Report to the Washington State Legislature

Fusion Energy Proviso FY 2023

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Melvin Weatherly
Environmental Public Health
Office of Radiation Protection

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For more information or additional copies of this report:

Environmental Public Health
Office of Radiation Protection
101 Israel Rd SE
Tumwater, WA 98501

360.236.3300
360.236.2255 (fax)
x-ray@doh.wa.gov

Report Authors
Melvin Weatherly (Report Lead – Radiation Health Physicist 3)
Richard Montemarano (X-Ray Section Manager)
Jill Wood (ORP Office Director)
John Martell (Air Emissions Section Manger)
Kristen Schwab (Waste Section Manager)
Mark Henry (Radiation Emergency Preparedness Section Manager)
Brennagh Greene (Materials Section Manager)

Umair Shah, MD, MPH
Secretary of Health

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Executive Summary

Fusion power production has been the dream of the scientific community for over half a century. It holds the promise of carbon-free energy production with relatively little waste. Recent advancements and investments in nuclear fusion technology have put Washington state at the forefront in the race for fusion energy. Spurred on by the Biden Administration's "Bold Decadal Vision," nuclear fusion startups in the state are planning for operational fusion pilot plants by the 2030s.

The Washington State Department of Health (WA DOH), Office of Radiation Protection (ORP) received a 2023 budget proviso to perform a gap analysis on fusion regulation. The purpose of this analysis is to identify what resources (legislative or staffing) will be required to regulate commercial fusion reactors. Washington state is an Agreement State with the Nuclear Regulatory Commission. As per RCW 70A.388.040, in 1961 WA DOH was deemed as the sole Radiation Control Agency for Washington state. In 1966 the NRC and Washington state entered into an agreement under the Atomic Energy Act. The regulations and oversight of Radiation Protection and Materials are delegated from the NRC to WA DOH.

The budget proviso was effective as of July 1 with a report deadline of December 1, 2023. Per the budget proviso, *"The legislature intends for Washington to support the deployment of fusion energy projects and larger research facilities by taking a leading role in the licensing of future fusion power plants."*

Fission vs Fusion: Key Differences

It is important to highlight that nuclear fusion and nuclear fission are *not* the same processes. Washington is no stranger to nuclear fission, with its role in the Manhattan project and subsequent nuclear weapons production. Even today, Washington still has an operating nuclear power plant in the Tri-Cities, the Columbia Generating Station. Nuclear fission is a process that breaks down heavy elements like Uranium-235, releasing large amounts of energy. This is the process used at Columbia Generating Station to produce electricity. But for fission's benefits, there are drawbacks. Fission produces a large amount of high-level radioactive waste that is very long-lived (thousands of years). Safety systems in the reactor vessel prevent "meltdown" scenarios (like Chernobyl, Fukushima, or Three Mile Island), but human error and natural disasters still render it a possibility.

Nuclear fusion, in contrast, combines lighter elements into heavier ones. A common example is the fusion process that powers the sun, which combines hydrogen into helium. This occurs in a star due to the enormous amount of gravity and heat present. The process can be replicated on Earth, but only for very short amounts of time (fractions of a second). A lot of energy is required to make fusion occur, but it produces far more energy than its fission counterpart.

The energy gained from a fusion power plant would be carbon neutral, aligning with our statutory mandate to achieve net-zero emissions by 2050. Depending on the type of fuel used, fusion can produce low-level radioactive waste (with a 12-year half-life). Another positive: fusion power plants cannot "meltdown." Once energy to a fusion device is shut off, the fusion reaction ceases, making these devices much safer than a fission nuclear reactor.

Current methods for attaining fusion in Washington involve raising the energy of deuterium gas to fusion temperatures. This releases fast neutrons and tritium gas. The fast neutrons can be captured for heat production (conversion to electricity). The tritium gas (weakly radioactive with a 12-year half-life) is rare on earth and very expensive. Current plans involve capture of this by-product, to be recycled into higher energy fusion reactions.

Evolving Regulatory Landscape

Currently three facilities in Washington (Avalanche, Helion, and Zap) are all in the Research and Development (R&D) phase for fusion energy production. The WA DOH Office of Radiation Protection's current rules, fee structures, and staffing levels can support the R&D phase. All three facilities currently have an active x-ray registration and air emissions license. At the time of this proviso, we have reviewed shielding plans for each facility and conducted numerous meetings and/or inspections.

The R&D phase will end when fusion devices can produce electricity that is sent to power grids and commercial operations begin. This is projected to occur in the next 10 years. Helion Energy, in Everett, has signed a power purchase agreement with Microsoft to deliver 50 MW of electricity by 2028. If successful, their R&D phase would end sooner than projections. This would require new rulemaking and resources to be attained quickly.

Zap Energy (also in Everett) is looking into a pilot plant location in Centralia, at a decommissioned coal plant. The pace of fusion energy technology is increasing, and a commercial plant may come along quicker than anticipated.

ORP Regulatory Obligations

Regulating commercial fusion power is a task that will involve all sections of ORP: radioactive materials, emergency response, environmental science, radioactive waste, air emissions, and x-ray. The fusion reaction itself creates ionizing radiation in the form of fast neutrons, and radioactive by-product called tritium. The following will be a break down, by ORP section, of needs for regulating commercial fusion power plants.

Radioactive Materials

The Radioactive Materials Section is a regulatory section and has the obligation of licensing use of radioactive materials in Washington state. Fusion energy startups keep a small inventory of radioactive sources for research purposes (Americium, for example). The tritium gas by-product, however, will be handled and stored in larger quantities as startups approach pilot-plant status. Successfully licensing the handling of tritium gas will be crucial to the future of the fusion industry in Washington.

New regulations will likely need to be written, specific to Washington state, to support the commercial power phase of fusion energy. Additional staff will also be needed, based on the needs of the growth in industry.

X-Ray

The X-ray Section is a regulatory section and, following the example of the Nuclear Regulatory Commission, has been treating devices from fusion start-ups as particle accelerators. Whereas particle accelerators have been traditionally used for research and medical isotope production, fusion energy devices are built with the purpose of electricity production. The fusion reaction itself will produce ionizing radiation in the form of fast neutrons. Fast neutrons are difficult to shield and present a hazard to occupational health. To shield from fast neutrons, one must use lightweight, hydrogenous materials. This decreases the energy of the neutrons, allowing them to be captured by atoms in the materials of the building housing the fusion device. Captured neutrons can induce radioactivity in these atoms (called activation). Activated building materials (steel, brick, etc.) release gamma radiation, presenting another occupational health hazard.

At the time of this report, the X-ray Section has not seen radiation exposure levels at fusion start-ups to cause concern. Devices are currently pulsed for testing. But to meet the 2033 deadline of a working fusion pilot plant, machines will need to be pulsed multiple times per second. This will drastically increase the number of neutrons produced, and subsequently any activation of building materials.

New regulations specific to Washington state will need to be written to meet the challenge of increased neutron flux and gamma radiation exposure from activated products. Additional staff will also be needed, based on the number of power plants concerned and growth in the industry.

Radiological Emergency Preparedness

The Radiological Emergency Preparedness (REP) Section currently has procedures in place for responding to radiological emergencies regarding nuclear fission plants. These procedures cover exposure to a litany of radioactive elements of concern in a fission accident. But for nuclear fusion, the only element of concern is the by-product tritium.

REP will need to develop new procedures and acquire equipment to respond to a tritium-based radiological release. The weak beta particle emission from tritium requires specialized equipment for detection. Planning, training, and evaluation of planned response for emergency response to tritium releases would increase REP section personnel.

Waste

The Waste Section is a regulatory section and handles disposal of radioactive waste in Washington state. Even with the goal of recovering tritium gas, the risk of equipment contamination is present. Additionally, activation of materials in a fusion power plant creates a radioactive waste stream.

There is currently no clear regulatory direction on disposal of low-level fusion waste. New regulations may need to be written, specific to Washington state, to support the commercial power phase of fusion energy. Additional staff may also be needed, based on the needs of the growth in industry.

Air Emissions

The Air Emissions Section is a regulatory section and currently licenses and monitors airborne release of radioactive materials into the atmosphere. Currently the atmospheric release of tritium falls under reportable quantities, though all fusion startups in Washington have active air emissions licenses. The goal of fusion startups in the state is to recover waste tritium for resale or reuse. Tritium will be captured through a complex filtration system, with minimal release through an atmospheric stack.

But this is only for normal operation. In the event of an accident that causes damage to the stack system, larger quantities could be released. The environmental impact of a tritium release near a populated area would be substantial. Additional sampling equipment, specialized in detecting tritium, will be required.

Rulemaking

Currently the NRC is conducting rulemaking for fusion. The NRCs goal is to have an updated chapter to NUREG-1556, ready to implement, by January 1, 2025. Currently one of ORPs section managers is part of the national work group with the NRC to update NUREG-1556. The regulatory authority will be held with the Agreement States. Prior to the commercial power phase, DOH will need to complete and implement new rulemaking for readiness of fusion power sales. Washington state DOH-specific fusion rules will need to be as conservative, if not more so, than the NRC rules.

Fee Schedule

ORP anticipates that a review of various fee structures across the office will be visited in the future and prior to the fusion facilities moving from R&D to commercial power phase.

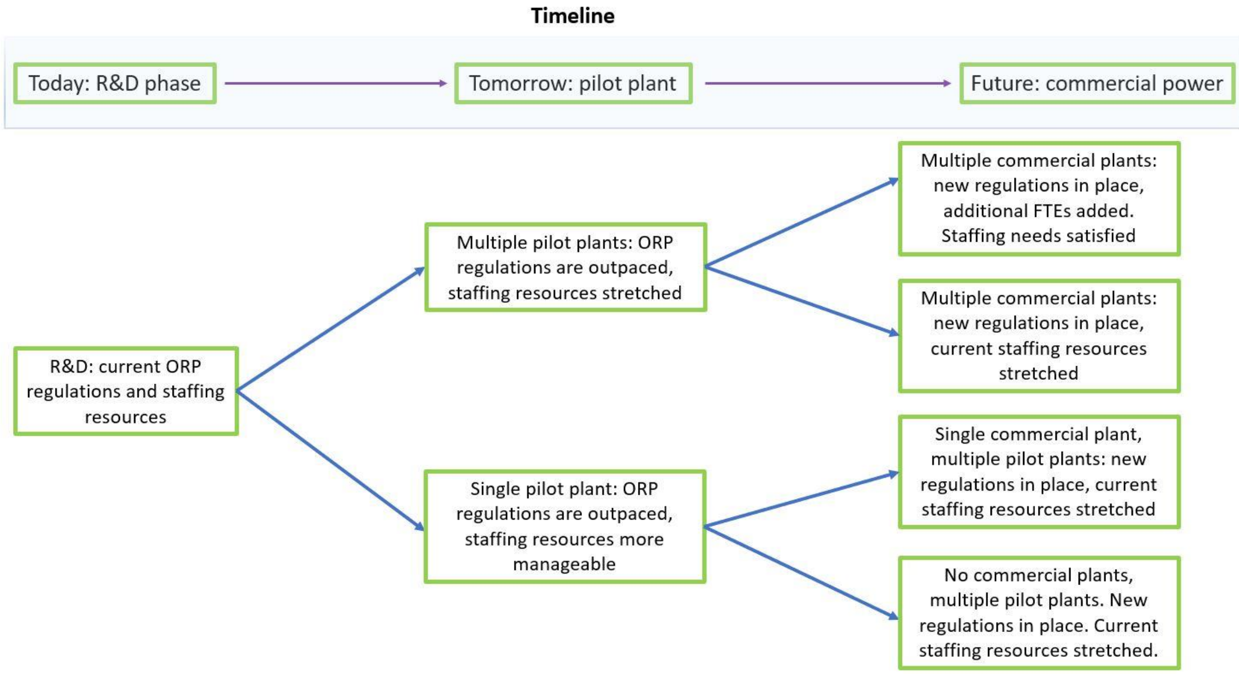
Opportunities

Due to time and budget, many topics requested from the budget proviso were not addressed. With a future opportunity, ORP would develop a more robust and comprehensive report by consulting with relevant state agencies, collaborating with tribes, and developing cost estimates for necessary staffing for the commercial power phase.

Recommendations

ORP recommends that the Legislature provide a clear path of regulatory authority to fusion power companies (both R&D and commercial power phases). The list of regulatory agencies that will be involved in commercial fusion power is extensive. Agencies may include, but not be limited to the following: DOH, Department of Commerce, Department of Transportation (DOT), Energy Facility Site Evaluation Council (EFSEC), Labor & Industries (L&I), and Department of Ecology (ECY). Clearly defined regulatory authority for fusion power generation is needed moving forward. Without clarity, long licensing and wait times will occur as well as additional costs to both government and industry.

There is no way to accurately predict what resources will be needed without knowing the success rate of fusion technology adoption. However, ORP has established potential pathways for the technology in the next 5 to 10 years, and the impacts on the office. Please see the diagram below.



From the diagram, we see possible pathways the next 5 to 10 years could take for fusion technology. Helion Energy has a signed contract to deliver power to Microsoft by 2028, only five years out. This would commence the pilot plant phase of their work. It is harder to predict the pilot plant timelines for each fusion energy company, due to the uniqueness of their individual processes. The pilot plant phase will see existing ORP staffing resources strained, whether there is one pilot plant or many.

The commercial power phase, roughly 10+ years from now, will see staffing extremely strained unless more FTEs are added. If fusion technology is widely adopted, with power plants installed across Washington state, a new section of ORP may need to be added. This section could bridge the gap between power production, radiation safety, and emerging science.

Another concern for the future is ownership/custody of purchased fusion power devices. Avalanche Energy plans to sell fusion power packs: small scale reactors for off-grid applications. Concerns of ownership/custody have cropped up in conversation in ORP, specifically facility end-of-life.

An applicable example comes from Texas in 2022. Well-logging companies utilize radioactive sources in their routine operation. In Texas, a well-logging company closed and liquidated all their physical assets. Instead of disposing of the radioactive sources properly, the sources were left in the empty building of the former business. The state of Texas had to step in and cover not only disposal of these sources but maintaining a chain of custody the entire time prior to disposal. It isn't inconceivable that this could happen with a smaller fusion power device.

Will Avalanche Energy retain ownership of their devices, including their proper disposal? Low level radioactivity will be present in any “used” fusion reactor and must be disposed of in a safe manner. Or will the purchaser be responsible for disposal of the device? What in the case of company closure and liquidation? What is to stop a purchaser from abandoning their fusion device upon vacating property? In this case, who is responsible for disposal? The manufacturer, or the state? If the latter, funds must be set up in advance of the commercial power phase to cover orphaned sites. Such funds would cover the cost of removing the fusion device for low-level radioactive waste disposal.

Conclusion

Fusion power is on the horizon and the State of Washington has the unique opportunity to support this technology and become a national example and leader of fusion energy regulation. Effective regulation of fusion has the potential to fight climate change and decarbonize the power industry in ways other technologies cannot in roles and understanding the framework to support the rapidly growing industry and regulatory landscape is key to success.

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