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AN EXPLORATIVE EVALUATION OF THE CLIMATE DEBT

Adeline Gueret, Paul Malliet, Aurélien Saussay, Xavier Timbeau
Sciences Po, OFCE

This *Policy brief* is an excerpt from one of the three chapters constitutive of the 2019 iASES report (independent Annual Sustainable Economy Survey, formerly iAGS) that will be published in January 2019. G. Allegre, C. Blot, B. Ducoudré, J. Creel, M. Dauvin, A. Gueret, L. Kaaks, P. Malliet, H. Perivier R. Sampognaro, A. Saussay, X. Timbeau as well as IMK (Berlin), ECLM (Copenhagen) & AKW (Vienna) have also contributed to this report.

The international process for tackling climate change endured several backslashes since the signing of the Paris Agreement in 2015. Issues around the respective responsibilities are not fully solved yet. The underlying question of how to share efforts in order to reach a Zero Net Emissions state remains largely unclear and the INDCs process has still to deliver a pathway for decarbonization.

In the last years, the concept of global carbon budget has emerged as one of the most direct ways to materialize the constraint from the climate. It mainly relies on the idea that only a limited quantity of carbon dioxide can be released in the atmosphere if we want to stay below the 2°C temperature change threshold above pre-industrial levels and, if possible, below +1.5°C, as agreed at the Paris Conference in 2015. By comparing what is in our carbon budget to what is done to reduce the carbon footprint of societies, we calculate a distance to the climate constraint. Expressed in euro this distance, called the "climate debt", measure how much we avoid paying by delaying climate change mitigation. Using different rules for sharing the burden, acknowledging there is no negotiated nor consensual way to share it, we calculate this climate debt for main EU countries.

The first step of the following work is to compute a carbon budget for both the European Union and member countries mixing population based sharing (egalitarian) for EU and rest of world budget and emission based sharing (grandfathering) for EU countries. In a second step, we determine how many years are left before these budgets are depleted at the regional and national levels, which requires assumptions on the future emissions trend. Combining these trends with assumptions on the abatement cost of remaining carbon dioxide emissions after the depletion date allows us to evaluate the "climate debt". More precisely, the "climate debt" is the amount of money that will have to be invested or paid by countries for them not to exceed their carbon budget.

This work led us to three key policy insights. First, there are few years left for major European countries before exhausting their carbon budget under the +2°C target. As for the +1.5°C target, carbon budgets are exhausted for EU main countries, which are thus running excessive climate deficits. Secondly, the carbon debt should be considered as one of the major issues of the decades to come since in the baseline scenario it represents about 50% of the EU GDP to stay below +2°C (120% for staying below +1.5°C). Thirdly, the results of the estimation of this carbon debt are subject to numerous moral, ethical and technical assumptions that should motivate further and urgent investigations on this subject, critical to climate change mitigation, from both state bodies and independent research institutes.

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Climate change and global warming are often spoken of in the same breath as limited natural resources and the optimal way to manage the small amount that is still available. Despite all the pledges that have been made so far, both on the national and global stages, there is still a lot to be done before countries dedicate enough economic and political means to really tackle this issue.

The 24th Conference of Parties that has been launched on the 3rd of December in Katowice, Poland, is part and parcel of the traditional diplomatic apparatus aiming at promoting fruitful talks and agreements with effects. This is an additional occasion to realize that some countries are not especially welcoming structural changes in their energy mixes. To be more precise, it seems to be the place where countries always try and advocate for differentiated historical responsibilities in the global warming phenomena currently happening as well as differentiated capabilities to address these issues.

In such a framework, it seems more urgent than ever to delineate countries' relative responsibilities and absolute contributions to emissions reductions in order to remain in line with the 2015 Paris Agreement. To do so, we outline in the subsequent work a methodology aiming at computing climate debts at the national and regional scales.

1. Carbon budget, historical carbon adjustment and burden share

Standard definition

In the last decades, it has become widely acknowledged that global warming is almost linearly related to cumulative emissions of carbon dioxide (Allen *et al.*, 2009; Matthews *et al.*, 2009; Raupach *et al.*, 2011). This relationship between temperature increase and carbon emissions can be used in order to define the cumulative quantity of carbon dioxide than can be emitted until we reach a given global temperature change target. In particular, it is the basis for the development of carbon budgets. More precisely, a carbon budget is a statistical indicator aiming at measuring how many tonnes of carbon dioxide can be released in the atmosphere before we cross given temperature change thresholds.

According to the Intergovernmental Panel on Climate Change (IPCC) Special Report on the impacts of global warming of 1.5°C above pre-industrial levels (SR1.5), if we want to ensure a probability of 67% that global temperature change will remain below +2°C from preindustrial levels, we should not emit more than 1,320 billion tons of carbon dioxide ($GtCO_2$) from now until the end of times globally.

Of course, the computation of the carbon budget is always disputable as it relies on climate models which, in turn, depend on many assumptions and hypotheses that can be discussed. Nonetheless, computing global carbon budgets remains less controversial than sharing these budgets between regions and countries.[1]

Allen, M. R., Frame, D. J., Huntingford, C., Jones, C. D., Lowe, J. A., Meinshausen, M., and Meinshausen, N., 2009. "Warming caused by cumulative carbon emissions towards the trillionth tonne", *Nature* 458(7242), pp.1163-1166.

Matthews, H. D., Gillett, N. P., Stott, P. A., and Zickfeld, K., 2009. "The proportionality of global warming to cumulative carbon emissions." *Nature* 459(7248), pp. 829-832.

Raupach, M. R., Canadell, J. G., Ciais, P., Friedlingstein, P., Rayner, P. J., and Trudinger, C. M., 2011. "The relationship between peak warming and cumulative CO_2 emissions, and its use to quantify vulnerabilities in the carbon-climate-human system." Tellus, Series B: Chemical and Physical Meteorology 63(2), pp.145-164.

1. See Caney S., 2013. "Justice and the distribution of greenhouse gas emissions." *Global Social Justice*, pp. 58-81.

Different ways of burden sharing among EU countries

As far as national environmental public policies are concerned, the global carbon budget needs to be broken down into smaller parts in order to enlighten decision makers and weigh in on public policy design. National budgets must be estimated to delineate countries' responsibilities and drive their emissions reductions. So far, the literature has underlined a continuum of burden sharing methods, whose two endpoints are the *egalitarian* approach on the one hand and full *grandfathering* on the other (Gignac et Matthews, 2015; Giraud *et al.*, 2017; Raupach *et al.*, 2014).

The *egalitarian* sharing method consists in allocating each and every human being the same right to emit carbon dioxide. This approach is utterly blind to structural inequalities between countries[2] and puts at the forefront present equality between people as a sharing principle. To some extent, it is a way to erase past differences between countries and hence make people equally responsible from now on when it comes to fighting global warming and climate change.

The *grandfathering* sharing method relies on the idea that the global carbon budget should be divided along the criterion of current carbon emissions. It means that the weight of each country in global emissions remains stable over time. This conservativeness can be interpreted to capture structural national elements that are only slowly modified or cannot be changed at all, which is for instance the case of the access to renewables or the exposure to particularly rough climate conditions.

Such measures leave aside the issue of historical responsibility. In order not to evade this issue, some authors such as H. Damon Matthews have suggested computing an additional measure of historical carbon adjustment. This indicator aims at determining, for each year, whether countries have emitted more or less than their quotas and aggregates the deviations from the quotas over the time period chosen.

Gignac R., et Matthews, H. D., 2015. "Allocating a 2°C cumulative carbon budget to countries." *Environmental Research Letters* 10(7).

Giraud G., Lantremange H., Nicolas E., et Rech O., 2017, "National Carbon Reduction Commitments: Identifying the Most Consensual Burden Sharing." *Documents de travail du Centre d'Économie de la Sorbonne.*

Raupach, M. R., Davis, S. J., Peters, G. P., Andrew, R. M., Canadell, J. G., Ciais, P., Friedlingstein, P., Jotzo, F., Van Vuuren, D. P., et Le Quéré, C., 2014. "Sharing a quota on cumulative carbon emissions." *Nature Climate Change* 4(10), pp. 873-879.

2. At least, those that are not endogenous to population size.

EU carbon budget

We attempt at estimating the European Union's regional responsibility, in aggregate, in the decarbonization process. To do so, we first use the egalitarian approach—with 2015 as reference year—in order to compute the regional carbon budget at the European aggregate level. Then, we allocate to each member country its proper national budget using full *grandfathering*—based on emissions ratios of 2015 too. Nonetheless, in order to consider differentiated national historical responsibilities since 1990, we compute in a second moment a *historical carbon adjustment* per country over the 1990-2017 period,[3] following Matthews' method. Finally, we compute adjusted carbon budgets both at the regional and national scales. To the extent our baseline carbon budget computing method cashes in on both the *egalitarian* and the *grandfathering* methods, we thereafter call it the "hybrid" approach.

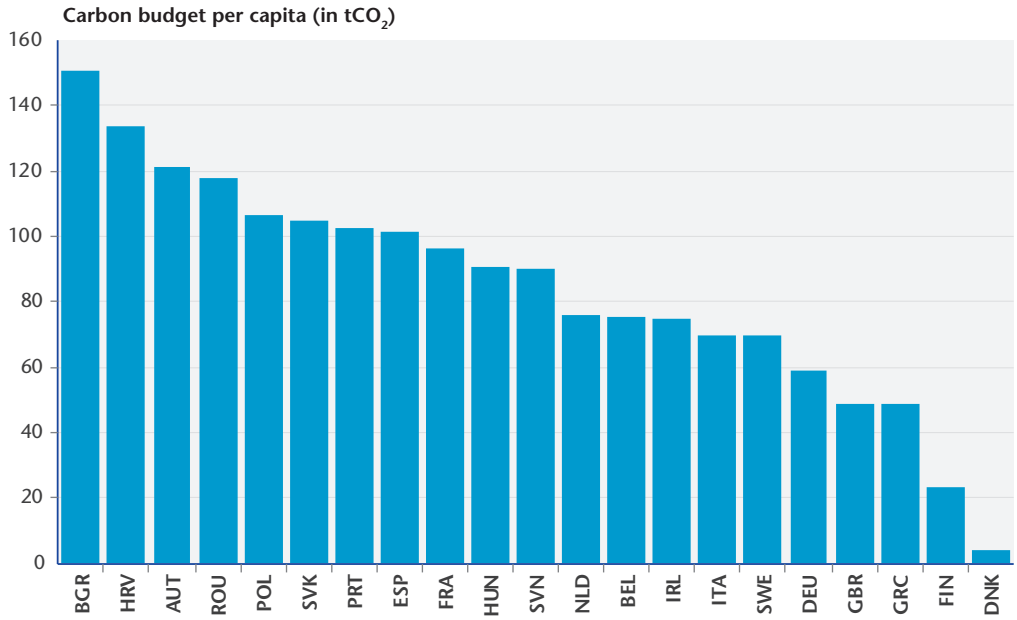
Using the hybrid sharing method with 2015 as a reference year credits the European Union with a carbon budget of 91 $GtCO_2$ if we consider the +2°C scenario. This amounts to approximately 30 more years if current emission levels remain unchanged. At the regional scale, the historical carbon adjustment since 1990 over the 28 member countries of the European Union amounts to 49.7 $GtCO_2$. This means that, updating previous results on the basis of historical carbon adjustments leads to a way smaller carbon budget for the European Union. More precisely, it falls down to 41 $GtCO_2$ under the +2°C constraint. Furthermore, carbon budgets are quite dispersed among member countries. Under the +2°C constraint, computing hybrid budgets makes France the country with the most important carbon budget with 6.2 $GtCO_2$ while

3. Since we only have emissions data until 2015, we assume that 2016 and 2017 CO_2 emissions levels are the same as 2015 emissions levels.

Germany settles at the second position with an adjusted carbon budget of 4.8 $GtCO_2$ (as opposed to 21 $GtCO_2$ before adjustment). Spain, Italy and Poland follow.

It is also instructive to cast a glance at per capita results, which largely redistribute emissions rights within the European Union. More precisely, Bulgaria, Croatia, Austria, Romania and Poland then appear to have the greatest carbon budgets per capita. France ends up at the 9th position while Germany and the United Kingdom respectively hold the 17th and 18th positions.

Figure 1. **Per capita adjusted carbon budget (in tCO_2)**



Sources: authors' computations, based on IPCC SR1.5, *UNFCCC emissions data*, Le Quéré *et al.* (2018) *Historical Carbon Budget* (version 1.3), *UN World Population Prospects* (2017 revision), *AMECO online* (11/2018) for 2017 GDP. Calculated for +2°C 2/3 probability, hybrid share and consumer approach.

2. From carbon budget to climate debt

Trend of emissions and exhaustion of carbon budget

The second step of this approach is to determine the emissions reduction pathways of the different EU countries. To do so, we use the ENERDATA *Enerfuture* Scenario, which profiles the trend of emissions until 2040.[4] The central scenario Ener-blue trajectory is built upon the current INDCs projection of emissions, leading to a +3°C increase in global temperature. This trajectory is following the same pace as the latest trend of emissions reduction observed in EU countries and can therefore be seen as a current policy scenario.

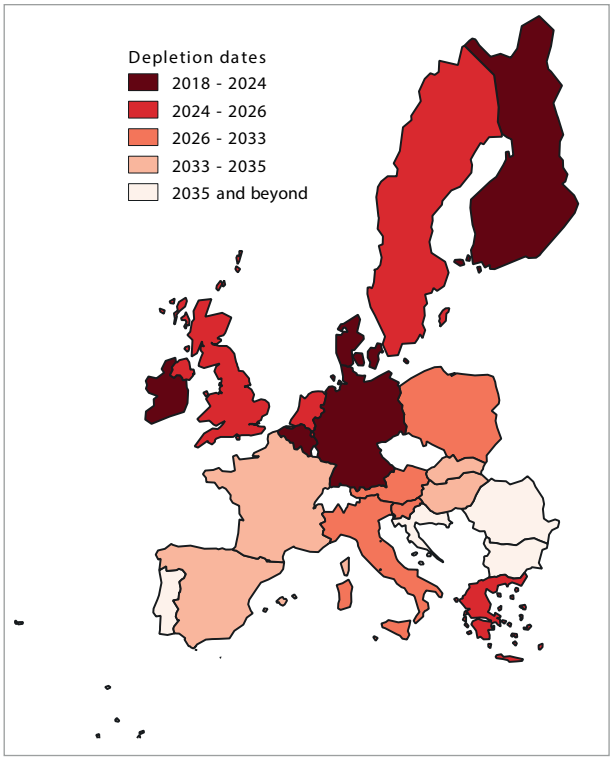
The baseline is defined for the +2°C target and what we deem to be a middle point in the burden sharing question, that is to say the previously details "hybrid" sharing method. Different views on the way to share the burden will lead to different allocations of the global carbon budget. Those are moral or political hypotheses and we are not to decide which ones are the right ones. Moreover, these results are depending on technical and forecasting assumptions that determine the pace in the emission reduction, and which are by definition speculative.[5]

4. The dynamic is extrapolated until reaching a zero net emissions level.

5. Sensitivity tests on the different dimensions that impact the carbon budget are presented in the main document of the IASES report.

The striking result exhibited in the Figure 2 is that the +2°C budget is nearly exhausted for almost all the EU countries, with on average only 10 years left. Such a short horizon means that a significant current share of the capital stock (productive capital, residential buildings, tertiary buildings, means of transportation, etc.) has to be considered as stranded under this carbon budget constraint. In other words, already built capital stock will eventually been decommissioned if not seriously retrofitted. This statement advocates for providing a monetary evaluation, which we attempt to do through the evaluation of a climate debt.

Figure 2. **Maps for the years before depletion**



Sources: authors' computations, based on IPCC SR1.5, *UNFCCC emissions data*, Le Quéré *et al.* (2018) *Historical Carbon Budget* (version 1.3), *UN World Population Prospects* (2017 revision), *AMECO online* (11/2018) for 2017 GDP. Calculated for +2°C 2/3 probability, hybrid share and consumer approach.

The climate debt valuation through abatement cost

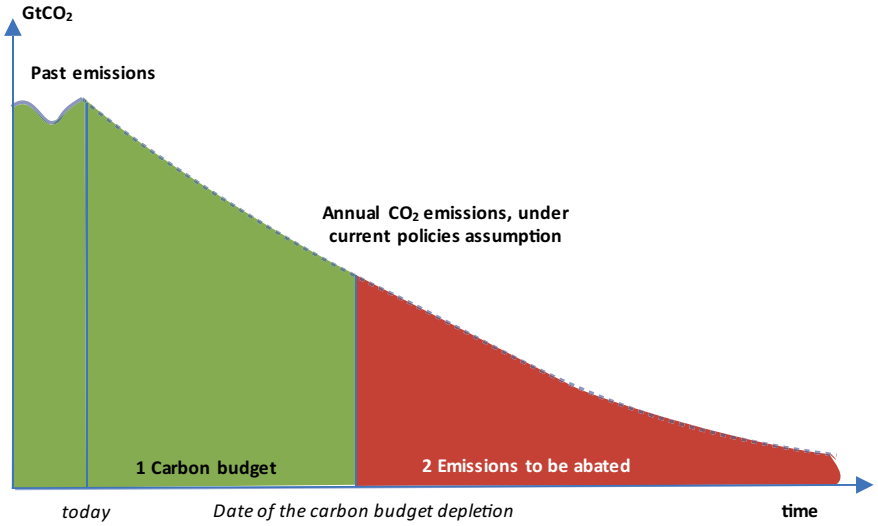
The climate debt for a given country is calculated by estimating the cost of a specific scenario. Once the carbon budget is exhausted, in order to fulfil its pledge, the country implements overnight and for the following years abatement techniques that shrink its remaining emissions down to zero.

We assume in our estimations that only a backstop technology can remove the remaining CO_2 in the atmosphere until the carbon budget depletion date. The set of assumptions around the existence of such a backstop technology is undoubtedly questionable (See the box), but from our viewpoint, it has the advantage of translating a physical metric (carbon budget in Gt) into a monetary one (Climate Debt expressed in $€_{2018}$). Another advantage is brought by the use of a discount factor, which weights less the long-term and reduce therefore the uncertainty around speculative projections.

Box. The backstop technology

The backstop technology does not replace a potential investment. It is only aiming at reducing emissions, in the sense that in does not provide any other benefit than removing CO_2. Such Carbon Dioxide Removal (CDR)[6] technologies are currently experimented in some places—Climeworks, Carbon Engineering being active companies in that field.[7] It is assumed to be more expensive than any other option and with a high enough potential capacity to achieve the targeted reduction, as the limit is physical only. The ability to scale up the deployment of such technologies is controversial, as well as the cost per tons of CO_2 removed from the atmosphere. The ability to store CO_2 underground definitively and the potential capacity to do so is also disputed. Current cost estimations are mostly industry side estimations with only prototype or experimental projects to back up over optimistic announcements.

Figure 3. **Discounting climate debt**



Source: authors calculations.

As depicted on the Figure 3, the areas under the emissions pathways serve as the basis for the valuation. As it is a flow with a complex time pattern, it is necessary to use a net present value to transform it into a stock. We use a standard discounted sum with a discount rate representing the social rate of time preference, and potentially, an effect of technical progress on this backstop and the uncertainty of future technological progress. The discount factor we use there has no implication on intergenerational equity, a point that was central to the Stern Review, and is therefore simpler to quantify.[8]

Observed emissions are projected with current policies scenario. Once the carbon budget is exhausted—area 1 in green on Figure 3—, at some date in the future, the remaining annual flow of emissions has to be fully abated–area 2 in red. Discount rate r is applied to the cost of abatement every year (the cost of abatement times the emissions to abate) and summed to get the net present value today of those future costs.

The Table displays important differences between countries. EU6 average is 53% for the baseline scenario, Germany climate debt is 66% and France one is 37%. Part of it comes from the historical adjustment. The rest is related to a more carbon intensive energy mix in some countries than in others. It is a strong divide between Germany and France. Recent transition of Germany towards renewable energy has not been enough to compensate for the exit from nuclear energy. Our point is not to promote

6. We do not consider here the use of Solar Radiation Management (SRM) technologies or, more generally, of geo-engineering since such technologies imply irreversibility and uncertainties far beyond what is acceptable.

7. See "Sucking CO_2 out of the atmosphere explained" on vox.org by Umair Ifran for a quick survey. Websites of Climeworks et Carbon Engineering provide commercial information. Some peer reviewed papers are published (Keith *et al.* (2018), "Joule 2", pp. 1573-1594).

8. Climate debt is thus calculated using the following expression:

$$ClimDebt = \frac{1}{(1+r)^T} \times \frac{CO_{2,\overline{T}}.p^{BS}}{r},$$

where r is the discount rate, T the number of years before the carbon budget is exhausted and $CO_{2,\overline{T}}$ the present value of emissions at the date $\overline{T}$, at which the budget is exhausted.

Table. **Climate debts, EU 6 largest countries**

	DEU	GBR	FRA	ITA	ESP	NLD	EU-6
Baseline *(see note for definition)*	66	53	37	51	41	62	53
(see note for definition) *(vs Consumer)*	29	20	11	18	17	49	22
No historical carbon adjustment *(vs HCA)*	4	8	17	12	22	20	12
EU population share *(vs EU emissions share)*	95	63	35	45	23	81	61
+1.5°C target *(vs +2°C)*	145	125	92	117	99	123	120

Note: EU6 is the aggregation of the 6 largest economies (2017 GDP).
Sources: authors' computations, based on IPCC SR1.5, *OECD emissions data*, Le Quéré *et al.* (2018) *Historical Carbon Budget* (version 1.3) and *UN World Population Prospects* (2017 revision), *AMECO online* (11/2018) for 2017 GDP.

one energy mix over another one. It is to acknowledge that our methodology amplifies existing state of the economies. [9]

Industrial structures—more industry in Germany, much less in France—play definitively a role, except in the baseline scenario where the consumer approach is taken. Without this approach, the relative climate debts of France and Germany are in the 1 to 3 range instead of less than 1 to 2. Again, methodological choices, based on moral or political considerations, can lead to a very different appreciation of the situation.

Alternatives assumptions, especially on how far responsibilities are imputed to EU countries may change a lot the evaluation of the climate debt. Accounting for no historical carbon adjustment relax the burden of EU countries by a large margin and allow for a lot of climate mitigation backloading. This does not point to a cynical direction to curb climate negotiation. This shows mainly that the responsibility issue is a major driver of the final estimate and neglecting this issue may encourage procrastination and fuel misunderstanding

How indicative is the concept of climate debt?

A monetary evaluation of this climate debt allows giving an alternative metric to the distance at which we currently are from reaching a temperature increase target—namely +2°C—in a unit that pin downs the potential trade-offs in an universally understandable way.

Although, Climate debt cannot be compared a public debt for several reasons. The climate debt remains uncertain by nature and respond to a set of hypotheses, which cannot be accepted by all the parties. On the opposite, public debt is the result of a contract between two parties with a well-defined (and universally agreed) flow of payments of interest and principal. Whereas Climate debt is a different notion, being the net present value of a flow of investment needed under an extreme scenario, where you choose to respect commitments but have done nothing so far to respect them.

For these reasons, climate debt has to be reckoned as a complement to other macroeconomic imbalances. A country may seem in a sustainable and prudent situation—a low public deficit, a public debt stable at a low ratio to GDP—but may be facing a wall due to climate change unpreparedness.

9. Climate debt is a quantitative indicator which cannot deal with every question in the choices to mitigate climate change. For instance, nuclear energy is a low carbon energy, hence improving climate debt when deployed, but implies a set of moral choices related basically to safety not involved in the debt quantification. Environmental policies should not be designed only based on emissions reduction targets. As safety concerns go over borders, at least a European Safety Agency for Nuclear Energy would be a necessary requirement to different paths for energy mix..

Conclusion

The quantification of years before depletion and debt are sensitive to various assumptions and hypotheses. Some of those assumptions are in the field of moral position and politics. They deal with burden sharing methods. It is not our task, in this report, to decide on those rules. Nevertheless, we have shown that the quantifications are very different for each scenario. That means that, implicitly, important transfers are done when you do not address those issues politically.

Some assumptions are technical issues, some others are related to the use of long-term forecasts. It means that the quantification is partly speculative in nature and that little can be done to reduce that unpleasant characteristic. This uncertainty has to be understood when discussing the burden sharing issue on the political point of view.

Climate debt and years before depletion concepts shed light on the urgency to mitigate climate change. As a rich and developed area, EU is now facing that cliff. We have exhausted our procrastination capital and the amount of debt is significant, in the range of 20% to 200% of GDP for the +2°C, our point estimate being close to 50% of GDP. For the more constraining +1.5°C target, it is much higher, the point estimate being close to 120% of GDP.

However, the quantification of the climate debt should not fuel excuses to despair in front of the responsibility ahead. Mitigating the climate is not undoable or too expensive. It is within our reach, making our failure to address it even more condemnable ■

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Directeur de la publication Xavier Ragot
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