CHAPTER 4

Sustainable Climate Engineering Innovation and the Need for Accountability

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CONTENTS

4.1 INTRODUCTION

Although still highly controversial, the idea that we can use technology to radically alter our environment to mitigate the challenges we now face is becoming an ever more discussed approach. The potential for cloud brightening, solar radiation management, and carbon capture technologies, among others, have been debated for a long time. Still, it was not long ago that research on such topics was largely suppressed. Much of this historical aversion to this research can be primarily laid at the feet of the idea being that there is a moral hazard involved in even exploring the *potential* for fixing our problems, not through a radical change in individual behavior, consumption, and the systems of production but through improving the symptoms. Moral hazard arguments are ubiquitous in the public debate and the academic literature on climate engineering, seeing it as a “techno-fix” compromise instead of addressing systemic and broader moral and institutional reforms (Wagner & Zizzamia, 2021). However, we are now seeing increasing acceptance of such technologies, and carbon capture and storage, in particular, is relatively close to mainstream. Many promoters of climate engineering argue that it is necessary to counteract climate change, with the need to serve the moral imperative of mitigation and provide

DOI: 10.1201/9781003325086-4

adaptation for vulnerable people across the globe (Horton & Keith, 2016). However, scholars recently recognized that these arguments often lack an in-depth analysis informed by moral and political theory since they neglect the power dynamics inherent in climate engineering research and implementation (Gardiner & McKinnon, 2020; Hourdequin, 2021; Smith, 2018).

This chapter highlights how both climate engineering innovation and SDGs framework should be seen not as policy-neutral and objective sites, but as sites for politics, sites for ongoing debate and deliberation on their normative ends and governance. Our aim is to show how a more nuanced, multidimensional definition of accountability is needed in order to permit responsible innovation of climate technologies that align with the ideal of sustainable development. This chapter is divided as follows. First, it starts by describing what climate engineering is and uses one particular form, carbon capture, usage, and storage (CCUS), as a use case. Second, it explores how the synergy between the responsible deployment of climate engineering innovation and the achievement of the SDGs targets should unpack the socio-political significance of both frameworks, since they are both depending on political preferences and social acceptability, and on how normative justifications and decisions about innovation and sustainable strategies and constraints are managed, taken, and communicated.

Then, this chapter concentrates on what accountability is, how it has been traditionally understood in the literature, and why a more expansive and polysemic definition of accountability is required if climate engineering technologies like CCUS are actually to support sustainable development. Specifically, this chapter discusses possible strategies to theorize and implement accountable and sustainable frameworks for climate engineering innovation, starting from the creation of shared standards to matters of responsibility among social actors and of answerability, which requires that conduct and information are reported, explained, and reasonably justified in the context of these climate models. Finally, the conclusions recap the main arguments sustained in this chapter and explore their connection to the key topics of the volume.

4.2 CLIMATE ENGINEERING

Climate Engineering technologies are a class or family of technologies proposed to ameliorate or mitigate climate change's causes and/or effects on both local and global scales. Although the term has been appropriated in the past as a theoretical application to terraforming another planet, like Mars (e.g., see Jakosky & Edwards, 2018), to be habitable, in this context, we are referring to the technology family that aims to act on the Earth's climate system to reduce atmospheric greenhouse gases or, more radically by transforming physical and/or chemical biosphere mechanisms to achieve direct climate control (Buchinger et al., 2022).

There are various member technologies of this technology family, including but not limited to carbon capture, usage, and storage (CCUS) and solar radiation management (SRM). The former refers to technologies that can remove existing CO_2 from the atmosphere, which, consequently, can feasibly ameliorate existing emissions, thus impacting temperature regulation (Bui et al., 2018; Hanssen et al., 2020). SRM, on the other hand, are technologies that are designed to transform how the biosphere interacts with solar radiation (Ming et al., 2014). One of the ways that this has been proposed to function on the global scale is by creating a dense cloud of particles in the stratosphere, which are designed to reflect part of the solar radiation, thus reducing global temperatures. However, there are more local approaches to SRM, such as employing heat reflection systems to protect and restore snow or glaciers (Applegate & Keller, 2015). The *time-to-market* of this technology family is considered "Short to medium for small and regional scale deployment, medium to long term for large-scale and global deployment, and most advanced applications" (Buchinger et al., 2022, p. 38). Given the relative urgency underlying the development of this technology family, as well as the high research and industrial relevance, it merits considering the various ethical concerns that emerge when considering CCUS and SRM, such as those concerning who will be impacted both directly and indirectly by them, who can or will have access to these technologies, who will decide how and where these systems will be implemented, as well as the various concerns surrounding the value of sustainability.

Naturally, there are various arguments in favor and against the design, deployment, and use of these climate engineering technologies (Brooks et al., 2022). For example, those in favor often levy arguments that since global climate warming is anthropogenic, it is likewise humans' moral imperative to take action to ameliorate such change. Likewise, arguments are made concerning our collective responsibility to future generations and their well-being, as well as the argument of delaying the inevitable consequence of warming, which is made for both CCUS and SRM (Stilgoe, 2016). In the latter case, proponents argue that SRM techniques would help deflect some proportion of the warming effect until atmospheric emissions are effectively reduced. At the same time, CCUS would feasibly permit more short-term warming, namely emissions which would then be ameliorated with later CCUS techniques.

However, some arguments against these technologies are usually political in their orientation, arguing that many of these approaches require crossing national and geospatial boundaries, thus implicating notions of the sovereignty of those countries wishing to use/not use such technologies (Proelss & Güssow, 2011). Similarly, given that the effects of such technologies across time are neither immediate nor certain, this questions whether and how we can intervene in a complex system like the climate with positive effects. In the event of adverse effects, can we have a reasonable certainty of the ability to reverse such impacts (Raza et al., 2019)? The findings of a review on geoengineering carried out by the UK Royal Society in 2009 revealed major uncertainties and potential risks concerning effectiveness, social, and environmental impacts of geoengineering projects (Royal Society, 2009). At the beginning of 2022, a coalition of scientists and governance scholars launched an initiative calling for a ban on research and deployment of SRM, claiming that the current global governance system is unfit to maintain a fair political control of it (Biermann et al., 2022). These are some of the arguments discussed within the discourse on climate engineering technologies like SRM and carbon capture, usage, and storage. The following subsection will take up CCUS as the case we will be looking at for this chapter.

4.2.1 Carbon Capture, Usage, and Storage (CCUS)

Spurred primarily by the United Nations Economic Commission for Europe's (UNECE's) objective of achieving net-zero emissions, carbon capture, usage, and storage (CCUS) systems have been proposed and sustained as one of the most conceptually effective ways of achieving this goal of removing large volumes of CO_2 from the atmosphere. CCUS systems are understood as technologies that capture CO_2 emissions from power generation sources that use fossil fuels and industrial processes for storage deep underground or re-use (Figure 4.1). This re-use is often for producing synthetic materials such as other fuels, chemicals, building materials, etc.

There are two general routes for CCUS: carbon usage and carbon storage. Concerning the latter, carbon is removed directly from either the air or facilities and industrial processes, stored in the compressed form, and then transported to sequestration areas to be stored permanently underground in geological formations like saline, oil, and gas reservoirs (Metz et al., 2005). Concerning carbon usage, the captured and compressed carbon is re-used in other processes such as being pumped into greenhouses to make them more efficient, in the synthesis of materials, chemicals, and fuels, as well as in essential commercial products like carbonated soft drinks (Ho et al., 2019; Psarras et al., 2017). Using captured carbon as fuels and in other industrial and manufacturing processes increases net efficiency while simultaneously reducing net waste, thus contributing to the infrastructure underlying the circular economy (Budzianowski, 2017). Still, sequestration could feasibly permit augmented usage of existing emission sources, given the ability to directly capture emissions from the atmosphere and these emission facilities (Tcvetkov et al., 2019).

Still, there are some barriers to both carbon capture and storage and carbon capture and usage. Concerning storage, many projects are currently in operation on a global scale; however, the technical equipment necessary for this process to be undertaken is exceptionally costly and serves as an obstacle for many sources of emissions, particularly in the Global South (Rubin & Zhai, 2012; Román, 2011). This goes hand in hand with other barriers, such as the lack of technical expertise necessary to run and maintain such systems and uncertain return on investment (Roussanaly et al., 2021). Unlike the more commercialized

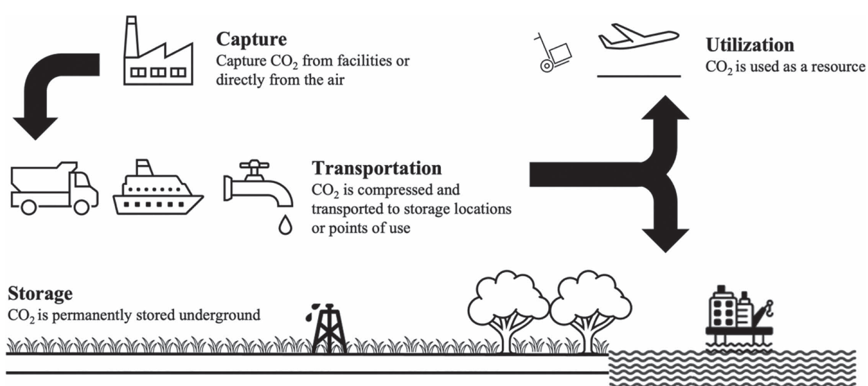

FIGURE 4.1 Carbon capture, use, and storage schema.

storage technologies, carbon utilization technologies are more novel. Likewise, to ensure that both the ecological and economic boons are achieved, thus ensuring long-term and ubiquitous adaptability of carbon utilization technologies, what is required is low-carbon hydrogen and vast volumes of renewable energy, all at affordable costs (Yu et al., 2021; Brändle et al., 2021).

4.3 A SITE FOR POLITICS

CCUS has entered the discourse on climate models to counteract or delay climate change. However, its long-term consequences are still unknown, as are its impacts as a broader paradigm shift that is different from adaptation and mitigation measures. Technologies such as CCUS have been said to be morally problematic "techno-fix" compromises to climate change, in the sense that they alone are inadequate solutions that address merely the setting of behaviors and not how behavioral failures come into being, that is, the failure of people to behave in an appropriate and climate-friendly way, and the underlying social, political, and economic dynamics (Scott, 2012; Borgmann, 2012). Moreover, CCUS is considered by many unjust and incompatible with the ideal of sustainable development, since they would have several detrimental effects, including the displacement and marginalization of local communities, the undermining of food rights and land rights, and, finally, the infringement of biosphere and natural ecosystems' integrity, leading to the creation of new vast-scale infrastructures and industries that can reproduce the emissions problem instead of ameliorating it (Schneider, 2019). For example, an SDG that is potentially impacted by CCUS is the SDG 6 on clean water, since such technologies can create significant land and water trade-offs, and adverse impacts on local water quality (IPCC, 2022, Chaps. 6, 12). Also, the SDG 7 on affordable and clean energy can be impacted due to the high energy demand of some of CCUS methods (IPCC, 2022, Chap. 12).

Widespread claims suggest that technologies like CCUS are intrinsically troubling: they are often embedded in undemocratic systems of innovation and knowledge that disregard the underlying causes and patterns of climate change and increase the dependence of developing countries and vulnerable groups while strengthening the power and control of developed countries and technocratic, corporate elites (Gardiner & McKinnon, 2020). In particular, in the range of potential injustices raised from climate engineering technologies, the most debated one is the exacerbation of power asymmetries and the fact that those tech-mediated climate models can generate profound and global relations of domination (Smith, 2018, 2021). Narratives or claims on climate engineering proposals might be portrayed as objective, unbiased, and policy-neutral; hence, they might de-politicize the climate change discourse, obscuring the political motivations behind their reasoning and legitimizing structures of power that perpetuate oppression and exploitation (Sikka, 2021; O'Lear et al., 2021).

However, even if the climate engineering literature tends to recognize equity concerns, often, no normative political dimension is adopted for evaluating the monitoring and control mechanisms for the assessment, development, and policy dimensions surrounding those technologies (McLaren, 2018). The governance frameworks and democratic processes needed to develop and sustain technologies such as CCUS responsibly remain largely neglected by policymakers and the academic research community at large (Bellamy et al., 2021). Similarly, scholars have noted how Responsible Research and Innovation activities often remain separate and self-referential, without appropriate processes for citizens' engagement (Stahl et al., 2021), by failing to be a "site for politics", that is, a site for ongoing debate and deliberation about the normative ends of innovation and its governance (Owen et al., 2021).

Also in the sustainable development literature, it is widely accepted that the achievement of the SDGs depends on democratic and effective governance mechanisms, to the point that governance has been considered the "fourth pillar of sustainable development" (Kanie et al., 2014, p. 6). Nonetheless, there is no consensus or clear conceptualization on the theoretical foundation of governance for sustainable development and its different aspects (Glass & Newig, 2019). Moreover, empirical studies have found how policies for the achievement of SDGs paradoxically obscure the trade-offs and political assumptions upon which sustainable development rests, leading to a situation of "anti-politics" that does not account for a space where incoherencies from dominant private, market-based organizations can be discussed and contested (Yunita et al., 2022). Detractors of SDGs have conceived this set of normative principles as a political framework or ideology that can compromise public decision-making mechanisms and privilege commercial interests, leading to unjust and exclusionary policies instead of promoting just structural change (Weber, 2017).

Therefore, a critical political question arises, asking to whom, by whom, and to what ends the sustainable development trajectories should be designed and deployed. At the same time, the central question for CCUS technologies is no longer whether but how, to what extent, by whom, and to whom they should be pursued (Bellamy & Geden, 2019). This means that the choice of CCUS technologies will depend on the evolution of political preferences and social acceptability, and on how sustainability constraints are managed by governments (IPCC, 2022, Chap. 12, p. 62).

Rather than being a purely technical matter, climate engineering innovation processes are political in the sense that they are strictly entangled with the same broader socio-political contexts and power structures in which are embedded (on the normative political dimensions of technologies see the recent Coeckelbergh, 2022; Waelen, 2022). Moreover, those processes cannot avoid confronting the theoretical underpinnings of sustainable development. Synergies between the responsible deployment of such climate models and the achievement of SDGs targets should unpack the political rationale in the transformative potential of the UN 2030 Agenda, and should encompass governance methods for inclusion and empowerment.

4.4 REVISITING ACCOUNTABILITY

Among the few scholarly studies on SDGs politics, a recent thesis that has been advanced is that sustainable development goal setting and fulfillment are particularly adapted to study long-term political decisions, interactions, and structures and are in urgent need of political normative frameworks that scrutinize normative qualities of governance such as legitimacy, responsibility, and accountability (Bexell & Jönsson, 2021). Leaving aside the questions of legitimacy and responsibility, these studies define accountability as the "retrospective mirror of political responsibility" and connect it to monitoring and sanctioning mechanisms: social actors that deal with sustainable development should be liable for how they exercise power and how they make strategic socio-political choices about goals (Bexell & Jönsson, 2017, pp. 17–18, 2021, p. 3).

Also, in the philosophy of technology literature, accountability has been identified as a form of retrospective, backward-looking (van de Poel, 2011) or passive (Pesch, 2015) responsibility, namely as a form of *ex-post* scrutiny that requires justification for a state of affairs and constitutes the basis for blameworthiness. Only in these last few years have some scholars recognized that accountability also has a preventive and anticipatory role since it engages with a relation between an actor and a forum, in which conducts are exposed, justified, and debated in a back-and-forth exchange (Verdiesen et al., 2021, based on Bovens, 2007; Bovens et al., 2014; Santoni de Sio & Mecacci, 2021).

This definition is more aligned with debates on accountability in normative political theory, where accountability has been the object of various discussions but usually refers to the self-determination of citizens that keep/hold their representatives accountable and responsive (Palumbo & Bellamy, 2010). In political studies, responsiveness has been identified as a "potential readiness to respond" (Pitkin, 1967, p. 233) to citizens with whom ultimate responsibility for the actions and decisions should rest (Urbinati & Warren, 2008). However, citizens need "meaningful" forms of participation, understood as opportunities for real influence in the polity (Pateman, 1970, pp. 70–71). This generates a whole range of problems, as responsiveness might be at odds with political equality and influence in civic life, especially when economic standing or socio-political resources and powers might make some individuals or groups more likely to voice concerns and influence policy strategies and outcomes (Papadopoulos & Warin, 2007). Thus, the establishment of meaningful forms of accountability and responsiveness implies not only the likelihood of substantive forms of representation but also, more importantly, a contribution to equality in policy outcomes and long-term fair distribution of public goods (Grimes & Esaiasson, 2014).

Therefore, accountability is not merely retrospective and connected to sanctioning measures but involves an ex-ante account of governance that involves mutual deliberation on public goods, the creation of shared standards, and monitoring and scrutiny mechanisms. As a normative concept, it consists of the respect of various dimensions in the accountability relation: to whom (accountees); by whom (accounters); for what and by which shared standards this relation is assessed; answerability, that is, through what process and in which modalities conduct and information are reported, explained, and reasonably justified and accountees informed; and enforceability, that is, what effects or consequences arise when someone is held accountable and violates the conditions necessary for a meaningful relationship with the accountees (on the multidimensional nature of accountability see also Mashaw, 2006; Buchanan & Keohane, 2006, p. 426; Callies, 2018; Villalona, 2021, p. 19).

Accountability has been explored to some extent in the UN 2030 Agenda, with an explicit reference to "effective, accountable and inclusive institutions at all levels" in SDG #16.[1] The UN 2030 Agenda envisages a follow-up and review framework to promote accountability to citizens and leaves this task to the institution of the High-Level Political Forum (HLPF) and to voluntary national review systems, which may have multiple different modalities in their national policy choices for SDGs implementation (United Nations, 2015, para 72–91; Karlsson-Vinkhuyzen et al., 2018, p. 1380-ff). In SDGs literature, accountability is depicted as an indispensable factor. Still, surprisingly there is no clear understanding of its nature and how it can facilitate the strategy design for SDGs implementation at the national level and social value creation (Abhayawansa et al., 2021). The most significant challenges to accountability in the Global SDG Accountability Report are the lack of institutional coordination across governments and the low public awareness of SDGs among citizens and stakeholders (Villalona, 2021, pp. 29–33, 36). Thus, the definition of accountable relations is not clear and settled in the SDGs literature. In the following pages, this discourse on the polysemic nature of accountability provides some interesting theoretical implications for the question of sustainable development and climate engineering innovation.

4.5 ACCOUNTABLE AND SUSTAINABLE CLIMATE ENGINEERING

Scholars involved in the normative discussion on climate engineering tend to focus on institutional legitimacy as a criterion to guide responsible climate engineering and climate engineering experiments (Callies, 2018; Bellamy et al., 2017). However, accountability might be an equally relevant normative criterion that both the sustainable development framework and climate engineering innovation should confront. Indeed, accountability as a criterion might provide a guide for complex processes by which parameters for sustainable development come to be defined, as well as an approach to responsibly conducting climate engineering innovation. SDGs have been considered a starting point for the development of criteria for climate engineering (Stelzer, 2020). However, as mentioned, even if intended to provide an inclusive approach to societal stakeholders, the SDGs framework still needs approximation and reflection on how to realize this global effort. Hence, the polysemic nature of accountability above delineated and its articulations in multiple dimensions might form a basis for philosophical reflection on how to responsibly implement climate engineering innovation, in modalities that also align with the ideal of sustainable development.

First, the dimensions of accountability require identifying accounteers and accountees, the need for shared standards upon which conduct and relations are assessed, and, consequently, a dimension of enforceability in scenarios of violations. Naturally, these shared standards could take the form of international law, given the global impacts of climate engineering technologies. No global roles, obligations, or rights exist concerning these technologies. However, existing ancillary international and regional frameworks do provide the foundations for such international treaties to be formed. Human rights law, State responsibility, Environmental law, Climate change law, Space law, and Maritime law provide starts for how law between nations governing international geographies can be approached concerning climate engineering technology innovation and deployment. Taking human rights law as an example, we can already see how framing the multidimensional understanding of accountability for climate engineering can take place. Procedural rights, for example, would implicate the need for citizens to have access to information, participate in public affairs, and, of course, have access to legal remedies. Substantive rights provide the grounding on which such procedural rights take place concerning climate engineering, particularly an individual's right to life, healthy environment, health, food, and water. More abstractly, however, there are also rights concerning the scientific research into climate engineering innovation, in particular, the freedom to conduct said research, the right to benefit from scientific progress, and, of course, the related moral and material interests derived from such research. Although there are no current international statutes delineating this concerning climate engineering, projects are undergoing aiming at providing shared standards for both the design of these technologies and their eventual implementation.[2]

However, some scholars argue that just formal or informal governance of climate engineering is impossible, since it would require novel international organizations with unprecedented enforcement powers (Biermann et al., 2022). Others have emphasized how, even if global climate change mitigation is recognized as a global public good (i.e., the benefits of which are available to everyone and nobody can be excluded) requiring aggregate efforts, the cooperation of some or most nations in this case may fail because it is vulnerable to cases of free riding and relies on unbalanced premises, since countries with the largest number of poor people tend to be those who have contributed least to the problem of climate change and to be less prone to be involved in a carbon-free development path (Barrett, 2007). Still, this does not mean that what restrains climate engineering from being an object of political governance and accountability in the context of climate change mitigation should be ignored. Instead, this point and the related issues deserve further attention, also to avoid ungoverned spaces, or situations of "de facto governance" on the part of industrialized, developed countries and private sector lobbies, in ways that do not involve the consideration of other countries or vulnerable groups (Gupta & Möller, 2019; Biermann & Möller, 2019).

An ideally "just" governance should be aware of the interlinkages between different dimensions (institutional, socio-technical, technical) in climate engineering innovation, and promote separate regulatory strategies and adaptive and progressive approaches toward risk allocation, in ways that are not unilateral and recognize common but differentiated responsibilities among social actors, who have different capabilities to adapt, different institutions, and different incentives to promote climate-friendly policies in the collective action problem of climate change (Barrett, 2008, 2014).

To avoid the spread of narratives on climate engineering proposals that pretend to be policy-neutral and objective, a societal reflection that evaluates what is "sustainable" in possible guiding governance principles should be put forward. For example, in the sustainable development literature, many have criticized the increasing "countability" as a guiding principle for sustainable proposals, which relies on quantitative indicators of outcomes that are depicted as value-neutral (Bexell & Jönsson, 2017, 2021). The same has been done in the climate engineering literature, where many have claimed how poorly might be a "portfolio" approach in the context of technologies like CCUS since rather than foster a coherent vision, it just adds and combines CCUS as an option within idealized and coordinated scenarios or portfolios, and so it does not consider the competing relations and trade-offs with other resources (land, energy, water) and with policy and institutional layers (Sovacool et al., 2022). Thus, in policy decisions regarding climate engineering, the implementation and justification of decisions should go beyond a mere quantitative assessment of risks and sustainable indicators and instead involve better-informed investigations dealing with the various normative uncertainties related to those climate proposals (see, e.g., Taebi et al., 2020). For example, an empirical study has recently demonstrated how a slow, robust, and bottom-up governance intervention for novel carbon-removal options might positively impact other dimensions, such as mitigating social backlash and improving technical and environmental design (Sovacool et al., 2022).

Regarding the modalities for implementing and monitoring shared standards or governance principles, one solution might be the promotion of forms of meaningful horizontal accountability, which works in contexts where there are no clear hierarchies but peer relations with various stakeholders (Schillemans, 2008). This kind of accountability might be the most decisive in the SDGs context, where different national and voluntary accountability mechanisms for implementation present competing powers, such as audit institutions, courts, and parliaments (Breuer & Leininger, 2021). Although the SDGs are not legally binding, national governments are expected to improve their governmental and intergovernmental mobilization efforts and develop specific indicators for climate engineering options. However, even if the inclusion of CCUS into mitigation portfolios has received an increasing consideration, few countries are pursuing a reliable implementation of carbon dioxide removal strategies into long-term national mitigation portfolios so far (IPCC, 2022, Chap. 12, pp. 39, 62).

At the international level, the UN Framework Convention on Climate Change (UNFCCC) and its Paris Agreement (PA) do not explicitly mention climate engineering technologies. Still, PA procedural mechanisms and nationally determined contributions might provide a basis for future deliberations on climate engineering proposals, promoting collective cooperation and transparency (Craik & Burns, 2019). The latest report from the United Nations' Intergovernmental Panel on Climate Change (IPCC) states that the governance of carbon dioxide removal methods can draw on a "political commitment" to formal integration into existing climate policy frameworks, and that a crucial governance challenge would be to establish reliable systems for monitoring, reporting, and verification (MRV) of the carbon flow and mitigation outcomes (IPCC, 2022, Chap. 12, p. 6). The report also affirms that the SDGs framework serves as a "template" to evaluate the long-term implications of mitigation on sustainable development and vice versa (IPCC, 2022, Technical Summary, p. 133). In this sense, the IPCC report suggests that coordinated and cross-sectoral policies integrating mitigation with SDGs on other sectoral policy actions (health, nutrition, equity, and biodiversity) should be adopted to alleviate or avoid many trade-offs of carbon dioxide removal methods (IPCC, 2022, Chap. 12). The creation and maintenance of shared standards on technologies like CCUS would thus require interaction and integration of different actions in the context of the SDGs to enable just transition pathways[3] and accountable infrastructures. As stated in the volume's introductory chapter, trade-offs between SDGs may emerge, and one crucial aspect of the governance of technologies is to acknowledge the interlinkages between different dimensions of sustainable development (Sætra, 2022).

Finally, the answerability dimension requires the practice of holding accounters as appropriate actors of justificatory challenge and thus susceptible to response about their conduct (Smith, 2012). Defining accountability as mere transparency concerning outcomes is a partial way to view it (Andersson & Wikström, 2014). The way carbon dioxide removal strategies are communicated is likely to influence their use and the way people conceptualize them; hence not only transparency ex-post is needed but also the framing of information presented to the public needs considerable scrutiny (Spence et al., 2021). Institutional commercial or scientific actors might misrepresent adverse information and frame climate engineering interventions as societal camouflages, reflecting how social actors prefer to instrumentally or implicitly describe technologies in ways that avert opposition or debate (Low et al., 2022). Public awareness of technologies like CCUS is still very low, but the engagement of public and civil society organizations is very relevant to shape equitable carbon-removal and storage projects that consider human health, energy needs, ecological integrity, and local community engagement (IPCC, 2022, Chap. 12, p. 65).

In this scenario, accountability may also require space for bottom-up and community strategies or for contestation (Heidelberg, 2017). Recent empirical studies on climate engineering models have reported the positive role of controversy and opposition from ENGOs, social groups, media, and delegates at the international conventions; in addition, they have also motivated the growing need for additional forms of societal appraisal, co-benefits methods, and citizen, indigenous and entrepreneurial involvement, which are still not settled for carbon-removal experimentation or are too vague for providing concrete public engagement (Low et al., 2022). Accountability as a normative criterion involves relations of responsiveness that aim to promote a dynamic co-variation of people's interests and policies (Morales, 2014). Thus, accountability for climate engineering innovation should deal with this co-variation, even if, due to the early research stage of these technologies, it is not clear how participatory RRI approaches and their emphasis on inclusivity can guide toward sustainable solutions, instead of introducing conflict-prone diversity perspectives that can also hamper or set-back research (Stelzer, 2020). Thus, "No one will be left behind" (United Nations General Assembly, 2018) is still a work in progress. A civil space that seeks to promote the participation of different views is necessary and valuable but still requires novel solutions and continued scrutiny to foster meaningful accountability relations for the governance of emerging technologies like those of climate engineering.

4.6 CONCLUSIONS

Climate engineering technologies are a technology family whose goal is to change the Earth's temperature such that we can readily combat climate change and remediate the damage that has already been done. This chapter took up a specific climate engineering technology, namely carbon capture, usage, and storage (CCUS) and showed how these technologies pose unique, global socio-political issues. This chapter has explored at how climate engineering innovation can be supplemented with a polysemic and multidimensional account of accountability. This has provided a theoretically informed basis for reflection on how to implement not only the responsible innovation of climate engineering technologies but also a dynamic landscape in which the innovation of climate engineering technologies can be built to support sustainable development more broadly.

Climate engineering innovation should avoid the risk of adopting an apolitical façade, which treats governance arrangements as neutral sites and fosters an illusory techno-optimism over the management of such a complex tech-mediated climate model. We have highlighted how the consideration of these models as mere techno-fixes does not go far enough. Indeed, techno-fix solutions can be included in the general vision of techno-solutionism and optimism, as the belief that technologies can contribute to good outcomes (see Chapters 1 and 2). But too much reliance on techno-fixes can lead to the progressive depoliticization of planetary environmental issues, and can foster a distorted binary vision in which the climate crisis is resolved by either withdrawing from technology (i.e., rejection) or accelerating it (i.e., solutionism) (Dillet & Hatzisavvidou, 2022). Instead, more balanced approaches that expand and deepen the understanding of socio-political responses, fundamental and complex social changes to the climate crisis, and the governance of technologies like CCUS are needed.

We have shown how climate engineering innovation should deal with analyzing power asymmetries and their problematic dimensions, in line with considerations on infrastructural technological change as sustained in the introductory chapters. Infrastructural technological change means that technologies may involve wide societal effects and relevant shifts in social structures (Barley, 2020). Therefore, our aim in this chapter has been that of highlighting how climate engineering innovation can be properly considered object of socio-political theorizing, since its core implications (e.g., the possibility of generating power asymmetries, and inequality more generally) can generate examples and paradigms of injustice, as well as require regulatory strategies, enforcements, and normative justifications on how decisions about innovation and sustainable strategies are taken and communicated. A reliable implementation of carbon dioxide removal and storage strategies into long-term national mitigation portfolios and public awareness of such strategies are still very low. And at the same time further work is needed to assess what responsible climate engineering innovation means, in modalities that also align with the ideal of sustainable development. In examining how and to what extent the concept of accountability is polysemic and multidimensional, our aim was to show how climate engineering innovation involves broad socio-political processes, and, more fundamentally, requires holistic approaches that take into consideration the responsibility of the actors involved, mechanisms of distribution and participation, and democratic governance on its sustainability-related impacts.

NOTES

1 UN 2015, target 16.6, but accountability is also present in SDG #17 in "Data for monitoring and accountability" and SDG #5 and #10, on gender inequality and inequality between countries, respectively.

2 For example, the TechEthos (EU Horizon 2020 Grant Agreement no. 101006249) project aims to provide "ethics by design" guidelines as well as legal recommendations for climate engineering technologies (among others), see TechEthos Project (2022) and Porcari et al. (2021).

3 In those recent years, "just transition" as a concept emerged from labor unions, environmental justice groups and the EU policy environment, encompassing the equitable shift toward

a regenerative economy in which principles and processes can respect and promote environmental and climate justice, see for example, Morena et al., 2020; *European Commission, Just Transition Platform, available at* https://ec.europa.eu/regional_policy/en/funding/jtf/just-transition-platform *(Last Access 7 Oct 2022).* The same SDGs framework that is based on the "leave no one behind" principle requires among its goals the pursuing of a just transition, as an energy transition that is shared widely and supports fair distribution (United Nations General Assembly 2015: Preamble). In this chapter, we do not devote much space to the "just transition" concept, since we are not exclusively interested in inclusiveness and matters of distributive justice in climate engineering innovation, that is, in the principles and processes that distribute benefits and burdens across members of society. However, we concentrate on the dimension of accountability, which is linked to matters of responsibility among members in society, and shared standards and normative justifications on actions. Justice issues related to energy or environment have not only components related to distributive justice but most importantly to responsibility, see Pellegrini-Masini et al., 2020. On the interdependence of different types of justice in energy justice, see the recent Astola et al., 2022.

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