	9	15
Fuel Cell	45	21	28	28	23	43	35	42	45	38	49	31	33	29	22	14	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

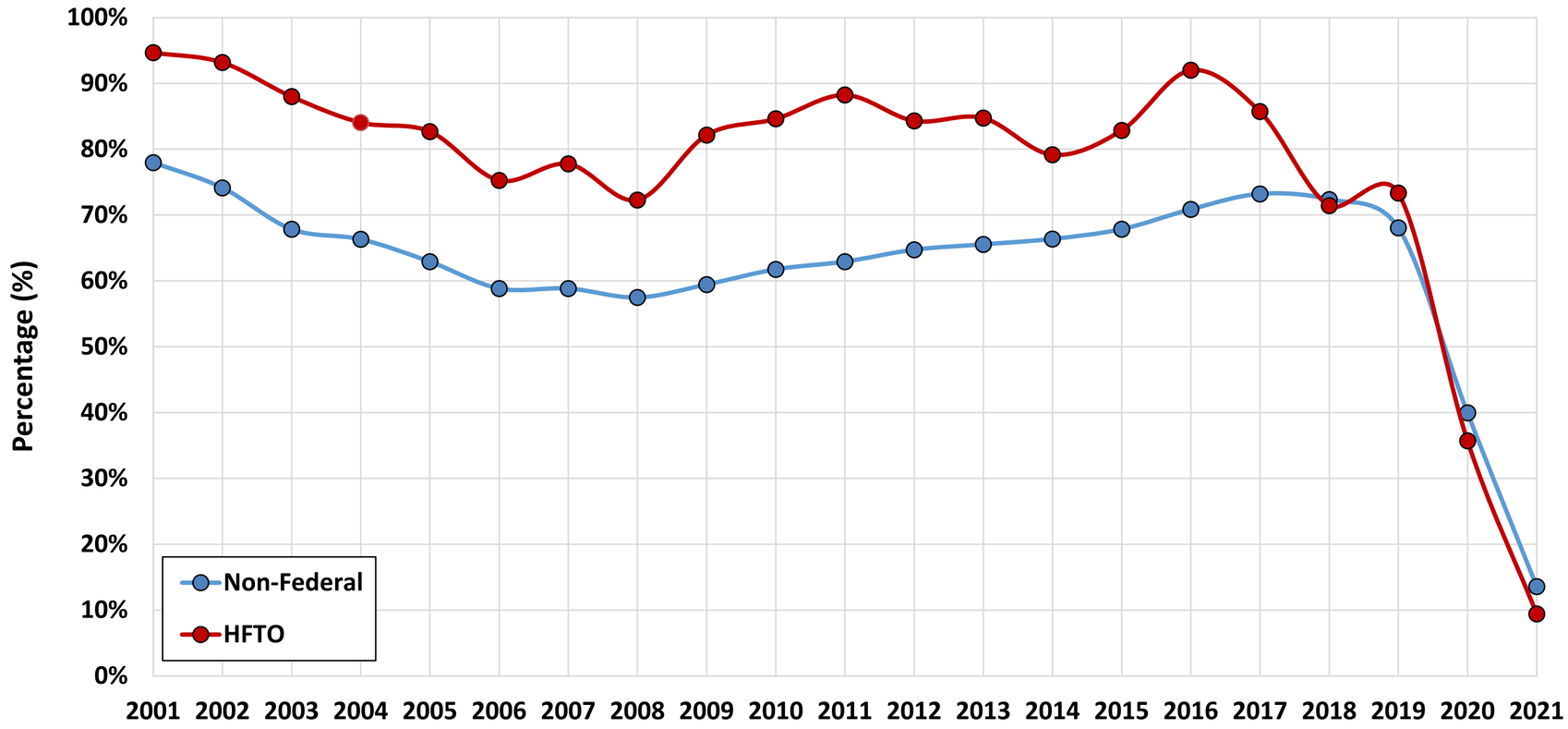
178 organizations receiving patent applications

- 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

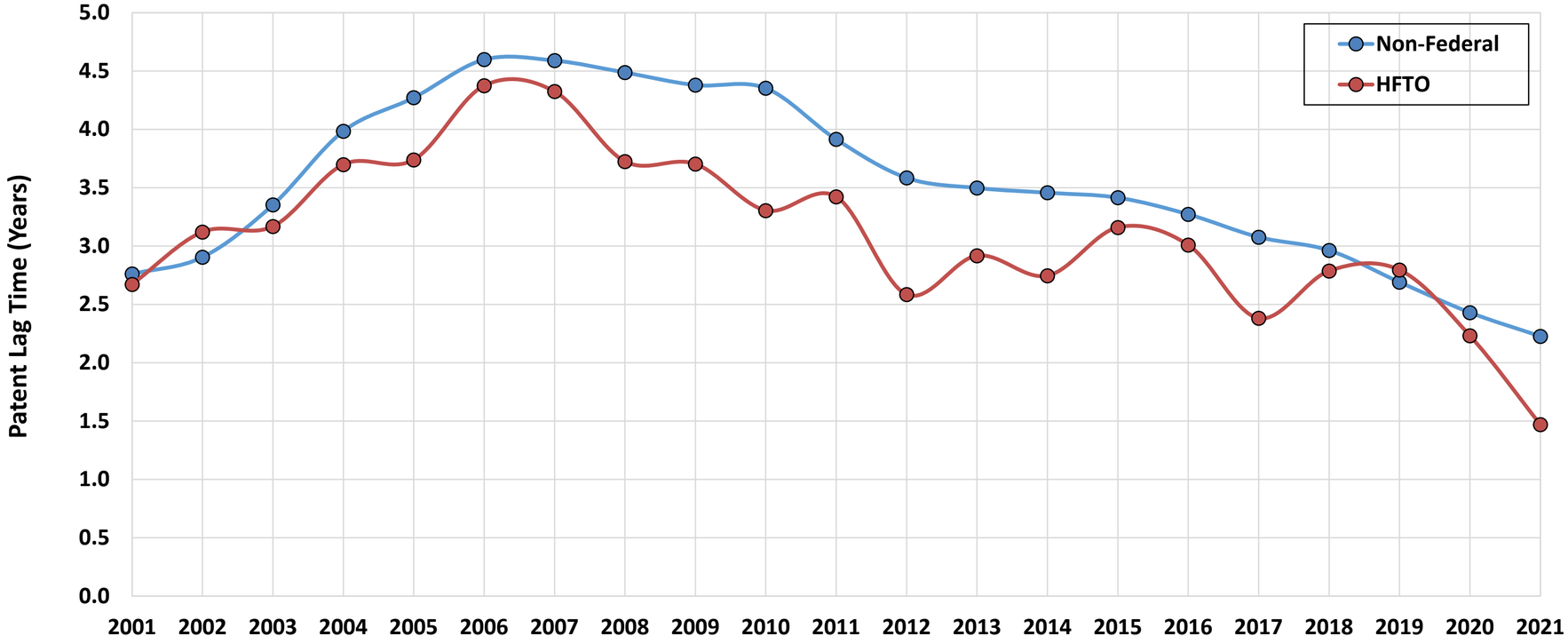


- 2020 and 2021 data is possibly affected by the 18-month pre-application publication period and legal litigation process

** 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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Technology Tracking History at PNNL

Over 450* HFTO funded R&D projects identified
Over 350 HFTO funded R&D projects investigated further
Over 200 technologies resulting from HFTO R&D funding
Over 75 technologies commercialized or in use
*** Includes SBIR and STTR-funded projects**

PNNL has tracked HFTO's R&D Project portfolio since FY2008

For the period 1995 – 2023 (HFTO APRs including predecessor programs)

- PNNL tracks technologies resulting from HFTO-funded R&D projects
- PNNL works with HFTO staff to determine which technologies should be investigated
- PNNL establishes contact with each organization to obtain technology information/status

Value from Tracking

- Budget defense
- Institutional memory
- Strategic planning
- R&D program performance (GPRA 1993 & 2010)
- Benefits (qualitative)
- Technology adoption, marketing, etc.

Technology Tracking Data Gathering Process

Data gathered from public domain, and POCs/PIs, as needed

- Technology Title
- Original Technology Developer and Partners
- Current Technology Owner/Developer/Distributer
- Applications
- Technical Description
- Graphics/Photographs
- Capabilities
- Benefits (qualitative)
- Contact Information
- Technology Status by year
- Year Developed
- Year Commercialized
- Year 1st Tracked
- Year Stopped Tracking
- Installations/Units Sold
- Technology History
- Marketing information
- Patents, Trade Pubs, and Journals

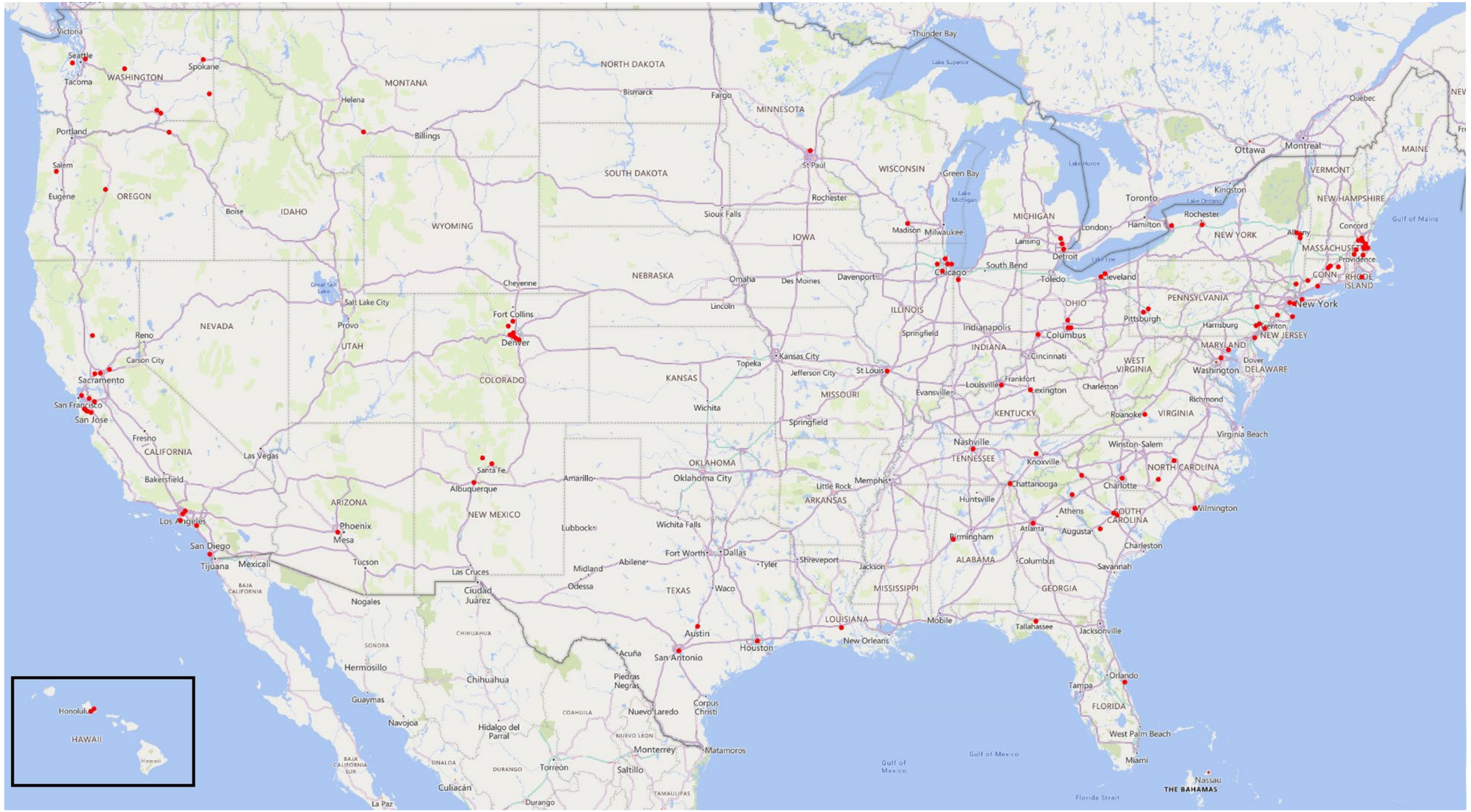
Technology Definitions

Commercial Technology Defined

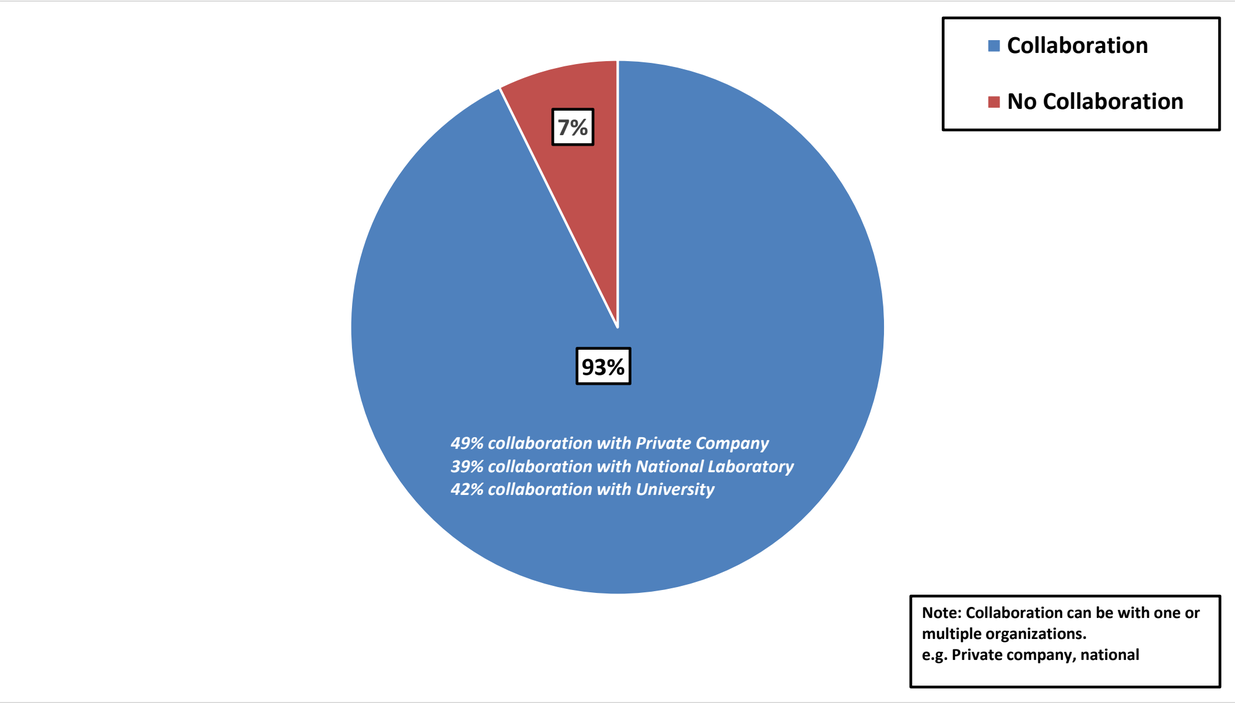
A commercial technology is defined as an invention or intellectual property that is developed into a technology (hardware, process, technique, design, machine, tool, material, or software) and enters the domestic market as “first sale”, “in-use in a production application”, or “sale of a commercial license”.

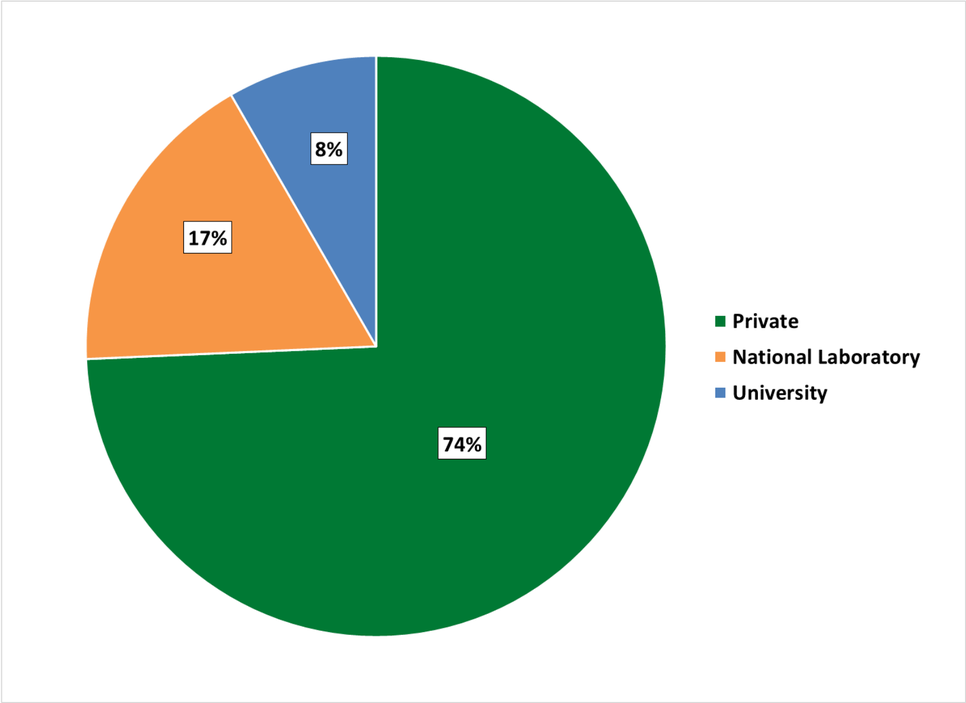
- **Commercial**: full-scale unit operational in United States and available for sale
- **Emerging**: under development; commercialization expected within next 3 years
- **Potential**: under development but commercialization expected more than 3 years out
- **Historical/Archived**: after 10 years in commercial operation tracking stops

Technology Tracking Results – Technology Developer Locations



Technology Development by Organization Type & Technology Development Collaboration





Technology Tracking Technology "Smorgasbord"