Supplement/Thank You
RE: PSE/IRP Hearing

UE-141170
UG-141169

Lon Freeman
5040 78th Ave. NW
Olympia, WA 98502
Lfreee99@gmail.com

March 6, 2016

Utilities and Transportation Commission
Chandler Plaza Building
Evergreen Park Drive
Olympia, WA

Attention: Chairman Danner, Commissioner Jones, Commissioner Rendahl

Dear Commissioners:

Thank you so much for the opportunity to participate in Friday's (March 4th) Public Hearing on the PSE IRP. It was a grueling day for all and well worth the effort for the diversity of views and collective expression of factual material presented from differing perspectives.

Due to the short notice I had of the hearing, I was not able to prepare any written material to submit pertaining to the substantive matter of my testimony (recent developments in nuclear fusion power technologies). Due to the necessarily short time for "end speakers" (quite understandable under the circumstances), I was not able to complete some key, salient points I had in mind as an outline for presentation. I would like to clarify some of my thoughts here.

It has not escaped my awareness that presenting on fusion futures, when there is already a budding and growing renewable energy industry in Washington State, including the particularly dynamic municipality of Olympia, which I love – could be seen as an attempt at undercutting the vitality of that sector of economic activity. Nothing could be farther from the way that I feel. The jobs being created in the clean, green, and sustainable energy economy are of the utmost importance both for the people engaged in that employment as well as for the social well-being and health of the neighborhoods, communities and national entities we are all striving to realize.

I think it is equally important to remain open in our perceptions and in our capacities for intelligent assessment of potentially new possibilities that may be on the horizon for social advancement, greater equity and realization of human potential, let alone for the mitigation and amelioration of human induced climate modification and its impacts. That goes for the benefit of inhabitants of the natural world as well as for those who inhabit the built environment. It is my view that certain types of small scale fusion devices can provide benefits for significant numbers of people and other critters.

Small scale, and I emphasize that it is small scale fusion technology that I am interested in may be enabling of greater community and municipal guidance in the energy infrastructure and in distributed networks in the linking and monitoring of electrical energy flows, including for new economic activity that may as yet be unforeseen. As example, the research and manufacture of new types of solar materials arrays i.e. of quantum dots, of broader spectrum materials for the

energy gap, once they are further characterized and mature.

Finally, there was an element I was hoping to communicate at the hearing on Friday evening that Jerry Pollit (whose efforts I have followed for years) brought to my attention. If there is an unfair or disadvantageous economic/cost disequilibrium which would impair the further growth of the renewable energy industry in WA (or elsewhere), I have little doubt that a more fair cost structure could be implemented which would obtain parity between the two types of energy technologies. It is rather a partnership of two distinct technological types of electrical generation that I am seeking. One, from the local conditions of geography, circulation and local climate on Earth – solar energy and wind generation -- that originates from the solar flux of photons when energized particles and ions are ejected from the surface of the sun, and the other is a mimicking of the fundamental processes that occur deep in the core of the sun that eventually produces the solar flux at the sun's surface transmitted to Earth through space – the fusion of light nuclei and the release of a part of the strong binding energy that only occurs in the inner recesses of the atomic nucleus when mass is converted to energy during fusion. Both of these processes may synergize in diminishing the harmful carbon compounds producing global climate change on Earth.

Please do not let the foolishness of times past and its legacy of radioactive contamination, waste and bellicose inclinations and threats cloud the clarity of what may be able to be achieved in a time when reason is being called upon to come again, for it would be foolish indeed to embargo one of the 4 fundamental forces (or "interactions", or "fields" as the physicists perceive these phenomena) of the universe. It is no longer sensible to call it a Faustian Bargain. It may be used with a deeper understanding and continuing growth of our knowledge. Please do not relegate the stuff of stars to a forgotten tradition of learned societies.

Futures Time Forecasting:

My comment on Friday evening that "I am not sure whether renewable energy sources would be sufficient in 2115" (when I was elaborating a rationale for assessing small scale fusion)…

1) As an expression of an environmental ethic, I can definitely relate to renewables. There is a beauty in the offering that is reminiscent of Aldo Leopold's Sand County Almanac, or alternatively the Norwegian Deep Ecologist Arne Naess. I have read Kirkpatrick Sale and E.F. Schumacher… and lived it as well.

2) A 100 year horizon is not realistic for any reliability in technological forecasting, but as a device for imagining it does make some bit of sense in comparing these two types of technological "approaches". A more common time horizon for academic futures methods is a 40 year horizon – what is termed the mid-term future.

3) Barring any catastrophic collapse, we would expect that electric demand in a 100 year scenario would increase dramatically, worldwide – to many more Quads than is currently being consumed.

4) It is a useful device to get people thinking in terms of possible futures rather than probable.

5) "I am not sure..." I meant that quite literally; I have no way of knowing. If it came across in a pejorative sense, I am sorry, I apologize.

Important Caveat: None, I repeat None! of the fusion devices anywhere in the world have attained a positive net power production as yet, that I am aware of. But it is getting closer. (There was a common remark among the Fusion community throughout the many years of efforts – "Fusion is now only 30 years away, and always will be.")

Type of Fusion Machines I Am Referring To:

1) By far, most of the experimental fusion machines in the world use a typical Deuterium-Tritium fuel mix because it is the most readily amenable fuel to exhibit fusion reactions – what is called the "Fusion Cross-Section" (the probability of acquiring fusion reactions in a distribution). The temperatures required for this type of fusion are typically 100 Million Celsius. Deuterium is a heavy isotope of Hydrogen but is not radioactive. Tritium is a heavier isotope of Hydrogen and it is radioactive. This is not the type of fusion machine or fuel I am referring to in my brief presentation, with the exception of:

1A) ...the fusion machine in development with Lockheed Martin. I think they are using the typical Deuterium-Tritium fuel (goes by shorthand D-T fuel or D-T machine). Some uncertainty about this because they are keeping information close to the chest. But I am calling them a D-T machine for the time being.

2) The type of machine(s) I am referring to are designed to use a different fusion fuel, typically ordinary Hydrogen and ordinary Boron11, neither being radioactive. That is important! The fuel constituents of this type of fusion machine are NOT radioactive. It is known as pB11 fusion because Hydrogen, after being stripped of its 1 electron during ionization simply is constituted as 1 sole Proton, hence the "p" in "pB11". So, the reactants are not radioactive. The amazing thing is neither are the products of the reaction (by in large) (I will return to this in following paragraph). The products of this reaction are 3 nuclei of the common element Helium (Helium4) – they are NOT radioactive. They are also called the Alpha particle. As Alpha particles they are dangerous because they are energetic and can get lodged in the lungs if respiration takes them in by chance. BUT, they are NOT radioactive. Once they are re-associated with bound electrons, they are no longer charged ions but are the whole, neutral, elemental atoms of ordinary Helium. pB11 fusion does NOT require a separate thermal cycle for electricity generation – no turbines at all, there is "Direct Conversion" – great cost savings.

There is also typically a .1% or less production of side reactions to this type of fusion that result in the emission of neutrons, a sparse quantity for certain, and an additional by-product, Carbon-11. The isotope Carbon-11 is subject to radioactive decay. It is a radioactive substance. It is a Beta emitter and is quite dangerous. However, the Half-Life of Carbon-11 is 20.3 minutes, a relatively short half-life. So, in a 5MW fusion reactor using pB11 fuel, in an accident scenario where there is an actual breach of the really small fusion vacuum chamber that is utilized, it is

calculated that the radiation level directly in the fusion vacuum chamber would return to background level within 9-12 hours (depending on the acceptable exposure standard that is used), and that is inside the fusion chamber itself. Because there are so few neutrons emitted in a pB11 fusion machine, less than .1% of the energy produced, this type of fusion is denoted as "Aneutronic" fusion. In a D-T fusion machine however, 80% of the energy produced is carried by neutrons, copious amounts of neutrons indeed; a drawback because neutrons being of neutral electrical charge fly through layers of material until they impinge on surrounding materials of the reactor itself, and due to the energetic nature carrying 80% of the fusion energy produced, they "activate" the surrounding reactor material to produce radioactive isotopes out of the reactor material. But it is nowhere near the long-lived radio-isotopes typical in fission reactor technologies. Even in a D-T fusion reactor, there is much less quantity and much shorter lived radio-isotopes that would need to be isolated, on a time scale of 100 years or so rather than the tens of thousands of years typical for fission reactor isotopes. AND FOR ANEUTRONIC FUSION REACTORS, LIKE THE pB11 type there is no Radioactive Waste, at all! None.

I will stop here with this section, which should provide a basic understanding of some of the salient issues to make inquiries about, and I will list for your use once again the 5 or 6 enterprises/labs I mentioned at the hearing:

1) "Compact Fusion Reactor" (CFR)
Developer: Lockheed Martin/ "Skunkworks" Division aka "Revolutionary Technology Programs" unit; Lead Director: Thomas McGuire
Has announced Prototype in 2019, Probable production line 2022-2024
Probable first use will be as space propulsion system, perhaps as electric generator unit, mobile capability/size is a business jet engine to be carried by truck. Sounds like D-T fusion type.
See Aviation Week and Space Technology, "Skunk Works Reveals Compact Fusion Reactor Details", Guy Norris, 2014-10-15

2) "Focus Fusion I Reactor" (FF-I)
A 5MW "Dense Plasma Focus" machine designed for Aneutronic pB11 fuel
Developer: LPPFusion, Inc. Location: Middlesex, NJ; A small startup fusion lab founded in 2009 making significant progress toward net fusion energy; publishing research in well respected, peer reviewed journals; Founder and Chief Scientist Eric J. Lerner, "LPPfusion.com"
A simple design going back to 1960s origins by Joseph Mathers, updated with design improvements based on sophisticated theoretical underpinnings including Quantum Magnetic Field/ High Field (MegaTesla field), Capacitor Bank electrical discharge into gas Decaborane ($B_{10}H_{14}$) stock fuel source ionized to pB11 fuel for fusion. Magnetic Pinch self-generated produces grouped filaments combining into a "Plasmoid" where fusion occurs. Uses D-D reaction for experimental test bed analysis/no radioactive materials. Has achieved >160kev ion temperatures (1.8 Billion Kelvin) for 20ns within parameter bounds for Lawson criteria, is working on meeting density parameters for achieving net energy within the next year or two. Is hoping to meet prototype date in 2018- 2019.

3

3) Polywell design, ("Wiffleball 8 or 9")
Developer: Energy Matter Conversion Corporation (EMC2)
Lead Director: Jaeyoung Park (also affiliated with USC); Location: California
Originally developed and theoretically articulated by Robert W. Brussard, died 2007.
Inertial Electrostatic Confinement, CUSP device hexagonal geometry, deep potential well electron trap. Designed for pB11 fuel. Tested through Naval Research Lab (NRL) for a couple years; validated soundness of theoretical design; in experimental development.
Original design was by Philo Farnsworth and Robert L. Hirsch titled as Farnsworth-Hirsch "Fusor" in 1970s. Updated design principles and experimental results by Brussard through the 2000s; Brussard gave a "Google Talk" sometime in early 2000s.

4) C2-U (C2-Upgrade) fusion reactor
Developer: "Tri Alpha Energy" (originally founded by Dr. Norman Rostoker – well known theorist – died last year), originally had affiliation w/ UC San Diego, and UC Irvine. I do not know who is heading the effort currently. The C2 device is at N. Carolina State U. Significant funding has been coming from Paul Allen (Vulcan, I think) but Paul Allen has significant interest in this project. Device is based on a double Theta Pinch Field Reversed Configuration (FRC). Designed for pB11 fuel. Has been making significant progress in development but no word on readiness yet. Two Plasmoids fired at each other from opposite ends of cylindrical tube meet in the middle region but separated by separatrix region creating a FRC and added rotation to each of the plasmoids for stabilization where fusion occurs.

5) Zap Flow Z-Pinch
Developer: University of Washington, Dept. of Aeronautical and Astronautical (AA) Engineering at the Plasma Science Innovation Center: For "Zap Flow Z-Pinch" (1 of 5 or 6 different projects at the center) project joint co-directors (PIs) are: Brian Nelson and Uri Shumlak; overall director of the center is Thomas Jarboe. Dennis Peterson also works on this project and is a science communicator professional and is also on the Board of LPPFusion in NJ, I believe. I think this machine also is configured for pB11 fuel ultimately. The facility is based in Redmond I think.

6) One additional came to mind after Hearing: I think it is simply called the "Fusion Engine":
Developer: "Helion Energy", a spin-off or subsidiary of MSNW: "Mathematical Sciences NorthWest", founder and chief scientist is John Slough who originally came from U. Wisconsin I think; it is based in Redmond also. It is being developed primarily as a fusion propulsion system and has been making significant advances toward commercialization – also has applications for electrical generation. The velocity of ion particles as exhaust is so much greater than chemical rocket exhaust velocities which is what generates Thrust in rocket engines. Dr. Slough's project has been funded through ARPA-e in their "Accelerated Program for Economical Fusion Technologies" funding round over the past 2 or 3 years. The fuel for this machine is somewhat unique in that it is a 2 stage process. First there is a D-D reaction which generates Helium3 as one of its fusion products, and then there is a 2nd stage which utilizes the self-generated Helium3 in a He3-He3 secondary reaction. This is innovative because He3 is very rare on Earth – sparse – although is found in space relatively abundantly. First several

meters of the moon's surface is abundant in He3 which the Chinese are considering mining for fusion fuels in future missions.

AND 7) Finally, I thought it would be of interest for you to know of a Bill that has been introduced into Congress by Representative Alan Grayson-Florida this past August. It is H.R. 3440 – Fusion Innovation Act of 2015.

RISKS:

1) In small scale or large D-T fusion machines, watch out for the high neutron flux and what it can do to the materials of the machine, in activation of radioactive isotopes. And if the machine is to have a "blanket" as first plasma-facing material for the self-generation of further fuel, what is the "blanket" to be consisting of – what chemical constituents? If it is a D-T machine, will there be a separate thermal cycle to drive steam turbines for the generation of electricity; how is it engineered to interact with the fusion cycle?

2) In pB11 fusion machines, the electricity generation is accomplished by Direct Conversion, a great economical feature which eliminates the need for turbines and a separate thermal loop cycle as heat exchanger, but these machines operate in much higher temperature regimes, close to 3 Billion Kelvin (or Celsius) necessary for the fusion reactions, compared to the 100 Million Kelvin of a D-T machine. How is the machine to be cooled?

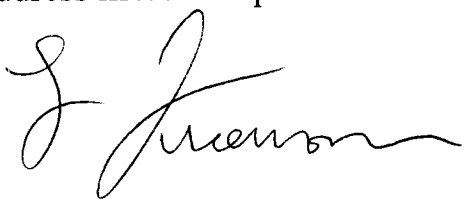
3) In pB11 machines the typical fuel stock is Decaborane (B10H14) which is disassociated into separate Hydrogen atoms and Boron11 atoms during the initial ionization. Decaborane is a toxic substance, is toxic through the tactile route of exposure so needs to be handled with care, and will need to be regulated when in widespread production and distribution. But only a very little is needed to run a 5MW fusion reactor for a year, as an example.

4) In the Focus Fusion (Dense Plasma Focus) machine, the electrodes are to be constructed of Berylium (which are transparent to X-Rays, also to be generated during normal operation). Berylium dust is a terribly toxic substance, so will have to be carefully controlled as a dust evacuation system in the fusion vacuum chamber. The Focus Fusion machine is designed to run as a pulsed power machine, at around 200 cps to generate its 5 MW. What is the effect on tolerances, on materials at 200 cps, at an operating temperature close to 3 Billion Kelvin?

These are a few Qs that I came up with concerning risk. I would be interested to see others. I am sure there are many more and I would like to see responses to the Qs as well.

Thank you for your interest, and the opportunity to have participated. If you have further questions for me specifically, or if I may be of any help, please feel free to contact me at the e-mail or mailing address listed at top.

Sincerely,
Lon Freeman



3/8/2016