Towards Fusion Energy in the Industry 5.0 and Society 5.0 Context: Call for a Global Commission for Urgent Action on Fusion Energy

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Abstract

This article provides a high-level review of the geopolitical status quo of nuclear fusion energy and outlines a vision for the future against the backdrop of Industry 5.0 and Society 5.0. In 2020, the year of the 75th anniversary of Hiroshima and Nagasaki, ITER, the world's largest fusion experiment, began its machine assembly, and next year, the DEMO (fusion power) stage of ITER planning is formally due to begin. With several countries now engaged in the design of DEMO-phase machines, we stress that a “burning plasma” self-sustaining fusion reaction event will be a critical juncture similar in status to the Trinity Test. In response, urging the need for US geopolitical engagement, we call for a “Global Commission for Urgent Action on Fusion Energy,” to be backed by the International Atomic Energy Agency and International Energy Agency (IEA), along the lines of the existing IEA “Global Commission for Urgent Action on Energy Efficiency.” We see the Commission serving a similar, this time international, role to the 1946 “Acheson-Lilienthal” report for fission and involving a global External Independent Review of the state-of-the art of fusion energy technologies. We suggest major “soft power” co-chairs from the Global West and North and from the Global South, thereby providing a geopolitical pivot which can unlock tens of billions of dollars in funding for multiple technology pathways, create a global regime to safeguard Intellectual Property, accelerate the transition from fossil fuels to a “Future Fusion Economy,” and prevent the geopolitical polarization of fusion energy.

Keywords Critical juncture · Fusion energy · Global commission · Industry 5.0 · Society 5.0

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Introduction

There is a saying that nuclear fusion is always two decades away, and scientific journals like the International Atomic Energy Agency's *Nuclear Fusion* have chronicled the long evolution of fusion energy. That said, in the year of the 75th anniversary of Hiroshima and Nagasaki, ITER, the world's largest fusion experiment, began its machine assembly (ITER 2020a), thus placing fusion energy within long-range military planning. The leader of at least one great world power is now publicly stressing that fusion energy should be used for peaceful purposes, a tacit admission of the alternative: the weaponization of fusion (Franceschini et al. 2013). As the DEMO (fusion energy) planning phase of ITER begins in the coming decade, and as the private sector and venture capital prepare to take over the baton from public sector against the background of Industry 5.0 and Society 5.0 (Holroyd 2020), we warn that a "burning plasma" event represents a "critical juncture" of the like the world has not seen since the Trinity Test.

In path dependence theory (Collier and Collier 2015), the critical juncture is where what happens becomes history and where that which does not happen is, as Robert Frost puts it, the path "less traveled by." In the case of the Trinity Test, the path taken led to Hiroshima and Nagasaki, with the failure of the Baruch Plan (Gerber 1982) being another critical juncture, one that led to the Cold War. A fusion "burning plasma" (National Academies of Sciences, Engineering, and Medicine 2019) is of the same level of import not only because of the potential for militarization but also because of its potential commercial impact and contribution to managing climate change.

In response, building on our suggestion for a global External Independent Review of fusion energy that could be co-chaired by the Global South (Carayannis et al. 2020), we call for an international Acheson-Lilienthal-style report (Department of State 1946) on fusion energy as part of an IAEA and International Energy Agency-backed "Global Commission for Urgent Action on Fusion Energy," a possible prelude to a global "Fusion for Peace" program designed to ward off fusion weaponization and head off a "New Cold War" mentality (Carayannis et al. MS in preparation). We set this call against the background of Industry 5.0 and Society 5.0, which demand visions for a better society.

Industry 5.0 and Society 5.0

Industry 5.0 is considered to be the answer to the question of a renewed human centered/human centric industrial paradigm, starting from the (structural, organizational, managerial, knowledge-based, philosophical, and cultural) reorganization of the production processes of industry. The urgency of this new perspective derives by reason of the fact that Industry 4.0 is only at the initial stage of its development and that the main achievements are occurring now, roughly as predicted, in the 2020–2025 timeframe (Lorenz et al. 2015). Furthermore, the normative dimensions (responsible/irresponsible, ethical/unethical) and policies that define global governance of Industry 4.0 are lacking a holistic vision that takes into account the real impact of such issues. Industry 5.0 aims to provide that vision and fusion energy will likely benefit from harmonizing and maximizing human-machine interaction, whether in optimizing test shots for a prototype fusion reactor (Strugatsky 2020) or human-robot

service and maintenance systems for reactor construction and cores (The Agility Effect 2016; Kidambi 2017), as well as from a common human vision of what fusion energy can offer industry and society, including facilitating humanity's expansion into space (e.g., Cohen et al. 2019).

Visions are important in our conceptualization of industry and society. The discussions on Industry 4.0 and society have tended to focus on either a dystopian fearful future shaped by the IoT where robots ("CoBots") with AI replace humans, or a future that will invariably be benevolent and prosperous for all with the introduction of the Industry 4.0. Both visions subscribe, however, to technological determinism (evolution in organizational behavior, acceptance of robots in the workplace, evolution in organizational structures and workflows, evolution in work ethics, discrimination against robots or people, privacy and trust in a human-robot collaborative work environment, education and training, redesign of workplaces for robots) (Demir et al. 2019), and as if the emergence of Industry 4.0 and its societal shaping and impacts are preordained and inevitable, they do not yet acknowledge the need to broaden the understanding of Industry 4.0 outcomes and its multiple possible futures in society (Özdemir and Hekim 2018; Paschek et al. 2019; Pereira et al. 2020). On the push of technological pervasiveness, Industry 4.0 extends its impact to the whole society, which can be considered a larger ecosystem. In fact, if on the one hand the digitization process concerned more specifically a series of measures attributable to the optimization of industrial production processes (supply chain management, manufacturing and production in smart factories), on the other, the digital transformation implies a reorganization of the sociocultural paradigms centered on the most disparate technological innovations (Nambisan et al. 2019).

At the basis of this broadening, the idea of Society 5.0 (or "Super Smart Society") is defined. This prototypical philosophy originated in Japan and was presented as a core concept in the "Fifth Science and Technology Basic Plan" by the Japanese "Council for Science, Technology and Innovation," and approved by Cabinet decision in January 2016 (Ferreira and Serpa 2018; Salgues 2018). It was identified as an overall growth strategy for Japan and was reiterated in "The Investment for the Future Strategy 2017: Reform for Achieving Society 5.0." In essence, Society 5.0 tries to provide a common societal infrastructure for prosperity based on an advanced service platform. Industry 4.0 follows Society 5.0 to a certain extent, but while Industry 4.0 focuses on production, Society 5.0 aims to put human beings at the center of innovation, taking advantage of the impact of technology and the results of industry 4.0 with the deepening of technological integration in improving quality of life, social responsibility, and sustainability (Önday 2019; Holroyd 2020).

This innovative perspective is not restricted to Japan, as it has points in common with those of the United Nations' Sustainable Development Goals (United Nations 2015), a roadmap which the coordinated global development of fusion energy would affect along multiple vectors, including "Energy for All" (Goal 7), "Industry, Innovation, and Infrastructure" (Goal 9), "Climate Action" (Goal 13), "Peace, Justice, and Strong Institutions" (Goal 16), and "Partnerships for the Goals" (Goal 17). Furthermore, unlike the concept of Industry 4.0, Society 5.0 is not constrained only to the manufacturing industry; in addition, it solves social problems with the help of integration of physical and virtual spaces. Society 5.0 is thus a society where advanced IT technologies (IoT, robots, artificial intelligence, augmented reality, etc.) are actively

used in people common life, in industry, health care, and other spheres of activity, not only for progress, but also for the benefit and convenience of each and every person (Fukuyama 2018).

It is clear that to ensure that implementation of Society 5.0 is not just a political-ideological concept, it is necessary to integrate several dimensions, such as innovation policy (from government side), entrepreneurial spirit (from society side), and entrepreneurial skills (from civil society and institutions) (Yousefikhah 2017). Fusion energy presents an ideal field for these multiple opportunities in policy innovation, entrepreneurial spirit, and entrepreneurial skills.

Towards a “Burning Plasma” Event via the ITER DEMO Phase and in the Private Sector

ITER, an international consortium consisting of the European Union (EU), China, India, Japan, Russia, South Korea, and the United States (US), is due to commence running plasma operations in its tokamak machine in Cadarache in France in 2025 and a deuterium-tritium mix in 2035 (Banks 2017), in the hope of achieving the Holy Grail of a “burning plasma,” net energy gain through a self-sustaining alpha reaction, within a few years of operations. ITER live-streamed the commencement of its machine assembly phase on July 28, at an event where multiple world leaders delivered messages. At the event, a statement by President Xi Jinping was read that included the proclamation that “The ITER project, one of the most important scientific collaborations in the world, embodies the human desire for the peaceful use of fusion energy” (ITER 2020b).

The ITER approach has numerous drawbacks, including the intrinsic difficulties of a decades-old tokamak-based design and the problem of tritium breeding. However, ITER is no longer the only major fusion energy contender. Also in the public sector, the United Kingdom (UK), likely because of its leaving the EU, is developing a Spherical Tokamak for Energy Production (Culham Centre for Fusion Energy 2020) due to deliver grid-connected electricity in 2040, as is a UK private sector company with its own spherical tokamak design, Tokamak Energy. Meanwhile, the Chinese are due to start constructing the China Fusion Engineering Test Reactor in the 2020s, also with the aim of electricity production around 2040 (Liu et al. 2017). While both these national machines can be cast as “DEMO”-phase ITER successor machines, General Fusion, the Canadian national offering, a commercial company with significant state backing, is aiming to leapfrog ITER with a burning plasma in the 2020s and a grid-connected commercial prototype in the 2030s (Day 2020).

Meanwhile, the American private sector has accumulated over 1.5 billion dollars in venture capital, mainly by TAE Technologies, followed by the MIT-backed Commonwealth Fusion Systems (Michaels 2020). These fusion companies, most of them members of the Washington-based Fusion Industry Association, formally launched in 2018, are hoping to utilize cutting-edge developments in reactor design and material sciences to promise commercialization of fusion energy within the same timeframe as General Fusion (Carayannis et al. (MS under review)), accelerating fusion power to address climate change within this century.

Although these companies face a clear credibility challenge, the US Department of Energy (DoE) is beginning to support them. This backing is not just via its ARPA-e “shoot for the stars” program, with its ALPHA, BETHE, and GAMOW projects (Nehl et al. 2019), but with the mainstream INFUSE public-private sector academic cooperation program (INFUSE n.d.) and a proposed public-private sector cost-sharing program (Department of Energy 2020), working towards national fusion power plant prototypes. This effort has similar aims to NASA’s Commercial Orbital Transportation Services program, i.e., jump-starting fusion sufficiently that the private sector can take over. Delivering affordable fusion power would be the ultimate geopolitical game-changer and is accumulating more significant support across the entire US fusion community as part of the Department of Energy’s Fusion Energy Sciences Advisory Committee’s Community Planning Process (APS-DPP 2020).

A Geopolitical Roadmap for Fusion Energy

It is against this background that we call for an Acheson-Lilienthal-style international report. It is a call consciously echoing a strong tradition in nuclear science, dating back to the Manhattan Project, of emphasizing that the world cannot sustain the risk of nuclear science being utilized for violence, a call in the tradition of the 1955 Russell–Einstein Manifesto (Russell 2003) and the Pugwash Conferences on Science and World Affairs. In terms of political science, it is theoretically predicated on the basic principles of Nonkilling Global Political Science (NKGPS; Paige 2002), first theorized by the political scientist Glenn D. Paige, which is now supported by the Honolulu-based Center for Global Nonkilling, a United Nations (UN) special consultative status nongovernmental organization. The basic paradigm of NKGPS is to promote change towards the measurable goal of a killing-free world by means open to infinite creativity, especially science and technology, and there are both diagnostic and treatment elements to NKGPS, or in Paige’s own words: “We need to know the causes of killing; the causes of nonkilling; the causes of transition between killing and nonkilling; and the characteristics of completely killing-free societies.”

We view an increasingly bipolar world and great power competition over technological supremacy as a potential cause of megadeath-level killing. In line with Paige’s conceptualization of the Funnel of Nonkilling Alternatives, and subsequent NKGPS research emphasizing that engineering and science must work towards the public good and peace (Pim 2011), we see that an Acheson-Lilienthal-style international report could launch a “Fusion for Peace” program. This would be a global intervention at the level of Paige’s “structural reinforcement zone,” which includes socioeconomic conditions, including energy, which can be pragmatically modified by science diplomacy (Turekian 2018), the purpose of ITER.

Fusion energy need not be commercially viable to have military applications, primarily for naval propulsion systems and as an energy source for a new form of warfare, directed energy weapons (DEWs) and electric weapons (EWs) (Beason 2005). Thus, it is correct to draw a comparison between a “burning plasma” event and the 1945–1946 period. It is also pertinent to recall the 1946 US Baruch Plan to stop an atomic arms race in its tracks and internationalize fission energy, which has haunted nuclear disarmament since its failure caused the Cold War (Kearn 2010; Mackby

2016). It is also topical to raise the issue, given the increasing speculation of an imminent “New Cold War,” this time between China and the US (Ross 2020; Zhao 2019), a matter of considerable concern given the stall of nuclear proliferation talks (Mackby 2016), worsening conditions for international stability (Piechowiak-Lamparska 2019; SIPRI 2020), and China’s recent increase in its nuclear arsenal (SIPRI 2020).

However, unlike fission, for which the world had little time to prepare in geopolitical or socioeconomic terms, the world still has years to prepare for a “burning plasma,” even in the most optimistic of private sector timeframes. This provides us with the opportunity to revisit the Baruch Plan, which was supposed to be the bedrock of the UN Atomic Energy Commission (UNAEC), founded on January 24, 1946, by Resolution 1 of the General Assembly and precursor to the International Atomic Energy Agency (IAEA), and meant to drive peaceful diplomacy via the UN (Gerber 1982).

The opportunity to revisit history at this scale appears but rarely, and what is at stake is cementing peace in place, perhaps by building on the concept of the global ceasefire, called by the UN Security Council on July 1 in response to the COVID-19 pandemic (Hazra 2018; International Crisis Group 2020). To achieve this lofty goal, we urge investigating the feasibility of a worldwide “Fusion for Peace” program, a 21st-century fusion equivalent to the US’ “Atoms for Peace” program (see Varnum 2014), now. The initiator would be a special “Global Commission for Urgent Action on Fusion Energy,” tasked with producing a fusion-based, international version of the original Acheson-Lilienthal-style report, as the prelude to a “New Baruch Plan.”

The Dangers of Militarized Fusion Energy

First, we underline the dangers posed by militarized fusion energy in an increasingly polarized world. As with fission, fusion energy, if feasible, can be weaponized. As less radiation is involved, fusion possesses an intrinsic benefit compared with fission for propulsion and as an energy source for DEWs, like lasers, and EWs, such as railguns (O’Rourke 2020a). China’s rise as a military power is generating considerable disquiet in US circles. However, many adopt a simplistic approach to both sides’ military capabilities, by postulating that despite China’s rapidly increasing its overall naval capacity, the US has an overwhelming military advantage due to its aircraft carrier group capability.

Fusion has yet to be factored into US strategic military thinking, at least in public, although for many years it financed the “polywell” fusion approach. Moreover, most China watchers, while acknowledging a sustained “New Cold War” is theoretically possible (the “Churchill Trap”—a new Iron Curtain falling; Yuan 2018), play down the risk of a “hot” conflict. One basic premise is that the era of interstate conflict is over. In addition, both China and the US are nuclear, and an escalating Sino-US military conflict is thus theorized to be constrained by Mutually Assured Destruction. Further, while US military planners have voiced serious concern over China’s rise as a naval power (O’Rourke 2020b), many still assume that in a naval conflict, a US carrier fleet would triumph.

Railguns currently being developed by both China and the US offer a sub-nuclear first-strike ship-killing capability, which has an advantage over missiles due to their

cheapness (O'Rourke 2020a) and ability to disable or degrade an enemy weapons platform without necessarily destroying it. That is, a railgun has the theoretical capacity to knock out an aircraft carrier, with few casualties. It is not a stretch to imagine a future in which fusion-powered railguns play a role in disputes over territories or resources.

One can argue that fusion energy would negate the need to exploit these reserves, yet without intervention, it could take many decades for the world to fully transition from fossil fuels to a fusion-and-renewables energy profile. It is in these decades that a fusion-powered conflict would be most likely to break out, especially if China's planning for a Churchill Trap means it prioritizes energy self-sufficiency and natural resources monopolization. The chances of an ITER-based traditional tokamak providing a route to commercialization are low (Lopes Cardazo 2019). Still, hopes for the rapid development of a next-generation fleet of magnetic confinement-based compact fusion power plants in the 2040s remain (Spangher et al. 2019), based in part on fission's initial progress being rapid. Seven years after fission generated commercial electricity, the world's first fission-powered aircraft carrier, the *USS Enterprise*, came into service in 1961. This development came about because fission was embedded in the broader military-industrial complex, boosted by the Cold War, and not because it necessarily made economic sense.

Compact fusion reactors would provide sufficient energy for powering ships and cooling and firing railguns. The result would have no countermeasures and so possess the potential to transform warfare tactically, impact theater operations, and potentially affect overall military strategy. Thus, it would threaten global political security, which presently hinges, for better or worse, on US carrier diplomacy. There also exists the issue of proliferation, with the possibility of rogue states obtaining fusion-powered railgun systems, transforming the nature of conflicts in other theaters. It is also technically possible that a rogue nation with a fusion reactor could breed its own plutonium (Franceschini et al. 2013).

Proposal for a “Global Commission for Urgent Action on Fusion Energy”

In response to a developing DEMO-era fusion energy race, the US could simply fund several of its own “burning plasma” national facilities, as was recommended by a 2019 National Academies' report (National Academies 2019). Initial funding would be through the DoE's fusion energy cost-sharing initiative, with the hope that more of its fusion companies could then attract enough venture capital to crack fusion power first. However, this may not overcome the “valley of death” innovation cycle problem that massive new energy infrastructure projects encounter in terms of financing improved iterations (Lopes Cardazo 2019). It also ignores the amount of state support that China can dedicate to accelerating fusion as the finishing line draws close. Finally, it abdicates responsibility for the geopolitics.

The US is the second largest producer of greenhouse gases yet is ambivalent, at best, towards the Paris Agreement. If it is to provide any input on global energy leadership, not to mention address whether or not fusion could help with climate change within this century, it must resist the temptation of wielding fusion as a geopolitical weapon and instead see it as a tool. The External Independent Review mechanism that we suggest as

part of a new Acheson-Lilienthal report would, as with the original Report, encourage the West to lay its cards on the table about the progress its private sector could make on fusion and simultaneously seek to minimize any threat of weaponized fusion.

Achieving this in an uncertain world requires a geopolitical pivot acceptable to all. To generate a fusion version of the Acheson-Lilienthal report, we urge the launch of a Global Commission for Urgent Action on Fusion Energy. The Commission should include IAEA- and OECD-based International Energy Agency (IEA) involvement, co-chaired by a major Western “soft power,” such as the UK, and by the Chair of the UN Group of 77 (G77) bloc of “Global South” countries (Toye 2014).

This initiative would, in effect, be a revisiting of ITER’s original role. Despite serious misgivings over cooperating with the USSR, mainly due to implications for technology transfer, the US decided on measured engagement. ITER began as a Reagan–Gorbachev initiative and was announced by President Reagan at the 1985 Geneva summit. The first ITER parties, namely the US, the Russian Federation (replacing the Soviet Union), the EU, and Japan, were then joined by China and South Korea in 2003, with India joining in 2005. The role of the IAEA, actually an autonomous international agency, was crucial in serving as a neutral scientific broker to facilitate the conceptual and engineering design phases of a fusion science experiment (Claessens 2019). In our approach, the IAEA would return to this role, now as the technical broker for an External Independent Review of fusion energy, essentially a baseline study tasked with making recommendations on the feasibility and viability of DEMO-phase fusion energy.

United States’ multi-agency involvement would be essential to the success of the initiative, given that it has the largest fusion ecosystem. However, the US cannot resuscitate its 1946 Baruch Plan strategy and simplistically dictate to China. If and when the genie is out of the bottle, the US cannot prevent China from manufacturing fusion reactors for the Global South. It can, nonetheless, establish a rule-based playing field by significantly increasing the likelihood that core US intellectual property is respected, by inviting the G77 bloc of 134 countries to participate in this fusion version of the Acheson-Lilienthal report.

To coordinate such a commission, the IAEA only requires a mandate from a UN Member State, with similar terms of reference to the IEA commission. We recommend a GEO-PESTLE approach, that is, one that considers geopolitical, economic, social, technological, legal and regulatory, and environmental aspects (Carayannis et al. 2020). Moreover, a model for international engagement on fusion already exists. The IEA in July 2019 launched its independent global high-level “Global Commission for Urgent Action on Energy Efficiency” (International Energy Agency 2020), which arose out of the International Partnership for Energy Efficiency Cooperation, originally a G8 initiative. The IEA energy efficiency commission, which delivered its recommendations within one year, was framed in terms of its implications for lower greenhouse gas emissions, less air pollution, and less dependence on energy imports. It was tasked to accelerate development and commercialization, with the ability to deliver policy recommendations in areas such as global regulation, socioeconomic development, technological development, and geopolitical management—similar bases as an External Independent Report of fusion would cover.

A “Commission for Urgent Action on Fusion Energy” would respond to the “urgent action” geopolitical call for climate action, be similarly framed, and would provide a

natural role for the IAEA in the impartial evaluation of global progress towards fusion energy. The IAEA is attempting to conduct a detailed socioeconomic analysis of how much is being spent on fusion. It could readily take up the role of reviewing which pathways, if any, may be most feasible and of investigating how much additional expenditure is needed to accelerate fusion energy development and the ultimate goal, fusion power.

One founding principle of the Commission must be that a “burning plasma” would be a Trinity Test–level critical juncture not just because of weaponization but because fusion energy has the potential to be disruptive in terms of existing primary energy supplies. Any potential for commercializing fusion will socioeconomically impact coal-producing nations, such as the largest Muslim country, Indonesia, which supplies coal into ASEAN countries, China, and internationally, as well as oil-producing countries, such as OPEC. A Commission approach would create policies to manage these and related issues.

An independent Global South–brokered commission could inject a healthy dose of reality into fusion energy long-range planning. It could boost the US domestic fusion ecosystem as well as that of other countries and help create a “Future Fusion Economy” (Carayannis et al. 2020). Basic market principles for an innovative industry require the development of the demand side, i.e., growing a customer base, including education in the product. Developing a customer base in the Global South is complicated due to the lower level of innovation in the majority of these countries, bar some exceptions, like Singapore. However, a G77–brokered commission would give Global South countries, which control over three trillion dollars via primarily fossil fuel sovereign wealth funds, a realistic insight into the prospects of fusion power plants within this century.

Motivating private sector companies to participate could be the most significant hurdle, although a US state–backed initiative should provide some reassurance regarding the compartmentalization of intellectual property. More fundamentally, the event could motivate members of the G77 bloc to invest in fusion energy. While fusion threatens oil economies, it could re-balance the traditionally Global North–dominated nature of fusion innovation, with India being the only Global South member of ITER. Petrostates which traditionally prefer to collaborate could invest via a portfolio approach (Ingersoll 2018).

The Commission should not be viewed as some kind of an attempt to extend a global liberal hegemony. Instead, it is a realism-based attempt at encouraging, within the United Nations System, the selective engagement between great powers, regional players, and principal G77 actors, like petrostates. It has multiple advantages for the primarily US-based fusion companies, which may initially be least comfortable with participating. By involving the G77, civil society, and environmental groups in the External Independent Report, we adopt the quintuple helix innovation framework, an extension of innovation economics that has already been applied to global warming (Carayannis et al. 2012). The quintuple helix builds on the traditional interaction of academic, the public sector, and private industry by adding the public, here the global public and international civil society, who would also be consulted, together with socioecological interactions with the natural environment, here, the climate. Depending on the findings, the status and credibility of the fusion private sector could be enhanced, and they could earn the support of the global “Green Lobby.”

If the Commission approach is successful and results in coordinated G77 backing of fusion energy, the fusion community would benefit in three ways. First, receiving significant funding from a single public funding source reduces reliance on uncertain venture funding. Second, as public sector projects would also be eligible, the private sector companies would form part of a single, managed, collaborative, and competitive (“co-opetive”—see Priestley 2008) innovation ecosystem that would interface with and have the goodwill of international public sector fusion. Finally, a separate independent review mechanism could exist for projects to feedback progress to G77 investors, which would likely be respected by current investors, thus minimizing paperwork.

The Commission approach would require knowledge sharing. One model is that the IAEA, working with the IEA under a G77 co-chair, provides oversight and ensures independent assessment of public and private sector fusion programs. Then, utilizing a “whole-of-government” approach (Ekhaugen 2020), national agencies, in the case of the US the Departments of Energy, Defense, and State, vet and green light companies to testify to the Commission. The companies themselves provide essential information while compartmentalizing and firewalling core IP. Meanwhile, the Consortium on Science, Technology, and Innovation for the South, an existing G77 mechanism, could create a “Fusion Task Force,” consisting of highly innovative regionally and developmentally representative countries. These countries, such as Brazil, South Africa, the UAE, Singapore, and Kazakhstan, would monitor progress and contribute resulting GEO-PESTLE technical reports as part of fusion’s Acheson-Lilienthal report.

Conclusion

We do not know what the findings of the “Global Commission for Urgent Action on Fusion Energy” will be. They could be pessimistic or optimistic; more likely, they will indicate tens of billions of dollars may be required to obtain a viable commercial fusion power plant approach capable of introducing significant amounts of fusion energy, globally, within this century. Yet, to manage what may be a Trinity Test-level critical juncture, we see no other option than to adopt a “whole-of-world” approach, as with the COVID-19 pandemic (Ebrahim et al. 2020). Injecting fusion into the energy mix via G77 co-development could rapidly deploy a ubiquitous energy source which will likely be innovated by the US, with high-end machines being mass-produced in the US, revitalizing its manufacturing base. Third parties would respect intellectual property because it will be G77 co-owned.

In geopolitical terms, the Commission approach avoids “New Cold War” “traps” and offers the possibility of a brighter future for all humanity. The seriousness of the emerging bipolar situation regarding separate Chinese and US scientific development is crucial as it creates a world in which conflict over fossil fuel and other resources cannot readily be mediated. It is also a world in which China is developing a parallel fusion energy private sector, notably via the ENN Group (Carayannis et al. [MS under review](#)). It is a world in which megadeath is possible, a world in which, unless humanity acts in concert, fusion-powered warfare will become part of military planning.

Creating a new baseline for international relations based on calculated persuasion rather than force and brokered by the Global South offers humanity an alternative future. Re-baselining the world along multipolar lines could be matched by economic

incentives through multiple, synchronized national whole-of-government approaches to the techno-industrial consequences of US-led fusion innovation. Fusion science diplomacy, and then fusion energy diplomacy, could considerably assist in highly speculative, expensive ventures where fusion reactors could play a role. In a world in which respect for fusion intellectual property becomes a new standard, fusion power, as an energy supply and form of propulsion, opens the way to internationalize our path to space, a target for Industry 5.0. At the same time, the co-development of fusion-powered railguns offers the prospects of a planetary defense system to detect/deflect/destroy near-Earth objects.

Failure to plan for the Trinity Test-level event is not an option. In a “New Cold War” scenario, US military planners will not accept the Chinese development of a superior technology capable of powering new weaponry that can shape theater-level conflicts. The history of fission shows us the cost of failure. In the Baruch Plan, the US proposed to decommission all its atomic weapons, for the world to put all fission energy under UNAEC oversight, and to solely employ fission for peace. The deal collapsed as it became clear that Stalin intended to pursue the Bomb and due to Soviet fears that the oversight body—the UN—was stacked in the US’ favor (Gerber 1982). The result was the Cold War, nuclear proliferation, and the expenditure of trillions of dollars on opposing military-industrial complexes (Schwartz 1998).

Fusion energy potentially presents a momentous global opportunity. The backdrop is one of momentous historical consequences, of a demand for visions for Industry 5.0 and Society 5.0, and the spirit of entrepreneurship, innovation, and science diplomacy. The Commission approach could re-energize the UN and the IAEA. It could render unnecessary a Sino-US “hot war,” particularly as its multilateral nature makes it more likely that all parties will respect intellectual property. Depending on the results, the fusion version of the Acheson-Lilienthal report could kick-start a global “Fusion for Peace” program to roll out “energy for all,” the dream embodied in the Baruch Plan and now in the UN’s Sustainable Development Goals, and also help address climate change. In the Commission, this would be achieved not through aid but via the kind of geopolitical and socioeconomic statecraft that opportunity provides once a century, or in Baruch’s own words, the chance “to make a choice between the quick and the dead.”

References

- APS-DPP. (2020). APS-DPP community planning process. APS-DPP. <https://sites.google.com/pppl.gov/dpp-cpp/>. Accessed 29 September 2020
- Banks, M. (2017). ITER council endorses new ‘baseline’ schedule. *Physics World*, 30(1), 12.
- Beason, D. (2005). *The e-bomb: how America’s new directed energy weapons will change the way future wars will be fought*. Berkeley: National Association of Science Writers.
- Carayannis, E. G., Barth, T. D., & Campbell, D. F. (2012). The Quintuple Helix innovation model: global warming as a challenge and driver for innovation. *Journal of Innovation and Entrepreneurship*, 1(1), 2.
- Carayannis, E. G., Draper, J., & Bhaneja, B. (MS in preparation). Fusion energy for peace building - a Trinity Test-level critical juncture. <https://doi.org/10.31235/osf.io/mrzuu>. Accessed 29 September 2020
- Carayannis, E. G., Draper, J., & Iftimie, I. (2020). Nuclear fusion diffusion: theory, policy, practice and politics perspectives. *IEEE TEM.*, 1–15. <https://doi.org/10.1109/tem.2020.2982101>. Accessed 29 September 2020

- Carayannis, E. G., Draper, J., and Iftimie, I. (MS under review). Accelerating fusion power to address climate change within this century through a global technology forecasting commission.
- Claessens, M. (2019). *ITER: The giant fusion reactor: bringing a sun to Earth*. Cham: Springer.
- Cohen, S. A., Swanson, C., Mcgreivy, N., Raja, A., Evans, E., Jandovitz, P., et al. (2019). Direct fusion drive for interstellar exploration. *Journal of the British Interplanetary Society*, 72(2), 37–50.
- Collier, R. B., & Collier, D. (2015). *Shaping the political arena*. Notre Dame: University of Notre Dame Press.
- Culham Centre for Fusion Energy. (2020). The Spherical Tokamak for Energy Production (STEP) is an ambitious programme to accelerate the delivery of sustainable fusion energy. CCFE. <https://ccfe.ukaea.uk/research/step/>. Accessed 29 September 2020
- Day, P. (2020). Fusion pioneers say tech will beat many SMRs to market. Reuters. <https://analysis.nuclearenergyinsider.com/fusion-pioneers-say-tech-will-beat-many-smrs-market>. Accessed 29 September 2020
- Demir, K. A., Döven, G., & Sezen, B. (2019). Industry 5.0 and human-robot co-working. *Procedia Computer Science*, 158, 688–695.
- Department of Energy. (2020). Cost-sharing partnerships with the private sector in fusion energy. Federal Register. <https://www.federalregister.gov/documents/2020/04/20/2020-08312/cost-sharing-partnerships-with-the-private-sector-in-fusion-energy>. Accessed 29 September 2020
- Department of State. (1946). *A report on the international control of atomic energy*. Washington, D.C.: U.S. Government Printing Office.
- Ebrahim, S. H., Zhuo, J., Gozzer, E., Ahmed, Q. A., Imtiaz, R., Ahmed, Y., Dombia, S., Mujeeb Rahman, N. M., Elachola, H., Wilder-Smith, A., & Memish, Z. A. (2020). All hands on deck: a synchronized whole-of-world approach for COVID-19 mitigation. *International Journal of Infectious Diseases*, 98, 208–215.
- Ekhaugen, L. (2020). Whole-of-government coordination for complex operations: symbolic politics or coordination failure? *Journal of Strategic Studies*, 1–24. <https://doi.org/10.1080/01402390.2020.1730819>.
- Ferreira, C. M., & Serpa, S. (2018). Society 5.0 and social development: contributions to a discussion. *Management and Organizational Studies*, 5(4), 26.
- Franceschini, G., Englert, M., & Liebert, W. (2013). Nuclear fusion power for weapons purposes. *The Nonproliferation Review*, 20(3), 525–544.
- Fukuyama, M. (2018). Society 5.0: aiming for a new human-centered society. *Japan Spotlight*, Special Issue, 47–50.
- Gerber, L. (1982). The Baruch Plan and the origins of the Cold War. *Diplomatic History*, 6(1), 69–96.
- Hazra, A. (2018). Evaluating the relevance of ceasefires in light of the UN global ceasefire quandary. *Modern Diplomacy*. <https://modern diplomacy.eu/2020/07/18/evaluating-the-relevance-of-ceasefires-in-light-of-the-un-global-ceasefire-quandary/>.
- Holroyd, C. (2020). Technological innovation and building a “super smart” society: Japan’s vision of society 5.0. *Journal of Asian Public Policy*, 1–14. <https://doi.org/10.1080/17516234.2020.1749340>.
- INFUSE. (n.d.). Innovation network for fusion energy. INFUSE. <https://infuse.ornl.gov/>. Accessed 29 September 2020
- Ingersoll, E. (2018). A portfolio approach to funding and commercialization. 1st IAEA Workshop on Fusion Enterprises. <https://nucleus.iaea.org/sites/fusionportal/Shared%20Documents/Enterprises/2018/Presentations/13.06/Ingersoll2.pdf>. Accessed 29 September 2020
- International Crisis Group. (2020). *Global ceasefire call deserves UN Security Council’s full support*. Brussels: ICG.
- International Energy Agency. (2020). Global Commission for Urgent Action on Energy Efficiency. IEA. <https://www.iea.org/programmes/global-commission-for-urgent-action-on-energy-efficiency>. Accessed 29 September 2020
- ITER. (2020a). President Macron to host virtual celebration. ITER. <https://www.iter.org/newsline/-/3473>. Accessed 29 September 2020
- ITER. (2020b). ITER Live: start of machine assembly. ITER. <https://www.youtube.com/watch?v=2-7GyVLKE6A>. Accessed 29 September 2020
- Kearn, D. W. (2010). The Baruch Plan and the quest for atomic disarmament. *Diplomacy & Statecraft*, 21(1), 41–67.
- Kidambi, M. (2017). Fusion drones: Robot technicians for nuclear devices. *Science in School*. <https://www.scienceinschool.org/content/fusion-drones-robot-technicians-nuclear-devices>. Accessed 29 September 2020
- Liu, X., Wang, Z., Ren, Y., Li, J., Yin, D., Li, L., et al. (2017). Mechanical performance evaluation of the CFETR central solenoid model coil design. *Nuclear Fusion*, 58(1), 016035.

- Lopes Cardazo, N. J. (2019). Economic aspects of the deployment of fusion energy: the valley of death and the innovation cycle. *Philosophical Transactions of the Royal Society A*, 377(2141), 20170444.
- Lorenz, M., Rüßmann, M., Strack, R., Lueth, K., & Bolle, M. (2015). Man and machine in Industry 4.0. BCG. <https://www.bcg.com/publications/2015/technology-business-transformation-engineered-products-infrastructure-man-machine-industry-4>. Accessed 29 September 2020
- Mackby, J. (2016). Still seeking, still fighting. *The Nonproliferation Review*, 23(3-4), 261–286.
- Michaels, D. (2020). Fusion startups step in to realize decades-old clean power dream. *The Wall Street Journal*. <https://www.wsj.com/articles/fusion-startups-step-in-to-realize-decades-old-clean-power-dream-11581001383>. Accessed 29 September 2020
- Nambisan, S., Wright, M., & Feldman, M. (2019). The digital transformation of innovation and entrepreneurship: progress, challenges and key themes. *Research Policy*, 48(8), 103773.
- National Academies of Sciences, Engineering, and Medicine. (2019). *Final Report of the Committee on a Strategic Plan for U.S. Burning Plasma Research*. Washington, DC: The National Academies Press.
- Nehl, C. L., Umstatt, R. J., Regan, W. R., Hsu, S. C., & McGrath, P. B. (2019). Retrospective of the ARPA-E ALPHA Fusion Program. *Journal of Fusion Energy*, 38(5-6), 506–521.
- O'Rourke, R. (2020a). *Navy lasers, railgun, and gun-launched guided projectile*. Washington, DC: Congressional Research Service.
- O'Rourke, R. (2020b). *China naval modernization*. Washington, DC: Congressional Research Service.
- Önday, Ö. (2019). Japan's Society 5.0: Going beyond Industry 4.0. *Business and Economics Journal*, 10(2). <https://doi.org/10.4172/2151-6219.1000389>. Accessed 29 September 2020
- Özdemir, V., & Hekim, N. (2018). Birth of Industry 5.0: making sense of big data with artificial intelligence, "The Internet of Things" and next-generation technology policy. *OMICS: A Journal of Integrative Biology*, 22(1), 65–76.
- Paige, G. (2002). *Nonkilling global political science*. Honolulu: Center for Global Nonkilling.
- Paschek, D., Mocan, A., & Draghici, A. (2019). Industry 5.0 – the expected impact of next industrial revolution. In *Management Knowledge Learning International Conference* (pp. 125–132). Reinhausen: KMedu Hub.
- Pereira, A. G., Lima, T. M., & Charrua-Santos, F. (2020). *Industry 4.0 and Society 5.0: opportunities and threats*. *International Journal of Recent Technology and Engineering*, 8(5), 3305–3308.
- Piechowiak-Lamparska, J. (2019). The beginning of a new Cold War? The failure of the NATO–Russia strategic partnership. In L. Czechowska, A. Tyushka, A. Domachowska, K. Gawron-Tabor, & J. Piechowiak-Lamparska (Eds.), *States, international organizations and strategic partnerships* (pp. 166–184).
- Pim, J. E. (Ed.). (2011). *Engineering nonkilling scientific responsibility and the advancement of killing-free societies*. Honolulu: Center for Global Nonkilling.
- Priestley, J. L. (2008). Knowledge transfer within interorganizational networks. In M. E. Jennex (Ed.), *Knowledge management: concepts, methodologies, tools, and applications* (pp. 1762–1774). Hershey: Information Science Reference.
- Ross, R. S. (2020). It's not a cold war: competition and cooperation in US–China relations. *China International Strategy Review*, 2, 63–72. <https://doi.org/10.1007/s42533-020-00038-8>.
- Russell, B. (2003). *The collected papers of Bertrand Russell: Man's peril, 1954–55*. London: Routledge.
- Salgues, B. (2018). *Society 5.0: industry of the future, technologies, methods and tools*. London: Wiley.
- Schwartz, S. I. (Ed.). (1998). *Atomic audit: The costs and consequences of U.S. nuclear weapons since 1940*. Washington, D.C.: Brookings Institution Press.
- SIPRI. (2020). *SIPRI yearbook 2020*. Stockholm: Stockholm Institute for Peace Research.
- Spangher, L., Vitter, J. S., & Umstatt, R. (2019). Characterizing fusion market entry via an agent-based power plant fleet model. *Energy Strategy Reviews*, 26, 100404.
- Strugatsky, L. (2020). AI and the quest for a commercial fusion reactor. *AI Business*. https://aibusiness.com/author.asp?section_id=789&doc_id=762441 &. Accessed 29 September 2020
- The Agility Effect. (2016). Robot to be deployed in reactor core. The Agility Effect. <https://www.theagilityeffect.com/en/article/robot-deployed-reactor-core/>. Accessed 29 September 2020
- Toye, J. (2014). Assessing the G77. *Third World Quarterly*, 35(10), 1759–1774.
- Turekian, V. (2018). The evolution of science diplomacy. *Global Policy*, 9, 5–7.
- United Nations. (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. New York: United Nations.
- Varnum, J. (2014). 60 years of Atoms for Peace. *Nuclear Engineering International*, <https://www.neimagazine.com/features/feature60-years-of-atoms-for-peace-4164653/>. Accessed 29 September 2020
- Yousefikhah, S. (2017). Sociology of innovation: Social construction of technology perspective. *AD-Minister*, 30, 31–43. <https://doi.org/10.17230/ad-minister.30.2>.

- Yuan, Y. (2018). Escape both the ‘Thucydides Trap’ and the ‘Churchill Trap’: finding a third type of great power relations under the bipolar system. *Chinese Journal of International Politics*, 11(2), 193–235.
- Zhao, M. (2019). Is a New Cold War inevitable? Chinese perspectives on US–China strategic competition. *The Chinese Journal of International Politics*, 12(3), 371–394.

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