

The Human Rights Commitments of Private Fusion Energy Companies

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Abstract:

Although the fusion energy sector is at a nascent stage, the private fusion energy market has grown. There are currently 38 private fusion energy companies around the world aiming to commercialize fusion energy technologies in early 2030s and 2040s. Given the capability of fusion energy in transforming today's energy paradigm and the global character of the market, it is important to analyze how these companies are interacting with international human rights standards.

Therefore, this work investigates the involvement of the private fusion energy sector with two voluntary international initiatives in particular: the UN Global Compact and the UN Guiding Principles on Business and Human Rights (UNGP). This study attempts to answer two research questions: (i) Are private fusion energy companies participating in the UN Global Compact? (ii) How are private fusion energy companies publicly implementing the UNGP? Content analysis of secondary data collected from the UN Global Compact, Fusion Industry Association, ITER and companies' official websites as well as published reports is adopted. In summary, this work finds that private fusion energy companies are neither participants nor signatories of the UN Global Compact. Their observance of the UNGP is also very poor.

This study contributes to the field by highlighting this gap which the private fusion energy companies need to consider and take measures towards, in order to create a salutary human rights sector.

Keywords: fusion energy; UN Global Compact; UN Guiding Principles on Business and Human Rights; private fusion energy companies.

JEL Classification: K32; K38; L99; M13; O13; Q42.

Introduction

Fusion energy is considered a game changer for our global energy future. Fusion is the process that powers the sun and thereby enables life on earth to exist. It occurs when hydrogen-like particles at extremely high temperature fuse to make a heavier element, like helium. In this process energy is released, eventually appearing as heat. Fusion electrical power plants would produce no carbon-based pollutants, have minimal long-lived radioactive waste, and benefit from an almost limitless fuel supply (Burbidge *et al.*, 1957; National Academies of Sciences, Engineering, and Medicine, 2019). Fusion energy has the capability of meeting the global surge in electricity demand expected in the coming decades. A kilogram of fusion fuel can produce as much energy as 10,000 tons of coal, oil, or natural gas, being able to supply all of the world's energy needs for millions of years without producing environmentally damaging waste and carbon dioxide emissions (McCracken and Stott, 2012). In November 2021 for the first-time fusion energy was part of the official dialogue of the 26th Conference of the Parties (COP26) in Glasgow and was recognized as a climate change mitigation power source (UK Atomic Energy Authority, 2021).

Although the fusion energy sector is at a nascent stage and there are still considerable scientific and technical difficulties being encountered with regards to its feasibility and the construction of commercial-scale fusion power plants and reactors, the private fusion energy market has grown. Just one private fusion energy company has attracted USD2 billion in investment (Wang, 2022). Their focus is on a commercial exit strategy and achieving a return on investment (Pearson *et al.*, 2020). There are currently 38 private fusion energy companies around the world aiming to commercialize fusion energy in early 2030s and 2040s. Commonwealth Fusion Systems, for example, aims to complete its first fusion power plant, called ARC, in early 2030s (Commonwealth Fusion Systems, 2021). TAE Technologies has a similar target for completion of its modular, portable, and scalable commercial hydrogen-boron fusion power plants (TAE Technologies, 2022). Fusion Reactors Ltd is developing a fusion reactor to deliver electricity to the grid from fusion energy by the end of 2032 (Fusion Reactors Ltd., 2022).

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Governments around the world are regulating fusion energy to make clear in law its regulatory treatment. The United Kingdom (UK) government, for example, has recently had an open consultation on its proposals for a regulatory framework for fusion energy (DBEIS, 2022). However, research in this field focuses mainly on technical and scientific issues, particularly on weaknesses and strengths of different technologies and commercialization issues (Costley, Hugill and Buxton, 2015; Wolf *et al.*, 2016; Whyte *et al.*, 2016; Wurden *et al.*, 2016, Chuyanov and Gryaznevich, 2017; Shahzad, 2020) as well as health and safety standards (Alzbutas and Voronov, 2015; Lukacs and Williams, 2020; Larsen and Babineau, 2020; Lomonaco *et al.*, 2021; Wang *et al.*, 2021). Given the capability of fusion energy of transforming today's energy paradigm (Sanchez, 2014), the growing number of private companies involved in the sector and the global character of the fusion energy market, it is important to analyze how these companies are interacting with international human rights standards.

There have been major attempts at the international level to incorporate respect for human rights into companies' behavior in order to reduce actual and potential damage from corporate activity to human rights (Bernaz, 2017). At the United Nations (UN) level there are the UN Global Compact and the UN Guiding Principles of Business and Human Rights. Although these instruments are non-legally binding (Deva, 2021), they are important features of the global governance of business in the area of human rights.

Companies can participate in the UN Global Compact by committing to implement its Ten Principles in the areas of human rights, labor rights and the environment and making sure they are not complicit in human rights abuses. In line with the UN Guiding Principles on Business and Human Rights, all business enterprises, regardless of their size, sector, location, ownership and structure have a duty to respect human rights and to put in place the management structures necessary to this end.

There are to date no studies that address the interplay between private fusion energy companies and international human rights standards. This work aims to contribute towards filling this research gap. It attempts to answer two research questions: (i) Are private fusion energy companies participating in the UN Global Compact? (ii) How are private fusion energy companies publicly implementing the UN Guiding Principles on Business and Human Rights?

In order to answer those questions, this study focuses on the content analysis of secondary empirical data collected from the UN Global Compact, the Fusion Industry Association, ITER and companies' official websites as well as published reports. Empirical data is combined with existing scholarship to render a comprehensive account of the interaction between private fusion energy companies and international human rights standards within the scope of the UN Global Compact and UN Guiding Principles on Business and Human Rights.

This paper is organized into three sections. The first section presents the research method and methodology. The second section discusses the involvement of the private fusion energy companies with the UN Global Compact. The third section assesses the implementation of the UN Guiding Principles on Business and Human Rights by private fusion energy companies, followed by the final remarks calling for action from the fusion energy sector to create, at least, a human rights policy. Further research on this field is also welcome, particularly on mapping the fusion energy companies' key potential human rights impacts within its activities as well as supply chain.

1. Methodology

The data was collected between 1 May 2022 and 30 June 2022. A variety of secondary sources were used, including data from the UN Global Compact, the Fusion Industry Association, ITER and companies' official websites as well as published reports (Windridge, Holland and Bestwick, 2021; Market and Research. Biz, 2022). All private fusion energy companies had an official website, except Compact Fusion Systems whose website only had the message "currently in stealth mode", Agni Energy Inc. whose website was not working and Breakthrough Fusion International which did not have an official website.

Initially a list of all private fusion energy companies was completed. Only private companies developing fusion reactors for commercial use and/or designing fusion power plants were included. The focus of the study is on the private sector. Therefore, public companies and research institutions such as Lockheed Martin Skunk Works and Culham Centre for Fusion Energy, respectively were not included in the research. The list of all private fusion energy companies worldwide is included in alphabetical order in Table 1:

Table 1. Private fusion energy companies worldwide in alphabetical order.

Name	Country-Headquarters	Fusion Reactor (Design/Approach)	Website
Agni Energy Inc.	USA	Alfvén-wave gyrating non-linear inertial-confinement reactor	https://www.agnifusion.org/
ALBOT Technologies Pvt Ltd.	India	Tokamak	https://albot.io/index.html
Avalanche	USA	Orbitron	https://www.avalanche.energy/
Breakthrough Fusion International	USA	PJMIF (Plasma Jet Magneto Inertial Fusion)	No website
Commonwealth Fusion Systems	USA	Tokamak	https://cfs.energy/
Compact Fusion Systems	USA	Liquid Liner Compressor	https://www.compactfusionsystems.com/
Crossfield Fusion Ltd.	UK	Inertial-electrostatic confinement	http://crossfieldfusion.com/
CTFusion, Inc.	USA	Magnetic Confinement Fusion – Spheromak	https://ctfusion.net/
ENN Science and Technology Development Co., Ltd	China	Spherical Tokamak	http://en.ennresearch.com/about/
EX-Fusion	Japan	Laser based fusion	https://www.ex-fusion.com/
First Light Fusion	UK	Impact Inertial Confinement	https://firstlightfusion.com
Focused Energy, Inc.	USA	Laser based fusion	https://focused-energy.world/
Fuse Energy Technologies Inc.	Canada	Various small-scale fusion reactors	https://www.f.energy/
Fusion Reactors Ltd.	UK	Magnetic Confinement Fusion	https://www.fusion-reactors.com/
General Atomics	USA	Tokamak	https://www.ga.com/
General Fusion	Canada	Magnetized target fusion	https://generalfusion.com/
HB11 Energy Holdings Pty Ltd	Australia	Laser Boron Fusion / Direct Laser Driven pB11	https://hb11.energy/
Helical Fusion Co., Ltd.	Japan	Magnetic Confinement Fusion	https://www.helicalfusion.com/
Helicity Space Corporation	USA	Merging Plasma Plectonemes	https://www.helicityspace.com/
Helion Energy, Inc.	USA	Field Reversed Configuration (FRC)	https://www.helionenergy.com/
HOPE Innovations Inc.	Canada	Converter and hybrid reactor	http://www.hopeinnovations.ca/
Horne Technologies	USA	Hybrid magnetic and electrostatic confinement	https://www.hornetechnologies.com/
Hyperjet Fusion Corporation	USA	PJMIF (Plasma Jet Magneto Inertial Fusion)	http://hyperjetfusion.com/
Innoven Energy	USA	Laser Inertial Confinement Fusion	https://innoven-energy.com/
Kyoto Fusioneering Ltd.	Japan	Tokamak	https://kyotofusioneering.com/en/company
LPP Fusion, Inc.	USA	Dense Plasma Focus	https://www.lppfusion.com/
Marvel Fusion	Germany	Laser Inertial Confinement Fusion	https://marvelfusion.com/

Name	Country-Headquarters	Fusion Reactor (Design/Approach)	Website
Magneto-Inertial Fusion Technologies, Inc. (MIFTI)	USA	Staged Z-pinch	https://miftec.com/
NearStar Fusion Inc.	USA	Hypervelocity Gradient Field Fusion (HGFF)	https://www.nearstarfusion.com/
Phoenix, LLC	USA	Hydrogen-based nuclear fusion reactor	https://phoenixwi.com/
Princeton Fusion Systems, Inc.	USA	Field Reversed Configuration (FRC)	https://www.princetonfusionsystems.com/
Pulsar Fusion Ltd	UK	Tokamak	https://pulsarfusion.com/
Renaissance Fusion	France	Stellarator	https://stellarator.energy/
SHINE Technologies, LLC	USA	Beam-target fusion devices	https://www.shinefusion.com/
TAE Technologies	USA	Advanced Beam-Driven Field Reversed Configuration	https://tae.com/
Tokamak Energy	UK	Spherical Tokamak	https://www.tokamakenergy.co.uk/
Type One Energy	USA	Stellarator	https://www.typeoneenergy.com/
ZAP Energy Inc.	USA	Z-pinch	https://www.zapenergyinc.com/

Source: Author's table

2. The Non-Participation of Private Fusion Energy Companies in the UN Global Compact

The UN Global Compact is part of the soft law initiatives within the United Nations which have blossomed in the field of business and human rights with a view of developing standards of behavior for corporations. It was formally launched in 2000 with nine principles in the areas of human rights, labor rights and the environment. In June 2004, a tenth principle relating to anti-corruption was added (Deva, 2021).

These principles were drawn from existing UN documents and agencies such as the International Labor Organization (ILO) and the Commission on Human Rights. These principles are also very similar to the Sullivan principles, which were drawn up by Reverend Sullivan, who had successfully promoted a similar idea in many African countries of making corporations more responsive to the social needs of the communities in which they operate (King, 2001).

The principles encompass two on the protection of internationally proclaimed human rights and non-complicity in human rights abuses; four on labor, focusing on elimination of discrimination and child and compulsory labor, as well as promotion of the freedom of association; three on the protection of the environment, supporting a precautionary approach to environmental challenges, the promotion of greater environmental responsibility and encouraging the development and diffusion of environmentally friendly technologies.; and one principle on anti-corruption and bribery (UN Global Compact, 2022a).

There is no agreed definition on the exact interpretation of these principles. Although the Compact Office publishes some guidance notes, the principles' vagueness can be counterproductive as insincere corporations can easily circumvent or comply with them without doing anything to promote human rights (Deva, 2006). Difficulties lie with the principles concerning human rights in particular as there are different views on what human rights are as well as how businesses are responsible for them (Brenkert, 2016). However, at the United Nations level, it is generally understood that, at a minimum, companies are responsible for respecting the rights set out in the International Bill of Human Rights and the principles concerning fundamental rights set out in the International Labour Organization's Declaration on Fundamental Principles and Rights at Work. International Bill of Human Rights cover the Universal Declaration of Human Rights (UDHR), the International Covenant on Economic Social and Cultural Rights (ICESCR), and the International Covenant on Civil and Political Rights (ICCPR) (Smith, 2020).

The UN Global Compact is part of the framework for voluntary initiatives for corporate sustainability and responsibility (Rasche and Waddock, 2014). It is considered the world's largest corporate sustainability initiative of more than 12,000 businesses and 3,000 non-business stakeholders across 160 countries (UN Global Compact, 2022a). If fusion energy companies intend to participate in the Compact, the highest-level executive (i.e. Chief Executive or Board of Directors) of the companies is required to send a letter to the UN Secretary-General

‘committing to implement the Ten Principles of the UN Global Compact, take action in support of the Sustainable Development Goals and submit an annual Communication on Progress (COP).

Most fusion energy companies are small and medium enterprises (SMEs) or micro-organizations. However, not only large companies, but also SMEs and micro-organizations can participate in the UN Global Compact as a participant or signatory. Since January 2020, the UN Global Compact has been accepting all businesses and organizations that fulfil the criteria for participation, regardless of the number of employees. All participating companies and organizations are required to have at least one direct employee and active operations in order to be eligible to join the UN Global Compact. Companies from any industry or sector are eligible for participation except those which are subject to a UN sanction, listed on the UN Ineligible Vendors List for ethical reasons (UNOPS, 2022), derive revenue from controversial weapons (antipersonnel landmines or cluster bombs) or from the production and/or manufacturing of tobacco (UN Global Compact, 2022b). This means that all 38 private fusion energy companies are eligible for participation unless their funds are partially or totally originated from the prohibited sources.

The analysis of empirical data from the UN Global Compact official website has demonstrated the non-existent engagement of the private fusion energy sector with this initiative as the private fusion energy companies are neither participants nor signatories of the UN Global Compact.

The reasons as to why the fusion energy sector are not participating in the UN Global Compact may be multifold. Firstly, the majority of private fusion energy companies are small and medium enterprises (SMEs) or micro-organizations. They may not be aware of the UN Global Compact and may not have the expertise and staff resources to put into practice voluntary initiatives on the business responsibility for human rights and to produce and submit an annual Communication on Progress.

Secondly, there may also be cost issues associated with joining the UN Global Compact. The majority of private fusion energy companies are surviving on a tight budget to develop the technology. However, in order to participate in the UN Global Compact there would be additional costs for fusion energy businesses as an annual contribution is required depending on the engagement tier (participant or signatory) and the company’s annual revenue (UN Global Compact, 2022b).

Thirdly, joining the Compact is also likely to put some additional burden on the fusion energy sector since companies would need to adopt some kind of code of conduct, and assign the responsibility of looking after the implementation of the Ten Principles to someone within the organization. Fourthly, there may be some reluctance in participating as that might serve as the basis of litigation against them if, for example, companies make public statements in line with the Ten Principles but are found to be misleading, such as the American case *Kasky v. Nike, Inc.* Lastly, some fusion energy businesses may object that they have human rights responsibilities altogether, and therefore, may be unwilling to participate in initiatives, such as the UN Global Compact, as it is required that companies make the Global Compact and its principles an integral part of their business strategy, day-to-day operations and organizational culture (Bernaz, 2017).

Based on information available on the companies’ website as of 30 June 2022, only 18.4% of the companies publicly elaborated on some of the human rights and labor values associated with the UN Global Compact Ten Principles: ALBOT Technologies Pvt Ltd., Fusion Reactors Ltd., Kyoto Fusionering Ltd., Phoenix, SHINE Technologies, Tokamak Energy and ZAP Energy Inc. Fusion Reactors Ltd. was the only company which expressly connected its activities in support of the Sustainable Development Goals (SDS). This does not lead to the conclusion that fusion energy companies are acting contrary to human rights standards as even without publishing information on their website and participating in the Compact, businesses could have non-published codes of conduct in line with international human rights standards, join other initiatives and meet their social responsibilities in an effective manner.

While the UN Global Compact does not have mandate to be a regulatory, compliance and monitoring body, it is important for private fusion energy companies to join the UN Global Compact in order to advance the case for responsible business practices in the fusion energy sector and participate in an initiative which aims to provide a platform for continuous improvement, public accountability, learning, and dialogue (UN Global Compact, 2022b). By participating it gives a message that the fusion energy sector is at least aware of the Ten Principles which can increase trust in the companies’ brand, the sector and attract investment support if, for instance, the Equator Principles on investments are followed (Equator Principles, 2022).

Companies in the energy sector, particularly in the extractive industries of oil and mining, which have huge impacts in communities in which they operate, have been subject to many claims of corporate human rights abuses. Examples of how pessimist appraisals of corporate human rights abuses have gained notoriety with time in this sector emerges from international disputes, such as *Wiwa et al v. Royal Dutch Petroleum et al.*, 226 F.3d 88 (2000),

Chevron Corporation and Texaco Petroleum Corporation v. Ecuador (II), PCA Case No. 2009-23 and South American Silver Limited v. Bolivia, PCA Case No. 2013-15.

Although the nature and character of the fusion energy companies' activities are very different from the oil and mining industries, bringing awareness to the fusion energy sector of international human rights standards while the sector is still incipient may assist in building this new sector in conformity to principles which incorporate protection of human rights, fair treatment of workers, environmental sustainability and elimination of bribery and corruption. As these companies expand their operations nationally and abroad, it is paramount that this takes place in a salutary human rights environment.

However, the role of the UN Global Compact in promoting business respect for human rights has been widely criticised (Deva, 2006; Rasche and Waddock, 2014; Prakash Sethi and Schepers, 2014). One of these criticisms concerns the inefficiency of the Global Compact to provide transformative guidance to businesses to change their business model from corporate impunity (Deva, 2021). Thus, the participation of fusion energy companies in the Global Compact may serve as a way to legitimize business as usual with a facet of corporate responsibility and potentially allow for its misuse as a marketing tool. The UN Global Compact's open acknowledgement of being an aspirational principle-based initiative rather than a compliance, monitoring and enforcement mechanism may also cause some issues in terms of its efficiency and efficacy in ensuring conformity to the principles and reducing existing lacunae between the principles and business practice.

The only compulsory requirement for businesses is to submit the annual Communication on Progress (COP). Failure to submit a COP may result in a participant's status downgraded from 'active' to 'non-communicating' and being expelled if it fails to submit the COP for two years consecutively (Deva, 2021). This means that, apart from some reputational damage which may occur and thereby, possibly, some negative impact on the companies' operations and success, there are no additional consequences for companies which are submitting the COP but making little or no progress on the promotion of business respect for human rights. This lack of serious consequences puts in check the efficiency of the UN Global Compact.

On the basis of the above findings, it can be reasonably concluded that the fusion energy sector is not being represented in the UN Global Compact. Despite its criticism, participation of the fusion energy sector in the UN Global Compact could be an initial attempt to stimulate these companies to publicly express their commitment to meet its responsibility to respect human rights, allowing, therefore, for an embrace of international human rights standards and assisting in the creation of business models that are just and inclusive.

The UN Global Compact serves as an important instrument to share good corporate practices and learn from each other's experiences. This is particularly relevant for the private fusion energy sector as this might help drive out bad practices from the sector at its emerging stage. Although the Global Compact lacks verification, independent monitoring and enforcement mechanisms, participation also adds some moral compass and possible reputational damage if it fails to embrace the Ten Principles. It could be relevant to have further in-depth investigation to understand the reasons behind non-participation, so that the issues may be tackled. In any case, the core purpose of this paper is that it contributes to the discussions in the field by highlighting this non-engagement.

3. Private Fusion Energy Companies Responsibilities under the UN Guiding Principles on Business and Human Rights

The UN Guiding Principles on Business and Human Rights (UNGPs) are part of a movement which aims to extend the accountability for human rights beyond governments and states, to businesses. Central to the UNGPs is the principle that corporations have a responsibility to respect human rights in their operations whether or not doing so is required by law and whether or not human rights laws are actively enforced (Cragg, 2015). Therefore, fusion energy companies have the task of embedding human rights considerations in their business strategy, identifying human rights risk in their activity and supply chains through due diligence, as well as taking the necessary steps to mitigate such risks or make public disclosures. In this context, this section focuses on the second research question and therefore analyze how private fusion energy companies are publicly implementing the UNGPs.

The UNGPs are a non-legally binding instrument which set the global standard of practice applicable to all states and all business enterprises, regardless of their size, sector, location, ownership and structure. They cover distinct, but complementary responsibility between states and companies. Fusion energy companies do not have to provide their consent to be subject to the UNGPs as all businesses are considered bound by the framework irrespectively of their willingness (Wettstein, 2015). The UNGPs reflect and build on the three-pillar structure of the "Protect, Respect and Remedy" Framework which consists of the State's duty to protect human rights, the corporate responsibility to respect human rights and the need for greater access to remedy for victims of business-related abuse (UN 2012).

Principles 11 to 24 of the Guiding Principles are aimed at corporations and their responsibility to respect human rights. In line with these principles, fusion energy companies are expected to avoid causing or contributing to adverse human rights impacts through their own activities, address such impacts if, or when, they occur; and seek to prevent or mitigate any adverse human rights impacts that are directly linked to their operations, products or services by their business relationships, even if they have not contributed to those impacts. These are not considered legal obligations, but a social norm, as a set of societal expectations of corporate behavior (Ruggie, 2017). This means that there is no legal enforcement for non-compliance.

In line with the UNGP, fusion energy companies are required to be proactive by (1) adopting a policy commitment to respect human rights which must be publicly available and communicated internally and externally to all personnel, business partners and other relevant parties; (2) conducting human rights due diligence (HRDD) to identify, prevent, mitigate and account for how they address their impacts on human rights; and (3) having processes in place to enable remediation of any adverse impact they cause or contribute to, particularly via the establishment or participation in effective operational-level grievance mechanisms for those potentially impacted by the business enterprise's activities (UN, 2012).

A human rights policy is considered a company's public expression of its commitment to meet its responsibility to respect internationally recognized human rights standards (UN Global Compact, 2022c). Although a human rights policy can take many forms and has no definitive template, there were no documents published on the private fusion energy companies' website entitled "human rights policy" or "statement of policy". There was no explicit commitment to respect all internationally recognized human rights standards either.

There were, however, a few publications of a code of conduct and/or company's values as well as a few public expressions which could be inferred as the company's commitment to meet its responsibility to respect human rights, such as the rights set out in the International Bill of Human Rights and in the International Labor Organization's Declaration on Fundamental Principles and Rights at Work (UN Global Compact, 2022c).

Table 2. Private fusion energy companies with code of conduct/values published on website

Name	Country-Headquarters	Code of Conduct/ Values connected to human rights	Website
ALBOT Technologies Pvt Ltd.	India	Diversity & inclusion, transparency and sustainable practices	https://albot.io/index.html
Fusion Reactors Ltd.	UK	Fairness, inclusivity, sustainability, honesty	https://www.fusion-reactors.com/
Kyoto Fusioneering Ltd.	Japan	Respect for colleagues and for the whole of society	https://kyotofusioneering.com/en/company
SHINE Technologies, LLC	USA	Inclusivity	https://www.shinefusion.com/
Tokamak Energy	UK	Teamwork (considering others), honesty, safety (taking care of each other)	https://www.tokamakenergy.co.uk/
ZAP Energy Inc.	USA	Diverse and inclusive workforce	https://www.zapenergyinc.com/

Source: Author's table

The wording of the published code of conduct and values was broad and not followed by much detailed information about what they entailed. Diversity and inclusion which are associated with articles 2 and 7 of the Universal Declaration of Human Rights as well as article 2 of the International Covenant on Economic, Social and Cultural Rights were the human rights more widely publicized appearing on four companies' websites. Wide-ranging wording, such as fairness, transparency, respect, considering others and taking care of each other could be associated with different human rights. Respect, considering other and taking care of each other, for example, could be connected with article 25 of the Universal Declaration of Human Rights which covers the right to a standard of living adequate for the health and well-being of oneself and one's family.

From these inferences, one can conclude that the elaboration of codes of conduct and human rights policies in the private fusion energy sector is very poor and vague. In addition to an explicit commitment to respect all internationally recognized human rights standards, information on how the company will account for its actions to meet its responsibility to respect human rights should be included in its policies. However, none of this information can be found on private fusion energy companies' websites. This is an invaluable finding of this study as it highlights

this gap which the sector needs to consider and takes the necessary measures to conform with the requirements under the UNGP. As a first step, a basic mapping of the fusion energy companies' key potential human rights impacts within its activities as well as supply chain should be conducted, so that their policies can be written in more detail and reflected in operational policies and procedures. Nonetheless, all fusion energy companies should at least have a published human rights policy committing to respect human rights.

The Guiding Principles 15 and 17-21 also outline a four-step human rights due diligence process: assessing actual and potential human rights impacts, integrating and acting on the findings, tracking responses, and communicating how impacts are addressed. In the context of the Guiding Principles, human rights due diligence comprises an ongoing management process that a reasonable and prudent enterprise needs to undertake, in the light of its circumstances (including sector, operating context, size and similar factors) to meet its responsibility to respect human rights (UN, 2012).

The content analysis of the companies' website demonstrates that no private fusion energy company has published any information on their website concerning human rights due diligence. The same conclusion also applies to the establishment or participation in effective operational-level grievance mechanisms for those potentially impacted by the business enterprise's activities elaborated under Guiding Principle 29. No private fusion energy company has published any information on their website concerning operational-level grievance mechanisms. From one point of view, they are considered one of the most systematic ways for an enterprise to provide for the remediation of adverse human rights impact (UN, 2012). Whereas, from another point of view, operational-level grievance mechanisms are heavily criticized as an ineffective remedy to victims of human rights violations (Deva, 2012; Zerk, 2012; Lukas *et al.*, 2016; Wielga and Harrison, 2021).

On the basis of the above findings, it can be reasonably concluded that private fusion energy companies are not engaging fully with their human rights responsibilities under the UN Guiding Principles on Business and Human Rights. Most of these businesses have not even adopted some kind of code of conduct. Given the voluntary nature of the UNGP and the lack of enforcement mechanisms, one may reach the interpretation that they can be dismissed as an instrument which a company is not required or obliged to follow (Knopfel, 2017). However, as the fusion energy sector has a global character, further research on the human rights risks of the fusion industry operation should be carried out, and the requirements under the UNGP followed in order to manage any adverse impacts on human rights. As a first step, the fusion energy companies should be creating their own human rights policies.

Conclusion

This work has examined the human rights commitments of private fusion energy companies through the prism of companies' participation in the UN Global Compact and through the principle of the corporate responsibility to respect human rights as described in the UNGP. Particularly, it focused on human rights policy, due diligence and operational-level grievance mechanisms.

Overall, the analysis revealed the non-existent engagement of the private fusion energy sector with the UN Global Compact as the companies are neither participants nor signatories of this initiative with only 18.4% of the companies having publicly elaborated on some of the human rights and labor values which could be associated with the UN Global Compact Ten Principles. The reasons as to why the fusion energy sector are not participating in the UN Global Compact may be multifold, such as lack of awareness of this initiative, lack of expertise and resources, litigation concerns or even complete objection to human rights responsibilities for businesses.

The observance of the principle of corporate responsibility to respect human rights under the UNGP is also very weak. No company made an explicit commitment to respect all internationally recognized human rights standards, and information on how any company will account for its actions to meet its responsibility to respect human rights is not found on their websites. Only six companies elaborated on a code of conduct or values which could be associated with human rights. However, the language used was broad and not followed by much detailed information about what they entailed. There was no publication on the companies' websites concerning human rights due diligence and operational-level grievance mechanisms.

Although both the UN Global Compact and the UN Guiding Principles on Business and Human Rights do not effectively address the question of corporate human rights responsibility due to their non-legally binding character and lack of enforcement, they do provide a platform to develop human rights standards in the fusion energy sector, and an initial attempt to stimulate these companies to publicly express their commitment to meet their responsibilities to respect human rights, allowing, therefore, for an embrace of international human rights standards and thus assist in the creation of business models that are just and inclusive.

Based on publicly available information, this study highlights the gap between the interaction of private fusion energy companies and international human rights standards in the context of the UN Global Compact and

UNGP. The private fusion energy sector needs to consider this lacuna and take the necessary measures to conform with the requirements under the UNGP, such as creating and publishing a comprehensive human rights policy, establishing a human rights due diligence and an operational-level grievance mechanism. This work also calls for further research in this field, particularly on mapping the fusion energy companies' key potential human rights impacts within their activities as well as supply chain(s), so that from the beginning this nascent sector can be more responsive to the social needs of the communities when fully operational.

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