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The NET effect: negative emissions technologies and the need–efficiency trade-off

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Non-technical summary. When developing and deploying negative emissions technologies (NETs), little attention has been paid to where. On the one hand, one might develop NETs where they are likely to contribute most to global mitigation targets, contributing to a global climate solution. On the other hand, one might develop NETs where they can help support development on a regional basis, justified by regional demands. I defend these arguments and suggest that they reflect the values of efficiency and responding to need, respectively. To the extent that these values conflict, they introduce what I call the Need-Efficiency Trade-off Effect ('NET Effect').

Technical summary. Unlike other geoengineering methods, the effectiveness of negative emissions technologies (NETs) tends to be sensitive to regional siting. This paper argues that this point raises morally and legally important implications by identifying a trade-off between 'efficiency' and 'need'. First, it introduces two arguments justifying NETs: one focused on contributions to global mitigation and the other focused on contributions to regional development. Second, reflecting the two arguments, the paper discusses the moral values of efficiency and need, respectively. For instance, if the strategy is to try to use NETs to maximize expected mitigation contributions to reflect efficiency, then deployment should occur in regions with the best prospects for success (e.g. Western countries). However, if the strategy is to try to use NETs to improve the chances of simultaneous development and mitigation to respond to need, then deployment should occur in regions with limited development and expected growth of demand for NETs (e.g. Asian countries). When these values conflict, I call that a Need-Efficiency Trade-off Effect ('NET Effect'). The paper concludes by considering the NET Effect in the context of bioenergy with carbon capture and storage as well as direct air carbon capture and storage.

Social media summary. Should negative emissions technologies be deployed in Western countries for most climate action or Asian where needed for development?

1. Introduction

Discussions of the ethics of negative emissions technologies (NETs), while increasing, still contain many underexplored areas.[1] In these pages, Lenzi (2018) noted that there are several characteristics of NETs that set their ethics apart from both other forms of mitigation – and from other forms of what has been loosely called 'geoengineering' (Shepherd et al., 2009).[2]

The purpose of this paper is to introduce a moral issue arising from one of the distinctive characteristics Lenzi identified: for many NETs, their success depends on the sub-national region in which they are implemented. That dependence means that different moral values, which I call 'efficiency' and 'need', have significantly different implications for how NETs should be developed – in particular, *where* they should be developed. Since these values support different strategies for deployment, I also draw out a practically important trade-off between ways of funding the development of NETs. Roughly speaking, the trade-off is between developing NETs in Western-industrialized countries where geological understanding and human capital is advanced and developing NETs in Asian countries where demand for NETs is expected to expand greatly over the coming decades.

I call this trade-off the 'Need-Efficiency Trade-off Effect' (NET Effect). The NET Effect is that, when considering where we should devote resources to developing NETs, we might confront a choice between choosing the regions with the *best prospects* for successful sustained mitigation benefits (efficiency) and the regions with the *greatest need* for NET capacity

[1]NETs are sometimes discussed under the heading 'carbon dioxide removal'. For my purposes, and following much of the recent literature, I treat these terms as synonymous. Roughly speaking, some of this growing ethics literature has supported development of NETs (Callies & Moellendorf, 2021; Mintz-Woo, 2022; Mintz-Woo & Lane, 2021; Peacock, 2022), while other literature has questioned it (Lenzi, 2021; Lenzi et al., 2018, 2021; Morrow et al., 2020; Shue, 2017, 2018).

[2]Technically speaking, geoengineering refers only to large-scale intervention of the climate system, whereas NETs may be implemented at any scale, so to compare like with like, this point would apply only when NETs are considered at large scale. However, I agree with Honegger et al. (2021) that NETs are more appropriately conceived of as mitigation rather than being subsumed under 'geoengineering'.

(need). These moral values can be justified by considering the global contribution that NETs can make to mitigation or by considering the regions that require NETs for development purposes, respectively.

In Section 2, I discuss two arguments which justify using NETs, one which is top-down (from a global point of view) and one which is bottom-up (from a regional point of view). Both support the development and deployment of NETs. In Section 3, I point out that these arguments support different moral values in terms of development and deployment: efficiency and need. Since these values practically conflict, I argue this generates a NET Effect. In Section 4, I consider whether two prominent families of NETs, BECCS and DACCS, might be subject to NET Effects. Finally, in Section 5, I conclude.

2. Morally defending NETs in practice

The purpose of this section is to present two distinct arguments which justify the development and deployment of NETs; one of these arguments is top-down (i.e. global) and the other is bottom-up (i.e. regional). NETs are deliberate human activities for removing greenhouse gases from the atmosphere, that is, after they have been emitted. In this context, two prominent NETs both involve carbon capture and storage (CCS).[3]

One CCS option commonly relied upon in the modeling community is bio-energy with carbon capture and storage (BECCS) and another is direct air carbon capture and storage (DACCS). I expand on different NETs later (Section 4). There are many other forms of NETs (e.g. Hale, 2011; Heyward, 2013; Lenzi, 2018), but the effects discussed in this paper occur when and to the extent that the NET in question is both (i) sensitive to which (sub-national) region it is being rolled out in (i.e. there is significant heterogeneity of regions in terms of the expected deployment success and capacity, which I call 'regional heterogeneity') and (ii) used to offset other emissions within the same country with respect to nationally determined contributions (NDCs) ('regional offsetting'). If and to the extent that these conditions occur, a tension can arise between developing NETs where there is the most efficient mitigation potential (i.e. the resources are most cost-effectively deployed) and where there is the greatest expected need (i.e. the NETs are expected to be most useful in offsetting morally or practically important emissions, especially in regional development). Roughly speaking, if we take NDCs as constraints on developing countries, then NETs are needed to address locked-in development emissions.

NETs include capture of carbon from the ambient air via both technological means (DACCS) and biological means (BECCS), as well as the most straightforward biological means of afforestation and reforestation and other biomass measures.[4] It also encompasses all technologies that capture emissions from smokestacks and other point sources (CCS), since emissions that are captured from smokestacks have been emitted as a byproduct, for example, of production activities. I expand on differences amongst NETs later (Section 4).

[3]CCS always involves the sequestration of carbon, but it only is a NET when the source of that carbon is atmospheric, such as when the source of the carbon is biomass (which embodies atmospheric carbon during growth). In contrast, if the source of the carbon is fossil, then that carbon is not removed from the atmosphere.

[4]There are other, more marginal, options like ocean fertilization (Hale, 2011). Since the unknowns are much higher for these options, it is harder to assess them.

While the modeling community has clearly indicated the significant challenge of meeting various carbon budgets in the absence of NETs (Minx et al., 2018; Riahi et al., 2015, 2021), less has been said about the moral arguments for their development in regional contexts. This is a problem when NET Effects could be relevant; one might want to consciously choose which moral values one's mitigation efforts reflect. If NETs are not deployed strategically, guided by moral values, they will be guided by market forces. For instance, almost all carbon storage has been deployed to contribute to enhanced oil recovery (injecting carbon into oil wells to increase extraction), which is not supported by any moral argument. In contrast, different moral arguments can be made to support the development of NETs (Mintz-Woo & Lane, 2021). We can distinguish a familiar global/efficiency-based argument (Section 2.1) from a less familiar regional/needs-based argument (Section 2.2). We might also be interested in how these arguments apply in practice (Section 2.3).

2.1 A globally necessary contribution

First, when considering the importance of NETs from a global perspective, they can be morally justified by appealing to the consequentialist rationale that achieving any given target carbon budget necessarily requires that NETs are part of the mitigation portfolio.[5] This is especially appropriate if the optimal level of mitigation involves massive and rapid deployment of NETs, as integrated assessment models suggest (Minx et al., 2018; Riahi et al., 2015, 2021).[6]

Assuming that it is morally imperative to achieve any given target carbon budget, we can justify methods like NETs that are necessary for achieving those goals. This is plausible at least in contexts where NETs are not unduly costly, either in terms of resources or risk. While I lack the space to defend the claim here (regardless, they have been discussed extensively by Morrow et al. (2020) and Minx et al. (2018)), I believe that the risks of NETs are fewer and better understood than geoengineering proposals such as stratospheric aerosol injection, and that denying NETs a place in the portfolio of mitigation options imperils the chance of avoiding serious climate harm (for similar claims, cf. Callies & Moellendorf, 2021; Peacock, 2022). Minx et al. (2018) convincingly argue that various types of NETs should be part of the mitigation portfolio in order to make it feasible to meet emission targets (also cf. Jebari et al., 2021).

However, standard consequentialist considerations suggest that, for any given marginal investment in NETs, we should maximize the expected benefits from that investment, which in this case concern climate mitigation. Given the regional heterogeneity assumption, some regions would be better suited to developing NETs, perhaps because they would be more likely to succeed, perhaps because they would be more likely to have significant capacity, or perhaps some weighted product of these factors.[7] The global argument says we are justified in scaling up NETs, and suggests that we should do so when the prospects for total mitigation

[5]For instance, in the European context, Galán-Martín et al. (2021) suggest that this is the case.

[6]This needs to be spelled out carefully, since it is not always clear what feasibility presupposes and allows for (Gardiner, 2021).

[7]For instance, some regions have greater innovative capacity; some have greater public and policy support; some have different levels of investment and material wealth. For my purposes, the primary focus is on the way that NETs require regional *customization* (Malhotra & Schmidt, 2020), being sensitive to the geological features, and being more likely to succeed given local human capital.

capacity are maximized. I call these regions the ones with the 'best prospects' (since a prospect is a set of outcomes and probabilities associated with an action). Since gases are well-mixed in the atmosphere, it does not matter where mitigation contributions come from – just their volume or size.

Note that one can adopt this global argument without being committed to any particular substantive moral principle regarding the just distribution of benefits and burdens with respect to the costs of an energy transition (Moellendorf, 2015).[8] For instance, one might believe that the costs of researching and developing NETs should fall on those who benefited (e.g. through inheritances and infrastructure swollen from historical emissions) (Atkins, 2018; Butt, 2014; Goodin & Barry, 2014; Meyer & Sanklecha, 2011; Page & Pasternak, 2014) or on those who are most capable of paying independently of their contribution to emissions (Caney, 2010; Miller, 2009). However, we might also focus on the emitters themselves, either because they polluted (Gardiner, 2004) or because the emitters have a responsibility to address socially externalized costs such that they are not left to society (Mintz-Woo, 2021). This argument is compatible with the burdens being shared with respect to any of these principles. For this reason – while I favor the final of these four principles – I will set this matter aside. The moral claims in this paper are independent of which stance one takes on this complex and contentious issue.

I am assuming that there is little likelihood that we will mistakenly end up with *too much* capacity for negative emissions. Given the volume of emissions that we expect to need to abate over the coming decades, as well as the elevated atmospheric greenhouse gas emissions that we would ideally reduce, this assumption seems warranted, but it is ultimately empirical. At the very least, it seems reasonable to believe that the risk of having insufficient capacity is far greater than the risk of having too much capacity.

2.2 A regionally justified contribution

Second, we can discuss a moral argument justifying NETs on the basis of regional need. This issue arises in the context of NETs more than with other kinds of climate responses, especially the forms of geoengineering that have received the bulk of attention from moral philosophers, namely, sulfur aerosol injection (SAI) (e.g. cf. Flegal et al., 2019; Pamplany et al., 2020). The effectiveness of some NETs is sensitive to features which vary significantly from region to region. SAI, in contrast, spreads aerosols quickly on a global scale, and would have immediate effects which are not regionally constrained. The regional nature of many NETs therefore distinguishes it, morally speaking, from other geoengineering technologies.

In many, but particularly developing, regions of the world, social and economic development is of significant moral importance. In some such regions, development could be put at risk if sufficient NETs remain unavailable. In these regions, carbon-intensive infrastructure – like fossil-fuel power plants and production facilities for smelting or concrete mixing – has been built and is needed for development goals. If these regions are also constrained by carbon reduction contributions, they will have to phase down this infrastructure. However, if they have access to enough NETs to balance these emissions, then they can both develop and contribute to carbon reduction targets. In short, if emission targets are required such that the governments take the targets as binding constraints, then they either can prematurely retire using this infrastructure or offset it using regional contributions from NETs.

There are at least two moral principles that are relevant in this context (Mintz-Woo & Lane, 2021). One moral principle is that, globally speaking, plans to address climate change should not add to the burdens of the globally worse-off (Moellendorf, 2014, 2015). Since prematurely retiring infrastructure could impede developmental goals in some regions, this principle holds that it is morally important to allow this infrastructure to continue (at least for some time). In global terms, we can expect that this is the case in places like developing Asia, where we would want to find ways of winding down use of this infrastructure that would not have adverse effects on people's economic development. In short, this principle supports only climate mitigation strategies which do not harm those worst off in global terms; here, that means continuing to operate fossil-fuel intensive infrastructure where that is needed for social or economic development.

A second moral principle is that those in regions with great need may have reasonable expectations that their infrastructure will continue to be used (Meyer & Sanklecha, 2011, 2014; Meyer & Truccone-Borgogno, 2022).[9] What would make these expectations reasonable? Following Rawls (1951), scholars like Brown (2017) and Meyer and Truccone-Borgogno (2022) argue that government generates expectations which are (a) beliefs about the future concerning (b) what agencies or governments should (not) do that are (c) justifiable, in the sense that they are formed on a reasonable epistemic basis. In the climate context, individuals and groups within regions with great need (whether for fossil-fuel intensive power or for the products and services which rely on fossil-fuel intensive processes) may have legitimate expectations in this sense. They may have set up their lives and careers in ways that rely upon the future fossil-fuel intensive operations, having reasonably or justifiably believed that these would not be interfered with by new government policies. If citizens develop legitimate expectations, these scholars suggest, there is a strong presumption against acting against these expectations by the government. In short, the government has a prima facie duty to not act contrary to these expectations; here, governments have a duty not to stop this fossil-fuel intensive infrastructure from continuing to operate.[10]

Both of these moral arguments converge in suggesting that governments should allow fossil-fuel intensive infrastructure which satisfies these conditions to continue. However, this infrastructure can be allowed to continue even while there are regional emission targets if, given the regional contributions assumption, the regions have access to sufficient NET capacity. 'Sufficient' in this context indicates that the capacity to offset the emissions associated with continuing to operate the fossil-fuel intensive infrastructure – at least for a transition or some other limited

[8]Of course, many scholars have advocated some mix of the following principles as well.

[9]Also compare critical comments by Culp (2011), suggesting that it might be difficult to reconcile the legitimacy and justice of a state that allows citizens to emit above the amount compatible with avoiding climate harms.

[10]One possibility, suggested by Meyer and Truccone-Borgogno (2022), is that if acting against these legitimate expectations, the governments could in various forms compensate those affected. Since the regions under consideration have great need, this need may be indicative of limited fiscal capacity, in which case this would not be a live option. However, in circumstances where those with legitimate expectations can be made whole and the fossil-fuel intensive infrastructure decommissioned, compensation could be a way of avoiding the NET Effect discussed in the following section.

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period. Sufficient NET capacity could allow this infrastructure to continue until, for instance, standard power plant lifespans are reached, or alternatives can be developed and rolled out. These twin regional needs-based arguments thus justify increasing NET capacity for regions where these needs are sufficiently great, legitimate expectations have been formed about their continuance, or premature shutting down would harm or undermine the development of the globally worst-off.

Beyond these moral arguments, in light of the Paris Agreement, an independent *legal* argument can also be proffered. The concept of common but differentiated responsibilities and respective capabilities still plays a bedrock role in global negotiations – and is explicitly endorsed in Article 2 of the Paris Agreement. Since different regions have different responsibilities and capabilities, the United Nations Framework Convention on Climate Change discussions and demands are sensitive to this heterogeneity. In this case of regions where increased NET capacity would be crucial for development and for meeting NDCs, we see an echo in Article 9.1 of the Paris Agreement, which requires developed countries to provide flows that facilitate mitigation and adaptation (Bodansky, 2016). Furthermore, Article 4 explicitly mentions the importance of promoting development and eradicating poverty, reinforcing this regionally justified contribution argument.

In order to meet NDCs, parties to the Paris Agreement are required both to track and indicate their progress in greenhouse gas inventories (Article 13.7) and to 'pursue domestic mitigation measures, with the aim of achieving the objectives of such NDCs' (Article 4.2) (Honegger et al., 2021). In short, if NETs are interpreted as mitigation contributions, developed parties to the Paris Agreement should assist with technology transfer of NETs to help developing countries reach their NDCs without compromising development. NETs can allow developing parties to offset their development-associated emissions while still aiming to achieve their NDC targets. Aside from the two moral obligations supported by the regionally justified contribution argument, this forms the basis for concluding that there is a similar legal obligation under the Paris Agreement.

Note that the regionally justified contribution framing differs significantly from the way that some of these discussions have been held. Many have pointed to the potential for NETs to be financially or environmentally costly to the regions in which these operations occur (Lenzi et al., 2018; Shue, 2017, 2018). In contrast, my point is that NETs are necessary for development and required to meet NDCs or other mitigation targets. In other words, I am drawing attention to the benefits of NETs to certain regions. This does not gainsay the likelihood that there will be costs, but the benefits I am drawing attention to have rarely been sufficiently appreciated, at least in the moral literature.

2.3 Using these arguments and an objection

While I endorse the top-down, globally necessary contribution argument as well as the bottom-up, regionally justified contribution argument, it is worth understanding how these arguments could be used, as well as their limitations. I first discuss the scope and applicability of these arguments, and second a concern that this kind of technological appeal might reinforce vulnerability via what Satz (2010) calls 'noxious markets'.

First, the relevance of these arguments might depend on the entities in question. Obviously, national and sub-national governments might be primarily concerned with regional or needs-based arguments, especially governments in regions with great current or future need. International fora, such as the Intergovernmental Panel on Climate Change or the United Nations Framework Convention on Climate Change, may be concerned with the capacity to scale up NETs in order to prevent the aggregate international effects that robust mitigation efforts could forestall or prevent. In this context, global or efficiency-based arguments might seem more appropriate. Regardless, a risk with failing to consider these regional justifiability arguments is failing to consider those who are particularly vulnerable.

The relevance of these arguments might also depend on the (time)scales at issue. For instance, the importance of NETs for regional needs would ideally be limited to offsetting the emissions associated with hard to decarbonize sectors or infrastructure which could be eventually be greened or decommissioned. In other words, regional needs could be more relevant on shorter timescales, but also for a much smaller quantum of mitigation. In contrast, both the time and volume of NETs required to make a sizeable dent in historical emissions may easily be decadal in both operation and construction. In short, the quantum of emissions associated with contributing to global mitigation targets is much greater than those needed to bridge hard to decarbonize operations or production.

Second, regardless of the argument adopted, one might object that introducing such NETs threatens justice in another way: we might see that this would generate 'noxious markets', where underlying poverty or vulnerability are exacerbated with the lure of resources for the regions with the best prospects (Satz, 2010).

I would respond by pointing out that the focus here is on the benefits to regions for developing NETs, in terms of (a) direct resource and technology transfer; (b) capacity to continue operating fossil-fuel intensive infrastructure which may be important for development; and (c) capacity to help meet NDCs. While it is beyond the scope of this paper to determine how potential environmental or social harms compare to these benefits, it is not immediately clear that such markets would exacerbate poverty or vulnerability – not least because the regionally justified contribution argument is explicitly intended to *facilitate* development. In cases where NETs would not facilitate development, this argument would not justify NET expansion.

Regardless, these arguments draw attention to two reasonable moral values that we might endorse when addressing NETs: need and efficiency. I believe that both of these arguments give us good reason – and independent grounds – to support NETs. However, the fact that these are two distinct values reveals the possibility that one could in practice face trade-offs between these values. I discuss such trade-offs in the next section.

3. The NET Effect

Two values that might inform our adoption and expansion of NETs are need and efficiency. In this section, I define these terms and provide examples in turn, explaining how these values could apply in the context of NETs.

A first value is:

Need: Given a risky technology, if one were implementing that technology to regions in terms of need, then one would provide the technology to regions where:

(1) those regions are materially deprived; and,

(2) if, or to the extent that, the technology succeeded, it would help address that regional material deprivation.

NETs are risky technologies, in the straightforward sense that there is uncertainty or significant risk with respect to the success of any given installation or operation. More precisely, they are subject to both significant complexity in construction as well as – and most importantly for my purposes – regional sensitivity and customization in terms of deployment (Malhotra & Schmidt, 2020). Success would be capturing carbon from a given installation and storing it underground (or capturing and storing carbon commensurate with antecedent expectations).

With respect to need, we can restrict ourselves to developing countries which are (relatively) materially deprived, and consider how NETs would affect or improve their development, thus addressing some of that deprivation. If the concerns are about both growing expected need for NETs and significant developmental benefits from NETs, Asian countries are a plausible focus. First, in Asian countries we can expect significant future demand for NETs involving CCS. For instance, one way of indicating how much scale-up is required is to consider the ratio of future demand flows of carbon sequestration to flows associated with recent oil and gas operations. If the ratio is high, it means that demanded future sequestration activity is greater than current oil and gas operations, indicating relative growth. When considering this indication, Asian countries like China and India tend to have much higher ratios compared to international counterparts (Lane et al., 2021). Second, development in China and India has involved lock-in with respect to carbon-intensive infrastructure; thus, it is difficult to see how absence of NETs, continued development, and commitments to the Paris Agreement targets can all be reconciled. In this manner, Asian countries both have developmental needs and expected growth in need for carbon sequestration, justifying a focus on these countries. Furthermore, there are also *direct* material effects which respond to need: when technology and financial resources are transferred to developing countries, material deprivation is also lessened, further addressing needs.

An alternative value to needs is:

Efficiency: Given a risky technology, if one were implementing that technology to regions in terms of efficiency, then one would provide the technology to regions with the best prospects for the overall success of that technology.

Overall success means maximum sustainable mitigation contributions, which might be evaluated over time or according to cost-effectiveness in expectation (e.g. highest emissions sequestered per monetary units). With respect to efficiency, depending on the NET in question, if regional heterogeneity applies, then different regions could dramatically differ in prospects for success.

In the specific case of NETs involving carbon sequestration (as discussed below), there are advantages to exploring potential sites which have high levels of related human capital and are geophysically well-understood. Both of these considerations tend to apply in places where large amounts of oil and gas exploration have been done. On the human capital side, this is because the expertise needed to *sequester* or store carbon is similar to (and sometimes overlaps with) the expertise needed to *extract* hydrocarbons. This is because, very roughly speaking, storing carbon in geophysical formations is the reverse of extracting hydrocarbons from those formations. Of course, the regions with the greatest level of oil and gas activities – and, generally speaking, the best prospects – include areas in the United States, northern Europe, and the Middle East.

Since there is no guarantee that the regions with greatest need and the regions with best prospects will overlap (and some reason to expect that they will not, as indicated above), we should be prepared for a trade-off between responses grounded in need and efficiency (Mintz-Woo & Lane, 2021). I call this the Need-Efficiency Trade-off Effect (NET Effect) (Mintz-Woo, 2022). In the current context, we could expect that the trade-off would be between regions which it would be efficient to develop NETs in (roughly speaking, Western countries and Middle Eastern countries) and regions where developing NETs would address both demand and development needs (roughly speaking, Asian countries). In order to address this NET Effect, we should be clear on the potential for this trade-off and then be careful about which values we wish to promote – or under which conditions to prioritize one over another.

First, it is worth being explicit that both need and efficiency can be of moral importance. There are a few ways of indicating this, but one comparison is about these values in the abstract while another comparison is about these values in the specific climate context. In the abstract, that someone is in need makes it more morally important to address that need on most views of distributive justice. For instance, utilitarians believe that, in line with diminishing marginal utility, those who consume the least will be benefitted the most when receiving resources; prioritarians believe that, above and beyond considerations of diminishing marginal utility, it is more socially valuable to benefit those who have the least welfare; while sufficientarians believe that those who are below thresholds of basic needs have a special moral priority.

In contrast, efficiency is morally important in the abstract as well. In principle, governments owe it to their citizens to use their resources in the most effective ways they can; as Broome (2012) writes, governments' duties are primarily 'duties of goodness' (duties to promote the best outcomes). In the context of investment in NETs, there are several preconditions for successful roll-outs in NETs, many of which involve costs to government. These are not limited to investment support and institutional capability to manage commercial risk, but also non-financial support including supportive regulatory regimes. Many of these costs, whether financial and institutional, require government effort (Lane et al., 2021). Governments owe it to citizens that these costs provide the greatest benefit; in the context of NETs, governments owe it to their citizens that their resources and efforts contribute to the most cost-effective expansions of NET capacity – and contributions to climate mitigation. In short, if governments have ways of supporting NETs, they should do so with an eye to supporting the best options in prospect.

Second, in the specific context of NETs and avoiding climate impacts, following NET investment development patterns that promote need and efficiency can also have morally relevant differences. In particular, near-term or long-term *distributive justice* in the climate context could be advanced by promoting need or efficiency, respectively. For instance, suppose that, in investing in NETs when prioritizing expected need for NETs, resources and technology transfer flow from wealthy developed countries (or their governments) to regions with higher needs. If we consider the global distribution of resources, wealthy developed countries control greatly unequal resources compared to the countries which we can expect to have the greatest expected need for NET in the coming decades (predominantly in China, India,

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and other Asian countries). This implies that, in facilitating these flows, governments could advance global distributive justice – at least in the short term.

In contrast, optimizing mitigation contributions from NETs (like any other form of mitigation) could help reduce future climate impacts, which have disproportionate impacts on the future global south. In other words, we can expect that avoided medium- and long-term climate impacts help increase future distributive justice by decreasing harms that accrue to regions which are especially vulnerable. In the long term, the effects of avoided climate harms are probably disproportionately beneficial to those who are worse-off globally.

In short, both needs and efficiency are morally important in general as well as in this particular circumstance. In this context, prioritizing NET development along the dimension of need can increase global distributive justice in the shorter term whereas prioritizing NET development along the dimension of efficiency can increase global distributive justice in the longer term.

The primary point of drawing attention to this NET Effect is to indicate that there are distinct values at issue, that this distinction has practical import, and that considering NETs from a primarily regional perspective can deliver moral and theoretical insights, which should be recognized by different stakeholders. In contrast, since many other climate interventions – such as geoengineering techniques like SAI – have side-effects which are predominantly *not* regionally isolated, the NET Effect does not apply to them, which makes the ethics of NETs distinctive. However, with respect to different NET options, the NET Effect may apply to a greater or lesser extent, as discussed in the following section.

4. Considering the NET Effect for two different NETs

Thus far, the discussion in this paper has not differentiated between different NETs. While the primary purpose of this paper is to introduce this NET Effect, it is worth indicating how this NET Effect could apply to two potential candidates NETs. I discuss BECCS first (Section 4.1) and DACCS second (Section 4.2).

4.1 Bioenergy with carbon capture and storage

There are two reasons to focus on BECCS in particular: first, a NET Effect is especially relevant with respect to this NET (BECCS is highly sensitive to regional siting, since it is complex in design and requires customization (Malhotra & Schmidt, 2020)); second, because it is plausible that large amounts of BECCS in particular would be required to continue to expand access to energy while mitigating emissions, at least given many optimized modeling pathways (Minx et al., 2018).

We can in principle separate the capture and storage sides of BECCS and consider their regional effects separately (although, in practice, storage in extant CCS instances has been closely correlated with capture locations). Consider capture first. Capture happens at power plant point sources. With BECCS in particular, this is where biomass has been used to produce electricity. Biomass production can have significant regional effects, including – but not limited to – increased demand for cropland and threats to biodiversity (Hanssen et al., 2022). On the capture side, regional heterogeneity is certainly relevant: for example, different regions have different prospects for growing biomass to fix carbon, and BECCS has to be customized for different regions (Malhotra & Schmidt, 2020).

However, the less obvious aspects of regional heterogeneity happen on the storage side. The prospects of storage are highly dependent on the geophysical features of potential reservoirs (Lane et al., 2021). For instance, some sites might have large capacity, but do not tolerate the extreme pressure coming from injected carbon flows. These features require significant upfront time and investment in order to investigate, and cannot be determined simply by referring to other potential reservoirs, even those that are geographically close. This mix of built complexity and geophysical customization means that it is not easy to learn by doing and that there are significant uncertainties which are regionally heterogeneous (Malhotra & Schmidt, 2020).

This suggests that the storage side of BECCS is highly affected by the NET Effect, meaning that the choice of which storage sites to develop can be driven by either need or efficiency, but not both with the same resources.

In light of the regional heterogeneities on both the capture and storage sides (the union of which we consider if assuming that practical considerations require that the storage be close to capture sites), BECCS is potentially highly sensitive to the NET Effect.

However, this NET Effect depends on the resources and technical capabilities of the time. In particular, the tension potentially could be lessened on the capture side if we have biomass production in globally ideal locations and on the storage side if we are able to transport carbon to globally ideal storage sites. If regional contributions can be measured where the carbon is captured, but the carbon can be transferred to sites with the best prospects, we can promote both needs and efficiency. However, even in this case, these values will not be maximally promoted. For instance, if carbon is being transported to storage sites rather than being captured close to those sites, this involves some expenditure (and increases the risks of leakage). In contrast, if storage development does not track need, this will lessen the technological and financial transfers to regions with need, even if those regions were able to include NET emission reductions for NDC and accounting purposes.

Regardless, my view is that these arguments suggest that being able to transport carbon to storage sites with the best prospects would have significant moral benefits. Doing so would allow us to capture in ways that offset regional developmental needs while storing wherever has the best prospects in such a way that we can potentially maximize climate mitigation benefits.

4.2 Direct air carbon capture and storage

While sharing the storage aspects of BECCS, DACCS is less susceptible to NET Effects on the capture side. This is because regional heterogeneity is less applicable (even if we granted that regions using DACCS would have credits in terms of regional contributions of emissions). On the capture side, DACCS could involve designs that are modular or non-regionally customized (Malhotra & Schmidt, 2020). Since gases in the atmosphere mix quickly (and internationally), DACCS would be less subject to atmospheric regional variation. If it were the case that carbon dioxide was highly concentrated in various regions – and did *not* mix the way it does – then we might expect some efficiency gains in regions with higher concentrations on the capture side.

Regardless, DACCS has major costs (even if we grant for the sake of argument that it can be scaled up) and the most important one is very sizeable energy consumption. This energy consumption could indirectly be subject to NET Effects. If we are

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measuring efficiency in terms of the net mitigation capacity (or lifecycle emission contributions), there could be regional heterogeneity in the emissions associated with the energy consumption needed for DACCS. If we construe 'efficiency' to mean the net contribution of mitigation relative to upfront or overall costs and investment, extra energy-associated emissions needed for DACCS operations could be regionally heterogeneous in the relevant sense.

In short, while one might think that DACCS on the capture side would not be as susceptible to NET Effects as BECCS, this is not necessarily the case. If we understand 'efficiency' broadly, then there still may be tensions between efficient regions (regions with the best prospects for relatively low-emission DACCS operations) and regions with the greatest need (regions where DACCS could be used to offset socially or developmentally important emissions as discussed in Section 2.2). In other words, NET Effects might be relevant to a broader variety of NETs than is immediately apparent.

5. Conclusion

In order to have a reasonable chance of keeping climate change to manageable levels, current models require large NET capacity. One could easily conclude that there is only one goal: to maximize the likelihood of having (at least) that capacity. The purpose of this paper is to indicate that, while this is a morally defensible goal (one reflecting the value I call 'efficiency'), there is an entirely independent morally relevant goal: responding to 'need'.

In fact, most NET deployment is not strategically aimed at maximizing total capacity, but tends to be driven by regional or national imperatives. Some of these imperatives may reflect morally important need, but if we are concerned about the moral importance of developmental and social need, then it behooves us to be more strategic in this aim.

The goal of drawing attention to NET Effects is to emphasize the potential for this trade-off – and to encourage scientists and policy-makers to consciously and carefully determine which values they want to pursue. Only if we recognize the moral values at stake can we strategically choose where and how to invest in new technologies.

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