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Green frontrunner or indebted culprit? Assessing Denmark's climate targets in light of fair contributions under the Paris Agreement

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Abstract
This paper contributes to academic and policy debates about climate leadership by illustrating an approach to examining national emission reduction targets focusing on Denmark. Widely recognized as a climate leader, Denmark is cherished for both its historical track record and its current climate targets. With a target of 70% emissions reduction by 2030 compared to 1990 stipulated in national law, central actors in Danish policymaking claim that domestic climate policy is aligned with the Paris temperature goals and present Denmark as a 'green frontrunner.' We examine the pledges and targets enshrined in the Danish Climate Act in reference to a 1.5 °C global greenhouse gas budget using five different approaches to burden sharing. For all five approaches, we find that the Danish climate target is inadequate given the 1.5 °C goal. Moreover, when only looking at equity approaches for distributive climate justice globally, the Danish target appears drastically insufficient. Denmark is, in this sense, not a green frontrunner but rather an indebted culprit, challenging the dominant narrative in Danish climate policy. Our results thus call into question the premise of the claim of Danish climate leadership, which works to legitimize existing policy and obscure the many dimensions of climate change.

Keywords Nationally determined contributions · Denmark · Burden sharing · Paris Agreement · Emission budgets · Distributive justice

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1 Introduction

How do we know if any given country is shouldering its share of the mitigation burden to respect the Paris Agreement temperature thresholds? While there is no answer to this question, evaluative criteria and approaches to examine them are needed to hold countries accountable for their efforts. This is particularly important as the Paris Agreement itself does not contain such criteria and approaches (Raiser et al. 2022) making it possible for countries to independently declare that they align with global goals (Geden 2016). Yet evaluations of national contributions and their fairness can help to improve accountability and facilitate peer pressure and international norms that could enable the ratcheting-up mechanism of the Paris Agreement (Karlsson-Vinkhuyzen et al. 2018).

Existing climate rankings and international commentaries often refer to a handful of wealthy nations in the Global North (e.g., Denmark, Sweden, and the UK) as particularly climate progressive with reference to their reduction targets and climate policies (Burck et al. 2021; Wolf et al. 2022). This tendency to highlight countries that are characterized by relatively high emissions has, however, been countered. For example, Anderson et al. (2020) argued that the climate policy targets of so-called climate-progressive nations, namely Sweden and the UK, are inadequate when examined in light of the principle of common but differentiated responsibilities and respective capabilities (CBDR-RC) that is enshrined in global climate governance and the Paris Agreement. Yet, despite numerous analyses illustrating how attention to fairness conditions burden sharing and, thus, claims of climate leadership (Anderson et al. 2020; van den Berg et al. 2020; Rajamani et al. 2021; Williges et al. 2022; Steininger et al. 2022), assessments of national contributions often fail to explicitly acknowledge their ethical foundation and/or rest on inequitable approaches to burden sharing (Dooley et al. 2021). If not engaged with moral questions, analysis of national-level climate policy efforts risks supporting inequitable claims of climate leadership, skewing the understanding of what fair national contributions under the Paris Agreement entail.

This paper contributes to the debate on climate policy targets in view of distributive justice by illustrating an approach to examining national emission reduction targets in light of global equity. We outline and operationalize different approaches to burden sharing, applying five different frameworks (responsibility, capacity, need, equal-per-capita, and grandfathering) to examine the case of Denmark. Denmark is an interesting case, as the country is often placed as a ‘green frontrunner’ in international comparisons and rankings of climate mitigation and policy efforts. Denmark was, for instance, ranked first both overall and in the climate policy component of Yale’s Environmental Performance Index in 2022 (Wolf et al. 2022) as well as in the 2022 Climate Change Performance Index (Burck et al. 2021) and has been highlighted as an example of ‘green growth’[1] (Stoknes and Rockström 2018). In this spirit, the Danish government claims that the country’s climate act of 2020 is ‘probably the most ambitious in the world’ (The Danish Government 2022a). In its original formulation, the act stipulates a 70% reduction of greenhouse gas (GHG) emissions by 2030 compared to 1990 levels and net zero GHG in 2050. Presented as ‘based on climate science’, this law purportedly aligns Danish climate policy with the Paris Agreement by setting a pathway for Denmark that is consistent with the global 1.5 °C temperature goal (Bahn 2019). This framing was backed by the Danish Council on Climate Change,

[1] Claims of green growth have, however, not been raised without controversy (see, e.g., Tilsted et al. 2021).

the main scientific authority on Danish climate policy, which in 2019 concluded that the emission target was ‘fairly consistent with the Paris Agreement’[2] (The Danish Council on Climate Change 2019a, p. 12).

Given the positioning of Denmark as a climate leader, we ask to what extent this framing holds up when considering different burden sharing approaches. To answer this question, we develop a global cumulative GHG budget that aligns with the 1.5 °C goal and use it to derive a global emission pathway for the period towards 2030. We use these pathways as the basis for quantifying Denmark’s share of global emissions under different approaches to burden sharing, which, to varying degrees, resonate with broadly recognized principles of equity. We compare the resulting five sets of cumulative Danish emissions (varying the probability of staying below 1.5 °C) with the expected total Danish emissions towards 2030 under current climate targets and show that irrespective of which burden sharing frameworks we deploy, the country’s emissions exceed its share of the cumulative global emissions for that period. Importantly, if we only consider approaches to burden sharing that align with elements of CBDR-RC, Danish climate policy falls far short of respecting the resulting national emission shares. Thus, we argue that the assertion that the Danish climate policy targets are in line with the Paris Agreement (and the related claim that the Danish Climate Act is particularly ambitious from a global perspective) relies on selective and partial framing, underpinning, sustaining, and promoting a myth of Denmark as a climate pioneer (Dyrhauge 2021).

We focus on the 2020–2030 period because it marks the timeframe from the introduction of the Danish Climate Act to the key near-term target of the 70% reduction, which works as a guiding principle for Danish climate policy (Danish Ministry of Climate, Energy and Utilities 2019). Moreover, the 2020s, labeled the ‘Decade of Action’ by the UN (Guterres 2019), is crucial for global climate action. Short-term reductions decrease the need for future negative emissions to stay below critical temperature thresholds (van Vuuren et al. 2018) and investments in this decade heavily influence both the prospects of continued carbon lock-in (Seto et al. 2016) and the amount of ‘committed’ emissions (Smith et al. 2019; Tong et al. 2019; IEA 2021). The choice of 2020–2030 as a timeframe is thus tied to the purpose of the paper. Do the claims made when the Climate Act was introduced hold up, or were the Danish climate policy targets in principle unfair from their conception in 2019? We use the 1.5 °C goal as a point of reference because this reflects the wording of the Danish Climate Act, which states that the Danish climate targets are made with this goal ‘in mind’ (Danish Ministry of Climate, Energy and Utilities 2021). The 1.5 °C goal is in itself a reflection of equity concerns, as any global warming above that level adds massively to the climate change-related damages and risks that disproportionally

[2] A 2022 report from the Danish Council on Climate Change later concluded that Danish climate policy objectives only aligns with 1.5 °C target if allowing for temperature overshoot and using an equal-per-capita approach to distributing mitigation efforts (The Danish Council on Climate Change 2022). This analysis used the Model for the Assessment of Greenhouse Gas Induced Climate Change to assess Danish climate targets, ‘scaling up’ Danish emissions to a global level by assuming that global emissions per capita corresponded to the modelled Danish emissions per capita (The Danish Council on Climate Change 2022). Following this analysis and public debate around the inadequacy of Danish climate policy targets, the recently elected Danish government declared in December 2022 that it will ‘evaluate’ whether the 2030 target should be strengthened and put forward a 2050 target of 110% reduction relative to 1990, suggestion net negative emissions after 2045 (The Danish Government 2022b, p. 28). At the time of writing, efforts to change the 2030 target remain to be seen.

fall on poor and vulnerable regions and people, although warming of 1.5 °C also entails substantial risks (Armstrong McKay et al. 2022).

Our study contributes to the climate policy and climate justice literature by presenting a simple and transparent assessment of national climate policy targets for the case of Denmark. In doing so, we add to ongoing debates concerning international climate rankings and comparisons placing high-income countries as global climate frontrunners. Our study also illustrates how equity-based approaches can be operationalized and applied with data for a specific country, drawing on multiple existing studies with broader foci. Finally, our study proposes an approach to taking non-CO_2 emissions into account alongside the global cumulative carbon budget when allocating mitigation responsibilities between nations. Following this introduction, we describe the carbon budget concept and its relation to emission scenarios, seeking to establish a GHG budget with relevance for climate targets that include non-CO_2 gases. We then review different approaches to burden sharing and elaborate on how we operationalize them. We go on to present our results before discussing their implications as well as the limitations of our approach. Finally, we summarize and conclude, emphasizing the need for transformative approaches to climate justice.

2 Deriving a global emission budget comparable with the official Danish target

For a given temperature goal, a cumulative remaining carbon budget can be estimated, relying on the roughly proportional relationship between cumulative CO_2 emissions and CO_2-induced temperature change (Millar et al. 2016; Matthews et al. 2020, p. 769). For example, Matthews et al. (2021) find that when accounting for geophysical and socioeconomic uncertainties, the 1.5 °C remaining carbon budget from 2020 onwards is 230–440 $GtCO_2$, for a 67–50% chance of not exceeding the target. This likelihood range arguably resonates with the wording of the Paris Agreement of pursuing 1.5 and limiting warming to well below 2 °C (United Nations 2015), also considering that 440Gt CO_2 represents a > 67% chance of remaining below 1.7 °C and a > 95% chance of not exceeding 2 °C. We therefore use the 230–440 $GtCO_2$ range as a basis for the comparison of Denmark's climate targets to a fair contribution to the Paris goal.

Next, three modifications of the global CO_2 budget estimate are needed to make it comparable to the official Danish targets, which dictate a 70% reduction of territorial GHG emissions in 2030 compared to 1990, with a 50–54% reduction in 2025 as a milestone (Danish Ministry of Climate, Energy and Utilities 2021). First, since the territorial emission accounting of nations, according to UNFCCC rules, omits international transport (mainly air travel and shipping of goods), it is necessary to correct the global carbon budget. We do this by downscaling the budgets by 3% since international transport currently accounts for about 3% of global CO_2 emissions (Friedlingstein et al. 2022), resulting in a budget range of 223–427 $GtCO_2$. This downscaling is based on the simplistic assumption that future emissions from international transport will maintain their current share of global emissions (3%).[3]

[3] Since heavy duty transport (including shipping and aviation) generally is considered 'hard-to-abate' (Bergek et al. 2023), international transport emissions´ share of global emissions may increase in the future. However, this potential increase is difficult to estimate.

Second, since the official Danish target covers other GHG emissions than CO_2, expressed in CO_2 equivalents (CO_2e) following the GWP100 metric[4] (Allen et al. 2022), it is necessary to extend the global CO_2 budget to a global GHG budget. Such an extension is necessarily approximative since there is not a linear relationship between cumulative emissions of short-lived GHGs and temperature change. For this approximation, we build on the approach of Meinshausen et al. (Meinshausen et al. 2018; Meinshausen 2019), which relies on the relationship between cumulative emissions of CO_2 and cumulative emissions of all greenhouse gases in scenarios of future greenhouse gas emissions. Drawing on the Integrated Assessment Modeling Consortium's 1.5 °C Scenario Explorer hosted by the International Institute for Applied Systems Analysis (Huppmann et al. 2019), we rely on a subset of 80 scenarios labeled 'Below 1.5 °C', '1.5 °C low overshoot', or '1.5 °C high overshoot'.[5] For each scenario, we consider the cumulative emissions in the period from 2020 to the year that net-zero CO_2 is reached (see Supplementary Information Figure SI1 for a graph illustrating the relationship between cumulative CO_2 and cumulative CO_2e given the GWP100 for these 80 scenarios). We find an approximated linear relationship between cumulative CO_2 and cumulative CO_2e ($R=0.80$) that can be expressed by $y=1.1614x+157.27$. This implies a budget of 416–653 billion tonnes of CO_2e, representing a 67–50% probability of meeting the 1.5 °C target (insert 223–427 $GtCO_2$ as x and calculate y).

Third, since the Danish targets are stipulated as point targets, dictating a reduction in the flow of GHG emissions in 2025 and 2030 relative to 1990, we convert the global cumulative GHG budgets to pathways for the 2020–2030 period. We do this by assuming linear reduction pathways from 2020,[6] which implies that the 50% probability estimate (653 billion tonnes CO_2e) corresponds to reaching net zero in 2045, while the 67% probability (416 billion tonnes CO_2e) requires net zero already in 2036 (see Figure SI2 in the Supplementary Information). We take these two linear reduction paths as given for the period 2020–2030, using them to estimate the Danish (fair) share of global emissions under different approaches to burden sharing. Given that these pathways imply a gradual reduction of the budgets, we in practice assume no net negative emissions globally after the year of net zero, implying a balance between sources and sinks.

[4] Global Warming Potential (GWP) refers to the 'time-integrated radiative forcing due to a pulse emission of a given gas, relative to a pulse emission of an equal mass of CO_2' for a 100-year time horizon (Shine 2009, p. 468). Note that a problem with national CO_2e reduction targets is that their temperature outcomes are sensitive to whether reductions in short-lived or long-lived GHGs are prioritized (the former strategy is associated with a lower mid-century peak warming, while the latter is associated with lower long-term warming) (Sun et al. 2021). Hence, more accurate assessments of the Paris alignment of national emission reduction targets can be made when nations set their targets separately for long-lived and short-lived GHGs (Allen et al. 2022; The Danish Council on Climate Change 2022).

[5] These scenarios include reduction pathways from 2020 to 2100 that, with a given likelihood, limits the temperature increase to 1.5 °C. They typically involve net-negative CO_2 emissions from around 2050 and have been subject to a range of criticism including that the scenarios rely on a limited set of assumptions around future growth trajectories (Hickel et al. 2021; Keyßer and Lenzen 2021) and substantial carbon dioxide removal (Anderson and Peters 2016; Dooley et al. 2018; Parson and Buck 2020; Carton et al. 2020). The amount of carbon dioxide removal modelled in these pathways allows for'overshoot', i.e., exceeding but returning to the temperature goal towards the end of the century. Staying within stipulated carbon budgets, by contrast, is expected to limit peak warming to 1.5 °C. For more on the relationship between carbon budgets and emission scenarios, see Matthews et al. (2021) and Matthews and Wynes (2022).

[6] Note that the global reduction path can take various forms. For simplicity, we apply a linear reduction path.

3 Burden sharing approaches

In this paper, we focus on the distribution of the climate mitigation burden across nations. Burden sharing here refers to approaches for allocating mitigation action, be it directly distributing the obligation to mitigate emissions or indirectly in the form of distributing a global carbon or GHG budget[7] (Fleurbaey et al. 2014). Approaches to burden sharing can be informed by various principles of equity that address issues of fairness. Here, we consider three different equity-based approaches that figure prominently within the literature on the topic: *responsibility*, *capacity*, and *need* (Fleurbaey et al. 2014; Dooley et al. 2021; Rajamani et al. 2021). To add perspective, we also consider two reference approaches that arguably do not adhere to principles of equity in relation to distributive justice on a global scale, namely equal-per-capita and grandfathering. Our application of the five burden sharing approaches is presented below and summarized in Table 1.

3.1 Responsibility

Responsibility has, in the context of climate change, been widely understood as a 'fundamental principle' based on 'common sense ethics' (Fleurbaey et al. 2014, p. 318) and is based on the idea that obligations follow from actions. Moral responsibility thus derives from contributing to global warming, aligning *responsibility* with the polluter pays principle[8] (Neumayer 2000; Caney 2005a) and the legal practice of holding agents accountable for harms and risks they create (Fleurbaey et al. 2014). The responsibility principle is integrated into both the UN Framework Convention on Climate Change via CBDR-RC as well as the Danish Climate Act, which speaks of a historical responsibility to 'lead the way' (UNFCCC 1992; Rajamani 2000; Danish Ministry of Climate, Energy and Utilities 2021). In relation to the distribution of the mitigation burden, *responsibility* recognizes that CO_2 largely remains in the atmosphere (Shine et al. 2005) and past emissions therefore contribute to current and future climate change. The principle stipulates that higher cumulative per capita historic emissions translate into a larger responsibility for mitigation. Thus, wealthy industrialized countries like Denmark, with high cumulative emissions per capita, bear most of the responsibility. In that sense, we can talk of a Danish 'climate debt' (Pickering and Barry 2012). Moreover, scholars highlight how, because high-emitters have benefitted (and possibly strengthened their capacity for mitigation) from using a common resource in the form of a global carbon budget, this use should be paid for (Shue 1999; Caney 2006, 2010).

We operationalize *responsibility* in an equal cumulative per capita emission rights approach (Höhne et al. 2014). As such, countries with higher-than-average historical per capita emissions will need to reduce emissions faster than what is required at the global level. This begs the question of how far back in time we should go, since the choice of timeframe can change results markedly (den Elzen et al. 2005). From what date should Denmark be held accountable? In this paper, we consider cumulative emissions since 1990, the year of the First Assessment Report by the IPCC, a reference point for the creation

[7] We use the term 'burden sharing' to be in line with the literature on the topic, although the term burden sharing does not capture that mitigation action typically entails important co-benefits (Fleurbaey et al. 2014), such as reducing other forms of pollution (Ürge-Vorsatz et al. 2014).

[8] Shue (1999), however, notes that whereas the polluter pays principle is future-oriented, demanding polluters to pay going forward, equity-concerns require that harm inflicted past actions is addressed.

Table 1 Burden sharing approaches and their operationalization in this paper

Approach	Description	Application in this paper	Operationalization
Responsibility	Equity-based approach, which holds that obligations follow from the degree to which actors are responsible for causing climate change	Ensure 'payback' of above-world average emissions since 1990 at the year of global net zero	$\text{Debt}_{DK,bp} = \sum_{bp}\left(\text{GHG}_{DK,t_{bp}} - \frac{P_{DK,t_{bp}}}{P_{world,t_{bp}}} \cdot \text{GHG}_{world,t_{bp}}\right)$ $\text{Yearly payback}_{DK} = \frac{\text{debt}_{DK,bp}}{\text{payback period}}$ $\text{GHG}_{DK,t} = \frac{P_{DK,t}}{P_{world,t}} \cdot \text{GHG}_{world,t} - \text{yearly payback}_{DK}$
Capacity	Equity-based approach, which holds that mitigation efforts should be distributed according to capacity to address climate change	Reduce frozen policy emissions adjusted by national relative to gross world product per capita	$\text{Emission gap}_{world,t} = \frac{\text{BAU}_{world,t} - \text{GHG}_{1.5°C,world,t}}{\text{BAU}_{world,t}}$ $\text{Capacity}_{DK,t} = \frac{\text{GDP}_{DK,t}/P_{DK,t}}{\text{GWP}_t/P_{world,t}} \cdot \text{emission gap}_{world,t}$ $\text{GHG}_{DK,t} = \text{BAU}_{DK,t} \cdot (1 - \text{capacity}_{DK,t})$
Need	Equity-based approach, which gives moral priority to emissions related to meeting human needs wherefore other emissions have lower priority and should be abated	Allow for GHG emissions associated with final energy demand required for decent living	$\text{FED}_{need,t} = \text{DLE}_{DK} \cdot P_{DK,t}$ $\text{GHG}_{int,\text{FED}_{DK,t}} = \frac{\text{BAU}_{DK,t}}{\text{FED}_{DK,2019}}$ $\text{GHG}_{DK,t} = \text{FED}_{need,t} \cdot \text{GHG}_{int,\text{FED}_{DK,t}}$
Equal-per-capita	Approach to burden sharing that assumes equal-per-capita emission rights. Arguably not an equity-based approach for global burden sharing amongst unequal actors	Distribute global budget on the basis of equal-emission-rights-per-capita for current and future emissions	$\text{GHG}_{DK,t} = \frac{P_{DK,t}}{P_{world,t}} \cdot \text{GHG}_{world,t}$
Grandfathering	Approach to burden sharing, which dictates that future entitlements follow from the past share of global emissions. Not equity-based	Allocate remaining global budget on the basis of national share of global emissions in 2020	$\text{GHG}_{DK,t} = \frac{\text{GHG}_{DK,b}}{\text{GHG}_{world,b}} \cdot \text{GHG}_{world,t}$

Debt climate or 'GHG emissions debt', *GHG* greenhouse gas emissions in a given year (CO_2e), *bp* basis period, *P* population, *t* time period (year), *BAU* emissions in year t in frozen policy scenario (business as usual), $GHG_{1.5\,°C,world}$ global emissions under 1.5 °C pathway, *GDP* real gross domestic product adjusted for purchasing power in year t, *GWP* real gross world product, *FED* final energy demand, *DLE* decent living energy, $GHG_{int,FED}$ emission intensity of final energy demand, *b* base year of the global climate regime, marking a point in time from which policymakers could no longer justifiably disregard their responsibility. The year 1990 is also the year of the first climate targets in Denmark and the 'plan of action' *Energi 2000*, which explicitly mentions the responsibility of countries with relatively higher emissions (Energiministeriet 1990).

To quantify a Danish contribution that adheres to the principle of *responsibility*, we calculate the Danish climate debt, which is found by adding up 'above-global-average' per capita emissions over the basis period (here 1990–2019). We then distribute the climate debt over a 'payback period', for which we use the time from 2020 (when the Danish Climate Act came into force) to the year of global net zero in our developed GHG pathways (years 2036 and 2045, respectively). We use relatively short payback periods to illustrate what equal cumulative emissions per capita within the same timeline as the global GHG budget entail. We find that Denmark, over the period 1990–2019, has accumulated a climate debt of 1101 Mt CO_2e. To compensate for this debt during the payback period, Denmark needs to have per capita emissions 41 and 61 Mt below the global average for the 50% and 67% probability budgets, respectively (in contrast, Danish territorial emissions in 2021 were around 44 Mt CO_2e (Statistics Denmark 2022)). To calculate a pathway for Denmark associated with *responsibility,* we subtract the 'yearly payback' from the global per capita emissions under the linear 1.5 °C pathways (see Supplementary Information).

3.2 Capacity

The principle of *capacity* holds that actors with a higher capacity for action have a greater responsibility to act (Caney 2010; Dooley et al. 2021). Shue (1999, p. 537) notes how *capacity* is 'widely accepted as a requirement of simple fairness' and the principle is also mentioned in both the Danish Climate Act, which notes that Denmark has a 'moral responsibility to lead' (Danish Ministry of Climate, Energy and Utilities 2021), and the UN Climate Convention, which emphasizes the notion of 'respective capabilities' (UNFCCC 1992). The *capacity* principle is relevant across issue areas and is for example captured in tax systems with progressive income taxation. In a climate context, *capacity* has been interpreted as wealth (often labelled 'ability to pay') as well as other characteristics that may make mitigation more or less difficult such as 'technological, institutional, and human' capacity (Fleurbaey et al. 2014, p. 319). In a recent review on distributive justice, Ryberg et al. (2020) identify income-based allocations as aligning with prioritarianism, which holds that those who are worse off should be prioritized in the distribution of benefits (Holtug 2017).

To get to a burden sharing approach, we use GDP per capita adjusted for inflation and price level differences (purchasing power parity, PPP) as a simple proxy for capacity[9] (for a more comprehensive approach, see Steininger et al. (2022)). Given that Denmark is well-positioned in terms of a number of dimensions of capacity (e.g. wealth, public support for climate action, and capability for deployment of renewables), a notion that is widespread in the Danish polity (Dyrhauge 2021; Voldsgaard et al. 2022), GDP per capita can be seen as a relevant, yet arguably conservative proxy for *capacity* in the Danish case. An important question in terms of operationalization is which inequalities we consider. By applying

[9] Concerns have been raised over the use of purchasing power parity exchange rates for estimating GDP in relation to the capacity principle given international sourcing of mitigation technologies. Using market exchange rates instead significantly increase discrepancies in GDP across countries and would imply increased capacity and thereby responsibility for high-income countries (Semieniuk et al. 2023).

capacity at the country-level, we do not account for inequalities within countries. Others have operationalized *capacity* by only considering individuals above a certain critical level of income, so that individuals in the worst positions are not subjected to mitigative responsibility (Kartha et al. 2009).

We follow van den Berg et al. (2020) and quantify *capacity* by distributing the effort of mitigation rather than directly allocating the global GHG budget (see Table 1). More specifically, we estimate the discrepancy between a global 'frozen policy' scenario and the global emission pathways (cf. Section 2), which can be understood as a global emission gap. This emission gap captures the extent to which global frozen policy emissions need to be reduced in percentage terms to stay within a stipulated global GHG budget. The capacity for Denmark to reduce its frozen policy emissions is then proportional to the relationship between its GDP per capita and the global GDP per capita. Our approach relies on a linear association between relative GDP per capita and capacity.[10] Specifically, Denmark's relative real GDP (PPP) per capita is projected to range from 2.6 to 2.9 in 2020–2030 (declining over the period), and the global emission gap ranges from 0% in 2020 to 45–66% in 2030 (depending on whether the 50% or 67% budget pathway is used as reference). Consequently, Danish emissions range from being 0% to 119–173% below the Danish frozen policy scenario during the decade to live up to *capacity*.

3.3 Need

The *need* principle dictates that all people should have their needs met. Notwithstanding differences in approach, utilitarian (Singer 2004), egalitarian (Caney 2005b), sufficientarian (Shields 2012), rights-based (Shue 2020), and social contract arguments (Moellendorf 2014) all point to the critical importance of enabling needs fulfillment (Brock 1998; Dooley et al. 2021). Thus, emissions related to addressing basic needs have moral priority. Opposingly, given the destructive impacts and prospects of worsening the conditions for meeting basic needs associated with climate change, emissions associated with activities not related to meeting human needs do not hold the same moral priority and should thus be limited or avoided. Giving priority to needs fulfillment resonates with eudaemonic notions of well-being (Lamb and Steinberger 2017) and can be related to the distinction between 'subsistence' and 'luxury' emissions (Shue 1993), the notion of 'decent living' emissions (Rao and Baer 2012), and sufficiency-oriented approaches to climate mitigation (Steinberger and Roberts 2010; Brand-Correa et al. 2020; Wiedmann et al. 2020). The *need* principle is also related to the 'right to development' enshrined in international law (Fleurbaey et al. 2014).

To operationalize *need*, we estimate a hypothetical level of GHG emissions that would in theory be required to satisfy the needs of the Danish population with existing technologies. Thus, for this principle, we do not directly translate a global budget to a 'fair share' for Denmark. To calculate the GHG emissions associated with *need*, we instead rely on Millward-Hopkins et al.'s (2020) estimates for the final energy required for decent living across countries (accounting for climatic and population density differences). These estimates rely on bottom-up scenarios that meet a range of needs, such as housing, food, hygiene,

[10] This choice means that the increase in capacity is proportional to increases in relative GDP per capita. In contract, van den Berg et al. (2020) take the third root of relative GDP per capita to find capacity, implying diminishing capacity to increases in relative GDP per capita.

education, health, mobility, and communication. In our operationalization, we scale decent living energy estimates with the population, assuming in principle a completely equal distribution of energy, drastically lowering total energy demand. In practice, our operationalization of *need* thus gives absolute priority to people living below the decent living energy threshold and considers emissions required to enable their needs fulfillment legitimate.

To quantify *need*, we find the emission intensity of final energy demand in Denmark (relying on 2019 energy statistics and frozen policy emissions). We treat the emission intensity as constant and use that to infer emissions given energy consumption in line with decent living energy estimates (see Table 1). Because Millward-Hopkins et al. (2020) in their baseline scenario focus on the year 2050, assuming full deployment of state-of-the-art technology and 'radical demand-side changes', we use estimates from their 'less advanced technologies' scenario, which relies on technologies widely deployed today. To reflect some of the uncertainty in the estimate of decent living energy, we consider an additional scenario from Millward-Hopkins et al. (2020). That is, we also consider estimates from a 'high energy demand-less advanced technologies' scenario, which increases final energy use from 26 to ~40 GJ/capita by assuming a modest increase in energy demand across consumption sectors (e.g., by decreasing the size of the average household). In comparison to the actual Danish final energy consumption in 2019 of 107.4 GJ/capita, these scenarios thus dictate that final energy use per capita falls by ~75% and 62%, respectively (Danish Energy Agency 2020; Millward-Hopkins et al. 2020).

Our approach is meant to illustrate the *need* principle rather than be an accurate assessment of Danish emissions in a sufficiency scenario. Our estimates are based on marked simplifications and various assumptions with corresponding uncertainties and value judgements, including energy efficiency, human energy needs, the relationship between energy needs and CO_2 emissions, and Danish energy production. For example, we take the Danish frozen policy scenario as given when calculating the emission intensity of final energy demand. Also, we assume the same energy mix regardless of level of consumption, while the drastic reduction in energy demand in our scenario would arguably lead to a cleaner energy mix than Denmark's current mix (assuming that renewable energy would still be produced at capacity). However, notwithstanding the shortcomings of our approach, there is clearly a substantial difference between current emissions associated with affluence and required emissions from a 'decent living' perspective (Rao and Baer 2012; Millward-Hopkins et al. 2020; Kikstra et al. 2021). The fact that final energy demand in Denmark today is far beyond decent living energy estimates does, however, not imply that everyone in Denmark currently has their needs met. The satisfaction of needs depends on how energy consumption is distributed,[11] how it is translated into services, and how these services address the satisfaction of needs (Brand-Correa et al. 2020; Jaccard et al. 2021; Oswald et al. 2021; Vogel et al. 2021).

3.4 Equal-per-capita as a narrow interpretation of equality

Equality, as an equity principle, rests on the equal worth and, thereby, equal rights of all humans, which is a common interpretation in international law (Fleurbaey et al. 2014).

[11] Inequality increases the energy needed to secure decent living standards substantially. If currently observed inequalities are to remain, the required energy consumption to secure everyone's needs are met doubles (Millward-Hopkins 2022). And like noted by a reviewer, increased energy use might itself lead to inequity above a certain threshold through widening power imbalances, as argued by Illich (Burke and Stephens 2018; Boyle 2023).

Equality can be interpreted as actors in equal positions carrying equal obligations (Dooley et al. 2021). Such an understanding of *equality* would grant a greater share of emission rights to the disadvantaged, reflecting, e.g., differences in needs,[12] responsibility, and capacity, thereby resonating with the three other principles introduced above. Because we apply *responsibility*, *capacity*, and *need* in ways that resonate with this interpretation of *equality*, we include an equal-per-capita emission rights approach in our analysis. Although equal-per-capita is a common approach to equality that has been associated with egalitarianism (see, e.g., Ryberg et al. 2020), it has rightly been subject to criticism. This criticism points to how equal-per-capita solely focuses on equality in relation to one parameter—i.e., emissions rights—while ignoring the multiple other ways in which people are unequally positioned (Dooley et al. 2021). In this paper, we, therefore, do not consider equal-emissions-rights-per-capita an equity-based approach. Critically, the equal-per-capita approach is what the Danish Climate Council applied to support the conclusion that Danish climate targets resonated with the Paris Agreement before the Danish Climate Act came into force[13] (The Danish Council on Climate Change 2019a, b).

Equal-per-capita can be applied to current and future emissions, as well as cumulative emissions. Given that the latter is the approach we use for *responsibility* (see Section 3.1) and thus address this dimension of inequality, we operationalize 'equal-per-capita' as equally distributing global emissions in 2020–2030 according to population shares throughout the decade. Quantifying equal-per-capita is rather straightforward. We take the share of the yearly emissions in our global linear reduction pathways that corresponds to the Danish fraction of the global population (taking projected demographic changes over time into account) (see Table 1). In 2020, the Danish share of the global population in the base year was 0.074%.

3.5 Grandfathering

Grandfathering is a burden sharing approach that dictates that future emissions should be proportional to past emission levels. It thus favours current high-emitters and has been advocated for on the basis of pragmatic and instrumental reasons (Knight 2013). The term itself dates back to the post-civil-war USA in the context of black disfranchisement and a racist legal clause that granted voting rights on the basis of descendance (Schmidt 1982). For distributive justice on a global scale, grandfathering enjoys little support and cannot be said to be an equity-based approach, because grandfathering goes against ethical imperatives related to climate justice (Meyer and Roser 2010; Caney 2012; Moellendorf 2020; Dooley et al. 2021). Still, grandfathering finds widespread use as a burden sharing approach when setting climate targets, for example, in the context of corporate emission reduction targets (Bjørn et al. 2021, 2022), and is arguably relevant for certain applications such as the allocation of sub-national carbon budgets (Kuriakose et al. 2022). We include grandfathering here as a point of reference but maintain a position akin to Dooley et al. (2021), namely that grandfathering does not resonate with equity principles for allocating

[12] See, for example, Steininger et al. (2022) for a study which operationalizes *need* as an interpretation of *equality*.

[13] As noted in an earlier footnote, a later report took up this question anew, offering a more nuanced conclusion, namely that Danish climate targets only aligned with the 1.5 °C goal if allowing for overshoot using an equal-per-capita approach while not aligning with the Paris Agreement temperature goals if applying a 'fair share' approach (The Danish Council on Climate Change 2022).

a global GHG budget as it attributes emission rights on the basis of an unjust allocation of the same rights.

To operationalize Danish emissions towards 2030 under grandfathering, we let the Danish share of global emissions in 2020 dictate the allocation of future emissions (see Table 1). We make this choice because the Danish Climate Act came into force in 2020 and because 2020 was also the basis year used in the assessment of the Danish climate targets made by the Danish Council on Climate Change (2019b). This leaves Denmark with 0.088% of the global budget.

4 Comparing Danish emissions pathways 2020–2030 under different burden sharing approaches

Overall, our findings illustrate that Danish climate policy targets cannot be considered fair under the Paris Agreement. For *responsibility*, *capacity*, and *need*, there are substantial gaps between pledged and fair contributions. Whereas a linear reduction pathway from 2022 onwards in line with Danish climate targets leads to cumulative emissions of close to 400 $MtCO_2e$, none of the three equity-based pathways implies more than 160 $MtCO_2e$ in the 2020–2030 period. In this section, we detail this overall result.

Figure 1 shows the emission pathways that result from our operationalization of the different approaches to burden sharing. These pathways reflect Danish emission flows that, from a distributive perspective, would align with 1.5 °C given the applied allocation key and GHG budget. In that sense, they illustrate pathways that are in line with the 1.5 °C pledge enshrined in the Danish Climate Act—emission trajectories that Denmark, in theory, could have followed to be in line with the wording of its climate policy framework from the time of its introduction in 2019. The cumulative emissions under these pathways are reported in Fig. 2. For the four approaches relating to the global GHG budget, we show the resulting national emissions budgets given, respectively, a 50% and 67% likelihood of staying below the 1.5 °C goal. For *need*, we illustrate the emissions resulting from our baseline as well as the higher energy demand scenario. To compare with the expected emissions under Danish climate policy, we construct two reference pathways (both presented in Figs. 1 and 2). The first reference pathway represents a frozen policy scenario, as estimated by the Danish Energy Agency (Danish Energy Agency 2021). The second reference pathway assumes a linear reduction from 2022 and onwards that aligns with Danish climate emission reduction targets in 2025 and 2030. The linear reduction path represents a scenario in which policies that could enforce the Danish targets had been enacted in the years immediately following the introduction of the Danish Climate Act. We start the linear reduction from 2022 onwards (following the frozen policy scenario up until then) to reflect the inertia associated with negotiations and implementations on passing the required climate policy.

Reflecting on the results, *responsibility* stands out as it dictates massive amounts of negative emissions (we take up the implications of this in the discussion). This finding follows from the fact that Danish territorial per capita emissions have been considerably above the world average since 1990, and the resulting climate debt of 1.101Mton CO_2e accrued in the 1990–2019 period, which is to be compensated for. Responsibility thus considers a period (in this case, 1990–2019) and the accumulated differences between high and low emitters in contrast to *capacity* and *need*, which use conditions in a single year

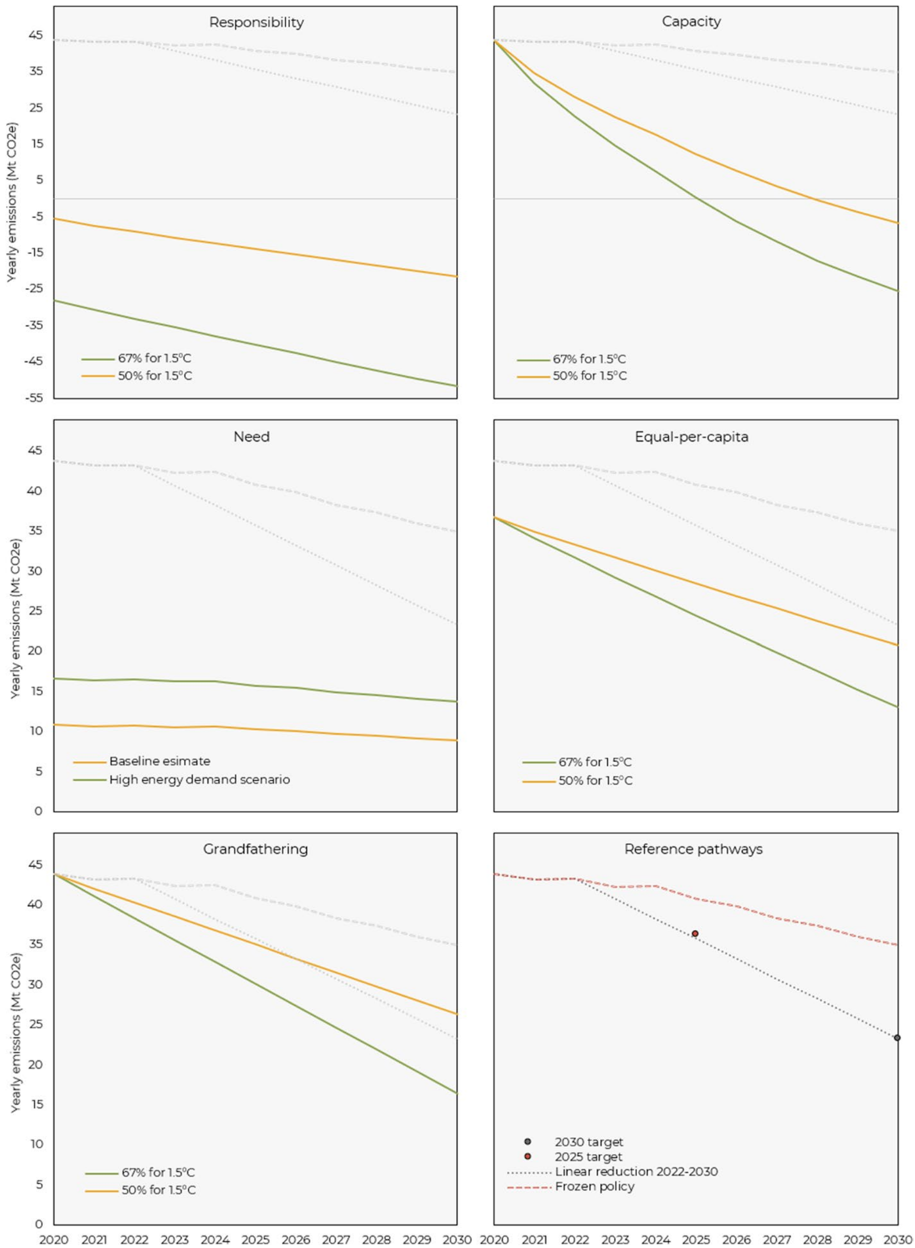

Fig. 1 Stylized emission pathways 2020–2030 under different approaches to burden sharing. *Note*: The emission scenarios follow from the operationalization described in Section 3. The cumulative emissions for each approach sum to the results reported in Fig. 2

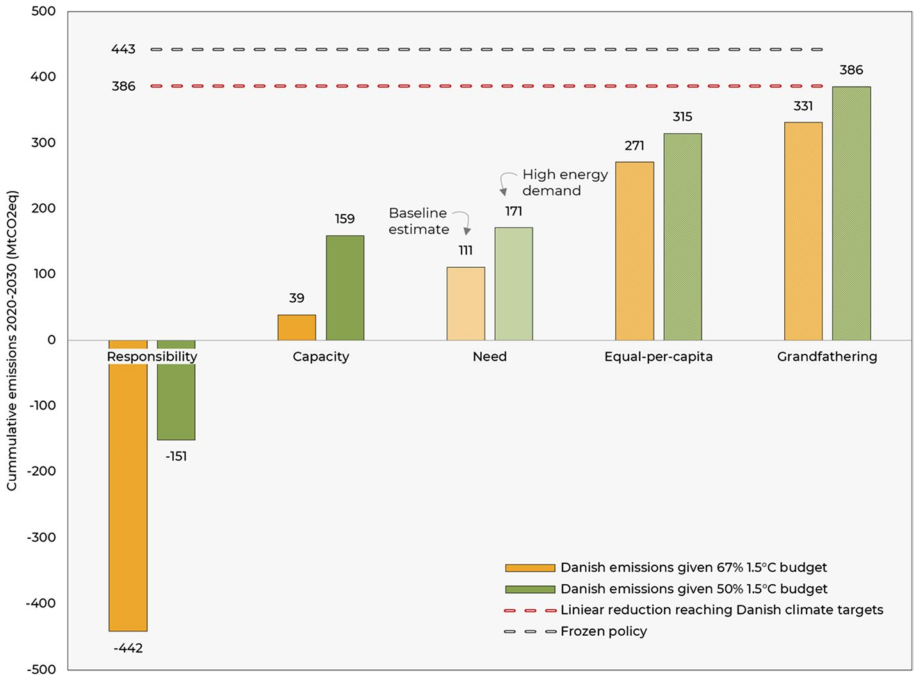

Fig. 2 Cumulative Danish emissions 2020–2030 under different approaches to burden sharing. *Note*: The figure includes two reference scenarios, namely a linear reduction pathway in line with the Danish climate targets of 50–54% in 2025 and 70% in 2030 relative to 1990 emissions. Note that *need* takes on a different colour to illustrate that it is not based on a global scenario. Moreover, grandfathering and equal-per-capita have been differentiated to illustrate that they are not equity-based approaches for national-level distribution of a global resource (see Section 3). *Source*: Author's calculation based on various databases (see supplementary information for details). Frozen policy scenario from Danish Energy Agency (Danish Energy Agency 2021). See Fig. 2 for the yearly emission breakdown

to reflect inequalities. Given that the debt is to be 'paid back' throughout the stipulated payback period, the length of this payback period greatly influences the yearly payback and thus the resulting yearly emissions.

In contrast to *responsibility*, *capacity*, as operationalized here, does not acknowledge previous inequalities but focuses instead on current ones (in capacity, that is). The approach is forward-oriented in that we consider the future emissions gap between our global pathway (see Supplementary Information) and a global frozen policy scenario in the 2020–2030 period. The resulting pathways start at 2020 levels, where there is no gap between the pathway and frozen policy, before drastically reducing yearly emissions, ending with negative emissions by the end of the decade, reflecting an increasing emission gap over the period. For capacity, there is a considerable difference between the cumulative emissions consistent with the 50% and 67% budgets, respectively. Under a GHG budget representing a 50% likelihood of staying below 1.5 °C, cumulative Danish emissions from 2020 to 2030 are four times higher than under a 67% budget. These results reflect that, for *capacity*, we distribute the obligation to address the global emissions gap (rather than a global budget) and that this gap varies substantially with the probability of staying below 1.5 °C.

The *need* pathways represent situations where final energy demand is substantially lower than current levels, all else being equal, assuming no further mitigation beyond what is implied by the frozen policy scenario projected by the Danish Energy Agency. Cumulative emissions associated with these pathways are higher than under *responsibility* and *need* but drastically lower than under the burden sharing approaches of equal-per-capita and grandfathering. In our baseline estimate for *need*, per capita emissions correspond to, respectively, ~25% and ~30% of actual Danish and global per capita emissions in 2020.[14] In the high energy demand scenario, the figures increase by ~50%,[15] thus still dictating substantially lower emissions for Denmark. The difference between the baseline and the high energy scenarios is less than for *responsibility* and *capacity*, given that *need*, as calculated here, does not relate to the global budget estimates but instead relies on different assumptions for decent living energy (see Section 3.3).

The two approaches that are recognized as inequitable in relation to the distribution of a global resource, namely equal-per-capita and grandfathering, result in substantially higher cumulative emissions. Of the two, an equal-per-capita distribution implies lower emissions than grandfathering throughout the decade. For grandfathering, emissions follow the global pathways, meaning that emissions in 2030 are reduced by, respectively, 40% and 63% relative to 2020. Grandfathering thereby barely aligns Danish climate targets with a budget representing a 50% chance of not exceeding 1.5 °C. Under equal-per-capita respecting a 67% 1.5 °C budget, however, cumulative Danish emissions are 30% lower than the level associated with a linear reduction in line with the country's official emission targets.

5 Discussion

The results we present above challenge the assertion that the mitigation path associated with the 2025 and 2030 Danish emission reduction targets is in line with the Paris temperature goals and bring into perspective the notion of Denmark as a 'green frontrunner'. In this section, we relate to issues of GHG accounting that condition our approach and discuss the implications of our findings.

The cumulative allowable emissions that follow from different equity approaches reframe the Danish narrative from a green frontrunner to an indebted culprit (responsibility in particular). These findings resonate with other and more general analyses (Anderson et al. 2020; van den Berg et al. 2020; Williges et al. 2022) and illustrate the consequences of examining national climate policies in light of distributive justice. These consequences hold important implications. They illustrate the risks of perpetuating partial and misleading notions of climate progressiveness if equity is ignored and underline how any assessment of national efforts relative to global goals assumes some burden-sharing approach, be it explicit or implicit (Dooley et al. 2021). We, therefore, need to pay attention to how these approaches align with principles of equity, as they are conceptualized in academic analysis and, importantly, agreed upon and written into international climate governance.

In Sections 3 and 4, we give weight to one approach at a time to illustrate their respective implications. Distributive climate justice is not, however, a matter of choosing and

[14] While Danish per capita territorial emissions amounted to ~ 7.6 $MtCO_2eq$ and global per capita emissions to ~ 6.4 $MtCO_2eq$, we calculate the baseline Danish emissions per capita for *need* as ~ 1.9 $MtCO_2eq$.

[15] In the high energy demand scenario, our estimate for Danish *need* emissions per capita in 2020 is ~ 2.9 $MtCO_2eq$.

then following one approach. Different approaches can be weighed against each other (Steininger et al. 2022) or combined into one (van den Berg et al. 2020) as with CBDR-RC (Anderson et al. 2020). For example, Denmark is particularly well placed to lower emissions (capacity), currently consumes much more energy than what is needed for decent living (need), and has historically emitted significant amounts of GHG on a per capita basis (responsibility). Given our results, any consideration of fairness would significantly raise the bar for Danish climate policy, while even the globally inequitable approaches of grandfathering and equal-per-capita demand more ambitious targets.

On top of that, we note that our estimated Danish emission budgets refer to the emission accounting rules of the UNFCCC, as do the official Danish climate targets. The conventions within those rules of considering territorial emissions (as opposed to consumption-based emissions), ignoring emissions from international transport, and ignoring biogenic emissions arguably benefit a country like Denmark (Tilsted et al. 2021). The country's consumption-based emissions are higher and have decreased at a slower pace than its territorial emissions (Danish Energy Agency 2023a, b); international transport emissions from Danish companies have increased since 1990 (Statistics Denmark 2022); biogenic emissions have increased along with the share of biofuels in the Danish power mix since 1990 (Danish Energy Agency 2023b). Hence, alternative accounting rules could increase the gap even further between Denmark´s current emission trajectory and fair levels of emissions.

In the face of the dwindling 1.5 °C budget (not to mention climate *realpolitik*), one might ask if the Danish budgets estimated in this study are simply infeasible and, thus, irrelevant. This objection is arguably pertinent for all equity approaches we consider, but particularly so in the case of *responsibility*, which suggests that Denmark should compensate for its climate debt through net-negative emissions already in this decade. Relying on carbon dioxide removal (be it either land-based or through negative emission technologies), with its implications for, for example, land and energy use, can lead to highly unjust outcomes[16] (Dooley et al. 2018; Carton et al. 2020, 2021; Bluwstein and Cavanagh 2023). In practice, the diminishing carbon budget arguably means that distributive climate justice related to mitigation has become a matter of achieving a 'least unfair' allocation (Morrow 2017; Stoddard and Anderson 2022, p. 3). Infeasibility, however, does not imply irrelevance. For example, Finland's climate act is based, in part, on an analysis by its national climate council, similar to the one we have done here (Ollikainen et al. 2019). The act seeks to address equity and justice concerns by combining more ambitious near-term targets with net negative emissions (as a way of paying off climate debt) from 2035 (relying on Finnish forests as carbon sinks) (Ministry of the Environment 2023). The apparent infeasibility of equity-based pathways also underlines the need to keep in mind other dimensions of distributive climate justice than mitigation and national reduction rates, namely adaptation and impact (Paavola and Adger 2006; Moellendorf 2015; Wallimann-Helmer 2015; Khan et al. 2020), for instance by pledging increased unconditional climate finance and compensation for loss and damage (Fanning and Hickel 2023). The purpose of our analysis is not to provide emission scenarios that correspond to 'truly fair' contributions of individual nations. Rather, we intend to speak back to narratives and rankings that deem certain actors and nation-states as climate progressive. Invoking 'an imaginary of the modern world as a

[16] In terms of what a fair approach to negative emissions could look like, recent studies illustrate how fairness considerations shape the distribution of carbon dioxide removal responsibilities across nations and regions (Pozo et al. 2020; Fyson et al. 2020) and how fairness considerations are crucial in relation to net zero targets (Khosla et al. 2023).

stratified order, whose actors are imagined as continuously striving to perform better than others' (Brankovic 2022, p. 801), such narratives and rankings constitute political acts that arguably reinforce and legitimize inequitable relations.

The very idea that the Danish Climate Act can be the 'most ambitious in the world' presupposes that climate policy can be reduced to a single comparable and accurately measurable dimension of performance. Pitting nation-states against each other in this way instils the notion that climate action should be considered first and foremost in relation to others rather than in its own right and renders obscure the dimensionalities and temporalities of socio-technical transformations (Beck et al. 2021). Framing Denmark as a green champion on a global scale helps fend off criticisms and pressures for change that demand a more transformative-oriented approach to climate policy. As such, incumbents rely on continuous disregard for global equity and distributive justice to defend non-transformative policies and strategies (Beck et al. 2021).

6 Conclusion

Claiming that the Danish Climate Act is among the world's most ambitious is a political act with stark implications. Relying on a climate leadership frame, Danish politicians fend off criticism leveraged against them for inadequate action and put aside concerns over the burden of responsibility that comes from historical emissions. Yet, pathways that follow the targets enshrined in the Danish Climate Act are significantly different from equity-based approaches (and the notion of CBDR-RC enshrined in international climate governance) for a reasonable likelihood of realizing the 1.5 °C goal. The *responsibility*, *need*, and *capability* approaches all entail significantly lower cumulative emissions in the current decade than what follows from Danish climate policy targets. Even when applying burden sharing approaches that are not equity-based, i.e. equal-per-capita and grandfathering, the Danish targets fall short. Our assessment is based on an evaluation starting from the year 2020 when the Danish Climate Act came into force and, hence, does not account for the inadequate global efforts and the drastic reductions in global carbon budgets since then. Nuancing the often-praised example of Denmark has the merit of illustrating that positing the role of a climate pioneer in this case requires sidelining moral imperatives. As such, the extent to which rich and 'over-consuming' countries (Fanning et al. 2022) are able to do so is integral to the politics of green transformations.

The results carry implications for, amongst other things, the degree and form of mitigation, international climate finance, and climate reparations. Our focus here on mitigation efforts as an aspect of distributive climate justice remains limited. Indeed, the scale and scope of climate justice (with its relation to other forms of injustice) demand a much broader and more comprehensive approach, i.e., one of transformative justice (Newell et al. 2021).

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Data availability All data generated or analyzed during this study are either included in this published article or publicly available (see supplementary information for full list of data sources).

Declarations

Competing interests The authors declare no competing interests.

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