Sharing the effort of the European Green Deal among countries

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Abstract

In implementing the Green Deal to align with the Paris Agreement, the EU has increased its climate ambition and is currently negotiating how the increased mitigation effort should be distributed among Member States. Such partitioning of targets among subsidiary entities is becoming a major challenge for implementation of climate policies around the globe. We contrast the recent EU Commission proposal - an ad-hoc decision based on a singular country attribute - with transparent and reproducible methods based on three ethical principles. We go beyond traditional effort-sharing literature and explore allocations representing an aggregated least regret compromise between different country perspectives. While the current EU proposal represents a nuanced compromise for many countries, for others a further redistribution could be considered equitable. We demonstrate the applicability of our approach for the necessary modifications to the effort sharing targets for 2030 among EU Member States.

Most climate targets are framed in terms of very broad scales, such as the implicit global emissions reduction target of the Paris Agreement[1,2], but these overall emissions reduction targets needs to be broken down to lower levels such as states, provinces or sectors of societies[3–5]. A similar task arises if large companies commit themselves to climate targets and need to agree as to what this means for their different branches and supply chains[6,7].

In political processes, quite often this effort sharing of a common target is done in a rather ad-hoc manner and is thus neither transparent nor reproducible and can be hampered by diverging viewpoints and preferences. Building upon the categorization of equity principles drawn upon in the effort sharing literature[8–11] we present an approach that overcomes these deficiencies and can contribute to a transparent decision process in the partitioning of an overall emissions target among subsidiary entities, aligning disparate views and defining an

allocation space where different parties could agree to an equitable compromise. Using the context of the ongoing EU negotiations to raise the 2030 effort sharing target[12], – while an overall target of 55% reduction compared to 1995 has been established, how that effort should be distributed among Member States is still undecided – we assess the implications of such an approach in terms of the possible resulting carbon budget allocation and corresponding reduction targets. We begin by exploring the implication of different effort sharing mechanisms and ethical considerations on a singular, country level, finding that the resulting ranges of possible emissions reduction burden can vary widely. In such a case, if each country were to favor the least-burdensome allocation approach, the overall target of the EU in 2030 would remain unmet. However, our proposed framework allows for systematically combining different interpretations of three major equity considerations – capability, equality, and responsibility – and allows us to explore compromises, where country targets are the result of a combination of different allocation schemes, thus weighting different allocation principles to find a common solution. By identifying interpretations of equity which result in agreement based on a target that minimizes the additional emission reduction effort required by countries (i) compared to the maximum possible budget they could achieve or (ii) previous commitments in the earlier less ambitious effort sharing agreement, we identify a possible space for decision-making which combines multiple equity considerations. We find that the possible combination of equity considerations, and the strength at which they are applied, results in a wide range of space for decision making which comprises a richer set of equity considerations than the current EU approach. We conclude with a discussion of how such a pure approach could be further adapted in specific negotiation and policymaking processes, and suggest additional constraints, e.g. a ratchet mechanism that limit adjustments to such that increase the target compared to previous agreements.

Equity principles

In analyzing how the EU emissions budget 2020-2030 can be allocated among the EU 27 we distinguish three principles, namely – following the IPCC's broad classification[13] – capability, equality, and responsibility and different interpretations of each of these principles. According to the capability principle the greater an agent's ability to pay for the solution of a problem (here the problem of reaching the 2030 EU reduction goal) the greater the proportion of the costs that the agent should be expected to pay[14–19]. This principle, often also dubbed ability to pay principle, reflects an egalitarian understanding of justice[20]. The principle relies on the idea of positive duties of the most and more advantaged to help those less advantaged and worst off. The principle in itself does not take into account who can be held responsible for the high emission levels achieved and who has so far been more or less benefited by emission-generating activities. The indicator most often employed in the literature, but also in past agreements e.g. by the EU, is GDP per capita serving as proxy for the differing abilities to pay. The magnitude at which differences in ability translate to differences in required emission reduction is implemented here via two different approaches. Both approaches are similar in their translation of differences in GDP per capita levels into emission reduction needs according to the capability principle (*C1-EU-capability* and *C2-GDP/cap*; for further detail, see Table 1 and the methodology section), but of note is that C1 is designed to mirror as close as possible the current EU proposal[12].

According to the equality principle everyone should be able to enjoy a level of wellbeing above the level required to secure basic needs[21–24]. Allocating the burdens of reaching the 2030 reduction goal should be compatible with countries securing the sufficiency level of wellbeing of all residents. Reaching the poverty line serves as proxy for reaching this critical level of wellbeing. So understood, the equality principle reflects the sufficiency principle[25–28] (abbreviated *E1-basic-needs*). As an alternative to the sufficientarian interpretation, the equality principle can be specified as the goal of all countries converging on the same equal

per capita emission level in 2030 (defined as *E2-ES-EPC* or *E3-Full-EPC*, indicating convergence of effort-sharing (ES) or all (full) emissions). Then, from 2030 onwards the EU 27 will pursue the 2050 reduction of net-zero without grandfathering[29,30], that is, without prolonging the inequality of the status-quo levels of emissions into the transformation period.

According to the responsibility principle, states should be responsible for their own emissions since they have been liable to know about the limited capacity of the atmosphere to absorb greenhouse gases, their countries' share of the use of this limited resource and that all plausible understandings of sharing the remaining carbon budget require drastic reductions of emissions of most countries, including all of the EU 27. The latest plausible date for attributing such liability seems to be 1995, the date of publication of the second assessment report of the IPCC, confirming the findings of the first report of 1990 concerning the anthropogenic causes of climate change, the likely consequences and what measures are required to hinder 'dangerous climate change' [31–34]. By moving the year of accounting back to 1995 the actual emissions caused since 1995 are attributed to the emitting countries. As interpretations to address historical considerations can take different forms, we utilize two approaches, indicated as *R1-hist-emi* and *R5-cumulative-emi/cap*, with their distinctions discussed in Table 1 and the methodology section.

The responsibility principle can also be specified in terms of taking into account the unequal benefits countries have received from the consequences of pre-1995 emission-generating activities[35]. Here the aim is to fairly distribute these benefits among currently living and future people[36] (*R2-Benefits* interpretation). The carbon emissions embodied in the countries' capital stock in 1995 serves as proxy for inherited benefits.

The third interpretation rejects the significance of the historically developed de facto unequal levels of per capita emissions among the EU 27 in 2020 and, instead, for the period of 2020-2030 relies on an equal-per-capita allocation of the overall EU27 carbon budget to country

budgets[37–39] (*R3-C-budget* interpretation). If so the EU 27 will pursue the 2030 reduction goal without grandfathering.

The fourth interpretation of the responsibility principle rewards countries' past efforts in improving emissions efficiency (i.e. raising output per emissions) by means of implementing renewables (*R4-RES-expansion*). When countries succeed in improving emissions efficiency they can realize a higher level of wellbeing with the same emission budget. Justice is concerned with both fair shares of wellbeing and absolute levels of wellbeing not only in terms of all reaching the critical level, but also above the sufficiency level. In its economic interpretation both relative and aggregative welfare are important concerns. Among other principles the so-called priority view takes into account both distributive and aggregative concerns[40]. Other things being equal (here if the likelihood of reaching the 2030 reduction goal remains the same) it is better when the EU 27 reach the goal with an on average higher per capita level of welfare, enabled by an expansion of renewables. Given the high interdependencies within the EU it seems likely that welfare gains realized in one country will benefit people in other countries of the EU as well. Countries can be understood to be responsible for such renewable expansion measures since 1995 when they have become liable for their emission-generating activities. The proxy for success of such measures – and granting an increased budget as a consequence - is the increase in the share of renewables since 2005.

Table 1. Alternative interpretations of the three equity principles (responsibility, capability, and equality) as applied in this work, in line with [8] Table 6.5.

Interpretation	Relevance and operationalization
Responsibility	
R1- Historical emissions from 1995 (*Hist-emi)*	Reflects the use of fossil fuels since the year 1995, when countries were liable to know the impacts of GHG emissions on climate and had the ability to abate. The point of time at which the remaining budget is allocated on an equal per capita basis is simply shifted back to 1995. The EU GHG budget for 2020-2030 is first extended by EU past emissions 1995-2019. Second, per capita budgets are allocated based on this aggregate number to each Member State (based on current (2019) population), before the budget already used up by each specific country in 1995-2019 are subtracted to give the remaining budget for 2020-2030 for each country.
R2- Inherited benefits of emissions (*Benefits)*	Incorporates the benefits a country has obtained due to emissions prior to the year 1995, interpreted here as being the embodied emissions in national capital stock. Using capital stock estimates, GHG budgets from 2020 to 2030 are scaled similarly to the past emissions consideration above, but here based on pre-1995 emissions embodied in each country's capital stock in 1995.
R3- C-budget	The total emissions budget for the ES sector, (calculated by a fictitious linear path from 2020 to 2030) is split among Member States according to population. The resulting emissions budgets produce target paths up to 2030 with a corresponding target distribution for the effort-sharing sector.
R4 - Expansion of renewables share (*RES-expansion)*	Reflects the difference of the Member States in terms of their change in renewable share from 2005 to 2019 compared to the EU-27 total. Countries with a higher change over that time period compared to the EU average are allocated as a reward a larger emission budget, i.e., a more relaxed emission reduction target. Similar to GDP per capita, countries receive more (less) emissions at an equal rate as their increase (decrease) in RES share compared to EU.
R5- Cumulative emissions per capita (*Budget/cap)*	Proposes an alternative method to address historic emissions as compared to *R1-Hist-emi*, by scaling future emission allowances based on differences in historical cumulative emissions per capita. Countries with a higher than EU-average cumulative historic emissions per capita from 1995 to 2019 are allotted higher reduction targets in 2030, and vice versa.
Capability	
C1- EU implementation based on GDP/capita (*EU-capability*)	This interpretation of GDP per capita corresponds to the current EU policy proposal that puts a cap on the relevance of countries' per capita GDP differences for the required emission reductions and is derived empirically from the current proposal. More specifically, the distribution is estimated in a regression based on GDP per capita from 2015-2018 and the previous (2018) ESD distribution (which in turn builds on GDP/capita) as explanatory variables. For full details, see the derivation of the distribution in the methods section.
C2- GDP per capita (*GDP/cap)*	This interpretation weighs the relevance of all per capita GDP differences equally in specifying the countries' required emission reductions, increasing or reducing emissions allocations based on the percentage deviation from the EU average GDP per capita. Countries with a higher GDP per capita (in 2019) are allocated a smaller emission budget, i.e., a stricter emission reduction target. For a full application of this interpretation, the emission reduction target for each Member State varies depending on the difference in GDP/capita from the EU-27 average. For each percentage point above or below average, reductions are increased (reduced) by the same percentage.

Equality	
E1- Basic needs	Separates allocation of emissions budgets into two stages; in the first stage, Member States are allocated the necessary emissions to meet the basic needs energy demands of the fraction of the population at risk of multidimensional poverty. Each member state is allocated the emissions corresponding to energy use (at current emission intensities) to fulfill such basic needs. After this initial step, the remainder (if any) of the budget is distributed in an equal-per-capita manner.
E2- ES-sector EPC convergence (*ES-EPC)*	Reflects a convergence to equal per capita emissions by 2030, based on country emissions in effort-sharing sectors (i.e. emissions not covered under the Emission Trading System).
E3-Full-EPC convergence (*Full-EPC)*	Reflects convergence to equal per capita emissions by 2030, based on all sectors' emissions (sectors in and outside the Emission Trading System).

The three equity principles discussed above, and their various interpretations, can all be utilized singly to allocate emissions budgets, but they can also be applied in concert, at varying intensities. Figure 1 provides a conceptual overview of such an approach. Each equity principle forms one corner of the triangle and is represented by an interpretation. The results of the chosen interpretations can be combined in a weighted sum to arrive at an allocation incorporating all three equity considerations.

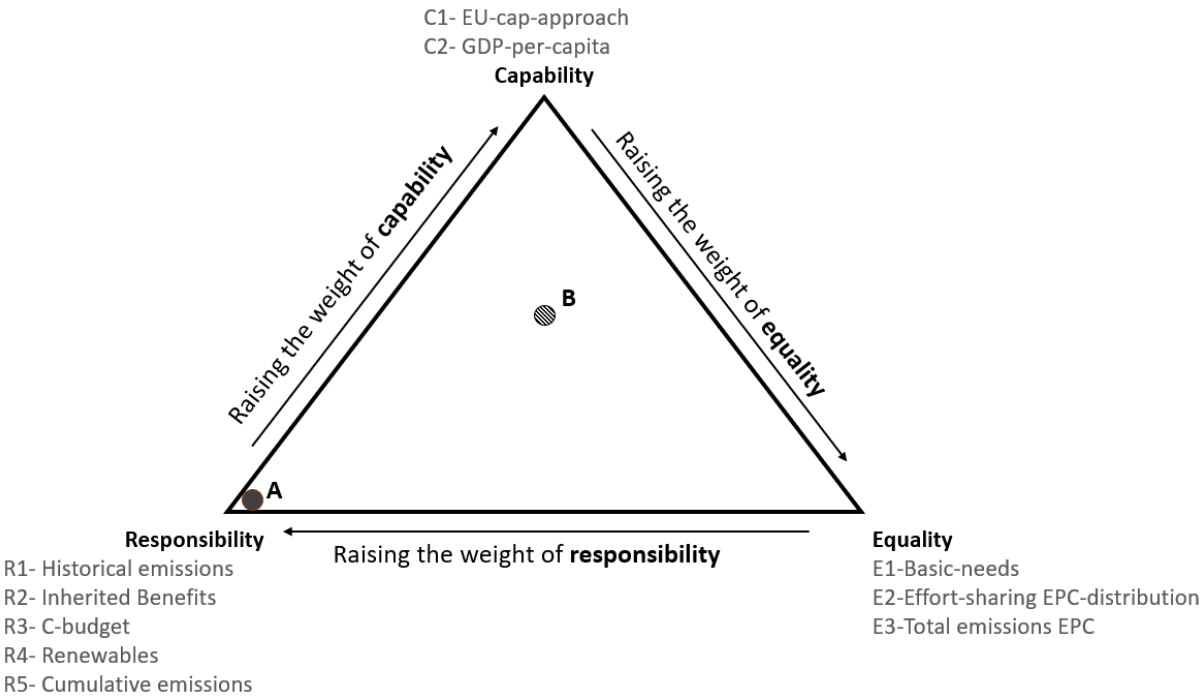


Figure 1. Conceptual overview of allocation approach. Each distribution consists of three components, addressing each of the three IPCC equity considerations of (i) responsibility, (ii) capability, and (iii) equality. These equity considerations are interpreted via a set of interpretations, listed under each corner. The interpretations used in the main scenario are indicated as R1, E1, and C1; alternative interpretations are listed with subsequent numbers, e.g. R2, where the inherited benefits from pre-1995 emission-generating activities replaces historical emissions in the scenario calculations. As an example, Point A would indicate an allocation scenario where only responsibility is given weight. Point B represents an allocation where equal weight is given to all three equity considerations.

Results

We first apply the interpretations discussed in the previous section in a single manner, determining individual country emission reduction targets as specified in the methodology section. Figure 2 illustrates the resulting country emissions reduction burden for the ten interpretations presented. The figure makes readily apparent the current approach of the EU to allocate 2030 budgets using a GDP per capita based allocation with some adjustments, as shown by the consistent proximity of our capability considerations to the current proposed

levels, barring a few outlier countries (e.g. Ireland and Luxembourg, with per capita GDP levels two to three times higher than the EU average). Beyond this, we are able to arrange the countries into three distinct groups; the first where the (majority of) equity-based allocations suggest a more stringent target than that proposed by the European Commission (EC), a second where no clear trend exists (results are above and below the EC proposal), and a third where equity-based allocations lead to a less stringent target. For clarity, we have organized these countries according to this trend, in panels A, B, and C.

For the first group of countries (Figure 2, Panel A) where allocation results tend to require *less* emissions reduction than the proposal of the European Commission, a number of factors are at play. The proposal of the Commission mainly adjusts for country differences in GDP/capita, and thus acknowledges mainly a capacity consideration. In this first group, countries are allocated more emissions (i. e. less emission reduction burden) for the bulk of the interpretations of the responsibility and equality dimensions, given these Member States are: (a) countries with a higher share of the population in poverty (beyond a mere low *average* GDP/capita), such as Bulgaria; and (b) countries for which responsibility indicates less future reduction, most often according to all of its possible interpretations, be it low historical emissions (e.g. Bulgaria, Cyprus, Spain, Italy or Portugal) or substantial realized success in emission reduction (Sweden), past success in renewable expansion (Sweden, Cyprus) or (for most of these countries: and) comparatively low emission per capita starting levels granting least reduction when the remaining carbon budget is allocated evenly across countries per capita.

For the second group of countries (Figure 2, Panel B) at least two equity dimensions would lead to either a stricter or less stringent reduction target, depending on their interpretations. For example, an acknowledgement of GDP per capita differences without the 50% emission

reduction level cap of the EU commission proposal would require a more stringent reduction from Germany, as would an acknowledgement of inherited benefits, while past success in renewables extension and consideration of historical emissions (more specifically, comparatively larger emission reduction already achieved) indicate the reverse, i.e. lower emission reduction target for this country. An equally divergent result, albeit exactly in the reverse direction for each of these interpretations holds for Hungary, Latvia, Croatia, Romania and Poland. For all the countries in this group the way the equity dimensions are specified matters for the direction they are impacted.

Finally, for the remaining group, consideration of the further equity dimensions will generally lead to stricter reduction targets than suggested by the EU proposal. For countries like Austria, Belgium, Denmark, Ireland, Luxembourg, and the Netherlands, and also Czechia and Slovenia, such consideration clearly increase reduction efforts demanded. For many of these countries there is a single (but if at all, generally only one) interpretation that would work in the reverse direction: for Austria, Denmark, Finland and Ireland an acknowledgement of past successes in renewable extension would reduce not increase the reduction target, and for Czechia and Slovenia an uncapped GDP-Capita consideration would do so.

Figure 2 thus indicates how strong emission reduction obligations change for each EU Member State, when following one or the other principle, respectively the indicator these are specified by. It also makes clear that if countries were to choose that single equity consideration and interpretation indicating least emission reduction for them, the overall emissions reduction target for the EU for 2030 would be missed by a wide margin, in particular as even interpretations can be found for a majority of countries which would require zero reductions compared to 1995 levels.

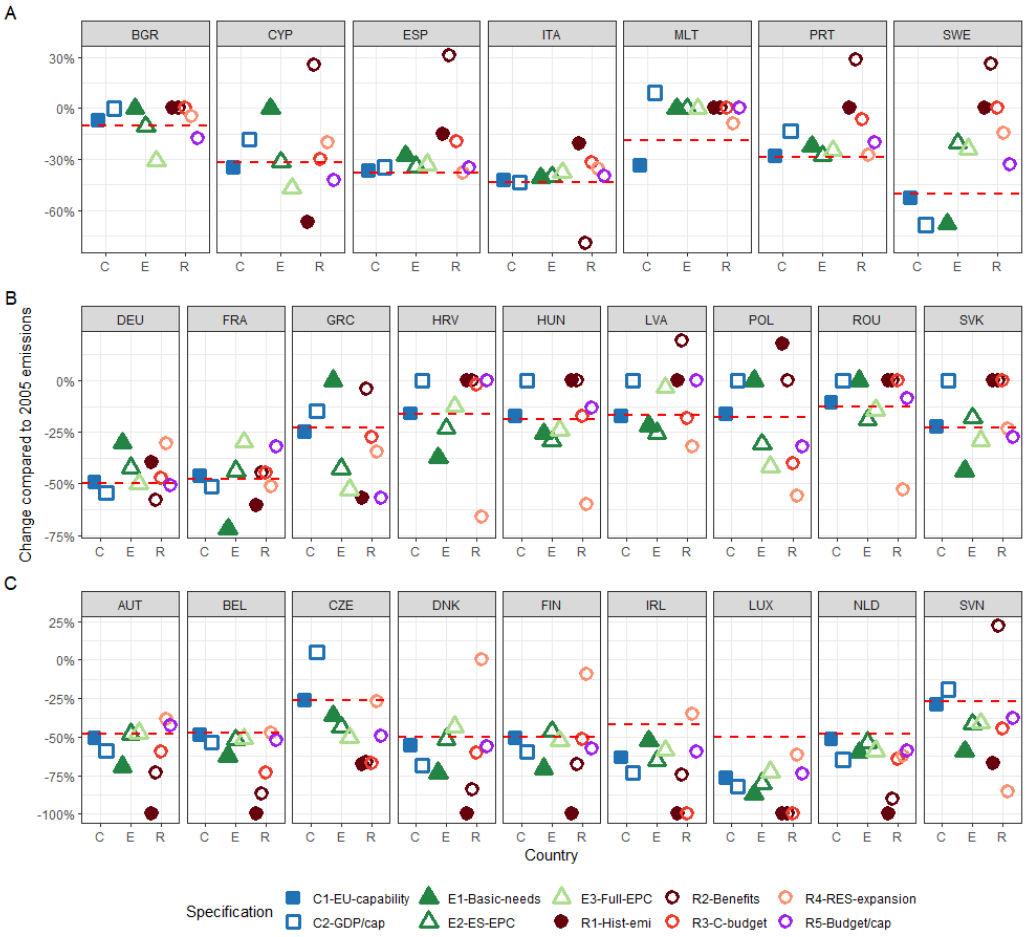


Figure 2. Possible country emission reduction targets by 2030 (relative to 2005) reflecting an EU27 overall 55% reduction target (relative to 1990) for an application of each single principle (and under different interpretations of them). The dashed red line indicates the target reduction put forward in the 'Fit for 55%' proposal. The x-axis is divided into 3 categories, the first (C) contains the results of capability interpretations, (E) equality interpretations, and (R) responsibility. Panel A consists of countries with allocation shares predominately above (i.e. less restrictive) than the current proposal. Panel B consists of countries with some scenarios leading to more stringent reductions, and others less, than compared to the current EU proposal, and panel C countries with the majority of scenarios leading to more strict reductions.

Implementing combinations of equity interpretations

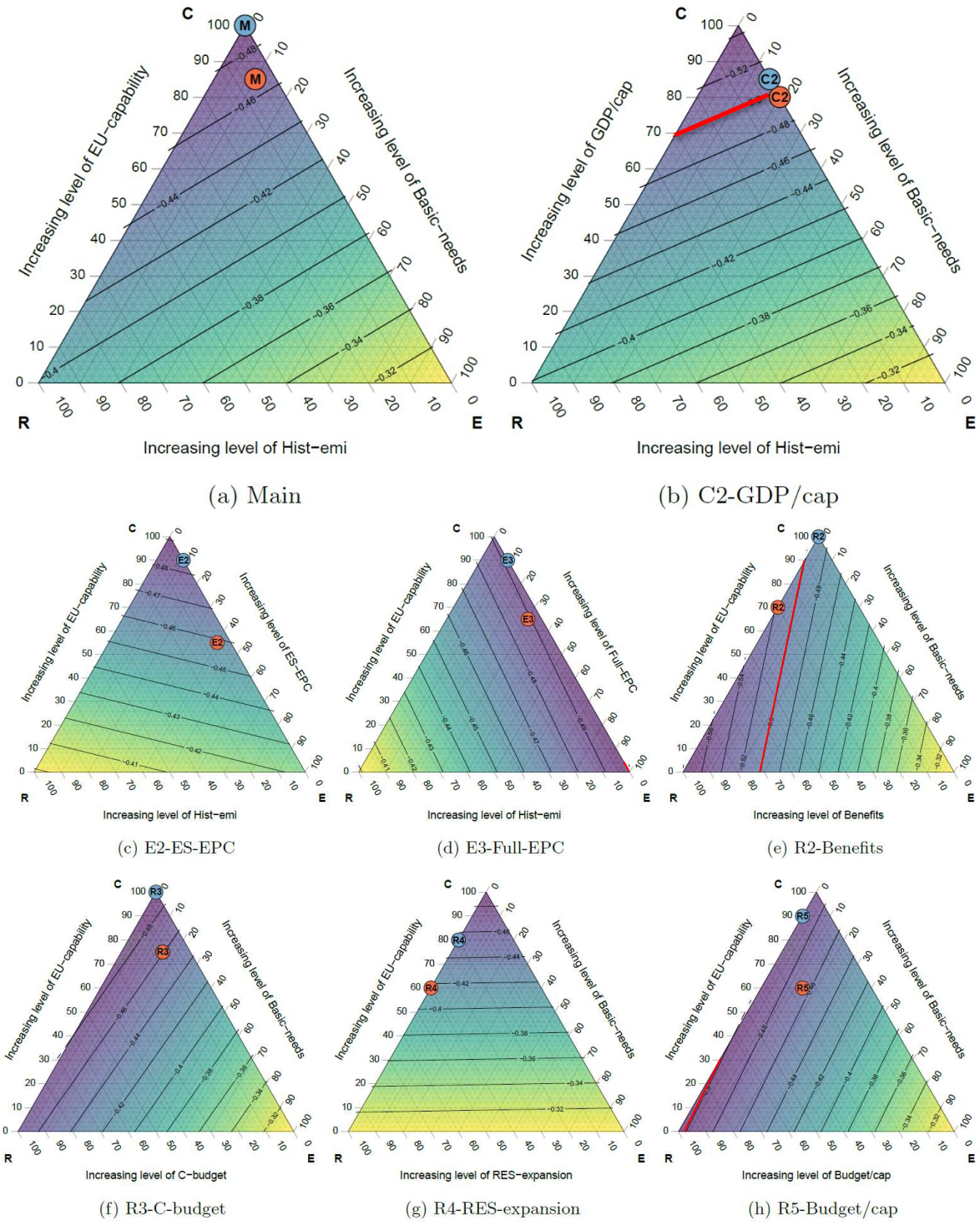
As laid out conceptually in Figure 1, we can move beyond the use of a single equity consideration by combining one representative interpretation from each principle (capability, equality, and responsibility). The structure of figure 1 allows for illustrating how the required emissions reductions change as the weighted combination of equity principle interpretations change. Figure 3 illustrates this for a single illustrative country, Germany, highlighting how systematically varying the weights among the three equity dimensions interpretations translates into different 2030 reduction targets (ternary charts for all 27 EU countries are provided in the Supplementary Material).

In panel (A) the main interpretations are implemented for each dimension (C1-EU-GDP per capita for capability, E1-Basic-needs for equality and R1-historic emissions since 1995 for responsibility). Moving from the bottom to the top along the left cathete, and thus increasing the weight of capability, increases the reduction target for Germany. The same holds when moving along the hypothenuse from right to left, thus increasing the weight of responsibility (i.e., here the relevance of considering historic emissions). While increasing the weight of equality (i.e., moving down along the right hand cathete) reduces emission reduction targets – the reason being that an increase in the weighting of this dimension necessarily decreases the weight of the other two dimensions, each of which imply stronger reduction target increases. The bottom right-hand corner being marked with the lightest color (and thus least emission reduction for Germany) indicates that avoidance of consideration of both capability and responsibility reduces emission reduction to its minimum.

As panels (b) and (f) show, this basic pattern does not change (albeit at a slightly differently scaled quantitative implication) if either the capability interpretation is switched to the non-capped GDP per capita interpretation (C2, panel (b)) or the responsibility interpretation is switched to equal carbon budgets (R3, panel (f)). If, however, equality refers to equal per

capita budget (or full equal per capita budget) giving weight to this dimension reduces emission reduction most (panels (c) and (d)). If responsibility refers to inherited benefits (panel (e)) or cumulative emissions per capita (R5, panel (h)), giving more weight to this dimension increases reduction targets most, and now even more than – as for all other cases – giving weight to capability. Finally, interpreting responsibility as rewarding countries for larger renewables increases implies a relative reduction of emission targets, as we see in panel (g) that is almost equal to the reduction due to changing weight of an equality consideration. In this case the reduction target is the lower the lower the weight of capability, but regardless of whether the weight is shifted towards responsibility or equality (reduction isolines are orthogonal to the left cathete along which capability weighting is varied).

Repeating the necessary calculations to derive these results for all EU countries (e.g. calculating the resulting emissions reductions requirement of any given combination of three interpretations) allows for identification of not only country preferences, but the rate of change in reduction levels as the weighted combination moves away from the minimum point or isoline. Combining this information on all EU Member States makes possible the identification of possible points of agreement in future effort-sharing negotiations, in Figure 3 marked as green points. Discussed in further depth in the next section, these points indicate the weighted combination of equity interpretations which result in the lowest possible aggregate deviation of all EU countries from a given preference, e.g. the equity consideration which requires minimal mitigation effort.



(a) Main (b) C2-GDP/cap

(c) E2-ES-EPC (d) E3-Full-EPC (e) R2-Benefits

(f) R3-C-budget (g) R4-RES-expansion (h) R5-Budget/cap

Figure 3. Equity triangles illustrating the required emission reductions for Germany arising from combinations of equity interpretations, based on a fully qualified distribution approach (e.g. the weights of the capability, responsibility, and equality interpretations sum to 1). The isolines indicate emission reduction targets (by 2030, relative to 2005) and are labeled accordingly. For each point on

an individual ternary chart, the color indicates the level of emissions reductions required, with yellow corresponding to lower levels, and blue higher. The level at each point is the result of a weighted combination of the three equity interpretations indicated on the chart axes. As an example, a point in the middle of panel A is the reduction amount given an equal combination of C1-EU-capability, E1-Basic-needs, and R1-Hist-emi. The red lines indicate the current EU suggested reduction level in the Fit for 55 proposal – for Germany, -50% – if the value falls within the range of the chart. The blue and red points labelled with the scenario index indicate potential negotiation agreement points; the combinations of three interpretations which minimize EU country aggregate divergence from the equity consideration that would require the minimal effort (red) or minimal change from the 2018 ESD (blue).

Possible negotiation convergence points

In negotiating an effort sharing agreement agents, in our EU case 27 Member States, could be motivated by a number of aims. One could be to minimize any additional effort above what could be considered a minimum. Implementing such a target in our analysis would mean that for each of the interpretations listed in Table 1 a relative weighting combination of the three equity dimensions can be identified that ensures that countries have to do the least additional effort beyond what would be the minimum effort under any weighting combination for these very interpretations. Alternatively, given that in this case Member States have previously agreed to some level of reductions by 2030 in 2018, they may want to do the least additional effort compared to this prior level. In this case, a combination of interpretations can again be identified which minimizes the aggregate effort of all EU countries beyond their prior agreement. Formally, the sum of squares of these deviations is minimized (see *Methods*). We define each of these weighting combinations “negotiation points” and calculate one for each possible combination of the three equity criteria interpretations discussed (30 in all). The results of these calculations for both a ‘minimal mitigation effort’ (marked in orange) and a ‘minimal change compared to 2018 Effort Sharing Directive (ESD)’ (blue points) case are identified in the ternary inset panel in Figure 4. These overall negotiation points are also

indicated in the country ternary figures (Figure 3 and respective Figures in the SI) to indicate the reduction target for each country that would result when implementing such a negotiation point.

The ternary subpanel of Figure 4 shows that these negotiation convergence points span the negotiation space, indicating a variety of combination weightings which could likely result from negotiations if member states follow this rationale. Some trends do emerge. Comparing a minimization of effort from the 2018 ESD to the alternative of minimizing effort entirely, we find the ESD-based negotiation points exhibit much more clustering (as point size indicates frequency), most agreement points are either almost fully capability-weighted, or roughly 50% capability, and the rest either responsibility or equality interpretations. As one of our two capability interpretations is based heavily on the 2018 ESD (see *Methods*), the clustering near a 100% capability allocation is not surprising. However, even for minimizations of aggregate EU Member State deviation from their own individual minimum reductions, a similar clustering occurs, although less strongly. Regardless of the minimization criteria or equity interpretation, what is consistent is the presence of capability in all negotiation points; the only equity criteria to do so. The negotiation points seem to explain the current EU negotiations, as these results would make it seem unsurprising that the current proposal emphasizes a GDP per capita-based allocation (and thus, the capability dimension).

While the negotiation points results do acknowledge the relevance of a capability interpretation, they also emphasize the possibility for a number of other negotiation points (e.g. points of agreement or compromise) that incorporate other aspects of fairness. These points thus represent solutions which may be on the whole less burdensome for the EU to adopt in terms of emissions reductions compared to previous agreements and may at the same time increase buy-in from countries which up to now may not have agreed with an approach emphasizing capability as the only relevant factor in budget allocation.

Wherever they fall in the ternary chart, these negotiation points imply a weighted combination of three equity interpretations leading to an allocation across EU Member States, which is illustrated in the main panel of Figure 4. The plot indicates the range of the 2030 reduction targets across all negotiation convergence settings, i.e. the range and extremes of country reduction targets that results across all negotiation convergence points for both the “minimal mitigation effort” and “minimal change from 2018 ESD” on a per capita basis. The distributions of these results can be compared to the solid black line, indicating the current proposed EU Member State 2030 targets. When comparing to the effort sharing proposal, we find that a broader acknowledgement of equity dimensions enhances the target variability. Countries that have lowest emission reduction obligations under the EU proposal tend to have even less restrictive ones when further equity dimensions are considered as well (e.g. Bulgaria, Romania, Latvia, Croatia). Reversely, countries with highest reduction obligation under the EU proposal tend to have even more stringent ones once one or both of the other equity dimensions are considered as well (e.g. Austria, Denmark, Netherlands, Finland). The notable two exceptions to the latter group are Germany and Sweden, who rank high in EU proposal obligations, but would not have to increase their reduction target under alternative considerations, most importantly due to their recent strong emission reduction, implying for example no additional reduction obligation from historic emissions consideration.

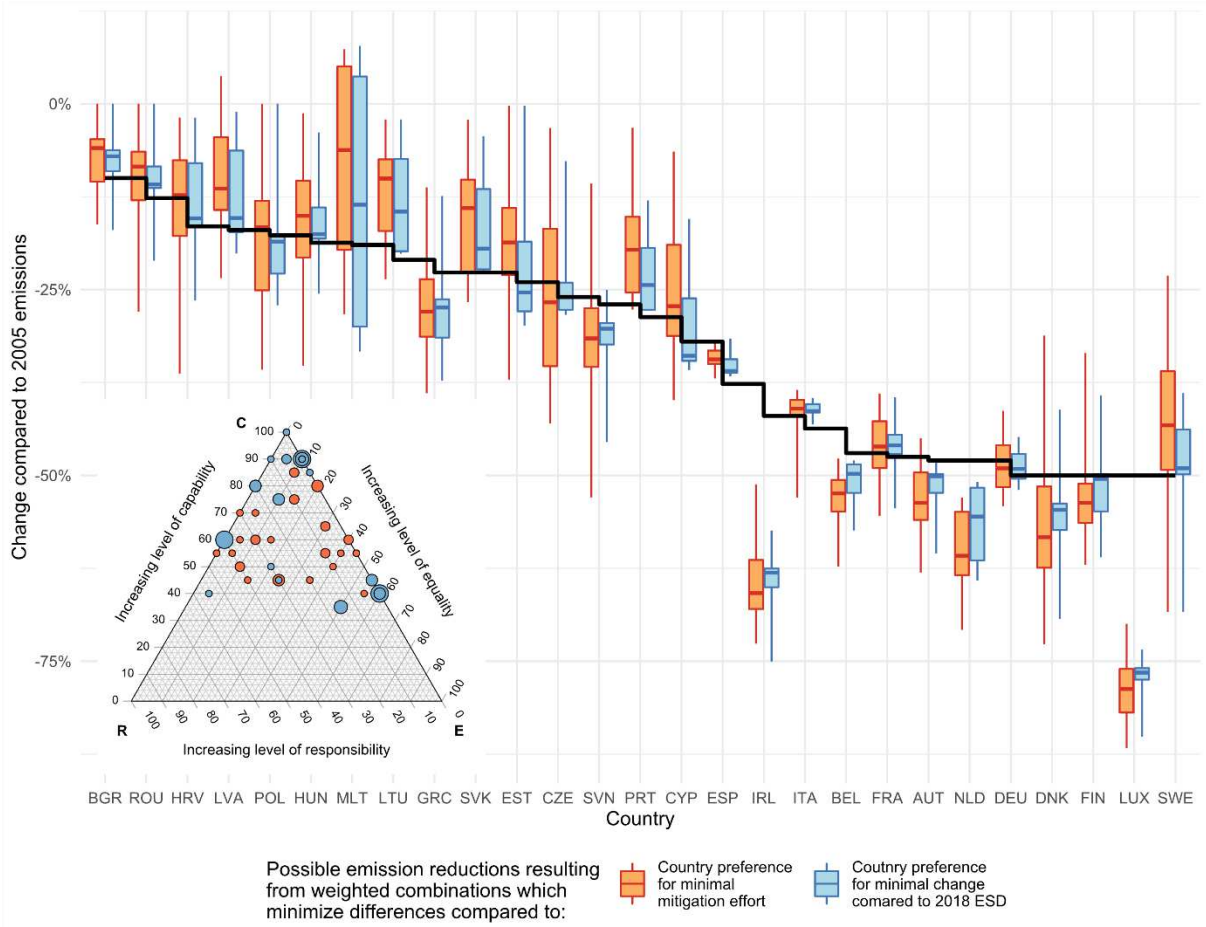


Figure 4. Negotiation points derived from optimal weighting of equity interpretations and their resulting reductions by 2030 by country. The box and whisker plots in the main panel show the resulting range of emissions reductions by 2030 by country, corresponding to the negotiation convergence points shown in the inset equity triangle. The black line indicates the current 'fit for 55%' reduction target for each country. Points in the inset ternary chart denote negotiation points when using an allocation approach comprised of weighted combinations of three equity considerations. Orange points and boxes are for minimizations of EU aggregate effort compared to country minimal mitigation efforts, and blue for minimal deviation from the 2018 ESD. Point size indicates frequency, i.e. multiple points at one location.

Conclusions

The paper introduces a systematic and transparent approach to evaluate national emissions reduction efforts according to different equity dimensions. We introduce a number of different

equity indicators and propose a novel method to assess possible convergence points that would minimize country efforts and thus help to identify acceptable negotiation outcomes.

Applying this approach to the ongoing effort sharing negotiations of the 2030 climate ambition across EU27 Member States, we find that the current EU proposal is for many countries consistent with our 2030 emissions estimates (from the negotiation convergence points).

The GDP per capita-based capability approach of the EU thus captures the dynamics of the majority of countries well. The dimensions of equality and responsibility, however, are equally important to consider. Introducing them increases the divergence of country reduction targets; countries with the lowest emission reduction targets resulting from capability interpretations alone, such as Bulgaria and Romania, tend to have even lower targets when using a combined approach, thus allowing for reducing their emission reductions for 2030. The converse is true for countries with high reductions from only a capability approach; considering other equity dimensions would lead to considerably higher burdens. This holds largely independently of which interpretations are employed for these two further dimensions.

Our results also can be read as one explanation of why the EU has referred to the capability approach guiding its effort sharing allocation. When EU Member States seek to minimize additional mitigation effort beyond the minimal amount required by a given equity interpretation, particularly if only one equity dimension is desired so as to keep the process's complexity low, we find that it is the capability dimension that is the indicator of choice – across all the potential negotiation space it has by far the highest weight among all dimensions and even when varying across all interpretations. And this is exactly what the EU has chosen in its last effort sharing decision agreed upon in 2018 and has based its current proposal on again.

However as we have shown, simple, transparent and systematic approaches to incorporate additional equity considerations are within reach, and more importantly, they can produce allocations which could lead to more buy-in than the current ad-hoc approach. [A tool based on the equity structure as described in this article and allowing for individual variation of assumptions and weights of equity interpretations is available to negotiators and the interested public.]

> To support the ongoing negotiations, an online tool is currently in final stages of development that will allow negotiators to vary the assumptions and weights in our equity interpretations, and thereby understand implications for emissions reductions and the potential acceptability of a given proposal. This is in parallel to the first review of this paper. For the case of a revise and resubmit, the tool will be available with the first revision, and is indicated here for the benefit of readers. Our core hope is that such a tool can support negotiation processes by increasing transparency, and thus acceptability, of different proposals in a systematic way.

Methods

Calculation of potential country budgets to 2030 occurs in 4 steps. The first step entails determining the total EU budget to 2030, given an assumed reduction target compared to historical emission levels, and assumptions on the share of (non)ETS emissions in total EU emissions.

Based on the resulting effort-sharing sector budget to 2030, the distribution across countries can be determined based on any number of desired allocation approaches. We develop a number of interpretations and assume they will be implemented in a package comprised of three components, (i) Responsibility, (ii) Capability, and (iii) Equality. Before combining these interpretations, their individual impact has to be determined, discussed in the section “Description and calculation of interpretations” below.

We first calculate a target distribution of emissions for an interpretation, i.e. distributing emissions as though the interpretation were the only factor being considered (so, 100% weight). We then combine the interpretations as described above (using a single interpretation for each equity consideration) using a combination of weights, which sum to 100% for the three interpretations.

In the final step, we find what combination of weightings of equality, responsibility, and capability interpretations would result in the least deviation from counties' individual preferences (i.e. a weighting of 100% for a given interpretation which allows for the highest individual country budgets or the least deviation from the 2018 EU effort sharing decision, respectively).

Unless otherwise specified, data was obtained from the EU's EUROSTAT database[41].

Determination of the effort sharing emission target level in 2030

The effort sharing budget from 2020 to 2030 is determined via the EU target goal in 2030 of an at least 55% reduction compared to 1990 emissions.

$$G_{EU}^{2030} = \left[\left(e_{EU}^{1990} * (1-r)\right) - \left(e_{EU}^{1990} * (1-r)\right) * ETS\right] + \Delta LULUCF$$

Where G_{EU}^{2030} is the target maximum emissions of the EU effort sharing sector in 2030, e_{EU}^{1990} the emissions of the EU in 1990, *r* is the total reduction percentage, *ETS* the ETS share of emissions, and $\Delta LULUCF$ the change in sinks due to land use, land use change and forestry when comparing 2030 to 1990. For our scenarios, we assume *r* to be 0.55, *ETS* 0.37, and $\Delta LULUCF$ to equal an increase in sinks at 98.8 Mt CO_2, the target specified in the EU Fit for 55 climate package[12].

Description and calculation of interpretations

This section gives an overview of the inputs used to derive the specific interpretations, such as GDP per capita, and the specific calculation steps for determining a fully weighted (i.e. 100%) interpretation. We use a number of interpretations for each of our corner equity concepts, and have eight different core scenarios, the main scenario and seven variations where we substitute one category's interpretation. These are discussed in further depth in the next section.

For interpretations which function by changing a baseline allocation (denoted as b_i) depending on the distribution of a given interpretation variable (e.g. GDP per capita), we utilize a baseline which assumes an equal percentage emission reduction by all countries to reach the emission requirement for 2030 (starting from 2019 values).

A common feature for all interpretations is a zero-restriction. For all interpretations, a zero-condition is imposed, wherein a country is prohibited from having a positive change in emissions compared to 2005. If the result of a raw interpretation is a positive change, the relevant country is allotted no reduction compared to 2005, and the additional positive allowance initially allocated to it is distributed to all other countries on an equal-per-capita basis.

We implement the following interpretations:

- **C1- EU implementation approximation (EU-capability)**: The EU proposed a set of country reductions to meet the 55% target, based on consideration of GDP per capita as well as other unspecified considerations, in two formulations, a "bound" version, with reductions limited between 10% and 50%, and an "unbound" set. We approximate the influence of GDP and the previous ESD reduction targets using a linear model to

provide a rough analogue of the EU's capability approach in our interpretation set. The results of the model can be found in Table 2.

Table 2. Linear approximation of the EU's use of GDP per capita in allocating 2030 emissions reductions, including consideration of the previous 2018 Effort Sharing Decision (ESD) reduction targets.

	Dependent variable:
	Fit for 55% proposed reductions
2019 GDP per capita	0.005***
	(0.0004)
2018 ESD country target	0.638***
	(0.053)
Constant	0.216***
	(0.012)
Observations	27
R^2	0.985
Adjusted R^2	0.984
Residual Std. Error	0.022 (df = 24)
F Statistic	798.251*** (df = 2; 24)
Note:	*p<0.1; **p<0.05; ***p<0.01

- **C2- GDP per capita (GDP/cap)**: Countries with a higher GDP per capita (in 2019) are allocated a smaller emission budget, i.e. a stricter emission reduction target. For an intensity of 100% for each Member State (MS) the change in GDP/capita from the EU-27 average is translated to an equal % deviation in the effort-sharing emission reduction from the EU-average.

  The process to calculate country emission shares using this interpretation is:

$$s_j = \frac{\frac{b_j}{f_j / f_{EU}}}{\sum_{j=1}^{J} \frac{b_j}{f_j / f_{EU}}}$$

  where s_j are country target emissions shares in 2030 for $j = 1,...,J$ for all J EU countries; b_j is the baseline emissions share (e.g. the distribution which occurs if weight is set to

zero, and the distribution which is altered by the GDP per person criteria), f_j the interpretation to be applied, e.g. here, country *j*'s GDP per capita, and f_{EU} the average GDP per capita in the EU.

- **E1- Basic needs**: Budget allocations for the basic-needs interpretation are based on work by Rao and Min[42] and Kikstra et al.[43] on the energy requirements to meet basic needs and attain decent living standards. The work of Kikstra et al. provides estimates of country-explicit energy requirements to achieve sufficient nutrition, housing, and transportation to meet established standards of living. We utilize these estimates to allocate a portion of the EU effort-sharing budget as a priority measure to be used in meeting basic needs thresholds for the portion of the population most at risk of poverty.

  Based on the EUROSTAT dataset "Persons at two-fold risk of poverty" the number of persons in a country which should be allocated a basic needs energy allotment are determined. The proportion of people living below this poverty line are *pre-allocated* a set amount of emissions, to be used to meet basic needs considerations from Kikstra et al. Country emissions necessary to domestically produce the energy required to fulfill the decent living standards for all those under the poverty threshold is calculated via current national emissions intensity data from the European Environment Agency [44]. Countries are in a first step given the necessary amount to cover all persons under the poverty headcount threshold for the period of 10 years. The remaining emissions are divided among countries in an equal-per-capita manner.

- **E2 and E3- Equal per capita convergence (ES- and Full-EPC)** Reflects a distribution of the budget to achieve equal-per-capita emissions in 2030. Thus, the calculation of country emission shares is simply:

$$s_j = \frac{p_j}{\sum_{j=1}^{J} pj}$$

where s_j are country emissions shares for $j = 1,...,J$ for all J EU countries and p_j is population of country j. There are two similar interpretations; **total emissions** per capita and total **effort-sharing sector emissions** per capita. As the names imply, total emissions per capita uses the total country emissions in the calculation, whereas the latter uses only effort sharing sector emissions.

- **R3- C-budget:** The total emissions budget for the ES sector, (calculated by a fictitious linear path from 2019 to 2030) is split among Member States according to population. The resulting emissions budgets produce target paths up to 2030 with a corresponding target distribution for the effort sharing sector.

  The calculation is as follows:

  1. **Establishing the total budget to 2030:**

$$B = \left[(e_{EU}^{2019} - e_{EU}^{2030}) * \frac{t}{2} \right] + t * e_{EU}^{2030}$$

  where B is the total budget, e_{EU}^{y} the effort sharing emissions of the EU in year y = 2019 or 2030 (the target emissions in the case of 2030) and $t = (t_{end} - t_{start}) + 1$ with t_{end} and t_{start} the ending or starting years in the budget calculation, 2030 and 2019.

  2. **Calculation raw country budgets**:

$$e_j^{2030} = B * \left(\frac{p_j^{2019}}{p_{EU}^{2019}} \right) * \frac{2}{t} - e_j^{2019}$$

  where e_j^{y} represents emissions in country j in either year y = 2030 or 2019 depending on the superscript. *t again* is the simplification of $\left((t_{end} - t_{start}) + 1\right)$ as in step 1 above, indicating the years between the start and end points of the budget

calculation (12), and p_j^{2019} and p_{EU}^{2019} representing 2019 populations of country *j* and the entire EU, respectively.

3. **Elimination negative budgets**: To avoid the imposition of negative emissions on countries, any negative emissions as a result of the interpretation are removed. The country in question is allotted a reduction of 100% compared to 2005 values, and the additional reduction needed to meet budget goals is instead distributed to countries not experiencing negative emissions.

4. **Calculation of the distribution of emissions to each country**:

$$s_j = \frac{e_j^{2030}}{G_{EU}^{2030}}$$

where G_{EU}^{2030} is the total emissions of the EU for the year 2030, allowing for calculation of the share of country emissions in 2030.

- **R1- Historical emissions from 1995 (Hist-emi):** reflects the use of fossil fuels since the year 1995. The point of time at which the remaining budget is allocated on an equal per capita basis is shifted back to 1995.

  The calculation follows similar steps as the R3- C-budget approach above, but with some changes to steps 1 and 2, as follows:

1. **Establishing the total budget from 1995 to 2030:**

$$B = \left((e_{EU}^{2019} - e_{EU}^{2030}) * \frac{t}{2}\right) + t * e_{EU}^{2030} + e_{EU}^{1995-2019}$$

where *B* is the total budget, e_{EU}^{y} the effort sharing emissions of the EU in either year (*y*) 2019 or 2030 (the target emissions in this case), with $e_{EU}^{1995-2019}$ the total EU emissions from the year 1995 to 2019 and *t* equal to $\left((t_{end} - t_{start}) + 1\right)$, the

number of years between the start and end points in the budget calculation, in this case, 12.

2. **Calculate raw country budgets**:

$$e_j^{2030} = \left(B * \left(\frac{p_j^{2019}}{p_{EU}^{2019}} \right) - e_j^{1995-2019} \right) * \frac{2}{t} - e_j^{2019}$$

Of note here – differing from the R3- C-budget calculation steps – is the removal of individual country emissions in the historical period from the calculation ($e_j^{1995-2019}$). Again, p_j^{2019} and p_{EU}^{2019} represent 2019 populations in individual countries and the entire EU, respectively.

Beyond this step, the calculations follow the same process as in derivation of R3-C-budget.

- **R2- Inherited benefits of emissions (Benefits):** incorporates the benefits a country has obtained due to emissions prior to the year 1995, interpreted here as being the embodied emissions in national capital stock. Using capital stock estimates, GHG budgets from 2019 to 2030 are scaled identically to the past emissions consideration above, but here based on pre-1995 emissions embodied in each country´s capital stock in 1995.

Calculation steps:

1. **Establishing the total budget to 2030:**

$$B = \left((e_{EU}^{2019} - e_{EU}^{2030}) * \frac{t}{2} \right) + t * e_{EU}^{2030} + kB_{EU}$$

where *B* is the total budget, e_{EU}^{y} the effort sharing emissions of the EU in year *y* = 2019 or 2030 (the target emissions in this case) and *t* the number of years between the start and end points in the budget calculation $\left((t_{end} - t_{start}) + 1 \right)$, in this case, 12. The variable kB_{EU} represents the total emissions embodied in capital

stock (a proxy for inherited benefits) calculated for the EU, based on Williges et al.[45].

2. **Calculate raw country budgets**:

$$e_j^{2030} = \left(B * \left(\frac{p_j^{2019}}{p_{EU}^{2019}} \right) - kB_j \right) * \frac{2}{t} - e_j^{2019}$$

Similarly to Step 2 in the calculation of R1, individual country estimates of inherited benefits through capital stock in terms of according embodied emissions (kB_j) are removed from total budget allocations.

Further calculation steps proceed in the same manner as the interpretations R1 and R3 above.

- **Renewables implementation (RES):** reflects the difference of the Member States in terms of their change in renewable share from 2005 to 2019 compared to the EU-27 total, calculated as a population-weighted average.

Calculation:

$$d_j = b_j^{2019} * \frac{RES_j^{2019} - RES_j^{2005}}{\frac{\sum_{j=1}^{J} \left(RES_j^{2019} - RES_j^{2005} \right) * p_j)}{\sum_{j=1}^{J} p_j}}$$

$$s_j = \frac{d_j}{\sum_{j=1}^{J} d_j}$$

where s_j is the share of emissions received by country *j* where *j* = 1,...,27 EU countries, RES_j^y is the share of renewables in country *j* in year *y*, either 2019 or 2005, and p_j is population in country j.

- **R5- Historical cumulative emissions per capita (Cumulative emi/cap):**

$$s_j = b_j \Big/ \frac{\left(\frac{e_j^{1995-2019}}{p_j^{1995-2019}}\right)}{\left(\frac{e_{EU}^{1995-2019}}{p_{EU}^{1995-2019}}\right)}$$

As in other interpretations, s_j represents the share of emissions of country *j* in 2030, b_j refers to the baseline emissions share, p_j^y the country population, summed for years (*y)* between 1995 and 2019, and e_j^y country emissions, again summed for years between 1995 and 2019, for either individual countries (subscript *j*) or the EU (subscript *EU*).

Combining interpretations into responsibility, capability, and equality framing

Using the interpretations listed in the previous sections, scenarios are defined as in Table 3, which frames equity concepts along the lines of capability, responsibility and need (or in this case, equality) as discussed in IPCC framing.

Table 3. Definition of main and alternative interpretation scenarios, and their contents.

Scenario	Capability	Responsibility	Equality
Main	EU-capability	Hist-emi	Basic-needs
C2	GDP/capita	Hist-emi	Basic-needs
E2	EU-capability	Hist-emi	ES-EPC
E3	EU-capability	Hist-emi	Full-EPC
R2	EU-capability	Benefits	Basic-needs
R3	EU-capability	C-budget	Basic-needs
R4	EU-capability	RES-expansion	Basic-needs
R5	EU-capability	Cumulative emi/cap	Basic-needs

For each scenario, we calculate a weighted combination of three interpretations (one from each equity cornerstone), with the sum of the weights of the three interpretations equal to 1. These scenarios are used to generate the ternary charts found in Figure 3 and in the Supplementary Material.

Calculation of minimal change agreement points

In addition to country emission budgets when applying different equity interpretations and weights, we calculate the combination of equality, responsibility, and capability weightings

which minimize (a) the sum of squared changes in country budgets from their maximum possible allowance to the commonly-weighted level, or (b) the sum of squared changes from the original 2018 ESD agreement to the common weighting. This minimization is calculated for all potential combinations of equity interpretations (2 capability x 3 equality x 5 responsibility = 30 combinations).

As shown below, the goal is to minimize the total (over all countries) squared percentage difference between an individual country maximum preference and the interpretation which results due to a common weighting of the three cornerstones.

$$\text{minimize} \sum_{j=1}^{J} \left(\frac{a_j^{max} - a_j(h,c,q)}{a_j^{max}} \right)^2$$

$$\text{subject to} \quad h + c + q = 1$$

where a_j^{max} are the maximum per capita country emissions allowances given across all possible interpretations under consideration for $j = 1,...,J$ for all J EU countries (or the allowances according to the EU effort sharing decision of 2018, respectively), and $a_j(h,c,p)$ indicates that country emissions are a function of the weights for h (historical) responsibility, c capability, and q equality weightings. Note that the three interpretation weights must add to one, i.e. the allocation is fully qualified.

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Author contributions

The authors confirm contribution to the study as follows: study conception and design: K.W.S, K.W., L.H.M., and K.R.; data collection and model generation: K.W. and F.M., analysis and interpretation of results: K.W., K.W.S., L.H.M., K.R., draft manuscript preparation: K.W.S, K.W., L.H.M. All authors reviewed and approved the final version of the manuscript.

Competing interests statement

The authors declare no competing financial interests.

Supplementary Information

The Supplementary Information supplies the ternary charts for each of the EU Member States.

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Figure legends

Figure 1. Conceptual overview of allocation approach. Each distribution consists of three components, addressing each of the three IPCC equity considerations of (i) responsibility, (ii) capability, and (iii) equality. These equity considerations are interpreted via a set of interpretations, listed under each corner. The interpretations used in the main scenario are indicated as R1, E1, and C1; alternative interpretations are listed with subsequent numbers, e.g. R2, where the inherited benefits from pre-1995 emission-generating activities replaces historical emissions in the scenario calculations. As an example, Point A would indicate an allocation scenario where only responsibility is given weight. Point B represents an allocation where equal weight is given to all three equity considerations.

Figure 2. Possible country emission reduction targets by 2030 (relative to 2005) reflecting an EU27 overall 55% reduction target (relative to 1990) for an application of each single principle (and under different interpretations of them). The dashed red line indicates the target reduction put forward in the 'Fit for 55%' proposal. The x-axis is divided into 3 categories, the first (C) contains the results of capability interpretations, (E) equality interpretations, and (R) responsibility. Panel A consists of countries with allocation shares predominately above (i.e. less restrictive) than the current proposal. Panel B consists of countries with some scenarios leading to more stringent reductions, and others less, than compared to the current EU proposal, and panel C countries with the majority of scenarios leading to more strict reductions.

Figure 3. Equity triangles illustrating the required emission reductions for Germany arising from combinations of equity interpretations, based on a fully qualified distribution approach (e.g. the weights of the capability, responsibility, and need qualifications sum to 1). The isolines indicate emission reduction targets (by 2030, relative to 2005) and are labeled

accordingly. For each point on an individual ternary chart, the color indicates the level of emissions reductions required, with yellow corresponding to lower levels, and blue higher. The level at each point is the result of a weighted combination of the three equity interpretations indicated on the chart axes. As an example, a point in the middle of panel A is the reduction amount given an equal combination of C1-EU-capability, E1-Basic-needs, and R1-Hist-emi. The red lines or points indicate the current EU suggested reduction level in the Fit for 55 proposal (if the value falls within the range of the chart). The green points indicate potential negotiation agreement points; the combination of three interpretations which minimize EU country aggregate divergence from the equity consideration that would require the minimal effort.

Figure 4. Negotiation points derived from optimal weighting of equity interpretations and their resulting reductions by 2030 by country. The box and whisker plots in the main panel show the resulting range of emissions reductions by 2030 by country, corresponding to the negotiation convergence points shown in the inset equity triangle. The black line indicates the current 'fit for 55%' reduction target for each country. Points in the inset ternary chart denote negotiation points when using an allocation approach comprised of weighted combinations of three equity considerations. Orange points and boxes are for minimizations of EU aggregate effort compared to country minimal mitigation efforts, and blue for minimal deviation from the 2018 ESD. Point size indicates frequency, i.e. multiple points at one location.

Tables

Table 1. Alternative interpretations of the three equity principles (responsibility, capability, and equality) as applied in this work, in line with [**8**] Table 6.5.

Interpretation	Relevance and operationalization
Responsibility	
R1- Historical emissions from 1995 (*Hist-emi)*	Reflects the use of fossil fuels since the year 1995, when countries were liable to know the impacts of GHG emissions on climate and had the ability to abate. The point of time at which the remaining budget is allocated on an equal per capita basis is simply shifted back to 1995. The EU GHG budget for 2020-2030 is first extended by EU past emissions 1995-2019. Second, per capita budgets are allocated based on this aggregate number to each Member State (based on current (2019) population), before the budget already used up by each specific country in 1995-2019 are subtracted to give the remaining budget for 2020-2030 for each country.
R2- Inherited benefits of emissions (*Benefits)*	Incorporates the benefits a country has obtained due to emissions prior to the year 1995, interpreted here as being the embodied emissions in national capital stock. Using capital stock estimates, GHG budgets from 2020 to 2030 are scaled similarly to the past emissions consideration above, but here based on pre-1995 emissions embodied in each country's capital stock in 1995.
R3- C-budget	The total emissions budget for the ES sector, (calculated by a fictitious linear path from 2020 to 2030) is split among Member States according to population. The resulting emissions budgets produce target paths up to 2030 with a corresponding target distribution for the effort-sharing sector.
R4 - Expansion of renewables share (*RES-expansion)*	Reflects the difference of the Member States in terms of their change in renewable share from 2005 to 2019 compared to the EU-27 total. Countries with a higher change over that time period compared to the EU average are allocated as a reward a larger emission budget, i.e., a more relaxed emission reduction target. Similar to GDP per capita, countries receive more (less) emissions at an equal rate as their increase (decrease) in RES share compared to EU.
R5- Cumulative emissions per capita (*Budget/cap)*	Proposes an alternative method to address historic emissions as compared to *R1-Hist-emi*, by scaling future emission allowances based on differences in historical cumulative emissions per capita. Countries with a higher than EU-average cumulative historic emissions per capita from 1995 to 2019 are allotted higher reduction targets in 2030, and vice versa.
Capability	
C1- EU implementation based on GDP/capita (*EU-capability*)	This interpretation of GDP per capita corresponds to the current EU policy proposal that puts a cap on the relevance of countries' per capita GDP differences for the required emission reductions and is derived empirically from the current proposal. More specifically, the distribution is estimated in a regression based on GDP per capita from 2015-2018 and the previous (2018) ESD distribution (which in turn builds on GDP/capita) as explanatory variables. For full details, see the derivation of the distribution in the methods section.
C2- GDP per capita (*GDP/cap)*	This interpretation weighs the relevance of all per capita GDP differences equally in specifying the countries' required emission reductions, increasing or reducing emissions allocations based on the percentage deviation from the EU average GDP per capita. Countries with a higher GDP per capita (in 2019) are allocated a smaller emission budget, i.e., a stricter emission

	reduction target. For a full application of this interpretation, the emission reduction target for each Member State varies depending on the difference in GDP/capita from the EU-27 average. For each percentage point above or below average, reductions are increased (reduced) by the same percentage.
Equality	
E1- Basic needs	Separates allocation of emissions budgets into two stages; in the first stage, Member States are allocated the necessary emissions to meet the basic needs energy demands of the fraction of the population at risk of multidimensional poverty. Each member state is allocated the emissions corresponding to energy use (at current emission intensities) to fulfill such basic needs. After this initial step, the remainder (if any) of the budget is distributed in an equal-per-capita manner.
E2- ES-sector EPC convergence (*ES-EPC)*	Reflects a convergence to equal per capita emissions by 2030, based on country emissions in effort-sharing sectors (i.e. emissions not covered under the Emission Trading System).
E3-Full-EPC convergence (*Full-EPC)*	Reflects convergence to equal per capita emissions by 2030, based on all sectors' emissions (sectors in and outside the Emission Trading System).

Table 2. Linear approximation of the EU's use of GDP per capita in allocating 2030 emissions reductions, including consideration of the previous 2018 Effort Sharing Decision (ESD) reduction targets.

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Adjusted R^2	0.984
Residual Std. Error	0.022 (df = 24)
F Statistic	798.251*** (df = 2; 24)
Note:	*p<0.1; **p<0.05; ***p<0.01

Table 3. Definition of main and alternative interpretation scenarios, and their contents.

Scenario	Capability	Responsibility	Equality
Main	EU-capability	Hist-emi	Basic-needs
C2	GDP/capita	Hist-emi	Basic-needs
E2	EU-capability	Hist-emi	ES-EPC
E3	EU-capability	Hist-emi	Full-EPC
R2	EU-capability	Benefits	Basic-needs
R3	EU-capability	C-budget	Basic-needs
R4	EU-capability	RES-expansion	Basic-needs
R5	EU-capability	Cumulative emi/cap	Basic-needs

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SISharingtheeffort.pdf