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GUEST EDITORIAL

Social Acceptance is as Important as Low Costs and Net Energy Production for Climate and Energy Poverty Impact

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Fusion, once commercialized, has the potential to be a significant source of energy to help humanity address climate change and energy poverty. In developed countries, fusion could help decarbonize transportation, heating and industrial processes. In developing countries, fusion could bring energy to those in desperate need. However, fusion will not be able to make these contributions if it is not accepted by society, *i.e.*, if it fails to secure a social license [1–3].

Fortunately, given the early stage of fusion's development, there is currently a window of opportunity to avoid the missteps of other energy technologies, like fission, and lay the foundation for long term social acceptance. In particular, the fusion community can anticipate and address public concerns pertaining to, for example, waste, water use, aesthetics, non-proliferation, supply chains, and the distribution of benefits, risks and harms, ***now*** by thoughtfully adjusting technology and business models, before technical and commercial choices are locked-in.

Although it is possible that the accomplishment of a burning plasma and the promise of a nearly unlimited fuel source is enough to secure social acceptance, it would be prudent to assume that this accomplishment will not be sufficient. Ignoring the challenge of social acceptance risks a future in which fusion plateaus as a niche energy source. Technologies that lack social acceptance have limited scale because of increased capital costs, litigation costs and risks, and regulatory burdens [4]. Almost all energy technologies face this challenge. For example, wind turbines and their associated transmission lines face siting challenges due to acceptance issues [5–9]. The social acceptance challenges of fission power have been perhaps the most studied. For the past thirty years, fission plants have generated about 20% of the electricity consumed in the U.S. and 10% of the electricity consumed worldwide, but fission has been unable to increase this fraction and struggles to maintain this level. The social license literature suggests that fission struggles not because it splits atomic nuclei, but rather, because it lacks social acceptance [10, 11]. Although some claim that fission struggles due to high costs created by regulatory burdens, the reverse may be more likely — the lack of social acceptance raises the cost of regulatory compliance because the industry has lost the public's trust. Extending these insights, it is conceivable that if fission had a social license, it would play a much larger role in powering humanity, to the climate's benefit.

The essential need for fusion to secure social acceptance has been widely recognized for many decades. Nearly thirty years ago, EPRI listed public acceptance as one of three key achievements needed for fusion to be a viable energy source [12]. Despite this long recognition, nuclear technologists have a poor track-record of securing such acceptance. Over the past forty years, scholars and commentators of nuclear technology have remarked that conventional approaches to acceptance, such as technical change [11, 13], regulatory compliance and reform, and better public relations through education and messaging [13], have failed. Likewise, these conventional approaches are unlikely to be sufficient for fusion: a more proactive approach is required.

Fortunately, there are established methods to achieve social acceptance, including a social license, bioethical review and responsible research and innovation [3]. The fundamental insight from these methods is that social acceptance can be facilitated by engaging in a two-way conversation between fusion developers, local communities and other public stakeholders [1–3]. This conversation can be thought of as an iterative two-step process that some scholars of technology development have called a process of co-design [6]. Step one involves listening to the public community, identifying their concerns, and deeply understanding those concerns. Step two involves meaningfully addressing those concerns by adjusting technology and business models. The

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process is in contrast to more traditional one-way outreach efforts, which have been characterized as "letting the public see the experts at work" [14]. The two-way conversation supplements, but does not substitute for, formal regulatory approval.

By considering input from non-experts, the two-way conversation addresses issues that the public worries about, rather than "what experts think they should worry about," a distinction that is often missed by highly-technical researchers. Non-expert input is helpful because non-experts "see problems, issues and solutions that experts miss," have a sensitivity to "social and political values that expert's models [do] not acknowledge" and have a better capacity for "accommodating uncertainty and correcting errors over time through deliberation and debate" [15]. The two-way process is powerful even if not all concerns are addressed because it creates a sense of "procedural justice" whereby "people affected by decisions" are able to "participate in making" such decisions [16]. This process also improves outcomes [17], creating a positive feedback-loop that enhances trust for future engagement [18].

The history of spent fuel repositories for fission waste offers an example of the power of early two-way conversations that address community concerns [1, 3]. The two-way conversational approach taken by Sweden and Finland has succeeded: their repositories are under construction and are generally well regarded by the host communities [19, 20]. In contrast, the top-down siting process that was imposed by the U.S. Congress when it designated Yucca Mountain as the location of the U.S. spent fuel repository has failed: there is no active repository in the U.S. The fusion community can draw upon this example when siting research facilities, commercial plants, and waste disposal facilities.

The private fusion industry may not be best positioned to undertake this critical two-way conversation. Early-stage companies likely do not have the requisite staff capacity and expertise. They are also likely to be perceived as biased. A neutral facilitator may be more effective for engendering public trust [17]. For example, a non-profit or university could undertake structured engagements, through processes like Deliberative Polling, ethical review modeled after formal bio-ethical review [3], or Participatory Technology Assessment [21]. Nevertheless, there are concrete activities that the private fusion industry can undertake, ***today***, to facilitate social acceptance: (i) treat social acceptance with the same level of importance as low capital costs and net energy gain; (ii) be open and transparent with the public and regulators regarding the risks and benefits of the technology (an independent health and safety review may be particularly helpful); (iii) see regulatory compliance as a mechanism of advancing social acceptance, rather than as a barrier to technology deployment; and, perhaps most importantly, (iv) be open to public feedback and adjust technology and business models accordingly.

Publicly funded fusion organizations, such as government agencies, can help this two-way conversation by funding structured engagement undertaken by neutral facilitators and by using their convening powers to facilitate knowledge exchange. Governments and academic plasma physicists, however, should approach direct engagement in the two-way conversation with caution. Like their private counterparts, they are likely to be perceived as biased advocates. In addition, power differentials between government agencies and local communities, if not handled properly, could lessen, rather than engender, public trust.

To summarize, fusion has an opportunity to distinguish itself from other energy technologies, not just in how it uses physics, but also in how it approaches society. The fusion industry, government funders and other stakeholders should seize this opportunity now and avoid a tragic future in which fusion's potential to address climate change and energy poverty is limited not by physics, but rather, by early missteps that impair its long-term social acceptance.

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