

Russia's cumulative carbon budgets for a global 2°C target

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ABSTRACT

Russia is the fifth highest emitter of carbon dioxide, having been in the top five for at least six decades. However, thus far no in-depth study has estimated Russia's cumulative emissions in the context of the global 2°C constraint. This is despite the IPCC reiterating the importance of cumulative emissions. Translating the global 2°C temperature commitment into a meaningful national context, this paper derives and evaluates 2°C-compatible carbon budgets for Russia, based on a range of apportionments. The work contributes to the debate by providing a deeper analysis of the principles of allocating carbon emissions to Russia. This analysis demonstrates how, if Russia is to make a fair contribution to global emission reductions in line with 2°C, its 2011–2100 cumulative emissions should stay within 20–26 Gt CO₂, commensurate with a 37–52% probability of exceeding 2°C. If Russia continues to emit carbon dioxide at current annual levels, this budget will be “spent” by the mid-2020s. The carbon budget estimated here for Russia appears technically feasible, if extremely challenging. Despite continuing to assert itself as a fossil fuel superpower, Russia has a wealth of opportunities for full and early decarbonization, including the potential to become a net exporter of renewable energy.

KEYWORDS

carbon budgets; cumulative emissions; major emitters; Russia; 2°C target

Introduction

The IPCC's Fifth Assessment Report (AR5) [1] estimates carbon budgets for 2°C of global warming – a temperature rise long associated with dangerous climate change, and adopted by the international community as a threshold not to be exceeded [2,3]. The report also estimates the quantity of cumulative carbon dioxide emissions (i.e., carbon budgets) corresponding to a small range of temperature rises, noting there is an approximately linear correlation between the two [4]. To translate the 2°C target into mitigation pathways, interim budgets must not, on aggregate, exceed the global 2°C carbon budget. At a country/region level, carbon budgets can provide a robust link between national mitigation pathways and global climate targets. In short, the 2°C carbon budgets within AR5 offer a scientifically credible basis for developing mitigation policies, and a necessary aspect of any evidence-based national target-setting.

However, in many nations it is annual end-point targets, outside the context of an overarching budget and pathway, that have come to dominate the policy arena despite having little direct correlation with the global temperature increase. Examples of such targets include the EU's commitment to cut greenhouse gas emissions 40% by 2030 and 80% by 2050 compared to 1990 [5–7], the US's proposed 26–28% reduction by 2025 compared to 2005 [8], and Russia's emission

reduction pledges of 25% by 2020 [9] and of 25–30% by 2030, both compared to 1990 [10].

The majority of countries with national climate targets, including Russia, have failed to link those targets to their global 2°C obligations in terms of cumulative CO₂. With Russia being the fifth largest emitter, currently responsible for about 5% of annual global fossil-fuel CO₂ [11], the country's failure to develop policy based on carbon budgets jeopardizes global efforts toward meeting international commitments on 2°C. As it is, Russia's national targets imply “business-as-usual” growth in emissions between now and 2020/2030 [12], as the emission level is presently about 30% lower than in 1990. In part, this is a consequence of Russia's carbon dioxide emissions dropping by nearly 43% between 1990 and 1998 due, primarily, to the economic downturn after the USSR breakup. Apart from a 5% dip during the 2008–2009 global financial crisis, the country's emissions have been increasing since the late 1990s. This makes for an atypical emission trajectory, compared to that of an average Annex 1 nation. Despite the large reductions in the 1990s, Russia's emission pathway is still at odds with what industrialized nations would need to deliver for 2°C carbon budgets.

Both past emission patterns and potential future emission trajectories of most major emitters (including the US, the EU and China) have been well researched; this has not been the case for Russia. Furthermore,

although the carbon budget concept is widely used in academic studies culminating in the IPCC's AR5, its application in the policy world remains largely limited to the UK [13] and potentially Norway [14]. Understanding what this global concept means for Russia, as one of the five largest emitting nations and with major influence on future emissions and climate change impacts, is therefore an important contribution. Of key relevance to the climate debate is that the country continues to assert itself as a fossil-fuel superpower on the global scene [15,16] (being the largest exporter of natural gas and the second largest exporter of oil [101]), and at the same time has a wealth of opportunities for full national decarbonization [17].

To understand Russia's role and responsibility in delivering on its international commitment to 2°C, this paper derives production-based (territorial) carbon budgets for the country. To this end, the paper first justifies the choice of the 2°C threshold [18] and associated probabilities; it then chooses global and Annex 1 nations' budgets for this temperature target; and, finally, it applies a range of equity principles to calculate and analyze Russia's carbon constraints, and discusses potential implications for both Russia's and global climate targets.

Climate change probabilities and cumulative emission budgets

Not only do cumulative emissions have a clear scientific link with global surface temperatures, but they are also central in operationalizing global targets at a national level. The 2°C threshold has emerged out of a political process, with nearly 200 nations signing up to it on numerous occasions since the UNFCCC Conferences of the Parties (COP) in Copenhagen in 2009 [2] and in Cancun in 2010 [3]. Similarly, Russia has repeatedly reaffirmed its commitment to 2°C in subsequent international agreements, including the Group of Eight Camp David Declaration in 2012 [19]. In the absence of ambitious domestic mitigation policies [20] and for the purpose of this paper, the Russian government's commitment to this quantitative framing of climate change is taken at face value and in good faith.

While not legally binding, the language of these international agreements can be reasonably interpreted as a resolve to ensure a very low probability of exceeding the 2°C threshold. For instance, if the IPCC likelihood terminology [21] is applied to translate the qualitative commitment into a quantitative probability, where "very unlikely" means < 10% probability and "exceptionally unlikely" means < 1% probability, it is appropriate to conclude that the language in the repeated intentions of Russia and other signatories implies at least a "very unlikely" chance of exceeding 2°C.

Some analyses [22] suggest that keeping the temperature rise below 2°C is virtually unachievable,

and increasingly so given the recent global emission trends. Compounding this, other assessments have effectively upgraded 2°C from a "dangerous" to "extremely dangerous" climate change threshold [23,24] – that is, more stringent mitigation is needed for the same climate change impacts. While Smith *et al.*'s [23] and Mann's [24] work was originally published in 2009, the majority of both policies and research since then have failed to take explicit account of this re-evaluation of impacts. If the "extremely dangerous" characterization is factored in, the remaining cumulative emission budget effectively reduces – that is, a lower probability of exceeding 2°C is required. This literature further supports the need to explore the relatively low probability of exceeding 2°C that is adopted here. As the probability of exceeding 2°C rises, so does the likelihood of temperature increases approaching 3°C or higher, with stronger climate change impacts disproportionately affecting poorer nations [25]. Hence, the climate change targets assigned a higher probability of exceeding a 2°C threshold are not commensurate with the equity principle embedded within Article 3.1 of the UNFCCC [26] and reiterated in subsequent COP documents.

The literature gives a range of global cumulative budgets consistent with a relatively low probability of exceeding 2°C, in line with the IPCC likelihood terminology. For example, Meinshausen *et al.* [27] suggest a 2000–2049 carbon budget of 886 Gt CO₂ with a probability range of 8–37%. A 1321 Gt CO₂ 21st-century budget is discussed by Macintosh [28] in the context of potentially stronger and earlier carbon cycle feedbacks. Macintosh takes into account non-CO₂ forcings, arguing that an assumption of negligible non-CO₂ forcings over the 21st century is "unrealistic" [28]. This paper uses Annex 1 budgets from Anderson and Bows [29] who draw on Macintosh's calculations to explore the share of Annex 1 countries in the global carbon dioxide budget. The chosen budget fits within the 510–1505 Gt CO₂ range for 2012–2100 provided in the IPCC AR5 for an unlikely chance exceeding 2°C [4]. Anderson and Bows [29] apply the CO₂-plus budgetary regime where global deforestation emissions and historical post-2000 emissions are considered "a global overhead." Since land use, land-use change and forestry (LULUCF) are assumed here to be a global overhead, Russia's forest sinks have not been explicitly taken into account when calculating the country's carbon budgets. In addition, there are multiple uncertainties associated with this area. Examples of such uncertainties in relation to Russia's boreal forests as sinks in particular include their maturity, which might hinder their absorptive capacity (although there is uncertainty about this too [30]) and poor management, which would again reduce their role in storing CO₂ [31,32]. Deforestation emissions are subtracted from a global

budget before it is allocated between Annex 1 and non-Annex 1 countries [29], with Russia being included in the former. Anderson and Bows's [29] "C+3" scenario gives a budget of 313 Gt CO₂ to Annex 1 countries with a 37% probability of exceeding 2°C (with 742 Gt CO₂ remaining for non-Annex 1 nations), while their "C+5" scenario Annex 1 budget is 363 Gt CO₂ with a 52% probability of exceeding 2°C (with 949 Gt CO₂ for non-Annex 1).

While there are arguments against a continued use of the Annex 1 versus non-Annex 1 split [33], it currently remains a valid distinction in the international climate change negotiations and existing agreements. The Annex 1/non-Annex 1 distinction is likely to change after the Paris COP, although it remains difficult to predict what might emerge instead. If the country groups are indeed revisited, it is reasonable to expect that Russia will stay part of the wealthier group with a historical responsibility for emissions and, hence, with an ethical obligation to take up a more stringent carbon reduction target than poorer countries.

Emission budget apportionment based on equity principles

To calculate Russia's share of an Annex 1 budget range, this paper applies the concept of equity principles (Table 1), based on both elements of fairness and practicality. Climate change is expected to negatively affect livelihoods in poorer parts of the world, thereby aggravating existing income inequalities [25]. Informing climate mitigation action with equity considerations may help to avoid political conflict and facilitate social cohesion [1]. Reflecting this, all international agreements on climate change entail an equity dimension, starting with the UNFCCC [26]. However, and despite having a section entitled "Consideration of fairness and ambition based on national conditions," Russia's own Intended Nationally Determined Contribution does not refer to aspects of fairness such as the country's responsibility for historical emissions or the low gross domestic product (GDP)/capita and low emissions/capita in industrializing economies [10].

There have been more than a dozen apportionment regimes suggested over the last decade based on different interpretations of equity and more or less pragmatic approaches as to what is "feasible." Table 1 summarizes the equity principles considered in this paper, using allocation-based parameters from Rose *et al.* [34]. More recently, the IPCC AR5 report [1] provides a version of a categorization of the same equity principles, drawing on Höhne *et al.* [35]. While Höhne *et al.* [35] give slightly different names to the categories, the substance remains essentially the same as in earlier studies [34]. Whichever approach is taken, it should be remembered that the ongoing delay in mitigation effort to date [36,37] has left a small and rapidly diminishing 2°C budget to apportion among nations. Annex 1 countries are, for example, already in emission debt if historical emissions are taken to be a significant dimension of any apportionment regime [29].

The final column of Table 1 details specific budget allocation parameters used in this paper to translate the equity principles into cumulative budgets for each country. Only per-capita parameters are considered here, as opposed to allocating budgets proportionally to non-normalized indicators (for example, total gross national product or total CO₂ emissions), in order to avoid a size bias. In the "egalitarian" and "sovereignty" principles, a country's budget share is calculated in direct proportion to allocation parameters. For the ability-to-pay and polluter-mitigates principles, the allocated budget share is *inversely* proportional to a budget allocation parameter. The simplicity of the calculations ensures they are transparent and intuitive, which is an important consideration when dealing with such a political issue as budget allocation. For example, a carbon budget for the sovereignty principle with the year 2000 as a baseline is calculated as follows:

$$B_i = B_{A1} \times \frac{C_i}{P_i} \frac{1}{\sum_{j=1}^{36} \frac{C_j}{P_j}} \quad (1)$$

Table 1. Equity principles, their interpretation and specific cumulative emission budget allocation parameters (as applied in this paper and adopted from Rose *et al.* [34] and Ringius *et al.* [54]).

Equity principle	Alternative name in literature	General interpretation	Specific budget allocation parameter
Egalitarian	Equal-per-capita	Every individual has an equal right to pollute or to be protected from pollution	Population in a particular year Cumulative population over a number of years
Sovereignty	Grandfathering principle	All nations have an equal right to pollute or to be protected from pollution; current level of emissions constitutes a status quo right	Per capita annual CO ₂ Per capita cumulative CO ₂
Ability-to-pay	Principle of capacity	The greater the current ability to pay, the greater the mitigation effort	The inverse of per capita gross national income (GNI)
Polluter-mitigates	Principle of guilt	The economic burden is proportional to emissions (eventually including historical emissions)	The inverse of per capita annual CO ₂ The inverse of per capita cumulative CO ₂

Note: Except "polluter-mitigates," the names and general interpretation of the equity principles are borrowed from the literature.

where B_i is country i 's calculated carbon budget; B_{A1} is a total carbon budget of the Annex 1 group of countries in the year 2000; C_i is country i 's annual emissions in the year 2000; P_i is country i 's population in the year 2000; C_j is country j 's annual emissions in the year 2000; P_j is country j 's population in the year 2000, where j changes from 1 to 36 (given that there are 36 countries in Annex 1).

Below is a step-by-step explanation of how the formula works for the same example of the sovereignty principle with the year 2000 as a baseline:

- Step 1: For each country in Annex 1, divide its annual CO₂ emissions in 2000 by its year 2000 population;
- Step 2: Sum up all emissions per capita from the first step of the calculations. The resulting number is meaningless on its own, but is a necessary step for further calculations;
- Step 3: Calculate a country's share in the Annex 1 carbon budget, by dividing the output of step 1 by the output of step 2. For example, it is 2.8% for Russia, which is the share of the Annex 1 emission budget Russia is eligible for, using this calculation method. The sum of all shares adds up to 100% by definition;
- Step 4: Multiply the output of step 3 (2.8% for Russia) by the total Annex 1 budget range consistent with a reasonable probability of staying below 2°C.

On the basis of the seven allocation parameters in Table 1 (right-hand column), Russia's cumulative emissions are calculated from a year 2000 baseline (Table 2), with the baseline year justified below. Columns "Min" and "Max" in Table 2 correspond to the budgets with a 37 and 52% probability of exceeding 2°C, respectively. For instance, Russia's 21st-century budget range as a result of the egalitarian distribution is around 37.1–43.1 Gt CO₂, as shown in columns two and three. Russia's cumulative carbon dioxide emissions over 2000–2010, including international bunker emissions, total an estimated 16.8 Gt CO₂, which, when deducted from Russia's 21st-century carbon budget, leaves 20.2–26.1 Gt CO₂ to emit for the rest of the century.

Table 2 demonstrates how applying the egalitarian principle leaves some room for Russia to continue emitting in the current decade. Similarly, the remaining emission budget range for 2011–2100 is in surplus for the ability-to-pay principle. The other two carbon budget allocations yield a negative budget, implying that Russia has already spent its 21st-century budget allocation and is now in a cumulative emission "debt." The variations between budgets arise from differences in the underlying allocation parameters (as explained in the next section). It is clear that, despite the post-USSR economic collapse, Russia's carbon budget is now so constrained that some equity principles leave no emission space.

Variation in the equity principle-based emission budgets

While the calculations in Table 2 are for the baseline year 2000, it is by no means straightforward to substantiate the reasoning behind the choice of a baseline. One approach is to select a year deemed "representative" of a country's typical socio-economic situation. In Russia's case, such "typical" conditions are challenging to identify as its economy, politics and social structure underwent dramatic changes in the last two decades of the 20th century. The years 1999–2006 were a period of relative stability in Russia with a reference to high global oil prices, the weak rouble and some political steadiness [38]. *Ceteris paribus*, this makes 2000 a reasonable baseline year, considering that it is also the starting point of the 21st-century carbon budget often referred to in the literature. The calculation method used in this paper does not explicitly "credit" Russia for the fall in its emissions that occurred in the 1990s. Nevertheless, choosing the year 2000 as a baseline does indirectly reward Russia for the 1990s drop in the ability-to-pay and polluter-mitigates allocations, as both emissions and gross national income (GNI)/cap in 2000 would have otherwise been higher.

Although arguments exist for the 2000 baseline, Table 3 scrutinizes this further by providing a sensitivity analysis to compare the year-2000 emission allocations to 1990 and 2010 baseline years, chosen in part

Table 2. Cumulative carbon emission budget ranges for Russia based on four equity principles with 2000 as a baseline year (own calculations based on Annex 1 budgets from Anderson and Bows [29], and data from the World Bank Databank [55] and the UNFCCC Online GHG Emissions Database [56]).

Equity principle	21st century (2000–2100) emission budget range (Gt CO ₂)		Remaining emission budget range for 2011–2100 (Gt CO ₂)	
	Min	Max	Min	Max
Egalitarian	37.1	43.1	20.2	26.1
Sovereignty: annual CO ₂ per capita	8.6	10.0	–8.3	–7.0
Ability-to-pay: the inverse of GNI per capita	23.6	27.3	6.6	10.4
Polluter-mitigates: the inverse of annual CO ₂ per capita	5.4	6.3	–11.5	–10.7

GNI: Gross national income.

Note: Negative values are in italics.

Table 3. Shares of Annex 1's 21st-century carbon budget allocated to Russia with 1990, 2000 and 2010 as baseline years (own calculations based on Annex 1 budgets from Anderson and Bows [29], and data from the World Bank Databank [55] and the UNFCCC Online GHG Emissions Database [56]).

Equity principle and allocation parameter	1990 baseline (%)	2000 baseline (%)	2010 baseline (%)
Egalitarian	12.6	11.9	11.1
Sovereignty: annual CO ₂ per capita	4.0	2.8	3.2
Ability-to-pay: the inverse of GNI per capita	5.4	7.5	6.8
Polluter-mitigates: the inverse of annual CO ₂ per capita	1.2	1.7	1.5

GNI: Gross national income.

Table 4. Russia's shares of Annex 1 21st century carbon budget with 1990–2000 and 1990–2010 as baseline periods for cumulative emissions allocation parameters (own calculations based on Annex 1 budgets from Anderson and Bows [29], and data from the World Bank Databank [55] and the UNFCCC Online GHG Emissions Database [56]).

Equity principle and allocation parameter	1990–2000 baseline (%)	1990–2010 baseline (%)
Sovereignty: cumulative CO ₂ per capita	3.1	3.0
Polluter-mitigates: the inverse of cumulative CO ₂ per capita	1.6	1.6

as they are the earliest and the latest years for which data are available for all allocation parameters. Russia's share of the Annex 1 budgets is summarized in Table 3, showing a proportion of Annex 1's 21st-century carbon budget taken by Russia, with 1990, 2000 and 2010 as baseline years for the four allocations. "Annex 1" is still assumed as a nominal grouping for the 1990 baseline calculations, despite its more recent inception. The calculations underlying Table 3 show that, for the 2000 baseline, Russia's remaining 21st-century cumulative emission allowance is positive if the country's share of Annex 1's 313–363 Gt CO₂ budget range exceeds ca. 5% (which is about 1.5% of the global carbon budget). In other words, between 2000 and 2011, Russia spent 5% of the Annex 1 budget range and would need a larger allocation to be able to continue emitting.

Given that carbon dioxide is a long-lived greenhouse gas, cumulative emissions may potentially serve as a basis for an additional emission apportionment regime. Similar to other budget-allocation parameters, the choice of a baseline needs to be justified. In particular, the period over which the accumulated emissions are taken into account may include the last few decades, the twentieth century, or even since the industrial revolution, with the latter option in particular allowing more space for industrializing countries to emit. The

further into the past, the higher data measurement uncertainty would be manifest. Moreover, country borders changing over time creates additional difficulties for the territorial apportionment of emissions. Russia as an independent state with its current borders only established itself in 1990, hence the 1990 starting point for the historical cumulative emissions in Table 4. The 1990–2000 baseline covers Russia's past emissions up to the beginning of the 21st-century carbon budget, whereas the third column extends the baseline period to include the first decade of this century.

It is evident that the size of Russia's carbon budget is highly dependent on the choice of equity principle and a baseline. The variation in budget share helps to identify relatively stable and "representative" allocation parameters. With climate change being a long-term process unfolding over decades, low volatility of a parameter is essential to ensure the apportioned budget stays relevant in the future. The deviations of the 2000- and 2010-based budget shares from the 1990-based shares are summarized in Table 5. The egalitarian principle is significantly more stable than either the GNI/capita or CO₂/capita parameters, which is intuitively clear from corresponding historical data. Overall, the 2010-based allocation results are slightly closer to 1990 than the 2000 results are, except for the

Table 5. The variation in the size of Russia's carbon budget for the four equity principles calculated with 1990, 2000 and 2010 as baseline years (own calculations based on Annex 1 budgets from Anderson and Bows [29], and data from the World Bank Databank [55] and the UNFCCC Online GHG Emissions Database [56]).

Equity principle	Variation in the budget size relative to the 1990-based budget shares (%)	
	2000	2010
Egalitarian	–5.7	–11.9
Sovereignty: annual CO ₂ per capita	–30.8	–20.9
Ability-to-pay: the inverse of GNI per capita	40.9	27.5
Polluter-mitigates: the inverse of annual CO ₂ per capita	47.4	29.8

GNI: Gross national income.

egalitarian principle. As for the 1990–2000 and 1990–2010 cumulative baselines, the variation among them is relatively low: between –6.6% and 3.3% (not included in the table).

There is only one other source identified that explicitly estimates cumulative emission budgets for Russia commensurate with a relatively low probability of exceeding a 2°C temperature increase. Mattoo and Subramanian [39] derive 2010–2050 budgets for Russia among other high-emitting countries, where they apportion a budget of 704 Gt CO₂, with a 67% chance of staying below 2°C, among 50 countries that were responsible for around 94% of global carbon dioxide emitted in 2008. Their results are comparable to the cumulative emission calculations here, for most equity principles. The lower bound of the 2011–2050 egalitarian budget range in this paper is similar to the “equal-per-capita” budget from Mattoo and Subramanian [39]. Their ability-to-pay allocation is also close to the calculation results in this paper for the same equity principle, regardless of the baseline year. Similar to the “polluter-mitigates” budgets developed here and which leave Russia in cumulative emission debt for any baseline year, Mattoo and Subramanian’s [39] “historic responsibility” scenario provides the lowest of their budgets (1.5 Gt CO₂). By contrast, their results under the “80–20 cuts” and “preserving future development opportunities” scenarios (40.1 and 65.8 Gt CO₂, respectively), for which there are no analogous calculations here, are higher than any budgets within this paper. Mattoo and Subramanian [39] also quantify implications for Russia of burden-sharing proposals from other studies, although the resulting cumulative emissions fail to comply with their global budget of 704 Gt CO₂.

The egalitarian equity principle: justification and caveats

For a number of reasons, the egalitarian equity principle is considered preferable for the purposes of this paper. From a methodological viewpoint, a low sensitivity to assumptions is an important consideration for policy-relevant research. Although population is not the only parameter that has remained relatively stable despite changes in Russia’s economy and energy system since 1990, it has additional advantages over other allocation parameters. From the political perspective, a survey of COP15 participants [40] indicates that a per-capita allocation of emission mitigation efforts is one of the top principles to which the respondents show wide support. From an ethical perspective, the egalitarian principle emphasizes each citizen’s right to and responsibility for emitting greenhouse gases. After a budget is allocated, a diminishing population will see a growing national per-capita budget.

Along with population, historical emissions are more stable than a GNI-based indicator in terms of the

baseline variation. A further advantage is associated with the importance of cumulative historical CO₂ for climatic change. However, “polluter-mitigates” budget allocations (as Table 2 shows) leave Russia in emission debt already by 2010, which renders this indicator impractical.

Another parameter often assumed to be reflective of welfare and equity is GNI. Although a carbon budget proportional to a per-capita GNI may partly capture the level of development, this indicator is generally a poor measure of well-being [41] and, hence, the fairness of the ability-to-pay budget allocation is questionable. In addition, to sustain the credibility of a long-term national target, a less volatile indicator needs to underlie emission apportionment. Compounding the GNI volatility is a necessity to compare cross-country and time-series data, where uncertainty originates from reducing nation-specific currencies and inflation rates to a common denominator.

Building on the argument so far, the egalitarian – that is, per-capita – allocation is deemed more appropriate for a carbon budget apportionment than other equity principles, for the purposes of this paper. Equity-related and practical limitations of the egalitarian allocation method are explored by Raymond [42]. The three potential drawbacks he identifies are as follows: it risks incentivizing population growth (before a cumulative budget is allocated); it ignores other regional differences such as living in warm versus cold climates or in urban versus rural areas; and it neglects potentially high costs of transitioning from high to low per-capita emissions. Raymond [42] suggests that a combination of the egalitarian and other allocation methods is more likely to achieve a multilateral agreement than when using a single allocation method. Similarly, Neumayer [43] argues that a per-capita allocation should be augmented to include historical emissions, which is implemented by Bode [44] in the form of a specific allocation function combining “contraction and convergence” with the historical responsibility criterion. In a more recent study, Vazhayil *et al.* [45] consider resources-to-mitigate in addition to per-capita and historical emissions, thereby integrating the ability-to-pay, polluter-mitigates and egalitarian principles. Although Neumayer [43] puts forward several valid reasons for such complex apportionment rules, and attempts to refute the main arguments against them, the study ventures into a philosophical and moral discussion that is outside the scope of this paper. For that reason and for the sake of practicality, historical emission “debt” is not included in the emission allocations considered here.

Discussion and conclusions

As one of the major emitters, Russia is among the nations with the greatest influence over future climate

change. For the country to play its “fair” part in maintaining the global temperature rise below 2°C, “consistent with science and on the basis of equity” [2], it is essential to derive nationally appropriate carbon budgets commensurate with the country’s 2°C obligations. As it stands, such a budget-based concept would be in stark contrast with Russia’s current emission target that in practice implies emission growth, at least out to 2020. If national CO₂ emissions were to stay at the targeted 2020 level (i.e., 25% below 1990) for just 2 years, the resulting cumulative emissions between 2011 and 2022 (21.2 Gt CO₂) would exceed the lower end of Russia’s 21st-century carbon budget range (under the egalitarian allocation). The upper end of this century’s budget would be exceeded in 2025, with cumulative emissions totalling 26.7 Gt CO₂. Other things being equal, the 25% target offers a reference scenario. It is in line with the lack of ambition globally, as nations’ current pledges collectively fail to deliver a future 2°C trajectory [46].

The choice of a particular budget allocation is intended to serve as an example of a national target that Russia *could* adopt, and as such provides a starting point for developing a pathway toward this target (via, for example, backcasting scenarios of a future low-carbon system). Nonetheless, whatever budget Russia chooses inevitably affects other countries (within a contained global total); the practicality of each country meeting its own budget ultimately depends on its specific national circumstances. Given a very constrained carbon budget remaining, this raises the question of whether a formal burden-sharing regime based on the equity parameters for 2°C is still viable in principle. Exploring different blends of practicality and equity is an increasingly important avenue for future research.

The budget approach demonstrates how little global emission space is now available for 2°C. The challenge of staying below 2°C is reflected in the probabilities chosen within this paper. The 37–52% chance corresponds to “as likely as not” in the IPCC likelihood terminology [21]. This is markedly different from interpreting Russia’s 2°C commitment as a “very unlikely” chance of exceeding this temperature threshold.

Set against the scale of the 2°C challenge, the carbon budgets derived for Russia within this paper can be interpreted as both generous and restrictive. On the one hand, the country’s share of the Annex 1 2011–2100 budget range is large in relative terms: around 10% for the egalitarian allocation principle. On the other hand, even such a generous allocation of the Annex 1 budget – and despite the dramatic decrease in Russia’s emissions in the 1990s – requires stringent emission reductions in absolute terms. The implementation of the carbon budget limit appears technically feasible, if extremely challenging, provided the low-carbon transition starts immediately.

A large-scale transformation of the Russian economy necessary for staying within this carbon budget would draw on the numerous decarbonization opportunities available. Such opportunities within Russia are both technological and socio-economic, and can be coupled with climate change adaptation and non-climate-related policies. On the technological side, Russia’s estimated technical potential for renewable energy exceeds the country’s energy needs by a factor of at least 30 [47], while its energy efficiency potential is comparable to that of the EU27 block as a whole [48,49]. The Soviet legacy of inefficient industry, transport and building stock requires urgent modernization that can be aligned with emission reduction measures. Reductions in energy inefficiency, fossil fuel subsidies and upstream methane emissions are three out of the four global “policy fixes” identified by the International Energy Agency [50] for maintaining the 2°C trajectory. All three are prominent issues within Russia and have worldwide repercussions for the climate. As to the climatic changes, the temperature of the Russian territory is expected to change twice as fast as the global average [51], which would thaw the permafrost soil adding to the emissions of methane and carbon dioxide. This would both affect the country’s infrastructure and accelerate global climate change. Given intensifying extreme weather events and other impacts, early emission reductions combined with adaptation to ongoing climatic changes would help to maintain socio-economic stability in the future. The consequences of transforming the economy in line with the carbon budget constraint would be far-reaching, but so would be the consequences of inaction.

With these issues in mind and regardless of whether the Annex 1 versus non-Annex 1 division continues to be part of the international negotiations, Russia remains a relatively prosperous and industrialized nation and should, considering equity implications, have less emission space to emit than poorer and still industrializing countries. Despite the post-USSR economic collapse, Russia is still a major emitter of greenhouse gases, a global supplier of fossil fuels and a scientifically advanced nation. As one of the “climate Great Powers” [52,53], it has the capacity to influence global emissions and lend credibility to the concept of carbon budgets through both domestic policies and international leadership. In this regard, there is a real opportunity for Russia to play a pivotal role in mobilizing action around the 2°C commitment while simultaneously restoring its position as a major industrialized nation.

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