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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

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

• European Patent Office website
  ▪ [https://worldwide.espacenet.com/](https://worldwide.espacenet.com/)

• World Intellectual Property Organization website
  ▪ [https://www.wipo.int/pct/en/](https://www.wipo.int/pct/en/)

• Google Patents website
  ▪ [https://patents.google.com/](https://patents.google.com/)
Patent Results
1113 patent awards, 12 issued in 2019
• 582 fuel cell
• 134 hydrogen storage
• 397 hydrogen production and delivery
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
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)
### 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

<table>
<thead>
<tr>
<th>Type of Organization</th>
<th>Number of Organizations</th>
<th>Fuel Cell Patents</th>
<th>Production/Delivery Patents</th>
<th>Storage Patents</th>
<th>Total</th>
<th>Patents per Organization</th>
<th>Percent Patent Awards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private</td>
<td>98 (62%)</td>
<td>301</td>
<td>201</td>
<td>28</td>
<td>530</td>
<td>5</td>
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<tr>
<td>National Laboratory</td>
<td>13 (8%)</td>
<td>203</td>
<td>104</td>
<td>80</td>
<td>387</td>
<td>30</td>
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<tr>
<td>University</td>
<td>47 (30%)</td>
<td>78</td>
<td>92</td>
<td>26</td>
<td>196</td>
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<td>582</td>
<td>397</td>
<td>134</td>
<td>1113</td>
<td>7</td>
<td></td>
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</tbody>
</table>
43% of patents relevant to current research
28% of patents are licensed or available for license
Patent Application Results

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
• 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

- 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)

44% private companies  
35% national laboratories  
21% universities

<table>
<thead>
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<th>Organization Type</th>
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<th>Production/Delivery</th>
<th>Fuel Cell</th>
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<tr>
<td>Private Companies</td>
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<td>Universities</td>
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<td>95</td>
<td>212</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>132</strong></td>
<td><strong>332</strong></td>
<td><strong>559</strong></td>
<td><strong>1023</strong></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Type of Organization</th>
<th>Number of Organizations</th>
<th>Fuel Cell Applications</th>
<th>Production/Delivery Applications</th>
<th>Storage Applications</th>
<th>Total Applications</th>
<th>Applications per Organization</th>
<th>Percentage of Applications</th>
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<td>Private</td>
<td>95 (57%)</td>
<td>256</td>
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<td>35.1%</td>
</tr>
<tr>
<td>University</td>
<td>58 (35%)</td>
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<td>332</td>
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<td>6</td>
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</tr>
</tbody>
</table>

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
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

- 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

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<th>Section</th>
<th>Class</th>
<th>Subclass</th>
<th>Main Group (00)</th>
<th>Subgroup</th>
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<td>Y</td>
<td>02</td>
<td>E</td>
<td>60/00</td>
<td>60/521</td>
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</table>

Section: 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: Technologies or Applications for Mitigation or Adaptation against Climate.
Main Group (00): Enabling technologies or technologies with a potential or indirect contribution to GHG emissions mitigation.
Subgroup: Proton Exchange Membrane Fuel Cells [PEMFC].
### 16 CPC Code Search from HFTO Patent Portfolio

- 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

<table>
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<th>No. CPC Classes</th>
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<td>B01N</td>
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No. CPC Classes: B01D, B01J, B01K, B01L, B01M, B01N, B01O, B01P.

2-Combos: B01D-B01I, B01D-B01J, B01I-B01J, etc.
3-Combos: B01D-B01I-B01J, B01D-B01I-B01K, etc.
4-Combos: B01D-B01I-B01J-B01K, B01D-B01I-B01J-B01L, etc.
5-Combos: B01D-B01I-B01J-B01K-B01L, etc.
6-Combos: B01D-B01I-B01J-B01K-B01L-B01M, etc.
7-Combos: B01D-B01I-B01J-B01K-B01L-B01M-B01N, etc.
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
Patents Awarded Over Time by Organization Type

- 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

<table>
<thead>
<tr>
<th>Year</th>
<th>Universities</th>
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<th>Private Companies</th>
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<td>2019</td>
<td>197</td>
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<td>1113</td>
</tr>
</tbody>
</table>
• 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
• 53% of national laboratory patents in fuel cells
• National laboratory research activity in production/delivery and storage approximately equal
• 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)

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.