CleanTech Alliance™

The Washington State Fusion Energy Landscape

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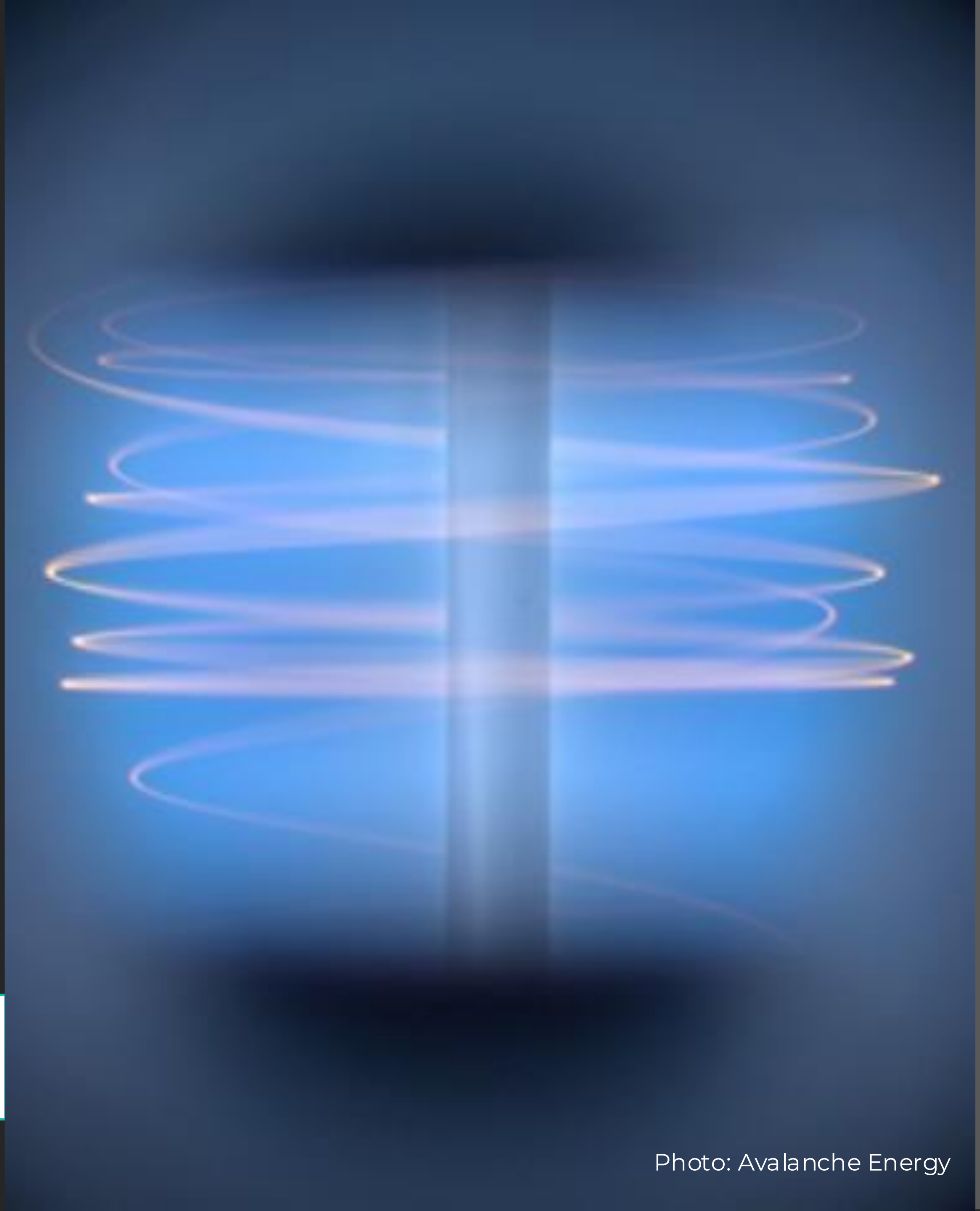

Photo: Avalanche Energy

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Executive Summary

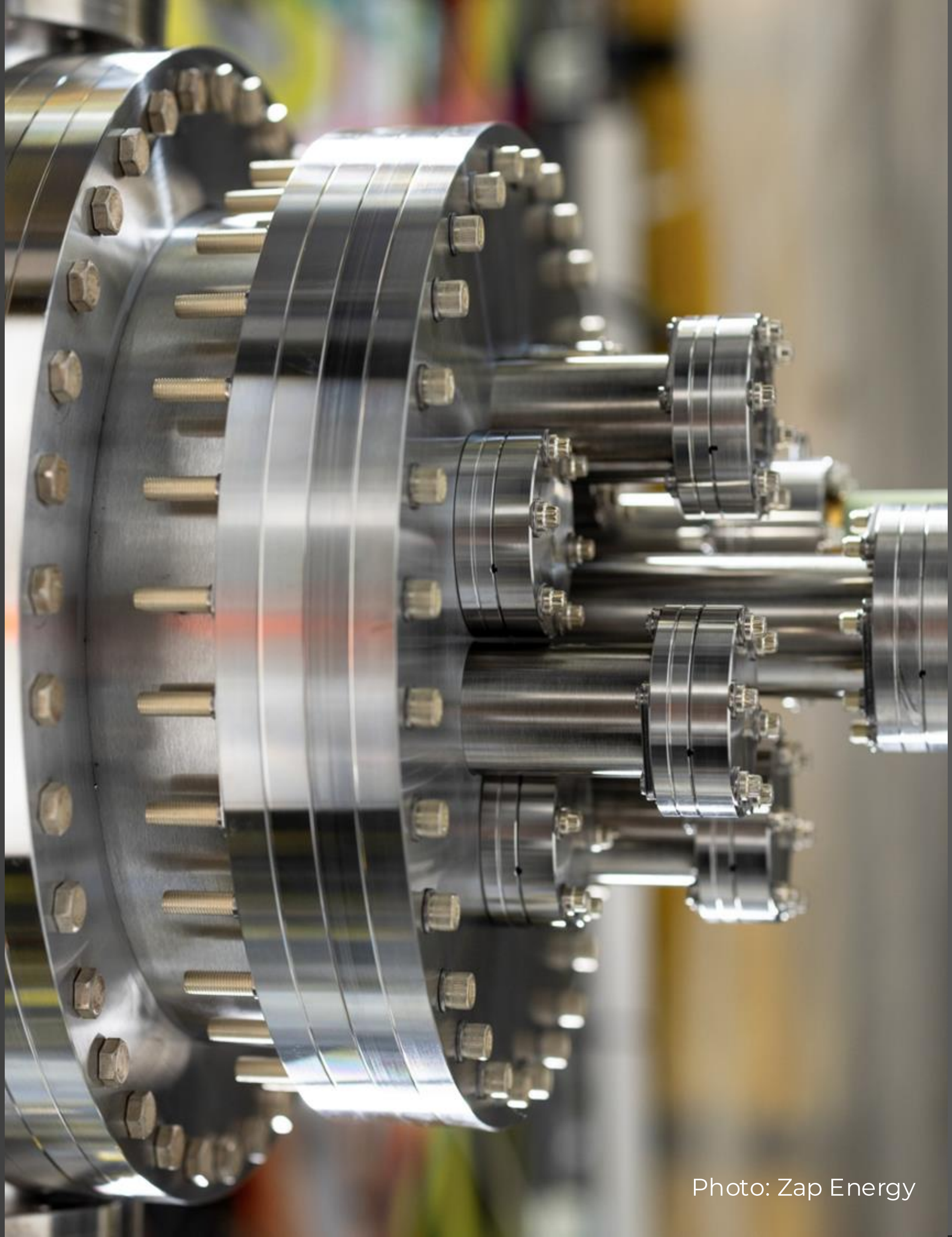
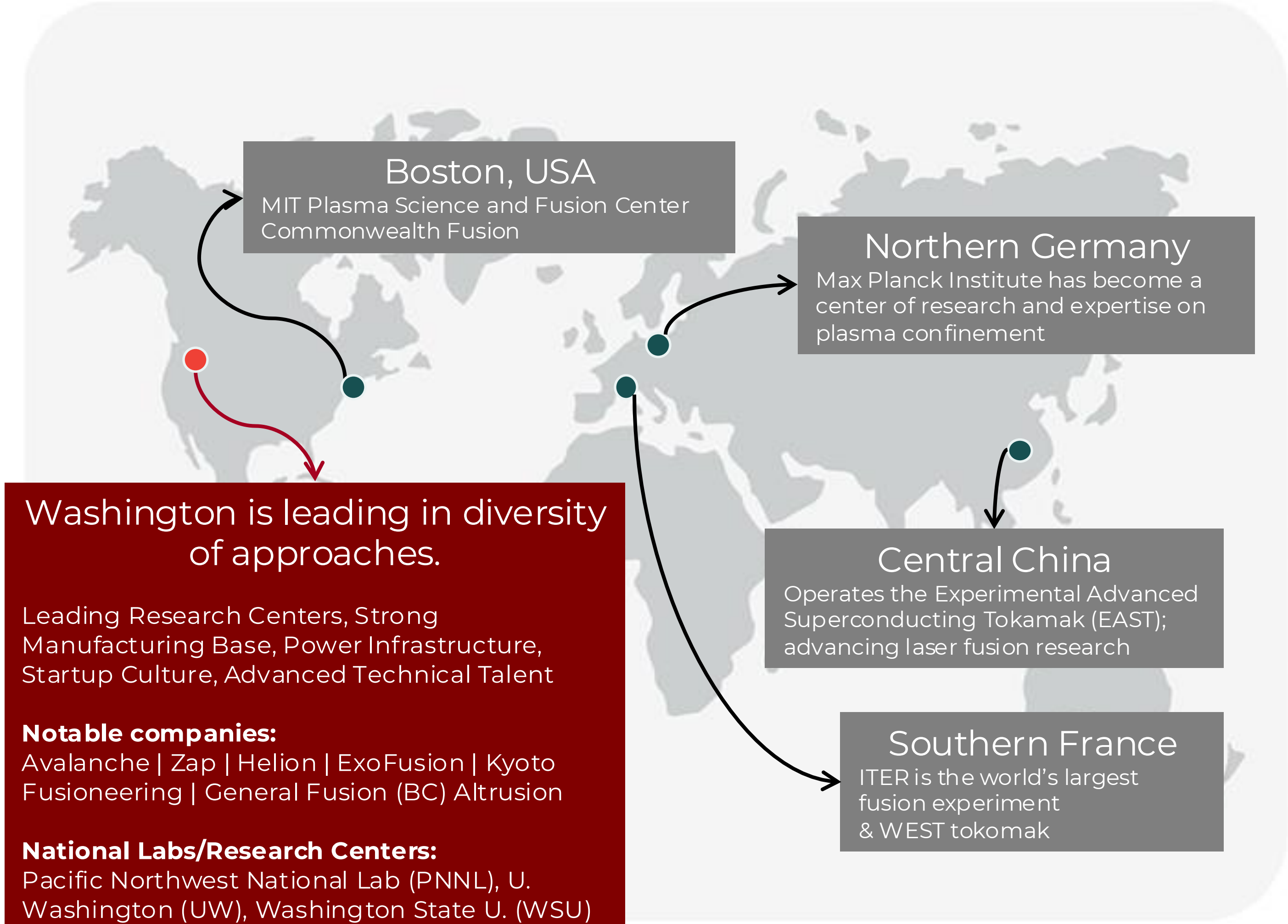


Photo: Zap Energy

Fusion Energy is transitioning from science to market — Washington's fusion cluster is emerging as a global leader.



Washington is leading in diversity of approaches.

Leading Research Centers, Strong Manufacturing Base, Power Infrastructure, Startup Culture, Advanced Technical Talent

Notable companies:
Avalanche | Zap | Helion | ExoFusion | Kyoto Fusioneering | General Fusion (BC) Altrusion

National Labs/Research Centers:
Pacific Northwest National Lab (PNNL), U. Washington (UW), Washington State U. (WSU)

- **Global competition is growing.**

  From long-time leadership from France to significant investment from China, the race to commercialize fusion is getting heated.

- **Growth in private investment is complementing National Lab Research.**

  Labs like LLNL and PPPL are advancing net energy breakthroughs and coordinating with the private sector.

- **Regional clusters are rising.**

  Domestically, Boston, Denver/Fort Collins, and Washington are growing fusion hubs.

- **Washington has a pivotal role in the industry's success.**

  Advantages in **startup-led innovation** in alternative, compact fusion concepts position WA to be able to deliver electricity to the grid through fusion-based solutions. **State support and resources** will be critical factors in the ability to develop a robust fusion cluster in Washington.

Washington State is emerging as a global leader thanks to advantages with research institutions, a skilled workforce, investors with a long-term horizon, and advanced manufacturing capabilities.

Washington State Landscape

Leading Research Institutions:

- University of Washington has a focus on plasma science research and spun-out Zap Energy.
- WSU-TriCities funds Institute for Northwest Energy Futures.
- The national lab, PNNL, receives DOE funding and is a critical partner.

Workforce:

- A skilled workforce in aerospace manufacturing, electrical engineering and advanced physics
- Mature start community and growing cohort of investors

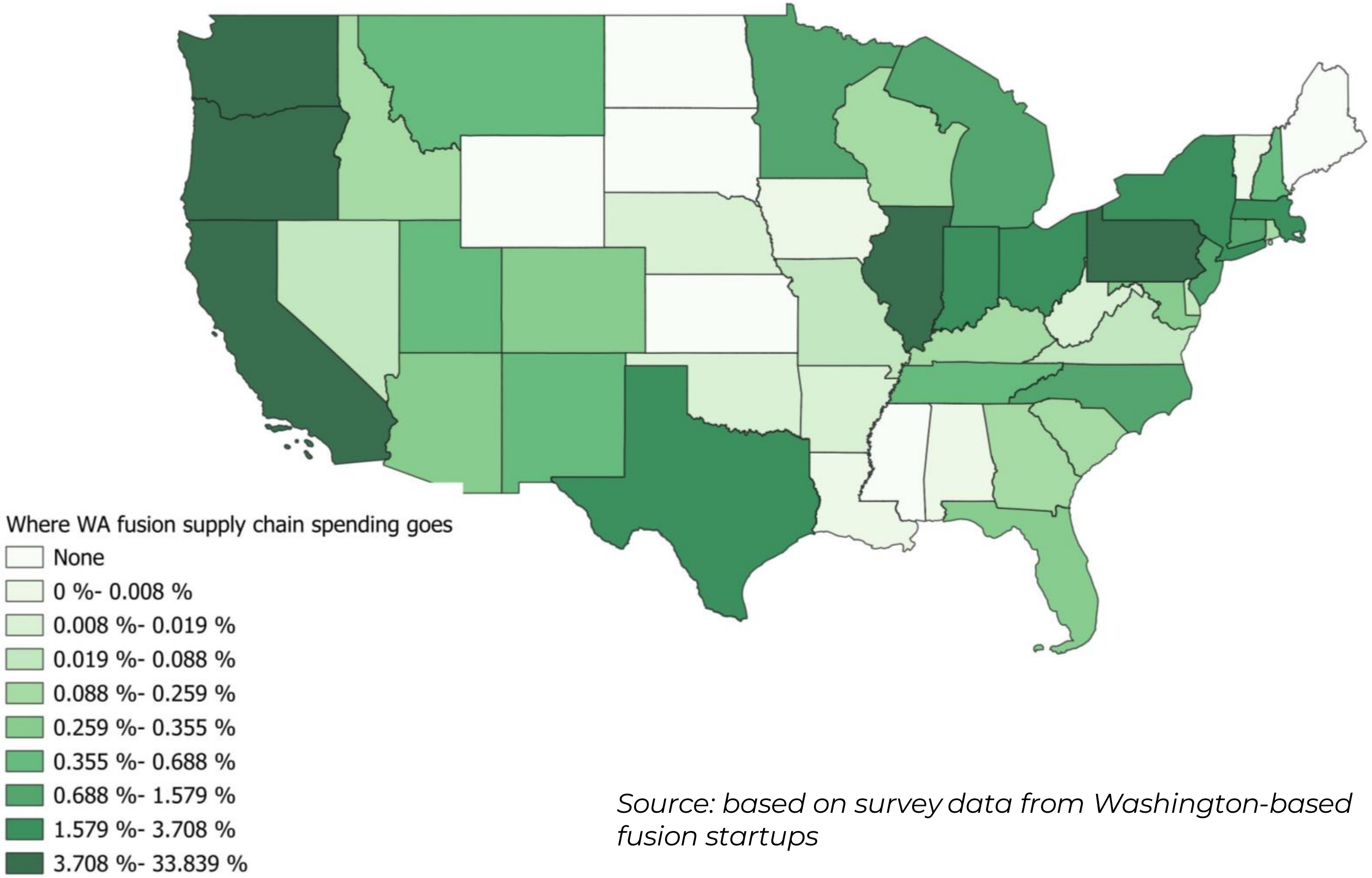
Sophisticated Investors:

- Jeff Bezos (Bezos Expeditions), Bill Gates (Breakthrough Energy), Cercano Management

Two-thirds of domestic supply chain value is spent outside of Washington State.

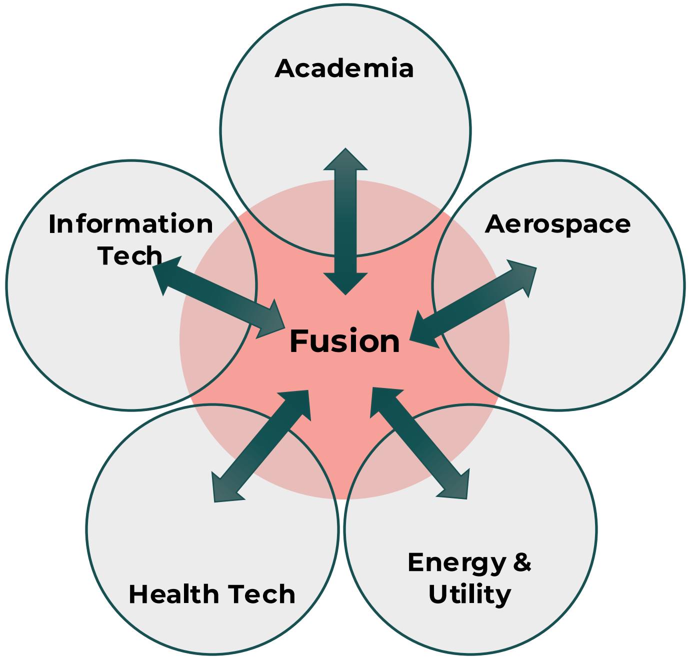
We surveyed Washington State fusion startups to analyze suppliers into their supply chain. This assessment revealed:

- Only 1/3 of domestic supply comes from in-state;
- Extensive west coast collaboration;
- There is an opportunity to attract more of the supply chain into the state.



Source: based on survey data from Washington-based fusion startups

Growing fusion cluster deepens capabilities that benefit existing Washington industries.



Capabilities and supply chains to support fusion have beneficial effects for the rest of Washington's economy.

Technology	WA State Benefit to Fusion	Fusion Industry Benefit to WA State	Examples of Workforce Cross-applications
Academia	• Deep research expertise • Existing lab infrastructure • STEM talent pipeline	• New research grants • Faculty-industry collaboration • Fusion-adjacent fields growth	• Physicists to fusion modeling • Engineering faculty in tech transfer
Aerospace	• Precision manufacturing • Thermal control systems • Advanced materials R&D	• Diversified supplier demand • Spin-off engineering tools	• Aerospace engineers to machine design • QA expertise to fusion hardware
Energy & Utility	• Grid infrastructure knowledge • Regulatory navigation • Power systems engineering	• Baseload clean energy • Incentives for grid modernization • Next-gen power applications	• Electrical engineers to fusion grid • Project managers to deployment
Health Technology	• Plasma diagnostics crossover • Precision manufacturing and controls	• Advanced radiation protection • High-precision heat control	• Device engineers to instrumentation
Information Technology	• AI & data science skills • High-performance computing • System integration capability	• Edge computing for fusion control • New platform development	• Systems engineers to fusion ops • Data scientists to machine analytics • Cybersecurity to control systems

Other Washington sectors benefit from the fusion supply chain.

	Academia	Aerospace	Energy	Health Tech	Information Technology	Fusion
high temperature superconductors	✓			✓	✓	✓
cryogenic systems	✓	✓		✓		✓
pulsed/high-voltage power components	✓	✓	✓	✓		✓
vacuum chambers	✓	✓		✓		✓
large parts machining	✓	✓		✓		✓
conventional steam plants			✓			✓

Meeting the fusion sector's workforce needs will require strategic investment in technical talent pipelines.

Anticipated Labor Needs

- Technicians
- Electrical Engineers
- Mechanical Engineers
- Materials Scientists
- Power Engineers
- Industrial Engineers

- Common B.S. disciplines include electrical engineering, material science, power engineering.
- As fusion gets closer to commercial scale, there is an increasing demand for technical professions, e.g. machinists, electricians.
- Sector still small, with about 530 direct workers in Washington state.
- There are few fusion-specific fields of study, e.g., plasma physicists, and no fusion-specific four-year degree programs. Fusion curriculum should be integrated into existing disciplines.

Fusion challenges: future workforce demand and supply

- Fusion workforce challenges are consistent with other high-tech sectors.
    - For example, lack of diversity, difficulty recruiting senior/managerial talent and experienced technical leaders who can also manage teams, regional affordability (e.g., housing costs), and labor costs.
- There are very few fusion-specific diversity recruitment programs. But many that are STEM- and tech-sector-wide.
- **The workforce demand will evolve as industry matures**.
    - Between 2025 and 2040, demand for industry research positions will still grow, but projected to be a smaller share of the total fusion workforce (11% reduction).
    - Future demand will focus on engineers, supply chain managers, and operations occupations.

Workforce Role	Share of Workforce 2025	Share of Workforce 2040	Change
Supply chain	50%	56%	+6%
Business	7%	6%	-1%
Operations	4%	13%	+9%
Engineering	3%	9%	+6%
Industry research	26%	15%	-11%

There are an estimated 16,200 workers nationwide in 2025 in the fusion industry, according to Ignition Research. As the industry evolves, roles such as operations will grow in share of the workforce, from 4% today to 13% by 2040

Source: Mike Heumann, "1M Fusion Jobs by 2040." January 14, 2025. Watts's Next. Ignition Research. Consultants' calculations based on report.

We recommend several areas of focus to advance fusion energy in Washington State.

Element 1: Market Assessment

Focus 1: Manufacturing Hubs – Establish manufacturing hubs for priority fusion components—such as semiconductors, capacitors, and high-field magnets—will strengthen the supply chain critical to scaling fusion energy.

Focus 2: Fusion Incentives – Explicitly include components like high-temperature superconductors, capacitors, and power electronics in Washington state clean technology incentives to support for local manufacturers.

Focus 3: Streamline Permitting – Create greater efficiency in permitting for fusion manufacturing to reduce uncertainty in facility development

Focus 4: Onshoring Precision Manufacturing – Support the creation and growth of precision manufacturing shops capable of handling small, custom orders is vital as the fusion industry transitions from R&D to commercialization

Full details on page 25

Element 2: Opportunity Pipeline

Focus 1: Funding Attraction – Represent industry at the federal level to attract interest from DoE funders, consider state-level match; recognize fusion in state's clean technology policy

Focus 2: Manufacturing Incentives – Create state-level fusion manufacturing funding strategy addressing incentives, investment attraction, and components

Focus 3: Cross-sector Collaboration – Advance fusion cluster; support inter-state collaboration; and support DoE efforts to advance fusion energy

Full details on page 30

Element 3: Workforce Assessment

Focus 1: Modular Training – Expand modular training in K-12.

Focus 2: Hands-on Experience – Expand internships, capstones, fusion academies, etc.

Focus 3: Community Outreach – Consider targeted high school certification programs, etc. for manufacturing in underserved communities

Focus 4: Address Barriers – Incorporate fusion jobs in housing affordability and affordable & accessible childcare considerations

Full details on page 34

Additional research may be needed to inform data-driven initiatives.

This report provides an initial assessment of the strengths of Washington's emerging fusion cluster. We suggest some additional research to support positioning Washington as the epicenter of this technology.

1) **Ecosystem Benchmark Report:** Baseline Washington State's strengths, weaknesses, opportunities, and threats against other fusions clusters to quantitatively and qualitatively assess how the state compares to other regions.
2) **Vulnerability Report:** Assess global supply chains required for various fusion technologies and map dependencies and risk factors
3) **Reshoring Analysis:** Identify global dependencies and develop recommendations for bringing the manufacture of these dependencies to the U.S., as well as supporting the growth of new manufacturing operations to WA.
4) **Degrees Benchmarking:** Analysis of fusion-related post-secondary degrees and how Washington institutions compare in conferrals with other fusion industry hubs.
5) **Fusion Career Awareness:** Analysis to identify best practices in other regions (national, global) for raising awareness of fusion careers and how these can be applied in Washington state.
6) **Fusion Investor Profiles:** Develop a comprehensive list of Investor names and investment capacity to inform a capital attraction strategy for the region.

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The Washington State Fusion Energy Landscape

Element 1

Market Assessment

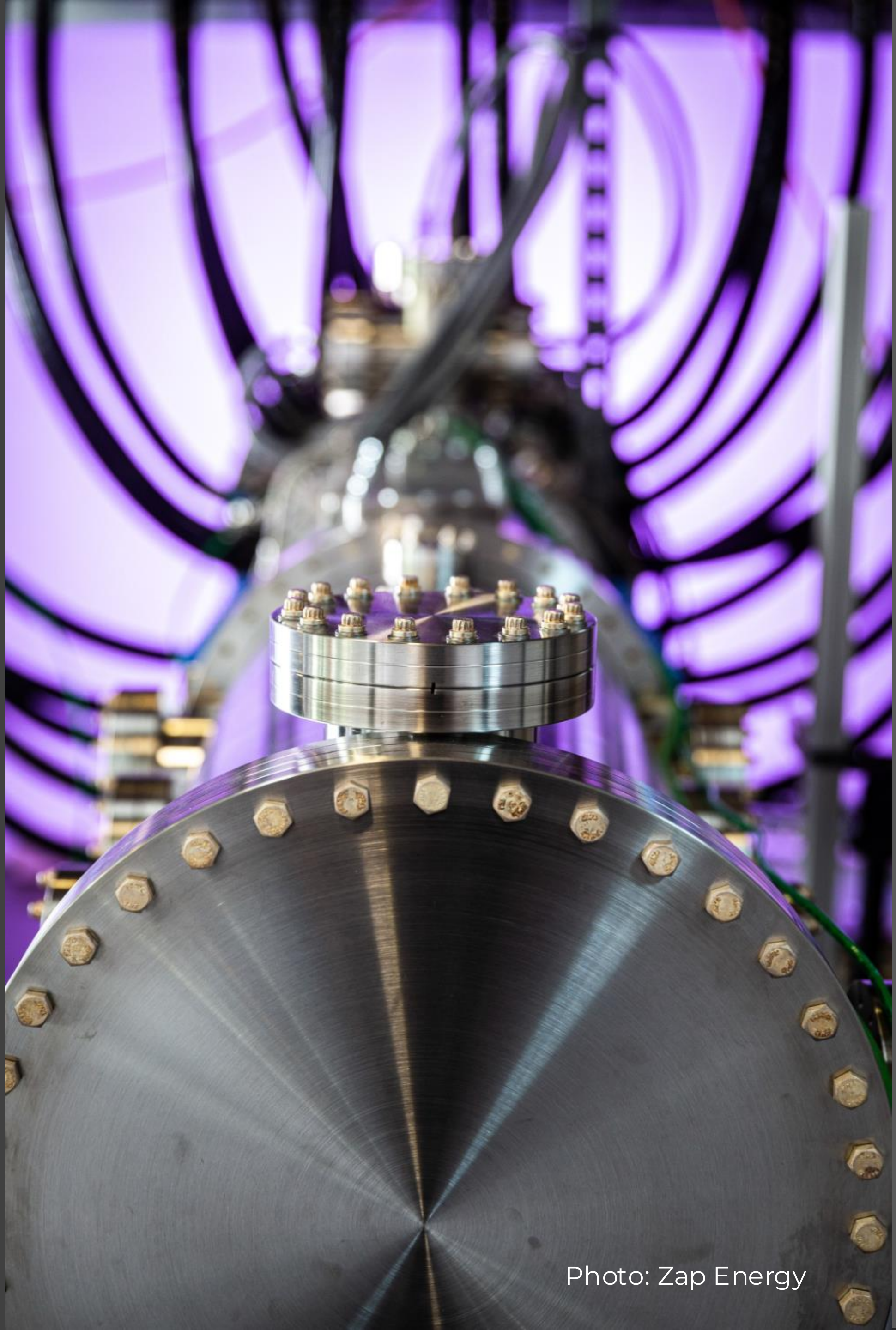


Photo: Zap Energy

Fusion delivers advantages to power generation, fuel, supply chains, and energy distribution over traditional energy platforms.

	Fusion	Solar/Wind/Hydro	Coal/NG/Fission
Power Generation	Dispatchable	Intermittent	Coal & Fission can only serve baseload; natural gas (NG) is dispatchable
Fuel	Fuel volumes are nearly immaterial; ^{2}H or ^{11}B extracted in small-scale industrial processes; ^{3}H or ^{3}He bred at fusion or fission facilities	Dependent on siting. Hydro impounds large volumes of running water; wind requires large areas though mitigated by shared use	Extraction induces local environmental impacts; coal and natural gas produce greenhouse gases from use; fission fuels produce long-lived radioactive waste
Supply Chains	Includes high-voltage electronics, precision machining, vacuum systems, cryogenic systems, high-temperature superconductors; thermal technologies require conventional steam electric generation (like coal/NG/fission)	Solar faces supply challenges for rare elements or compounds; and waste management. Wind demands novel materials and delivery logistics. Hydro benefits from conventional materials, albeit in very large quantities	Over the plant's life-cycle, fuel needs dominate the coal & NG supply chains, and are substantial for the fission supply chain
Energy Distribution	Small-to-medium unit size allows distributed generation	Dependence on site invokes large transmission distances, with attendant challenges of intermittent demand for transmission capacity	Can be built near load centers, albeit with local health & safety concerns

Major Recent Milestones in Fusion: Global and Local Progress

Scientific & Technological Breakthroughs

- **Zap Energy (WA) advancing compact fusion device prototypes**
- **Avalanche Energy (WA) developing fusion microreactors for space and defense**
- NIF (CA) achieved net-energy gain — a global fusion milestone
- China's EAST sustained a 17-minute plasma at 158 million degrees
- U.S. breakthrough: 20-Tesla high-temperature superconducting (HTS) magnet prototype
- ITER received and installed its first central solenoid magnet
- UK's JET set a world record for longest sustained fusion pulse (5 seconds)
- LaserNetUS expanded — U.S. leadership in high-intensity laser fusion research

Funding & Investment Growth

- Global private fusion funding rebounded to $1.2B+ in 2024
- **50+ investors fueling WA startups; $1.3B+ raised in WA**
- **Helion Energy (WA) signed the world's first fusion PPA (50MW) with Microsoft**
- Department of Energy (DOE) announced $49M for foundational fusion materials and nuclear science research (2024)
- Virginia announced first grid-scale fusion plant (CFS) — major commercial step

Policy & Academic Research Momentum

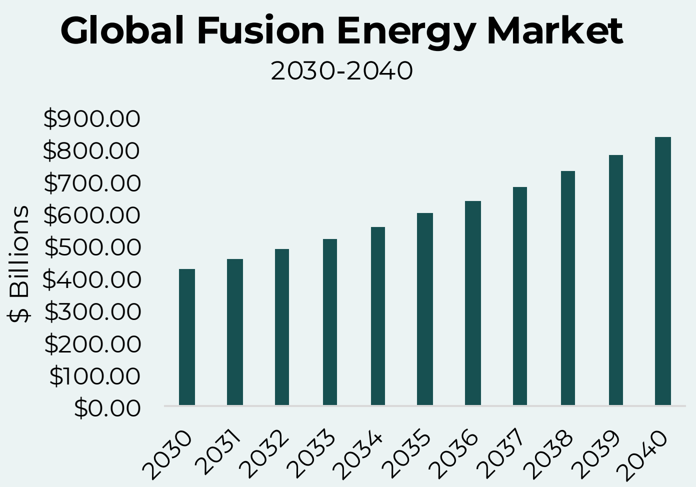
- DOE *Building Bridges* fusion commercialization strategy
- DOE Fusion Energy Sciences: workforce, plasma R&D focus
- LaserNetUS expanded for high-intensity laser research
- Fusion now eligible for California clean energy tax credits
- Virginia state incentives for fusion deployment
- **WA universities growing fusion R&D (UW, WSU)**

Local highlights noted in **bold**

There has been significant recent spending on fusion energy.

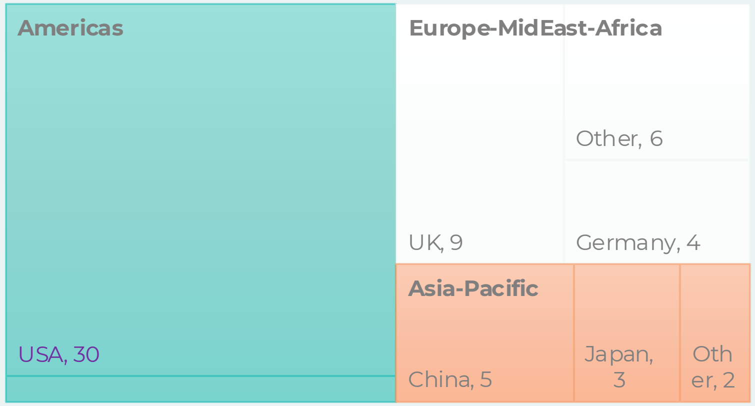
Global:

- The fusion market is expected to be over $430B in 2030, growing at a CAGR of 6.9%.
- Funding saw an increase in 2021, reaching $1.8 billion. Following a decline in investment in 2022 and 2023, the amount surpassed $1.2 billion in 2024.
- Additionally, in 2024, several funding deals were announced, totaling $538 million.



National:

- The USA is at the forefront of the fusion landscape with 30 companies located in the USA. The UK places 2nd with 9 companies and China 3rd with 5 companies.
- The National Ignition Facility (NIF) in California reaching an energy yield eight times its previous record, nearing ignition, and offering a greater diversity of approaches.



* Chinese numbers are uncertain due to limited information.

Local:

- Fusion energy is progressing from theoretical possibilities to practical applications. While experimental power generation through fusion is expected within 8-10 years, the industry remains in a development phase, requiring significant ongoing investment without generating revenue in the near term.
- Washington State companies have raised over $1.3B in venture capital with over 50% of investors based out-of-state and 15% international.
- Of the 30 fusion companies in the U.S., 17% are headquarter in Washington, disproportionate to Washington's percent of the population (2.3%) or the GDP (2.8%).

Washington State startups are taking diverse approaches to fusion commercialization, with important implications for fuel, supply chain, manufacturing, and workforce.

Avalanche Energy

AVALANCHE

Headquarters (Est. Date): Seattle, WA (2018)

Overview of Approach: Developer of a compact fusion machine designed for carbon-free distributed energy, mobility, space propulsion, and power applications. The company's platform allows harnessing a self-sustaining fusion chain reaction instead of thermonuclear fusion.

Leadership: Robin Langtry, CEO

Amount Raised: $45.13M

Investors: Beyond Earth, U.S. NSF, Autodesk, ClearPath, Climate Tech Circle, Climate Capital, Course Correction, Founders Fund, Impact Assets, Lowercase, MCJ, Neglected Climate, Shrug, The Atlas, Toyota Ventures, Vision Capital, Congruent, Lowercarbon, Prime Impact, Grantham Foundation

Helion Energy

HELION

Headquarters (Est. Date): Everett, WA (2013)

Overview of Approach: Developer of plasma accelerator technology specializing in generators based on magneto-inertial fusion with a fifty-megawatt module and energy regeneration generating zero-carbon electricity from fusion. Helion utilizes a pulsed approach, where fusion reactions occur in short bursts rather than requiring a continuous, self-sustained "ignition" state, which is a major hurdle for other fusion concepts. D-He3 fuel cycle and plans for direct energy conversion differentiate their approach.

Leadership: David Kirtley, CEO

Amount Raised: $1.03B

Investors: Nucor, Lightspeed, Mithril, Good Ventures, SoftBank, AllianceBernstein, Altimeter, Appaloosa, Arrive Opportunities, BlackRock, Franklin Templeton, Kohlberg Kravis Roberts, Luxor Capital, Ontario Teachers' Pension Plan, ParkWest, Sam Altman, Dustin Moskovitz, Reid Hoffman, U.S. DoE, Capricorn IG, Sand Hill Angels

Zap Energy

ZAP ENERGY

Headquarters (Est. Date): Everett, WA (2017)

Overview of Approach: Developer of a compact and scalable fusion technology designed to produce sustainable energy. The company is developing and commercializing fusion energy using the sheared-flow-stabilized (SFS) Z-pinch, a configuration that produces fusion by confining and compressing plasma without superconducting magnets or powerful lasers.

Leadership: Benj Conway, CEO

Amount Raised: $326.61M

Investors: BAM Elevate, Emerson Collective, Leitmotif, Mizuho, Soros Fund Mgmt, Xplor, Breakthrough Energy, DCVC, Shell Ventures, Valor, Addition, Energy Impact Partners, Chevron Technology Ventures, Lowercarbon Capital

Public funders: U.S. DOE, ARPA-E

Other Key Industry Players

KYOTO FUSIONEERING

Japan-based company developing advanced technologies and components for fusion

EXO FUSION

Bellevue-based early-stage fusion co. using Super-XT divertor

generalfusion

Vancouver, BC based fusion company backed by Bezos Expeditions

Five segments of the fusion supply chain have direct cross-applicability to incumbent industries.

1.

vacuum systems

Already a very mature industry. Standard instrumentation and pumps are easily available, but the fusion industry requires custom, high-tolerance vacuum chambers, which is a highly specialized skill.

$0.7 billion global market as of 2030.

2.

pulsed/high voltage power electronics

Includes high-voltage capacitors and fast-switching semiconductors. Washington has limited existing manufacturing capacity.

$2.2 billion global market as of 2031.

3.

precision machining

Already has a strong presence in WA. This is a service industry but does require specialized (capital) equipment.

$180 billion global market as of 2030.

4.

high-temperature superconductors

No existing presence in WA. Usually delivered in tape format. Multiple applications in a wide variety of industries.

$1.2 billion global market as of 2031.

5.

cryogenic systems

Cryogenic systems create and maintain cold temperatures – needed for high-temperature superconductors. Includes manufacture of the cryogens themselves: liquid nitrogen, liquid oxygen.

$33 billion global market as of 2025.

Supply chain segment 1

Vacuum systems

What's in this sector: pumps

Vacuum systems include a very wide spectrum of subsectors and parts, each of which features its own unique engineering and fabrication skillset. At the center of the vacuum systems sector are **pump** manufacturers, which in turn are oriented around several pump architectures:

- **positive displacement** pumps are what you normally think of as a pump and handle the "easy" stage of evacuation. Technical approaches include *rotary vane*, *liquid ring*, *diaphragm*, *scroll*, *Roots*, *claw*, and *screw* pumps.
- **turbomolecular** pumps assist with achieving ultra-high vacuums by accelerating particles toward the vacuum chamber exit.
- **entrapment** pumps handle the most extreme stages of evacuation by waiting for remaining particles and "getting" them.

The vacuum pumps subsector is very mature and diverse, making development of a Washington cluster both difficult and of marginal additional value to Washington's fusion industry.

What's in this sector: vacuum chambers

Vacuum chamber manufacture is a specialized corner of the high-precision large parts machining described as supply chain sector 3. Vacuum chamber manufacturers deal in specialized materials science knowledge, vacuum-tight welding skills, electropolishing and other surface treatments, and leak testing.

This subsector of vacuum systems is more technically homogenous than the pumps subsector, and therefore better suited for industrial cluster development. It leverages Washington's existing strength in machining, and can build on at least one existing shop, **Atlas Technologies** of Port Townsend.

Role in fusion

A vacuum is necessary to support plasma formation. Hence, vacuum systems are integral to all fusion equipment.

Non-fusion customers

Many other industries besides fusion are consumers of vacuum systems:

- semiconductor manufacturing
- space simulation (for aerospace product testing)
- scientific research
- food preservation
- metallurgy & advanced manufacturing

Valuates Reports estimates the global market size for vacuum systems to be about $0.7 billion as of 2030. Within Washington, potential consumers include semiconductor manufacturers like **SEH**, **Micron**, and **TSMC**, advanced metals fabricators like **Honeywell** and **Pacific Metallurgical**, research universities **UW** and **WSU**, and space systems giant **Boeing**.

Supply chain segment 2

Pulsed / high-voltage power electronics

What's in this sector

Pulsed power electronics includes

- large capacitors
- switches
- pulse forming networks
- high-voltage power supplies
- cabling and transmission supplies

Pulsed power fusion typically requires delivery of extremely high quantities of electric energy in a very small time, testing the limits of what the electronics manufacturing sector typically provides. Indeed, one of Washington's fusion developers, Helion, has resorted to manufacturing their own capacitor banks to deliver the needed power.

Cables, and the copper from which they are made, are frequently a supply chain challenge. Large, high-quality cables are needed both to deliver the electric pulses and to create the electromagnetic fields that control plasma.

Role in fusion

Most, but not all, candidate fusion technologies rely on pulsed power. Because plasma is so challenging to contain, pulsed technologies correlate to more economically viable development pathways. In a pulsed system, engineers only need to hold the plasma in obedience for a moment, before letting it go.

Non-fusion customers

Pulsed, high-voltage power is somewhat unique to fusion. Some military technologies require it as well: rail guns and high-power microwave weapons. Other technologies share a smaller overlap of high-voltage electronics needs:

- HVDC electricity
- rail transportation
- food sterilization
- scientific research
- advanced manufacturing

Kings Research estimates the global market size for high-voltage electronics at $2.2 billion as of 2031. Within Washington, potential consumers include research universities **UW** and **WSU**, and space systems giant **Boeing**.

Supply chain segment 3

Precision machining

What's in this sector

Precision machining is a service sector, yet the services depend on ownership and mastery of specialized equipment. Equipment varies depending on each shop's specialty, but a primary distinction is made between manual equipment (motorized, but an operator manually directs position & orientation) and CNC (computer numerically controlled) equipment. Most modern shops are dominated by CNC equipment.

Some shops are focused on "one-off" parts used in experimental equipment or functioning as a tool. Other shops prefer small production runs, producing multiple copies of a part used in low-volume manufacturing.

Washington State features an unusually mature precision machining sector, largely driven by the aerospace industry. Examples include **Janicki Industries** (Sedro-Woolley) and **Western Machine Works** (Tacoma)

Role in fusion

Fusion is still experimental and single, specialized parts are often needed to support a given experiment.

Even once commercialized, fusion machines will be high precision, low-volume products for which short-run machined parts are a viable part of the commercial supply chain.

The mechanical expertise of machine shop specialists is part of a labor market shared with the fusion industry.

The fusion industry's most specialized machining need is for large parts, which makes for a dual challenge with high precision specifications, and perhaps a triple challenge if novel materials are required.

Global Supply Chain Realities in Fusion Manufacturing

For the needs of the fusion sector, machine shops in China have historically been more responsive and flexible than U.S. shops and have drawn a large share of the business. The overseas shops are both able to turn around high-pressure experimental or development projects at speed, and are willing to set up short production runs in their workflow without prohibitive minimum orders or wait times.

Non-fusion customers

Many other industries besides fusion are consumers of precision machining:

- automotive
- aerospace
- medical devices
- electronics
- research & development generally

As revealed by the mature presence of this sector in Washington already, there is no shortage of Washington businesses who will benefit from further strengthening of this sector through the fusion industry's challenging fabrication needs.

Supply chain segment 4

High-temperature superconductors

What's in this sector

Superconductivity is a property of materials that can conduct electricity with zero resistance, meaning zero loss of energy to heat. Superconductivity occurs only at very low temperatures, usually requiring liquid helium to cool the system to about 4 K (4 kelvin). Liquid helium is a relatively expensive cryogen. High-temperature superconductors (HTS) are those that achieve superconductivity at 77 K or higher, the temperature of liquid nitrogen which is much cheaper than liquid helium.

There are several commercially available HTS materials: yttrium barium copper oxide (YBCO) and bismuth strontium calcium copper oxide (BSCCO). Both materials are typically delivered in a tape format. YBCO is part of the broader class of Rare Earth Barium Copper Oxides (REBCO). Other HTS materials are in development but unlikely to be commercialized soon.

There are currently no suppliers of YBCO or BSCCO in Washington State.

Role in fusion

Superconductors allow current to circulate indefinitely in a closed loop circuit. Closed loop electric flow produces the magnetic field needed for plasma confinement. Though not all plasma confinement approaches are magnetic, for those that are an affordable approach to superconductivity is essential.

Non-fusion customers

HTS is important to a fair number of non-fusion industries, but in all cases the applications are still experimental or under development (similar to fusion). Examples are:

- Power transmission
- Quantum computing
- Scientific research
- High-efficiency dynamos and/or motors
- Maglev trains
- Medical imaging technology

Medical imaging technology is a particularly promising venue for deployment of more HTS if the large, existing fleet of helium-cooled MRI machines are ever displaced with HTS machines.

Metastat estimates the global market for HTS to be $1.2 billion as of 2031.

Supply chain segment 5

Cryogenic systems

What's in this sector

Equipment and services for providing and handling cryogens: liquids with very low boiling points such as helium (4K), nitrogen (77K), oxygen (90K), or argon (87K). Equipment includes dewars (thermos flasks), vacuum-insulated piping and hoses, compressors and cryocoolers (refrigerators), valves and sensors. Services include system design, installation, maintenance, and repair, as well as delivery of prepared cryogens.

Washington State already hosts a mature network of cryogen suppliers that includes a mix of large, national supplier outlets (for example **Linde**, **Airgas**), and local firms (for example **Central Welding Supply**, **Cryogen USA**).

Role in fusion

The primary role of cryogenic systems is to allow the functioning of HTS-based magnets. Secondarily, though, cryogenics also provide thermal shielding between magnets and the reaction chamber, and assist with maintaining vacuum inside the reaction chamber. An integrated cryogenic system associated with a fusion machine may deliver cooling to several locations at different temperatures.

Non-fusion customers

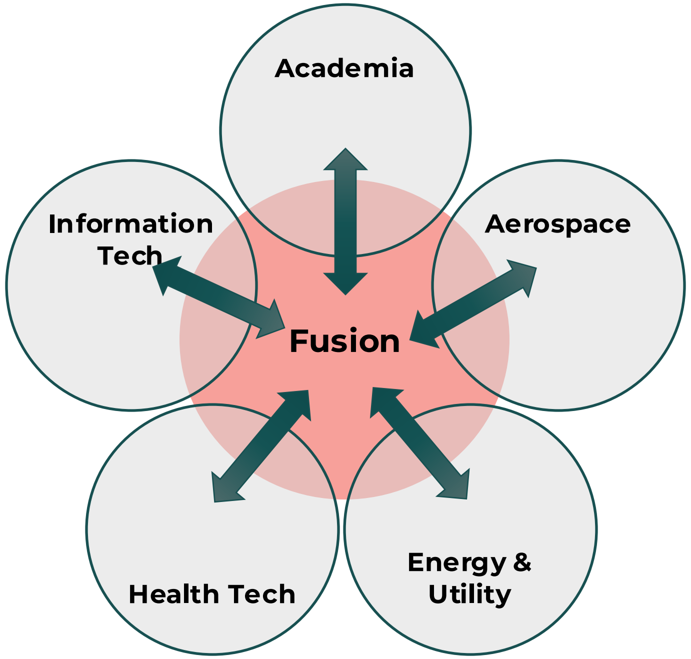
There are multiple, fully commercialized applications of cryogenic systems:

- Metallurgy
- Energy industry (specifically, for supporting liquified natural gas (LNG))
- Chemical & petrochemical
- Semiconductor manufacturing
- Medical imaging (MRI) equipment
- Food preservation

As well as scientific research, and occasional uses in aerospace.

The Business Research Company estimates the global market for cryogenic equipment to be $33 billion as of 2025.

Much of the fusion supply chain is also part of other sectors supply chains such as aerospace, health tech, and information technology.



Capabilities and supply chains to support fusion have beneficial effects for the rest of Washington's economy.

Technology	WA State Benefit to Fusion	Fusions Benefit to WA State	Examples of Workforce Cross-applications
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Aerospace	• Precision manufacturing • Thermal control systems • Advanced materials R&D	• Diversified supplier demand • Spin-off engineering tools	• Aerospace engineers to machine design • QA expertise to fusion hardware
Energy & Utility	• Grid infrastructure knowledge • Regulatory navigation • Power systems engineering	• Baseload clean energy • Incentives for grid modernization • Next-gen power applications	• Electrical engineers to fusion grid • Project managers to deployment
Health Technology	• Plasma diagnostics crossover • Precision manufacturing and controls	• Advanced radiation protection • High-precision heat control	• Device engineers to instrumentation
Information Technology	• AI & data science skills • High-performance computing • System integration capability	• Edge computing for fusion control • New platform development	• Systems engineers to fusion ops • Data scientists to machine analytics • Cybersecurity to control systems

Our analysis suggests four focus areas to advance supply chain and manufacturing for fusion in Washington state.

Focus 1: Manufacturing Hubs

Recommendation: Establishing manufacturing hubs for priority fusion components—such as semiconductors, capacitors, and high-field magnets—will strengthen the supply chain critical to scaling fusion energy. These specialized parts are often scarce or imported, slowing innovation and increasing costs. By co-locating production with R&D centers, the industry can accelerate prototyping, reduce lead times, and foster regional economic growth. High-field magnets, for instance, are essential for confining plasma in fusion reactors and are currently a bottleneck due to limited global suppliers.

Focus 2: Include Fusion in Clean Tech Incentives

Recommendation: Recognizing fusion manufacturing components in Washington State's clean energy policy would align regulatory and funding frameworks with the needs of this emerging industry. By explicitly including components like high-temperature superconductors, capacitors, and power electronics, the state can unlock incentives and support for local manufacturers. This recognition ensures fusion is treated alongside solar, wind, and batteries—positioning Washington as a leader in advanced energy technologies and supporting job creation in high-tech manufacturing sectors.

Focus 3: Streamline Permitting

Recommendation: Streamlining state permitting for fusion manufacturing will reduce delays and uncertainty that hinder facility development and investment. Current permitting processes are often tailored to traditional industries, creating mismatches for advanced technologies like fusion. By creating clear, expedited pathways specifically for fusion-related manufacturing—such as facilities producing magnets, vacuum systems, or power components—states can attract private capital, accelerate deployment, and maintain leadership in the global clean energy race.

Focus 4: Onshoring Precision Manufacturing

Recommendation: Supporting the creation and growth of precision manufacturing shops capable of handling small, custom orders is vital as the fusion industry transitions from R&D to commercialization. These shops fill a critical gap by producing specialized components—like custom vacuum flanges or prototype magnet assemblies—not yet needed at scale. Investment in such flexible infrastructure ensures faster iteration, supports startups, and builds a domestic ecosystem ready to scale when demand grows, reducing reliance on overseas suppliers and long lead times.

CleanTech Alliance™

The Washington State Fusion Energy Landscape

Element 2

Funding Opportunity Analysis

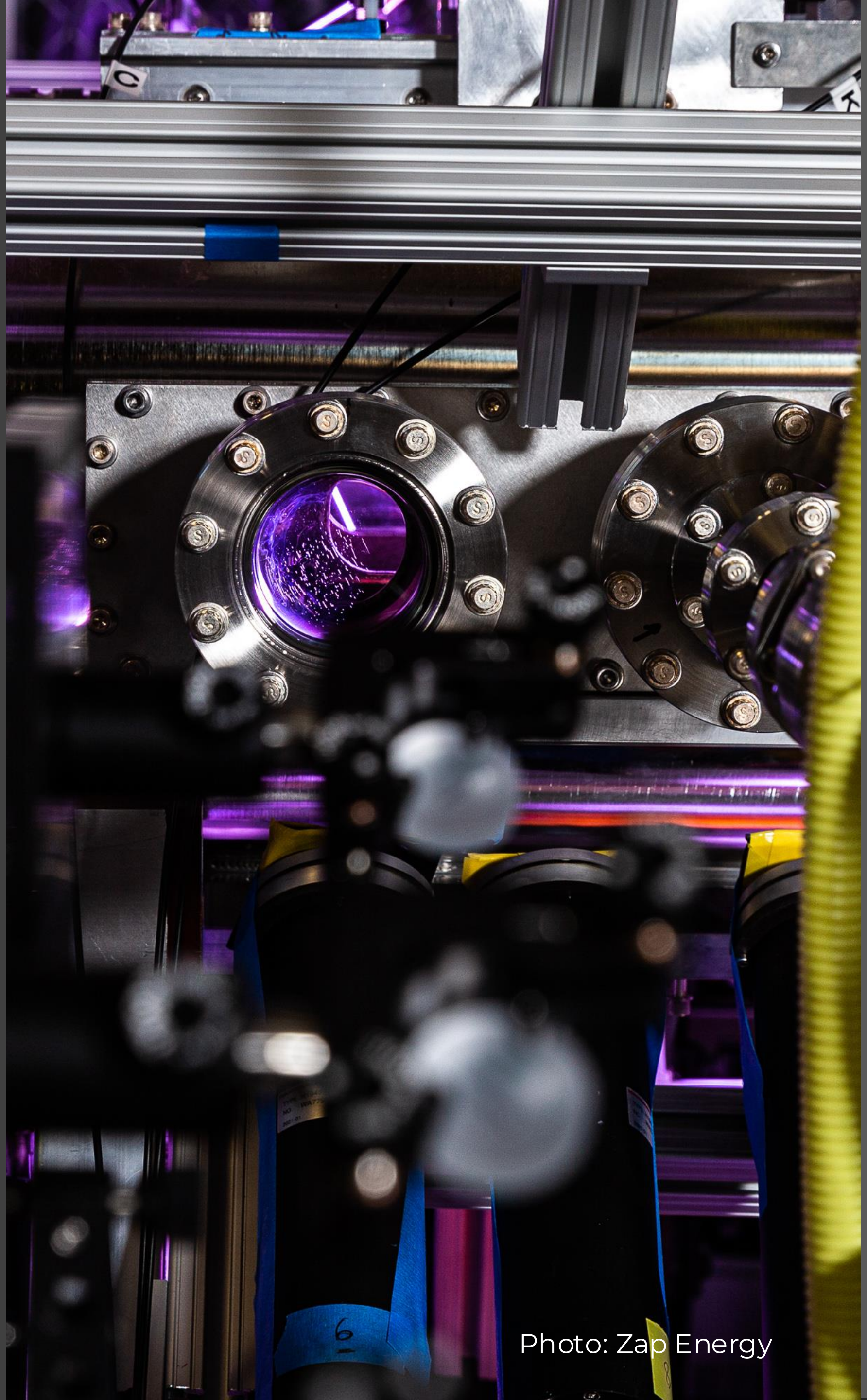


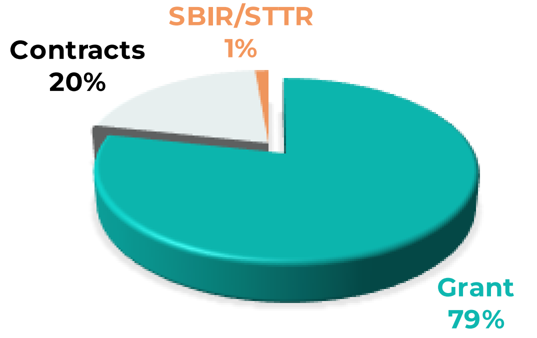
Photo: Zap Energy

Federal uncertainty in fusion funding is affecting American competitiveness.

US Federal Funding

- Federal fusion spending is significant focused on research and development.
- Few funds are earmarked for commercialization support

U.S. FEDERAL FUSION FUNDING 2024
R&D VS. COMMERCIALIZATION

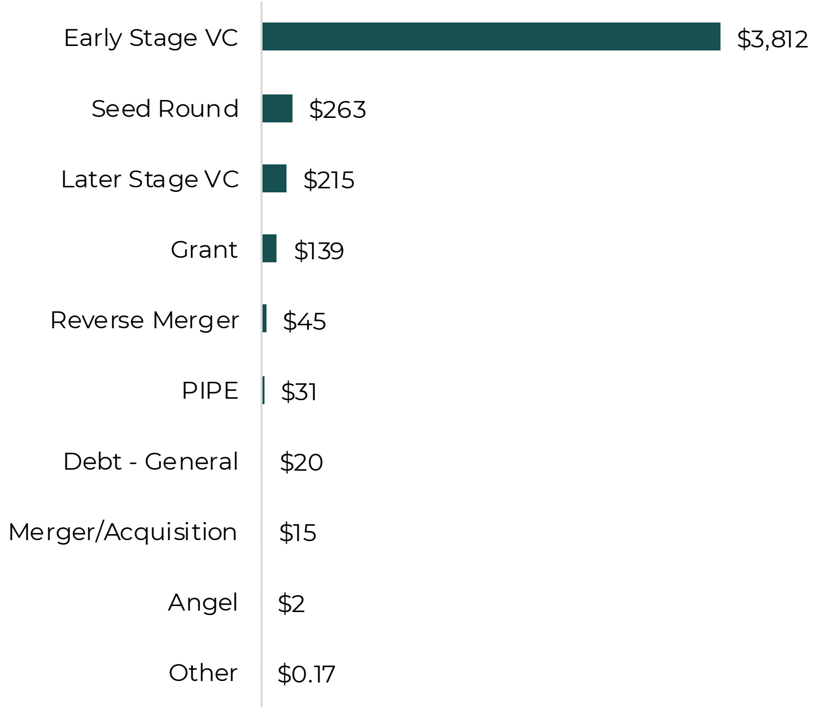


Competitiveness

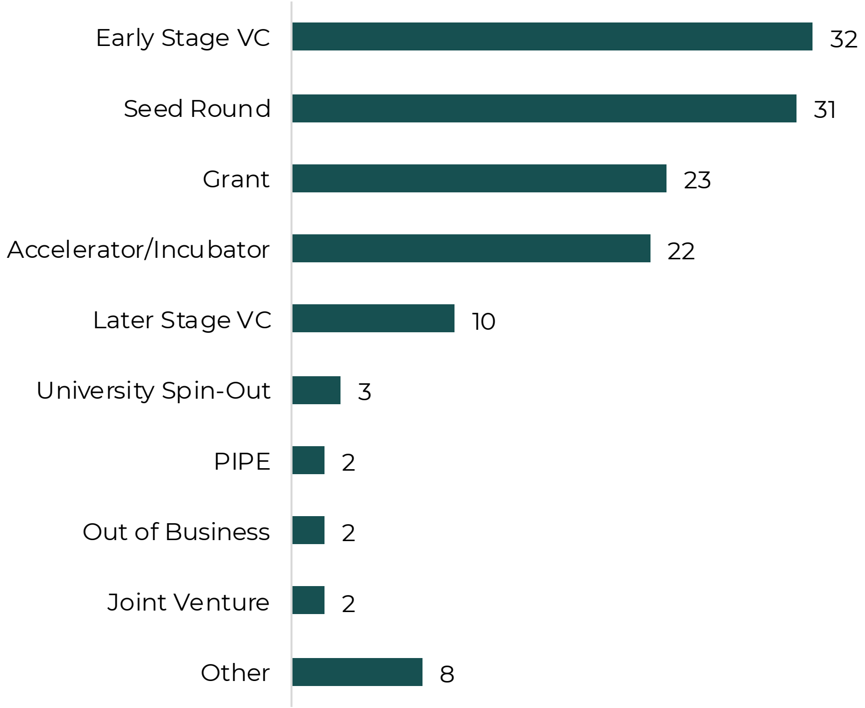
- Significant international fusions clusters include France, Japan, and China.
- Though the specific numbers are not reliable, China is spending roughly $1.5B per year on fusion. Recent projects illustrate the scale of China's investments:
  - The Comprehensive Research Facility for Fusion Technology (CRAFT), a $700 million campus, is under construction in eastern China and includes a new advanced tokamak called BEST, expected to be completed by 2027.
  - China has also greenlit a 100 MW fusion-fission hybrid plant in Jiangxi province, with an investment of over 20 billion RMB (about $2.7 billion USD), targeting operation by 2030.
  - In Shanghai, a 10 billion-yuan ($1.4 billion) government fund is supporting state-backed fusion ventures, adding to the already substantial national investment.at current federal spending levels, the U.S. is being outpaced by China by orders of magnitude.

Early Stage dominates fusion investments in real dollars; later stage deals are more common in more recent years.

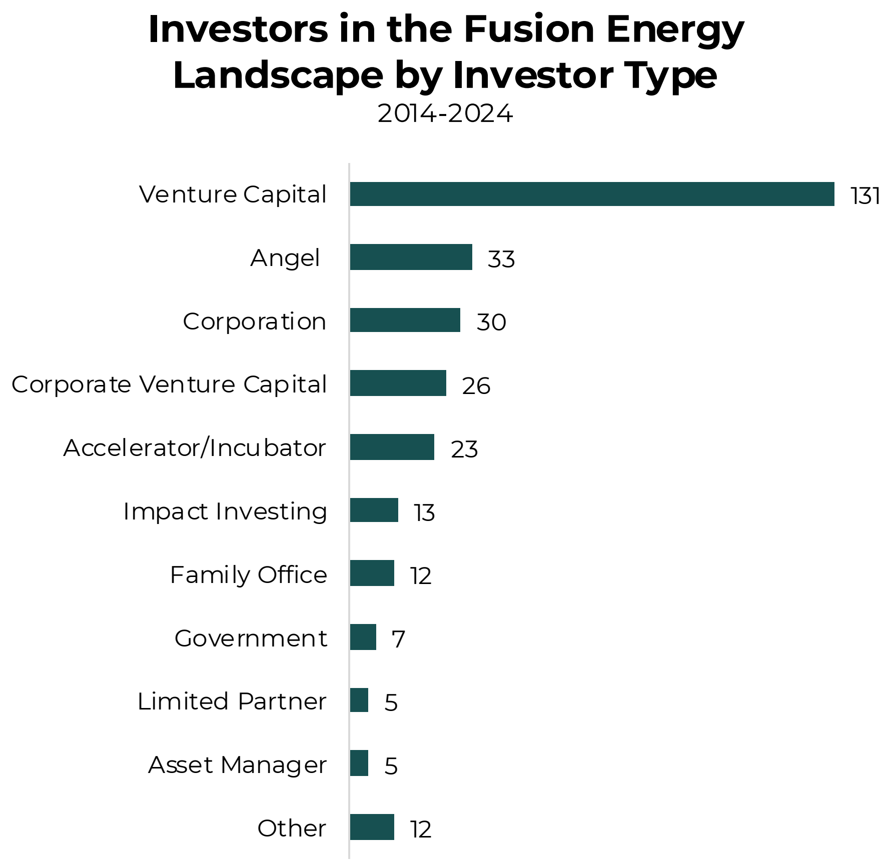
Total invested in the global Fusion Landscape by Deal Type ($M)
2014-2024

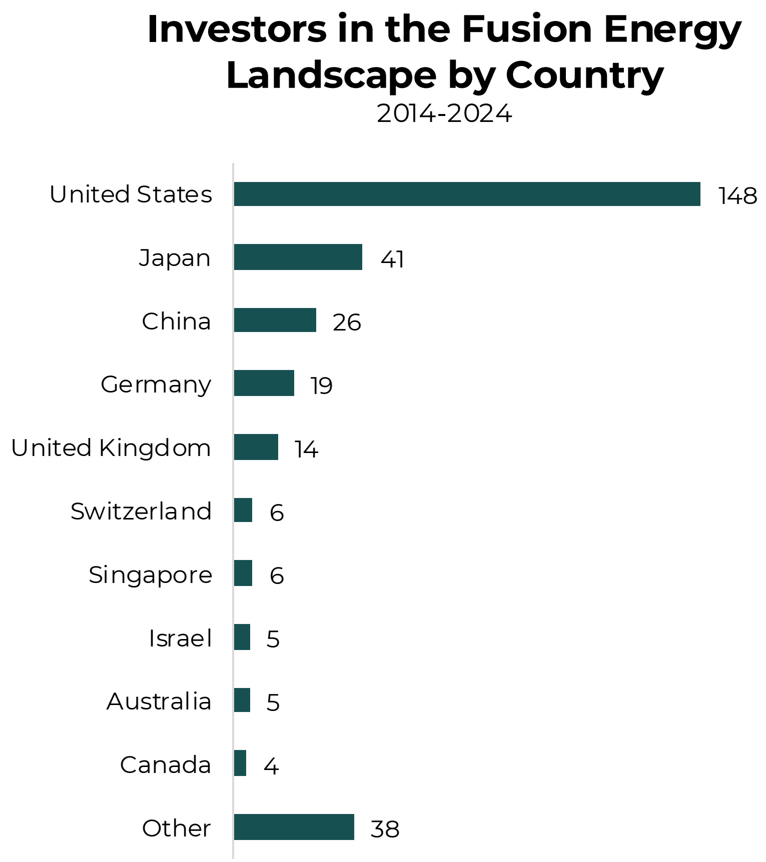


Number of deal types in the global Fusion Landscape
2014-2024



US-based institutional investors are the largest share of fusion energy investors; significant activity from Japan, China, Germany, and UK as well.





Our analysis suggests three focus areas to enrich the pipeline of opportunities for fusion funding in Washington state.

Focus 1:

R&D and Commercialization Funding

Recommendations:
- Expand public fusion funding focused on commercialization and deployment in addition to R&D
- Recognize fusion in WA clean energy policy (like 45Y/48E at federal level)
- Provide state matching funds through WA Clean Energy Funds to amplify the impact of Federal fusion funding.

Focus 2:

Incentivize Manufacturing

Recommendations:
- Create state-level fusion manufacturing tax credits
- Streamline state siting & interconnection for fusion projects
- Attract investment via 45X/48C-aligned manufacturing credits for HTS, cryogenics, HV electronics
- Build WA-specific bridge fund (modeled after DOE Loan Program Office)

Focus 3:

Catalyze Cross-sector Collaboration

Recommendation:
- Develop fusion hubs in priority regions, including near large load demands and economically distressed regions
- Fund "Agreement States" to build fusion-relevant regulatory capacity
- Support reestablishing DOE's Office of Fusion Energy that can serve as a clearinghouse to connect fusion developers with adjacent sectors like materials science, advanced manufacturing, aerospace, and AI

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The Washington State Fusion Energy Landscape

Element 3

Workforce Assessment

Photo: Avalanche Energy

Key Findings

- The fusion manufacturing/supply chain requires a trained workforce. Those skills are different than startup PhD needs.
- Most fusion jobs are like other technical industries. We can expand jobs that support fusion and other sectors at the same time.
- Most jobs across fusion manufacturing and supply do not require a bachelor's degree, let alone a PhD. The perception that PhDs are required can deter prospective applicants.
- In the future, as fusion transitions from R&D to commercial scale operations, the workforce will skew more to technical workers, e.g., machinists, electricians.
- Undergraduate and trade pathways growing. Many roles are now accessible to candidates with BS degrees (e.g., electrical engineering, mechanical engineering) and technical certifications, particularly in machining, welding, and electrical work.

As the fusion industry matures, so will workforce demand.

Fusion NOW

- **Sector still a small employer**. The three main firms (Helion Energy, Zap Energy, Avalanche Fusion) combined directly employ **~530 workers**, with nearly 2/3 at Helion.
- **Still heavily research-oriented**. Skewed **to PhDs and scientists** with training at labs and in research. At this stage, greater focus on research, design, testing. (Closest analogue: semiconductor industry ascent in 1970s.)
- **Only a small subset of skills specific to fusion, e.g., plasma physicists**. Much of the pathway is similar across the technical industries until the final specific training requirements kick in.
- The **supply chain** also needs a trained workforce, and those skills are different from the startup PhD needs (e.g., precision machinery).

Fusion in the FUTURE

- **Much larger sector.** Potential employment growth of 10x or more.
- **Workforce more tech-focused**. As the industry moves toward commercialization, there will be more demand for engineers, technicians, machinists, and plant operators.

Our analysis suggests four focus areas to advance the fusion workforce in Washington State.

Focus 1: Modular Training

Recommendation: Expand modular training in K-12, community, and technical colleges for skillsets overlapping with fusion.

Focus 2: Internships and Hands-on Experiences

Recommendation: Create more opportunities for hands-on experiences, including internships, capstones, fusion academies, and centers of excellence.

Focus 3: Reach Underserved Communities and Areas

Recommendation: Expand programs to address underserved areas, including with targeted high school certification programs for manufacturing & fusion skillsets.

Focus 4: Address Other Barriers to Workforce

Recommendation: Address other barriers to workforce, including housing affordability and affordable & accessible childcare for working parents.

Fusion jobs are not specific to fusion but span traditional engineering and technical occupations.

Fusion Occupation	Fusion-Relevant Description	Nearest Match
Mechanical Engineers	Design and build mechanical systems in fusion machines; top hired major in fusion private sector	Mechanical Engineers
Physicists (e.g., Plasma Physicists)	Conduct plasma research critical for understanding and sustaining fusion reactions	Physicists
Electrical Engineers	Develop power supply systems, control electronics, and diagnostics for fusion systems	Electrical Engineers
Aerospace Engineers	Contribute expertise in high-temperature materials, thermal management, and vacuum systems	Aerospace Engineers
Materials Scientists	Develop materials for plasma-facing components and breeder blanket technologies	Materials Scientists
Cryogenic Engineers	Engineer cooling systems for superconducting magnets and thermal shields in fusion machines	Engineers, All Other
Vacuum Engineers	Design and operate vacuum pumping systems critical for plasma containment and fueling	Engineers, All Other
Manufacturing Engineers	Scale up precision manufacturing for mass production of fusion machine components	Industrial Engineers
Instrumentation and Controls Engineers	Develop control systems and diagnostics to operate and monitor fusion devices	Electrical and Electronic Engineering Technologists and Technicians
Robotics and Remote Handling Specialists	Develop robotic systems for handling components in extreme fusion environments	Engineers, All Other
Technicians (Skilled Technical Workforce)	Support manufacturing, installation, maintenance, and operational aspects of fusion systems	Engineering Technicians, Except Drafters, All Other

Source: National Science Foundation. Accelerating the Fusion Workforce: A Report from the National Science Foundation Funded Clean Energy Technology Conference. January 2025. Washington D.C.

Fusion is not yet a focus or field within engineering curricula.

- **Fusion-Specific Curriculum is Nascent:** Fusion is too niche for most schools to offer dedicated degrees, but embedding fusion tracts into physics, EE, ME, or materials science is a promising path.
- **Hands-on Experience & Modular Training:** Interviewees suggested fusion clubs at universities (low-cost, ~$40k per program) and short courses or 8-hour foundational modules on power systems
  - Development of 2-year technician certifications in community and technical colleges
  - K-16 Engagement Critical: Getting students interested in STEM early is essential; by college, it’s often too late to redirect paths into fusion-related fields.
- **Need to balance training and the industry timing needs:** Invest in STEM training and education now for the needs of the industry in 10 years to minimize having a trained workforce but jobs aren't ready.

Fusion workforce challenges are consistent with other high-tech sectors.

- **Young, Lab-Experienced Recruits Preferred:** Many hires are fresh out of grad programs. Startups value flexibility and experimentation over rigid expertise.
- **Hard to Recruit Senior/Managerial Talent:** Experienced technical leaders who can also manage teams are rare and hard to hire.
- **High Competition & Poaching:** Limited talent pool leads to aggressive hiring by well-funded players (e.g., Pacific Fusion in Fremont, CA). National labs and tech sector companies (e.g., Meta Labs, Amazon Kuiper) offer stiff competition on pay and benefits.
- **Housing Affordability a Major Issue:** Key deterrent to talent attraction and retention, particularly for early-career hires.
- **Gender & Representation Gaps Persist:** Not enough women and underrepresented minorities entering or staying in STEM/fusion careers. Industry exploring long-term strategies through outreach and role-modeling.

Demand in Fusion-Aligned Occupations

Washington State, 2023 Q1 and 2027-2032 (forecasted)

- Fusion occupations are too niche to be captured in existing data sources.
- However, there are common fields fusion firms hire from, including mechanical engineers, physicists, and material scientists.

Field	Annual Growth Rate 2027-2032	Related Fusion Fields
Mechanical Engineers	0.9%	Mechanical Engineers
Physicists	1.9%	Physicists (Plasma Physicists)
Electrical Engineers	0.5%	Electrical Engineers
Aerospace Engineers	0.4%	Aerospace Engineers
Materials Scientists	1.2%	Materials Scientists
Engineers, All Other	0.8%	Cryogenic Engineers, Vacuum Engineers, Robotics and Remote Handling Specialists
Industrial Engineers	1.0%	Manufacturing Engineers
Electrical and Electronic Engineering Technologists and Technicians	0.8%	Instrumentation and Controls Engineers
Engineering Technicians, Except Drafters, All Other	0.3%	Technicians (Skilled Technical Workforce)

Source: Washington State Employment Security Department, "Occupational Projections." July 2024. Olympia, WA.

Baccalaureate Degrees Conferred

Fusion-related fields, 2022-2023 academic year, Washington State institutions

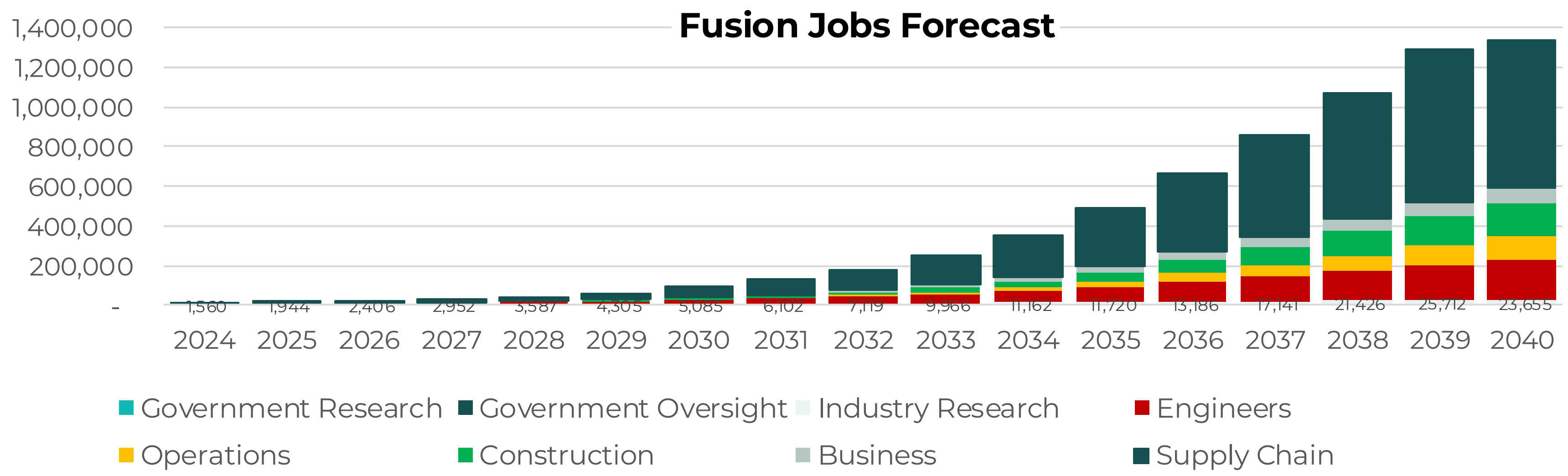
- Washington State institutions do not confer degrees specific to fusion.
- However, there are many fields that align or intersect with fusion, e.g., physics, mechanical engineering, and materials engineering.

Field	BA / BS / BSE Degrees Conferred
Mechanical Engineering	588
Physics, General	241
Computer Engineering	146
Materials Engineering	50
Electrical and Computer Engineering	40
Mechanical Engineering Related Technologies/Technicians	36
Energy Systems Technologies/Technicians	14
Electrical/Electronic Engineering Technologies/Technicians	12

Source: U.S. Department of Education, "Integrated Postsecondary Education Data System." 2025.

The fusion workforce will shift from research to operations as the industry matures.

Workforce Role	Share of Workforce 2025	Share of Workforce 2040	Change
Supply chain	50%	56%	+6%
Business	7%	6%	-1%
Operations	4%	13%	+9%
Engineering	3%	9%	+6%
Industry research	26%	15%	-11%



According to Watts Next, the share of the fusion workforce will shift away from industry research (-11% change) and towards operations, supply chain, and engineering activities as the industry matures.

Source: Watts Next, "1M Fusion Jobs by 2040." January 14, 2025. Consultants' calculations based on report.

Workforce Pipeline

Programs to support diversity in engineering hiring, Washington State: statewide

- **Washington MESA (Mathematics, Engineering, Science Achievement):** Administered by the University of Washington, MESA offers enrichment programs for middle school, high school, and college students from underrepresented backgrounds to prepare them for STEM careers. Programs include College Prep, Transfer Prep, and the MESA University Program.
- **STEM Education Innovation Alliance:** Advises the Governor on policies to align and advance STEM education across the state, aiming to meet workforce needs and promote diversity in STEM fields.
- **Million Girls Moonshot:** A national initiative active in Washington, working with afterschool and expanded learning programs to increase diversity and equity in STEM by engaging more girls in engineering and computer science.

Workforce Pipeline

Programs to support diversity in engineering hiring, Washington State: university-based

- **UW Louis Stokes Alliance for Minority Participation (LSAMP):** A National Science Foundation-funded initiative focusing on increasing access and retention of minority students in STEM majors through research opportunities and mentorship.
- **UW DO-IT Center (Disabilities, Opportunities, Internetworking, and Technology):** Aims to increase the successful participation of people with disabilities in STEM fields through programs like AccessSTEM and AccessComputing.
- **WSU Tri-Cities – Empowering the Future Energy Workforce Program:** Recognized for encouraging and assisting students from underrepresented groups to enter STEM fields, focusing on climate change and its impact on disadvantaged communities.

Workforce Pipeline

Programs to support diversity in engineering hiring, Washington State: community & nonprofit initiatives

- **Technology Access Foundation (TAF):** Founded by Trish Millines Dziko, TAF promotes STEM skills to students of color through an equity-driven program emphasizing critical thinking and project-based learning.
- **iUrban Teen:** Founded by Deena Pierott, this program exposes underrepresented youth (ages 13–18) to STEM and arts education through career-focused learning, mentorship, and hands-on workshops.
- **Native Girls Code:** A Seattle-based program providing computer coding skills grounded in traditional Indigenous knowledge for Native American girls aged 12 to 18 through workshops and mentorship. (Native Girls Code)
- **CodeDay:** A non-profit organization headquartered in Seattle, offering diverse opportunities for underserved students to explore technology through events, workshops, and coding competitions.

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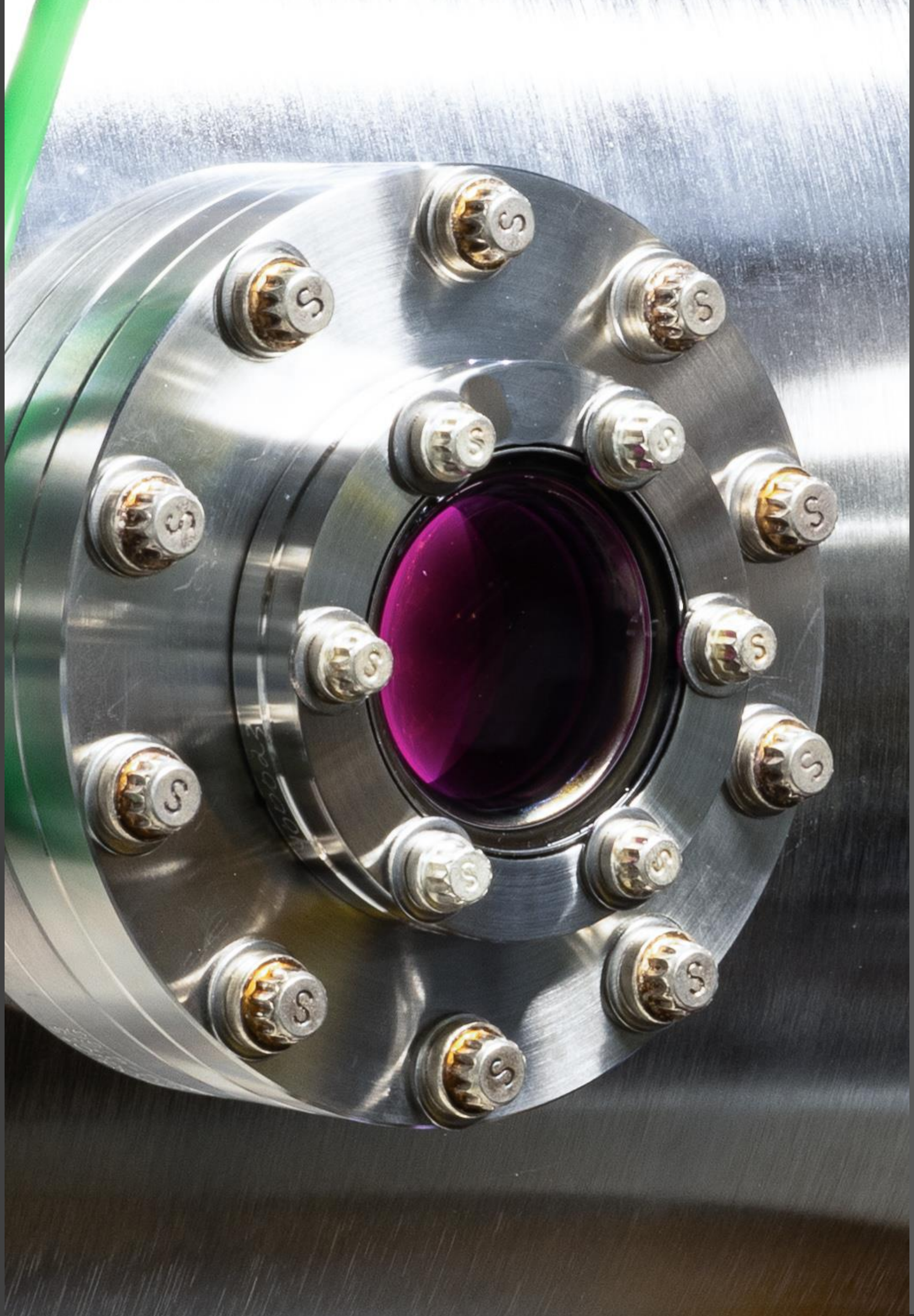
Appendix



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Washington State Department of Commerce

This initiative aligns with the Department's broader commitment to advancing clean energy innovation, economic development, and environmental stewardship across the state.