**Toxic pollution and human rights implications of some climate change solutions**

Submission for the Special Rapporteur on hazardous substances and wastes

*March 2023*

1. The Center for International Environmental Law (CIEL) is pleased to submit the present written comments to the Special Rapporteur on the implications for human rights of the environmentally sound management and disposal of hazardous substances and wastes, regarding his upcoming report on issues related to the toxic pollution and human rights implications of some climate change solutions[[1]](#footnote-1), and commends his choice to focus on this topic.
2. CIEL’s submission focuses primarily on the toxic impacts and human rights implications of technologies that purport either to **(i)** capture carbon dioxide from an emitting source before it enters the atmosphere and inject it underground or use it in another process or product (**carbon capture and storage (CCS) or carbon capture utilization and storage (CCUS)**), or **(ii)** remove carbon dioxide from the atmosphere (**carbon dioxide removal** **(CDR)**), such as through **direct air capture with carbon storage (DACCS)** or **bioenergy with carbon capture and storage (BECCS)**. While proponents often claim that CCS/CCUS, DACCS, and BECCS are climate “solutions”, these technologies are unproven at scale, face multiple feasibility constraints, and divert attention and resources from the only possible pathway to avoiding catastrophic climate change while respecting human rights - namely, rapidly reducing greenhouse gas (GHG) emissions through the immediate phase-out of fossil fuels, scale-up of renewable energy, increase in energy efficiency, and reduction of energy demand.[[2]](#footnote-2) Moreover, CCS/CCUS and CDR technologies also pose significant documented risks to human rights and the environment.
3. The following sections address these indirect and direct impacts and threats to human rights and the environment, with particular attention to the toxicity of the chemicals and processes involved in the deployment of CCS/CCUS and CDR, and their relationship to existing sources of pollution and climate-related harm.
4. This submission also addresses the hazards and risks to human rights posed by hydrogen and ammonia, which are touted as alternative energy sources for the future, despite the fact that virtually all hydrogen produced today (and ammonia made with it) is made from fossil fuels, especially gas. Rather than a key “bridge” or destination fuel in the needed transition to renewable energy, hydrogen is a tether to the fossil economy and its deleterious impacts, and a source of new risks associated with its volatility, combustion emissions, and the water-intensity of its production.
5. CCS/CCUS, CDR technologies, and hydrogen (particularly fossil hydrogen) jeopardize the enjoyment of a broad range of human rights, including the rights to life, to health, to a clean, healthy and sustainable environment, to water, to food, as well as the right to non-discrimination. In respect of the latter, it should be noted that toxic impacts of CCS/CCUS and CDR technologies are often felt more acutely by certain groups, in particular Indigenous peoples, ethnic minorities, and persons of African descent.
6. **CO2 leakages and air pollution from CCS and CCUS processes**
7. CCS and CCUS refer to processes for the collection of CO2 generated by an emitting facility or activity, such as coal or gas-fired power plants or petrochemical manufacturing, and its injection underground for storage or utilization in industrial processes.[[3]](#footnote-3)
8. In one of its most recent reports, the Intergovernmental Panel on Climate Change (IPCC) categorized CCS/CCUS technologies as among the mitigation options with the highest cost and lowest potential to contribute to emissions reductions by 2030.[[4]](#footnote-4) Consequently, the potential for CCS/CCUS to contribute to the reduction of net emissions in the near term - the period when significant emissions reduction is the most important, in order to keep global temperature rise under 1.5°C and avoid the irreversible consequences of overshoot – is negligible, while their financial costs are high. Furthermore, CCS/CCUS technologies can also be harmful to peoples’ rights and the environment - including through the exacerbation of toxic pollution,[[5]](#footnote-5) raising safety and health concerns.[[6]](#footnote-6)

*Direct impacts*

1. The entire CCS/CCUS process involves risks of toxic impacts, starting with the capture of CO2 itself. In order for the CO2 from an industrial facility to be captured, the most common type of CCS units use amine-based solvents,[[7]](#footnote-7) relying on large amounts of chemicals for the process and releasing significant quantities of ammonia.[[8]](#footnote-8) The release of ammonia (whose “high toxicity”[[9]](#footnote-9) is undisputed) from the CCS/CCUS process represents a hazard for neighboring communities and a threat to neighboring people’s rights to life, to health and to a clean, healthy and sustainable environment - in particular for children and people in vulnerable situations .[[10]](#footnote-10)
2. The transport of captured CO2, by pipeline or by ship, also entails several risks. At high concentrations, carbon dioxide is a toxic gas and an asphyxiant, which can cause “‘circulatory insufficiency’, coma and death.”[[11]](#footnote-11) In addition, depending on the source of capture, compressed CO2 may be mixed with other contaminants such as the hydrogen sulfide, whose presence increases the risk of pipe corrosions and leaks, and whose qualification as a “poisonous chemical”[[12]](#footnote-12) compounds the health risks and potential hazards for people and animals in case of exposure.
3. The injection and storage of CO2 in ​​underground reservoirs entails a series of complex issues and risks, since it increases the pressure in these underground geological formations, which in turn can lead to earthquakes (“induced seismicity”) or “to the pollution of potable water”[[13]](#footnote-13) in the event of a leak or due to contamination with produced water or brine displaced by CO2 injection, among other impacts.[[14]](#footnote-14) Geological carbon storage produces high-salinity brines[[15]](#footnote-15) that may contain toxic metals and radioactive substances, and that have to be reinjected or disposed of to avoid polluting ecosystems and prevent harmful effects on the environment. Even the reinjection and disposal of these brines, however, can be “environmentally challenging”.[[16]](#footnote-16) The resulting environmental and health damage threatens the rights to health, to a clean, healthy and sustainable environment, and to water.

*Indirect impacts*

1. The inseparable link between CCS/CCUS and the fossil fuel economy compounds the toxic impacts of these technologies and their risks to rights. Because CCS/CCUS technology is applied to an underlying source of pollution by design, it risks locking in place fossil fuel-reliant facilities and processes, exacerbating environmental injustice in communities already burdened by the associated pollution.
2. This is particularly the case with increased air pollution linked to the additional fuel consumption necessary to power CCS/CCUS processes. These technologies require a lot of energy to function, leading to a significant energy penalty at the underlying emitting facility. For example, applying carbon capture to a coal or gas power plant “increases the fuel requirement for electricity generation by 13–44%.”[[17]](#footnote-17) In other words, applying CCS/CCUS to a fossil-fuel burning facility requires that facility to burn more fossil fuels for the same output, increasing associated air pollution – particularly of hazardous emissions other than CO2, which are not captured by CCS such as NOx. As the European Environment Agency (EEA) notes, nitrogen oxides “seem to increase almost proportionally with the increase in primary energy demand needed to run the capture unit.”[[18]](#footnote-18)
3. The indirect impact of the CCS/CCUS energy penalty has led the EEA to state that “the lifecycle emissions from the CCS/CCUS chain, particularly the additional indirect emissions from fuel production and transportation, may also be significant in some instances. The magnitude of the indirect emissions, for all pollutants, can exceed that of the direct emissions in certain cases.”[[19]](#footnote-19)
4. In some instances, the increased pollution load due to increased fuel consumption from CCS/CCUS technologies has been cited by private companies - including Chevron Phillips,[[20]](#footnote-20) Dow Chemical[[21]](#footnote-21) and ExxonMobil[[22]](#footnote-22) - to justify not incorporating carbon capture technology into their facilities.
5. Finally, the impacts of air pollution and release of toxic substances from CCS/CCUS often disproportionately affect marginalized communities, including low-income populations, Indigenous Peoples, and other people in vulnerable situations many of whom are “already overburdened by the heavy concentration of toxic industrial pollution,”[[23]](#footnote-23) in violation of these communities’ rights to non-discrimination.
6. **Chemical pollutants byproducts and air pollution from Direct Air Capture**
7. Direct air capture (DAC) [also called DACCS] is a process through which CO2 molecules are pulled directly from the atmosphere, where they exist in smaller concentrations than at industrial point sources of emissions (to which CCS/CCUS can be applied). Due to the difficulty of collecting CO2 present in low concentrations, DAC requires far more energy per ton of carbon dioxide removed than CCS/CCUS, and it is also more expensive.[[24]](#footnote-24)
8. Two processes are currently the main focus of research around DAC, using two different chemicals and chemical reactions to obtain the capture of the CO2: the first one relies on hydroxide sorbents, a product of chlorine (Cl2) synthesis, contained in water solutions, while the second one uses amine materials, especially monoethanolamine (MEA).[[25]](#footnote-25)

*Direct impacts*

1. Deploying either of the DAC processes described above at scale would involve the use of significant quantities of toxic chemicals whose upstream production and downstream release entails risks for the rights to health and to a clean, healthy and sustainable environment. When it comes to DAC processes using hydroxide sorbents, the main byproduct of the process is chlorine gas,[[26]](#footnote-26) which raises “concerns about its handling, since it is a highly poisonous gas and a potential ingredient in chemical warfare,”[[27]](#footnote-27) “posing risks which are difficult to evaluate a priori.”[[28]](#footnote-28) Other processes relying on amine materials necessitate chemicals such as MEA, a product of the synthesis of ammonia and ethylene oxide, both of these toxic substances “come from fossil fuel precursors, mainly oil and natural gas.”[[29]](#footnote-29)
2. The risks posed by the chemical pollutants contained in the sorbents used by DAC technologies are so significant that they have been identified as a possible obstacle to their deployment at scale.[[30]](#footnote-30) Overall, studies indicate that the solid waste from the recovery cycles of the separation processes implemented by DAC “will have similar environmental implications and disposal guidelines as the reclaimer waste in conventional amine scrubbing operations.”[[31]](#footnote-31)
3. Although touted by proponents and included in some climate mitigation models, DAC is a nascent technology that has not been implemented or proven at scale, and its side-effects have not been discussed in depth by literature,[[32]](#footnote-32) especially with regard to production of chemical waste. What is clear is that any large-scale DAC “will require extensive amounts of materials, and therefore mineral extraction, refining, transportation and waste disposal infrastructures,”[[33]](#footnote-33) which in turn will have significant impacts on health and the environment.

*Indirect impacts*

1. Like the deployment of CCS, the deployment of DAC technology would have indirect toxic impacts due to the additional energy, land, water and resources it would require. Moreover, counting on DAC to remove CO2 in the future could delay emissions reductions in the near term, prolonging the production and use of fossil fuels, which are hazardous to communities, and locking in an overshoot of 1.5°C, with irreversible impacts.[[34]](#footnote-34) Even if it were effective-which is by no means certain–, DACCS could not meaningfully remove CO2 from the atmosphere until 2050 or later.[[35]](#footnote-35)
2. In its most recent report, the IPCC found that large-scale use of DAC could have “a significant land footprint” and can also “significantly impact food prices via demand for land and water,”[[36]](#footnote-36) potentially negatively impacting the right to food, especially of vulnerable peoples. Other studies have also found that deployment of DAC at large scale would require an amount of energy and materials that is “unrealistic even when the most promising technologies are employed.”[[37]](#footnote-37)
3. DAC processes can be powered by fossil fuels or renewables. If powered by fossil fuels such as fossil (“natural”) gas, DAC equipment will contribute to increasing “air pollution due to the combustion and upstream emissions associated with natural gas”[[38]](#footnote-38).
4. Since DAC equipment does not contribute to the capture of pollution emitted from fossil fuel-based power facilities (including CO, NOx, SO2, organic gases, mercury, toxins, black and brown carbon, fly ash, and other aerosol components), deploying DAC technology to justify or prolong continued reliance on fossil fuels will have significantly more harmful impacts when compared with replacement of those same facilities with ones powered by renewable energies.[[39]](#footnote-39)
5. The materials required by DAC processes are energy-intensive and hazardous to produce,[[40]](#footnote-40) and not currently available at the volumes required to implement DAC at climate-relevant scale. The massive increase in chemical production that would be required to implement DAC at scale – necessitating, for example, quantities of ammonia and ethylene oxide orders of magnitude greater than the current market size[[41]](#footnote-41) – would increase risks to communities on the fencelines of petrochemical facilities and those through which the toxic substances are transported.
6. In light of all the above, taking into account its unrealistic deployment at scale in the short-term, DAC can only be seen as “an energetically and financially costly distraction in effective mitigation of climate changes at a meaningful scale,”[[42]](#footnote-42) which will however have very real direct and indirect impacts on human rights due to its requirement for and generation of significant volumes of toxic substances.
7. **Land demand and air and water pollution from BECCS**
8. BECCS consists in the combustion of biological material (biomass or biofuels) combined with CCS to capture and store emissions produced when burning it.[[43]](#footnote-43) The most important side-effect in the deployment of BECCS at scale is the immense amount of land it would require, which would entail “[c]ompetition with food crops, implications for biodiversity, potential deforestation to support bioenergy crop production, energy security implications from bioenergy trade, point-of-use emissions and associated effects on air quality, and water use and fertiliser use,”[[44]](#footnote-44) hindering the realization of peoples’ rights to food and to water[[45]](#footnote-45). The conversion of land to bioenergy also would, among other impacts, lead to different forms of land grabbing.[[46]](#footnote-46) Large-scale monoculture of biofuel crops requires an increased use of agricultural chemicals, including fertilizers and pesticides, which heavily impact human rights to life, to health and to a clean, healthy and sustainable environment.[[47]](#footnote-47) As the Special Rapporteur has previously noted, pesticides often disproportionately affect Indigenous communities living alongside fields.[[48]](#footnote-48) As stressed by several UN Human Rights Treaty Bodies, the rights of children, women and farming communities are particularly threatened by the harmful impact of the use of pesticides, fertilizers and other agrochemicals.[[49]](#footnote-49) Diverting water to irrigate BECCS plantations could also “double the global area and population living under severe water stress compared to the current baseline.”[[50]](#footnote-50)
9. Further toxic impacts of BECCS are related to the CCS part of this approach, which, as discussed above in Section (1), can cause air pollution, pollution of potable water and environmental and health risks in the event of CO2 leaks,[[51]](#footnote-51) endangering the enjoyment of the rights to health, to water, to a clean, healthy and sustainable environment and to non-discrimination.
10. **Toxic nature of hydrogen and ammonia**
11. Hydrogen has been proposed as a “solution” for the decarbonization of the industrial, energy and transportation sectors. However, with the exception of green hydrogen (i.e., hydrogen made by running electricity from exclusively renewable sources through water to separate it into its constituent parts, hydrogen and oxygen), whose potential contribution in terms of climate solutions will be modest[[52]](#footnote-52) and which would divert renewable energy from more direct uses, nearly all hydrogen is today produced from fossil fuels, and as such does not contribute to solving the climate crisis - quite the contrary.[[53]](#footnote-53)
12. From a toxics perspective, hydrogen–whether made from fossil fuel or water with renewables–is an explosive substance, difficult to transport; even though it does not contain contaminants or particulates, hydrogen produces nitrogen oxides when burned, thus “creating toxic risks if it is used in industrial applications or domestic gas lines.”[[54]](#footnote-54)
13. Finally, one of the largest current uses of hydrogen is for the production of ammonia, principally for synthetic fertilizer production (the other most significant use of hydrogen is for petroleum refining).[[55]](#footnote-55) Ammonia, which is widely known to be extremely toxic: at moderate concentrations, it can irritate the eyes, the nose and the respiratory tract, while at high concentrations it can be “promptly lethal”[[56]](#footnote-56) if inhaled, ingested or absorbed through the skin, with a disproportionate risk for children.[[57]](#footnote-57) Exposure of any kind to ammonia can be dangerous; upon combustion (even when properly done), ammonia can “release toxic nitrogen oxides, as its constituent nitrogen is combined with oxygen in the air.”[[58]](#footnote-58)
14. **Conclusion**

1. CIEL thanks the Special Rapporteur for the opportunity to present this submission and remains available to provide any further information on any of the aforementioned topics.

1. For any questions or clarification, please do not hesitate to reach us at sfeit@ciel.org, sduyck@ciel.org and nreisch@ciel.org.
1. Not all actions undertaken in the name of climate change are climate change “solutions.” Indeed, what qualifies as a solution is at the heart of debates over climate action and accountability today. As suggested in the Special Rapporteur’s call for inputs to this report, responses to climate change, including certain technologies that purport to mitigate greenhouse gas emissions or mask their impacts, may adversely affect human rights. This submission focuses on just several of the many technofixes and interventions that pose such concerns. [↑](#footnote-ref-1)
2. *See* Center for International Environmental Law (CIEL) and Heinrich Böll Foundation, [*Beyond the Limits: New IPCC WG II Report Highlights How Gambling on Overshoot is Pushing the Planet Past a Point of No Return*](https://www.ciel.org/reports/ipcc-wg2-briefing), 2022; CIEL and Heinrich Böll Foundation, [*IPCC Unsummarized: Unmasking Clear Warnings on Overshoot, Techno-fixes, and the Urgency of Climate Justice*](https://www.ciel.org/reports/ipcc-wg3-briefing/), 2022; CIEL and Heinrich Böll Foundation, [*Lost in Translation: Lessons from the IPCC’s Sixth Assessment on the Urgent Transition from Fossil Fuels and the Risks of Misplaced Reliance on False Solutions*](https://www.ciel.org/reports/lost-in-translation-lessons-from-the-ipcc-sixth-assessment/), 2023. [↑](#footnote-ref-2)
3. Center for International Environment, [*Confronting the Myth of Carbon-Free Fossil Fuels*](https://www.ciel.org/wp-content/uploads/2021/07/Confronting-the-Myth-of-Carbon-Free-Fossil-Fuels.pdf), 2021, available at p. 2; *see also* CIEL, [Carbon Capture and Storage: (CCS): Frequently Asked Questions](https://www.ciel.org/carbon-capture-and-storage-ccs-frequently-asked-questions/#Is%20CCS%20the%20same%20as%20carbon%20dioxide%20removal). [↑](#footnote-ref-3)
4. IPCC, *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, 2022, available at <https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_SummaryForPolicymakers.pdf>, at figure SPM.7 p. 38 [↑](#footnote-ref-4)
5. Fogarty J., McCally M., *Health and Safety Risks of Carbon Capture and Storage*, in JAMA, 2010, 303(1), available at <https://jamanetwork.com/journals/jama/article-abstract/185135> [↑](#footnote-ref-5)
6. Sekera, J., Lichtenberger, A., *Assessing Carbon Capture: Public Policy, Science, and Societal Need*, in Biophys Econ Sust, 2020, 5(14), available at <https://doi.org/10.1007/s41247-020-00080-5> [↑](#footnote-ref-6)
7. Hambdy L. B. et al., *The application of amine-based materials for carbon capture and utilisation: an overarching view*, in Material Advances, 2021, 2 5843-5880 [↑](#footnote-ref-7)
8. EEA Technical report no. 14/2011, *Air pollution impacts from carbon capture and storage (CCS)*, 2011 available at https://www.eea.europa.eu/publications/carbon-capture-and-storage, at p. 10 [↑](#footnote-ref-8)
9. Report of the Special Rapporteur, Okechukwu Ibeanu, *Adverse effects of the illicit movement and dumping of toxic and dangerous products and wastes on the enjoyment of human rights*, 2007, report no. A/HRC/5/5, available at

<https://undocs.org/Home/Mobile?FinalSymbol=A%2FHRC%2F5%2F5&Language=E&DeviceType=Desktop&LangRequested=False> at p. 8 [↑](#footnote-ref-9)
10. See Agency for Toxic Substances and Disease Registry, Toxic Substances Portal, Medical Management Guidelines for Ammonia,

https://wwwn.cdc.gov/TSP/MMG/MMGDetails.aspx?mmgid=7&toxid=2 [↑](#footnote-ref-10)
11. Parfomak P. W., Folger P., *Congressional Research Service, Carbon Dioxide (CO2) Pipelines for Carbon Sequestration: Emerging Policy Issues*, 2007, available at <https://www.everycrsreport.com/reports/RL33971.html>, at p. 15 [↑](#footnote-ref-11)
12. Report of the Special Rapporteur on the adverse effects of the illicit movement and dumping of toxic and dangerous products and wastes on the enjoyment of human rights, Okechukwu Ibeanu, 2008, report no. A/HRC/9/22, available at <https://undocs.org/Home/Mobile?FinalSymbol=A%2FHRC%2F9%2F22&Language=E&DeviceType=Desktop&LangRequested=False>, at p. 4 [↑](#footnote-ref-12)
13. Fuss S. et al., *Negative emissions--Part 2: Costs, potentials, and side effects*, in Environmental Research Letters, 2018, 13 063002, available at

<https://iopscience.iop.org/article/10.1088/1748-9326/aabf9f/meta>, at p.14 [↑](#footnote-ref-13)
14. See ​​Buschecka T.A. et al., *Pre-Injection Brine Production for Managing Pressure in Compartmentalized CO2 Storage Reservoirs*, in Energy Procedia, 2014, 63:5333 – 5340, available at <https://reader.elsevier.com/reader/sd/pii/S1876610214023807?token=1FF1E7D8B00E1C1098F3647F82BE3D278A7C4A405D299DB00FE50A249034FFBDCB8889BD47FFBBB5838B7C65B67EF18F&originRegion=eu-west-1&originCreation=20230308103928> [↑](#footnote-ref-14)
15. IPCC, Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, *supra* at footnote no. 4, at p. 705 [↑](#footnote-ref-15)
16. Santibanez-Borda E. et al., Maximising the Dynamic CO2 storage Capacity through the optimisation of CO2 Injection and Brine Production Rates, in International Journal of Greenhouse Gas Control, 2019, 80(76-95) available at <https://doi.org/10.1016/j.ijggc.2018.11.012>, at pp. 76-77 [↑](#footnote-ref-16)
17. IPCC, *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, *supra* at footnote no. 4, at p. 642 [↑](#footnote-ref-17)
18. EEA Technical report no. 14/2011, *Air pollution impacts from carbon capture and storage (CCS)*, *supra* at footnote no. 8, at p. 27. [↑](#footnote-ref-18)
19. *Ibidem*, at p. 7 [↑](#footnote-ref-19)
20. U.S. EPA, Archive Document, *PSD Greenhouse Gas Permit Application*, 2012, available at <https://archive.epa.gov/region6/6pd/air/pd-r/ghg/web/pdf/chevron_response031912.pdf>, at p. 11 [↑](#footnote-ref-20)
21. U.S. EPA, Archive Document, *PSD Greenhouse Gas Permit Application Revision*, 2013, available at <https://archive.epa.gov/region6/6pd/air/pd-r/ghg/web/pdf/dowchemical-lh9-app-09202013.pdf>, at p. 37 [↑](#footnote-ref-21)
22. U.S. EPA, Archive Document, *Exxon Mobile Baytown Olefins Plant Response*, 2012, available at <https://archive.epa.gov/region6/6pd/air/pd-r/ghg/web/pdf/exxonmobil-olefins-response.pdf>, at p. 22 [↑](#footnote-ref-22)
23. Report of the Special Rapporteur on contemporary forms of racism, racial discrimination, xenophobia and related intolerance, E. Tendayi Achiume, *Ecological crisis, climate justice and racial justice*, report no. A/55/749, 2022 available at

<https://www.ohchr.org/en/documents/thematic-reports/a77549-report-special-rapporteur-contemporary-forms-racism-racial> , at p. 20; see also Report of the Special Rapporteur on the implications for human rights of the environmentally sound management, *Implications for human rights of the environmentally sound management and disposal of hazardous substances and waste*, report no. A775/290, 2020, available at

 <https://documents-dds-ny.un.org/doc/UNDOC/GEN/N20/205/17/PDF/N2020517.pdf?OpenElement> [↑](#footnote-ref-23)
24. Center for International Environmental Law, *Fuel to the fire - How goengineering threatens to entrench fossil fuels and accelerate the climate crisis*, 2019, available at <https://www.ciel.org/wp-content/uploads/2019/02/CIEL_FUEL-TO-THE-FIRE_How-Geoengineering-Threatens-to-Entrench-Fossil-Fuels-and-Accelerate-the-Climate-Crisis_February-2019.pdf>, at p. 23 [↑](#footnote-ref-24)
25. Realmonte G. et al., *An inter-model assessment of the role of direct air capture in deep mitigation pathways*, in Nature Communications, 2019, 10(3277), available at <https://doi.org/10.1038/s41467-019-10842-5> at p. 2 [↑](#footnote-ref-25)
26. Chatterjee S., Huang K-W, *Unrealistic energy and materials requirement for direct air capture in deep mitigation pathways*, in Nature Communications, 2020, available at https://doi.org/10.1038/s41467-019-10842-5 [↑](#footnote-ref-26)
27. Realmonte G. et al., *An inter-model assessment of the role of direct air capture in deep mitigation pathways*, *supra* at footnote no. 25, at p. 10 [↑](#footnote-ref-27)
28. Chatterjee S., Huang K-W, *Unrealistic energy and materials requirement for direct air capture in deep mitigation pathways*, *supra* at foote no. 26, at p. 1 [↑](#footnote-ref-28)
29. Realmonte G. et al., *An inter-model assessment of the role of direct air capture in deep mitigation pathways*, *supra* at footnote no. 25 at p. 10 [↑](#footnote-ref-29)
30. *Ibidem*, at p. 8 [↑](#footnote-ref-30)
31. Fuss S. et al., *Negative emissions--Part 2: Costs, potentials, and side effects*, *supra* at footnote no. 13 at p. 19 [↑](#footnote-ref-31)
32. *Ibidem*,at p. 19

 [↑](#footnote-ref-32)
33. *Ibidem* at p. 34 [↑](#footnote-ref-33)
34. Center for International Environmental Law and Heinrich Böll Foundation, Lost in Translation: Lessons from the IPCC’s Sixth Assessment on the Urgent Transition from Fossil Fuels and the Risks of Misplaced Reliance on False Solutions, supra at footnote no. 1, at p.6 [↑](#footnote-ref-34)
35. IPCC, *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, *supra* at footnote no. 4, at pp. 1264-1265 [↑](#footnote-ref-35)
36. IPCC, *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, *supra* at footnote no. 4 at p. 1266; IPCC, *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, 2022, available at <https://www.ipcc.ch/report/ar6/wg2/>, at p. 654 [↑](#footnote-ref-36)
37. Chatterjee S., Huang K-W, *Unrealistic energy and materials requirement for direct air capture in deep mitigation pathways*, *supra* at foote no. 26 at p. 1 [↑](#footnote-ref-37)
38. Mark Z. Jacobson, *The health and climate impacts of carbon capture and direct air capture*, in Energy and Environmental Science, 2019, 12, available at <https://web.stanford.edu/group/efmh/jacobson/Articles/Others/19-CCS-DAC.pdf>, at p. 3571 [↑](#footnote-ref-38)
39. *Ibidem* [↑](#footnote-ref-39)
40. Realmonte G. et al., An inter-model assessment of the role of direct air capture in deep mitigation pathways, supra at footnote no. 25 at p . 7 (discussing the current scale of the chlorine market, and the energy intensity of sodium hydroxide production). [↑](#footnote-ref-40)
41. Ibidem, at pp. 7-8 (indicating that markets for ammonia and ethylene oxide would have to increase from 177 and 35 Mt/year to 15-26 Gt/year and 3-5Gt/year, respectively). [↑](#footnote-ref-41)
42. Chatterjee S., Huang K-W, *Unrealistic energy and materials requirement for direct air capture in deep mitigation pathways*, *supra* at footnote no. 26 at p. 1 [↑](#footnote-ref-42)
43. Fuss S. et al., *Negative emissions--Part 2: Costs, potentials, and side effects*, *supra* at footnote no. 13 at p. 9 [↑](#footnote-ref-43)
44. IPCC, *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, *supra* at footnote no. 4 at p. 645 [↑](#footnote-ref-44)
45. See also IPCC, *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, *supra* at footnote no. 4, at p. 654, recognizing that diverting water to irrigate BECCS plantations could also “double the global area and population living under severe water stress compared to the current baseline.” [↑](#footnote-ref-45)
46. Committee on Economic, Social and Cultural Rights (CESCR), General comment No. 26 (2022) on land and economic, social and cultural rights, UN Doc. E/C.12/GC/26, at para. 56 [↑](#footnote-ref-46)
47. Center for International Environmental Law, *Fuel to the fire*, *supra* at footnote no. 24 at p. 14 [↑](#footnote-ref-47)
48. Report of the Special Rapporteur on the implications for human rights of the environmentally sound management and disposal of hazardous substances and wastes, Marcos Orellana, *The impact of toxic substances on the human rights of indigenous peoples*, 2022, report no. A/77/183, available at <https://www.ohchr.org/en/documents/thematic-reports/a77183-impact-toxic-substances-human-rights-indigenous-peoples-report>, at pp. 9-10 [↑](#footnote-ref-48)
49. See respectively Committee on the Elimination of Discrimination against Women (CEDAW), Concluding Observations to Colombia (2016), CEDAW/C/HND/CO/7-8; Committee on the Rights of the Child (CRC), Concluding Observations to Brazil (2015), CRC/C/BRA/CO/2-4; Committee on Economic, Social and Cultural Rights (CESCR), Concluding Observations to Sri Lanka (2017), E/C.12/LKA/CO5 [↑](#footnote-ref-49)
50. IPCC, Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 2022, supra at footnote no. 4, at p. 654. [↑](#footnote-ref-50)
51. Fuss S. et al., *Negative emissions--Part 2: Costs, potentials, and side effects*, *supra* at footnote no. 13 at p. 14 [↑](#footnote-ref-51)
52. The IPCC notes the “modest role played by hydrogen” in integrated assessment model (IAM) scenarios, estimating that hydrogen will amount to only 2.1% of final energy consumption in 2050. IPCC, *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, supra at footnote no. 3, at p. 1315. See also Earthjustice, *Reclaiming Hydrogen for a Renewable Future: Distinguishing Oil & Gas Industry Spin from Zero-Emission Solutions* (Aug. 2021) (discussing limited applications of green hydrogen). [↑](#footnote-ref-52)
53. Ghavam S. et al., *Sustainable Ammonia Production Processes*, in Frontiers in Energy Research, 2021, 9(3), available at <https://doi.org/10.3389/fenrg.2021.580808> [↑](#footnote-ref-53)
54. Center for International Environmental Law, *Fuel to the fire*, *supra* at footnote no. 24 at p. 31; *see* Clean Energy Group, [Five Reasons to Be Concerned about Green Hydrogen](https://www.cleanegroup.org/wp-content/uploads/Five-Reasons-to-be-Concerned-About-Green-Hydrogen.pdf) (Sept. 2021). [↑](#footnote-ref-54)
55. See International Energy Agency (IEA), Global hydrogen demand by sector in the Net Zero Scenario, 2019-2030; IEA, Global demand for pure hydrogen, 1975-2018. See also CIEL, Fossils, Fertilizers and False Solutions: How Laundering Agrochemicals Puts the Climate and Planet at Risk (2022) (discussing the use of hydrogen for ammonia-based fertilizer production, and, in Part 2, hydrogen and ammonia as risky, false climate solutions). [↑](#footnote-ref-55)
56. The Fertilizer Institute, *Health Effects of Ammonia*, Washington DC: The Fertilizer Institute, 10, available at <https://www.tfi.org/sites/default/files/documents/HealthAmmoniaFINAL.pdf> [↑](#footnote-ref-56)
57. See Agency for Toxic Substances and Disease Registry, *supra* at footnote no. 10 [↑](#footnote-ref-57)
58. Center for International Environmental Law, *Fossils, Fertilizers, and False Solutions*, 2022, available at <https://www.ciel.org/reports/fossil-fertilizers/>, at p. 34, citing Kobayashi H. et al., *Science and technology of ammonia combustion*, in Proceedings of the Combustion Institute, 2019,37(1): 109–133, available at <https://doi.org/10.1016/j.proci.2018.09.029> [↑](#footnote-ref-58)