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Calculating Climate Debt. A Proposal

Introduction: Aims, Outline, Delimitations

The notion of climate debt[1] has attracted widespread interest in the last years. First conceptualized in 1999 within the Millennium movement for (financial) debt cancellation, it was from the start a bottom-up approach, elaborated within the solidarity and environmental movements rather than by states or academia. The peak of its importance so far started in 2009, when demands to repay the climate debt were raised by hundreds of organizations mainly from the global South and also by states such as Bolivia and the group of the 49 Least Developed Countries. The following year, climate debt was included in the so-called *People's agreement* adopted by the well-attended People's World Conference on Climate Change and the Rights of Mother Earth in Cochabamba, Bolivia.

Climate debt is regarded as only one part of a wider *ecological debt,* a concept that was first introduced by *Instituto de Ecología Politica* before the Rio Earth Summit 20 years ago. Both concepts switch the commonly perceived positions of debtors and creditors in the world economy. While most other approaches to quantifying ecological and climate inequalities[2] have been developed by researchers and have quite rigorous methodologies, climate debt and ecological debt are more of "open access"

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[1] Including similar notions such as carbon debt, carbon indebtedness, emissions debt, etc.

[2] Such as ecological footprints, environmental space, material flow analysis, polluters pay principle, historical responsibility, greenhouse development rights, etc.

concepts and lack unified ways of defining, conceptualizing and calculating. A number of proposals for quantifying the notion has been suggested over the years, mainly by NGOs, but I will not detail them in this reasonably short paper[3]. In recent years, however, sophisticated methodologies for quantifying ecological debt, including carbon debt, have been developed by scholars. The arguably most elaborated one, by Erik Paredis and his colleagues (Paredis et al 2004, 2008, Goeminne & Paredis 2010), will be the most important reference in this paper. The starting-point of this paper is however the environmental and climate justice movement's definitions of climate debt.

One of the main goals of the research project Environmental Justice Organizations, Liabilities and Trade (Ejolt), of which this author is part, is to empower Environmental Justice Organizations (EJOs) by a transfer of scientific methodologies of use in their struggles. Ecological debt, including climate debt, is identified as one of the key concepts. According to Ejolt's description, "[t]here is a demand from international EJOs and also from government officials for the instruction of the methodology of such calculations in terms that activists and citizens can understand" (Ejolt 2010: 20).

This paper is an attempt to respond to this demand. The aim is to find a method for quantifying climate debt that is a) in line with the definition of climate debt that has emerged from the environmental and climate justice movements, b) scientifically accurate, c) applicable on existing data, and d) user friendly, i.e. relatively easy to grasp and use by activists and citizens. These aims are, admittedly, not phrased in a way that makes them fully operationalizable but will serve as "soft" guidelines for the following exploration. In order to meet the aims, I will first recall the discussion on climate debt within the environmental and climate justice movements, than explore whether the methodology proposed by Paredis et al meets the aims, and thereafter suggest some modifications. The modified method will be applied on the data of 154 states from 1850-2008, and finally the result will be presented and briefly analyzed.

The scope of the paper is thus fairly limited, and does not include, for instance, discussion on if and how the debt ought to be repaid, including the pros and cons of swapping the debt from tons of carbon dioxide into money. Actually this paper only explores one part of the climate debt: It is seen as two-fold, consisting of an emissions debt and an adaptation debt, and only the first part will be the matter here. Finally, there are methodological questions raised in the paper that remain unresolved. It is therefore to be regarded as a work in progress, and any constructive criticism is very welcome.

3 Thorough background and comparisons between approaches is provided in Warlenius 2010 and Paredis et al 2004, 2008.

Climate Justice Movement's Definition of Climate Debt

Ecological debt was launched in the run up to the 1992 Earth Summit in Rio de Janeiro by *Instituto de Ecologica Politica*, mainly as a way of highlighting North's resource exploitation of South from the days of colonization and onwards. From the start it was used as a way of framing the debate on South's external debt crisis, initiating a debate on which debt – the financial or the ecological – is larger. To really calculate ecological debt is however difficult since it consists of almost innumerable parts. But one of its most important parts – arguably *the* most important part, i.e. emissions of carbon dioxide ("the main effluent of affluence"[4]) – is easier to quantify. So when the notion of carbon debt was first introduced in the late 1990s, it was with the direct aim of quantifying it and comparing it with South's financial debt, as revealed already in the title of the pioneering work: *Who owes who?* (Simms et al 1999). The authors were all part of the British movement for debt cancellation, which have continued to campaign for the repaying of the climate debt (Jubilee Debt Campaign 2007, Simms 2009, Action Aid 2009, Christian Aid 2009). Also environmental organization such Friends of the Earth (FOEI 2005) and UN bodies (UNDP 2007, UN 2009) have used similar concepts and calculations in order to concretize climate inequalities, while some scholars have elaborated on it or on the wider notion of ecological debt (Azar & Holmberg 1995, Botzen et al 2008, Srinivasan et al 2008, Rice 2009).

Most important for the aims of this paper, however, is how climate debt is used and defined by the environmental and climate justice movement as well as by its closest ally among nation states, Bolivia. This tendency became public in the spring of 2009, when the declaration *Repay the climate debt. A just and effective outcome for Copenhagen* (TWN 2009a) started to circulate – it was later signed by 254 organizations, mainly from the global South (TWN 2010) – followed by the more technical paper *Climate Debt. A Primer* (TWN 2009b). In April 2009, Bolivia also submitted a paper to UNFCCC AWG-LCA evaluating "historical climate debt" (UNFCCC 2009).

These efforts were primarily directed at the UN climate conference in Copenhagen in December 2009, but the failure of COP 15[5] was not the end of the movement. In April 2010, a *People's World Conference on Climate Change and the Rights of Mother Earth* was arranged in Cochabamba, Bolivia, supported by over 200 organizations as well as the ALBA[6]-affiliated states Bolivia, Cuba, Ecuador,

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[4] "[T]he so called 'ecological debt' from North to South, which includes the 'carbon debt'–i.e., damages from rich countries caused by excessive per capita emissions of carbon dioxide (the main effluent of affluence)" (Martinez-Alier 2009: 59). See also: "The debt of climate change, however, proves to be the biggest, most life-threatening and urgent to address of all the ecological debts" (Simms 2009: 83).

[5] "The failure of Copenhagen was worse than our worst-case scenario" (Dimitrov 2010)

[6] *Allianza Bolivariana para los Pueblos de Nuestra América (*Bolivarian Alliance for the Peoples of Our America)

Nicaragua and Venezuela. In Cochabamba, a *People's agreement* was adopted (PWCCC 2010a) and a working group particularly on climate debt presented some conclusions (PWCCC 2010b). The resolutions from the Cochabamba conference formed the foundation of a new Bolivian proposal to the UNFCCC AWG-LCA (UNFCCC 2010).

In the mentioned documents climate debt is defined as two-fold, as the sum of an "emissions debt" and an "adaptation debt". The first consists of developed countries' "excessive historical and current per person emissions – denying developing countries their fair share of atmospheric space", while the latter is a result of their "disproportionate contribution to the effects of climate change – requiring developing countries to adapt to rising climate impacts and damage" (TWN 2009a).

While the emissions debt is repaid mainly by "freeing up environmental space" for the developing countries, the adaptation debt requires "those who have benefited in the course of causing climate change [to] compensate the victims of climate change" (TWN 2009b). The industrialized countries should repay their emissions debt through "the deepest possible domestic reductions and by committing to assigned amounts of emissions that reflect the full measure of their historical and continued excessive contributions to climate change", and their adaptation debt by "committing to full financing and compensation for the adverse effects of climate change on all affected countries, groups and people" as well as making available "the financing and technology required to cover the additional costs of mitigation and adapting to climate change, in accordance with the Climate Convention" (TWN 2009a). It follows that while the unit in which the emissions debt is measured is tons of CO_2 or GHGs, the adaptation debt is primarily compensated by transactions of technology and finance and thus measured in monetary terms. Further, while the size of the emissions debt is seen as a result of historical emissions above a fair per capita level, the adaptation debt equals the needs of the climate change "victims" for adaptation, mitigation and catching-up development. This paper will not deal further with the adaptation debt part of climate debt, but only with the emissions debt.

For a more elaborated discussion on methodology, one has to turn to Bolivia's contributions to the UNFCCC process. In its 2009 submission, it is stated that the repayment of the emissions debt

> should be quantified on the basis of a clear and objective methodology that reflects, among other factors:
>
> - The historic responsibility of developed countries for current atmospheric concentrations;
> - The historic and current per-capita emissions of developed countries; and

- The share of global emissions required by developing countries in order to meet their first overriding priorities which are the economic and social development and poverty eradication. (UNFCCC 2009: 47)

In the Appendix of the submission, another comment on the methodology of climate debt is made:

> Quantifying the extent of developed countries' emissions debt and their associated future mitigation commitments should take into consideration, among other factors, the historical and proposed emissions by Annex 1 countries as well as the needs of developing countries for sufficient environmental space to achieve their rights to development (Ibid.: 48)

Here, climate debt is quantified as Annex 1 emissions above its per-capita share of actual global emissions from 1900 to 2050, thus including both historical emissions and proposed assignments up until mid-century. Global emissions are supposed to be reduced by 80 percent until 2050 (compared with 1990). Even though the emissions of Annex 1 are supposed to be reduced by 85 percent, it will still have significantly over-used its fair, per-capita emission space for the whole period (see fig. 1).

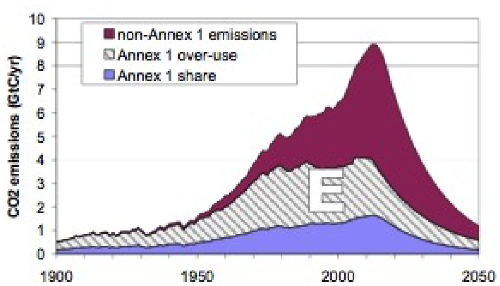

Figure 1: Annual emissions with 80% global reduction by 2050 showing Annex 1 over-use (E) defined as its historical and assigned emissions minus its per capita-share. *Source: UNFCCC 2009: 49*

This over-use equals the "carbon debt" of Annex 1 (Ibid.: 50). Although this is an interesting method and this author certainly sympathizes with its basic ontological perspective, I will proceed along a path that deviates from this method in two aspects.

First, it is understandable that movements and governments, as representatives of certain interests trying to influence important decision-making processes, focus not only on the historical debt but quickly turn to the repayment of the debt. From an academic perspective, however, it is doubtful to dub highly uncertain *future* emissions as part of a "debt", which is a term that usually refers exclusively to past events. Prognoses of debt development as well as how it could be repaid are central issues, but ought not to be analytically conflated with the debt itself. In this paper, the focus will only be on the historical accumulation of the emissions debt. When it is sorted out, I hope to be able to return to its repayment in another context.

Second, the method proposed by Bolivia in 2009 does not directly deal with what must arguably be an integrated part of any conceptualization of climate debt, especially since it is generally seen as part of an ecological debt[7]: a discussion on what constitutes a sustainable level of emissions. Its starting point is the carbon emissions as a historical fact and as a future prognosis, but it does not methodologically deal with whether these emissions have been or will be sustainable in the sense of not harming the eco-systems. The assumed 80 percent reduction of global emissions until 2050 could be seen as a sustainability criteria, but insufficiently so since no clear efforts are made to show that this reduction would heal the harm done historically. This methodological weakness gets even more more acute if debt and repayment are dealt with separately, as argued above. However, reflecting the *People's agreement* from Cochabamba as well as the conclusions of the working group on climate debt (PWCCC 2010a, 2010b), a more ecologically concerned definition of climate debt occurred in Bolivia's 2010 submission to UNFCCC. Here, not only developing countries are seen as climate creditors, but also "mother Earth":

> [B]y over-consuming the available capacity of the Earth's atmosphere and climate system to absorb greenhouse gases the developed countries have run up a climate debt to developing countries and mother Earth (UNFCCC 2010: 15)[8]

This partition of the climate debt in two parts – for being unfair (to developing countries), but also for being unsustainable ("over-consuming the available capacity", harming "mother Earth") – could motivate a change also in the method for calculating climate debt along the same lines; and this definition actually fits well with the method proposed by Paredis et al, to which I now turn.

Paredis et al's Definition of Carbon Debt

To conclude the above part, I will proceed by trying to find an adequate method for calculating emissions debt as part of total climate debt, defined as national, historical emissions above what is fair

7 The view that climate debt is part of a larger ecological debt is clearly stated by both climate justice movement (TWN 2009a, PWCCC 2010b) and Bolivia (UNFCCC 2009: 47).

8 An almost identical formulation was used in 2009 but without referring to mother Earth: "By overconsuming the Earth's limited capacity to absorb greenhouse gases, developed countries have run up an "emissions debt" which must be repaid to developing countries" (UNFCCC 2009).

and sustainable and without involving future emissions assignments. My departure will be Paredis et al's methodology for calculating carbon debt. They define the carbon debt of country A in the following way:

> (a) over-emission of CO_2 by country A over time with respect to a sustainable level; i.e. emission levels that overshoot the absorption capacity of the atmosphere and are thus causing ecological impact in other countries and ecosystems beyond national jurisdiction;
>
> (b) over-emission of CO_2 by country A over time at the expense of the equitable rights to the absorption capacity of the atmosphere of other countries or individuals. (Paredis et al 2008: 150)

The "equitable rights" of a country is based on a per capita interpretation of justice: responsibility for climate change is distributed among countries on their per capita contribution over time (Ibid.: 152). Historically high per capita emissions have resulted in a carbon debt, while low emissions have led to a negative debt (or a claim). So far, the approach is identical to how the climate justice movement defines the emissions debt. But here, also the perspective that total emissions above a certain level are unsustainable and cause ecological damage is added. Thus, the definition very well serves the aim of this paper.

The choice of where to put this "sustainable level" is however not straightforward but "based on a selection of assumptions concering the pressures nature can withstand and estimations of the level of environmental pressures and risks a society is willing to accept" (Ibid.: 152). Paredis et al base their choice on an IPCC estimation that a 60 percent global cut of greenhouse gas emissions below 1990 level is needed to stabilize the climate system.

In order to account for both of these factors – equity and sustainability – Paredis et al differ between a Historical Carbon Debt (HCD), which is the *intra-generational interstate debt* referring to inequalities between countries and populations historically and today, and a Generational Carbon Debt (GCD) which is the *inter-generational debt* that our generation owes to coming generations, i.e. emissions above the sustainable level. Together, HCD and GCD make up the total Carbon Debt (CD) (Ibid.: 152-154). This division actually fits well into the cateogories of climate debt as owed to both developing countries (HCD) and "mother Earth" (GCD). "Future generations" does not equal "mother Earth" in other senses, but if the aim is to identify a creditor of historical climate debt, making it human is definitely an advantage from the perspective of social science.

To operationalize the concept, Paredis et al propose two different models. In Model 1, priority is given to settle the generational debt. The means claimed by future generations are first withdrawn from the debtors, i.e. the Northern countries. Thereafter the historical, intragenerational debt is settled. Model 1 is defined by the following formula (Ibid.: 154-156),

$$CD_C = \sum_{i=\delta}^{\varepsilon} \left[e_C(i) - \frac{Pop_C(i)}{Pop_W(i)} S_W(i) \right] \qquad (1)$$

where CD_C stands for the carbon debt of country C, δ is the start year of accounting the debt, ε the end year, $e_C(i)$ is C's CO_2 emissions year i, $Pop_C(i)$ is C's population year i, $Pop_W(i)$ is the world population year i, and $S_W(i)$ is the sustainable emission level for the world year i.

Model 2 works the other way around. First, the historical inequality – the intragenerational debt – is settled by relating the historical per capita emissions of a country to the world average. After that, we deal with "a notional average consumer (this generation)" (Goeminne & Paredis 2010: 706), and thus, the generational debt is settled on a strict per capita-basis. In Model 2, HCD and GCD are calculated seperatly before added together to the total Carbon Debt.

$$HCD_C = \sum_{i=\delta}^{\varepsilon} \left[e_C(i) - \frac{Pop_C(i)}{Pop_W(i)} e_W(i) \right] \qquad (2)$$

and

$$GCD_C = \sum_{i=\delta}^{\varepsilon} GCD_C(i) \qquad (3)$$

with

$$GCD_C(i) = \frac{Pop_C(i)}{Pop_W(i)} \left(e_W(i) - e_{Sust}(i) \right) \qquad (4)$$

In Paredis et al 2004 and 2008, but not in Goeminne & Paredis 2010, a different way of calculating historical debt is applied to Model 2: it is related to the amount of CO_2 a country has emitted over time in excess of the world average per capita emissions *which still remain in the atmosphere*. The so-called Siegenthaler formula (Siegenthaler 1983) is used to estimate Earth's absorption speed of emissions, and according to it, 40 percent of the CO_2 is still in the atmosphere 100 years after the original emission (Paredis et al 2008: 156-157).

A (not entirely) hypothetical example

For readers uneasy with formulas as those above to be able to better understand these two models, a hypothetical example will perhaps be of help. Imagine that the world consisted of only two countries, North and South, and that we calculate their carbon debt for the time period 1980 to 1989 using the two models. The emissions and populations of the two hypothetical countries North and South – which actually are the same as for Annex 1 and Non-Annex 1 in the real world – are listed in Table 1. The sustainable level in this example is set to 9 $GtCO_2$ per year, which is a 60 percent reduction of the 1990 global emissions of CO_2[9] (excluding LULUCF[10][11] but including international bunkers). In this example, the Siegenthaler formula is not used.

Table 1. CO_2-emissions and populations in "North" (Annex 1) and "South" (Non-Annex 1) 1980-1989

	CO_2-emissions ($GtCO_2$)			*Population (bn)*		
	North	*South*	*Total*	*North*	*South*	*Total*
1980	14.1	4.7	18.8	1.1	3.4	4.5
1981	13.7	4.7	18.4	1.1	3.4	4.5
1982	13.4	5	18.4	1.1	3.3	4.4
1983	13.4	5.1	18.5	1.1	3.4	4.5
1984	13.7	5.4	19.1	1.1	3.6	4.7
1985	14	5.6	19.6	1.1	3.7	4.8
1986	14.1	5.8	19.9	1.1	3.6	4.8
1987	14.4	6.1	20.5	1.2	3.8	5
1988	14.8	6.4	21.2	1.2	3.8	5
1989	14.9	6.7	21.6	1.2	3.9	5.1
Total:	**140.5**	**55.5**	**196**			

Source: CAIT

Using Model 1, we start by calculating total carbon debt as in formula 1 above (yearly emissions minus population rate times sustainable level). For the first year we get the following result:

CD_{North} (1980) = 14.1–(1.1/4.5*9) = 11.9

CD_{South} (1980) = 4.7–(3.4/4.5*9) = -2.1

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9 The sustainable level proposed by Paredis et al

10 Land use, land use change and forestry

11 Including LULUCF would increase the emission figures strongly for late-developing states but not at all affect the figures for early developers, which arguably would be a model bias. LULUCF is therefore excluded in this example.

This operation is repeated for every year, and summed together the result is:

CD_{North} (1980–1989) = 118.9

CD_{South} (1980–1989) = -12.9

According to Model 1, the intergenerational debt (GCD) for the 1980s amounts to the total emission above the sustainable level (i.e. 196–(9*10) = 106), and the responsibility for GCD lies entirely on North. The intragenerational carbon debt (HCD) is based on South's CD (or total carbon claim), in this case -12.9 Gt and, for North, 12.9 Gt.

Using Model 2, the operation starts with calculating the historical debt as in formula 2 above, which is defined as the deviation from the world average emission (country emissions minus population rate times world emissions). The result for the ten years in Table 1 are:

HCD_{North} (1980–1989) = 93.6

HCD_{South} (1980–1989) = -93.6

The generational debt is then calculated as in formula 3 and 4 above (population rate times the world emissions above the sustainable level):

GCD_{North} (1980–1989) = 25.3

GCD_{South} (1980–1989) = 80.7

The results from both models are summarized in Table 2.

Table 2. Comparison of the results according to Model 1 and Model 2

	Model 1			Model 2		
	North	*South*	*Total*	*North*	*South*	*Total*
HCD	12.9	-12.9	0	93.6	-93.6	0
GCD	106	0	106	25.3	80.7	106
CD (HCD+GCD)	118.9	-12,9	106	118.9	-12,9	106

As shown in this simplified example, North has the same carbon debt and South the same carbon claim regardless of what model is used. The distribution between total historical debt and generational debt is also the same: from the historical debt being a zero-sum game follows that the sum of North's and the South's historical debts must be 0. Total generational debt is also the same in both cases, since it is the result of emissions in excess of the sustainable level. The generational debt therefore sums up to 106 in both models.

The only difference is the distribution of historical and generational debt *within* North and South. Is it of any importance? If these debts were posssible to settle through payments to different bank accounts, in Model 1 North would have to deposit 12.9 $GtCO_2$ on South's account and 106 Gt on Future's account, all in all 118.9 $GtCO_2$. In Model 2, North would have to deposit much more, 93.6 $GtCO_2$ on South's account, but only 25.3 on Future's (still 118.9 all in all, though). In the latter case, South would seem merrier since they had received a larger debt payment, but it would not last for long since they would immediately have to deposit 80.7 $GtCO_2$ on Future's account. So they would still only be able to claim 12.9 $GtCO_2$ – just as in Model 1.

Because of the principal similarities of the models revealed at a closer look, the whole operation of using two different models for calculating Carbon Debt seems superfluous. That is, unless using the different approaches are connected to some practical proposal that renders it meaningful. So far, I can not see any such such meaning. But as mentioned above, another difference between the models are that the Siegenthaler formula is applied to Model 2. Is that a reasonable motivation for using two models?

The Siegenthaler formula

The Siegenthaler formula (Siegenthaler 1983) is a method for estimating the remaining fraction of carbon in the atmosphere as a function of time past since the original emission. According to Paredis et al (2008: 156-157), it is "an analytic expression substituting complex oceanic and biospheric model calculations" that "gives reasonable results". The reason for using the Siegenthaler formula instead of merely summing up yearly emissions is the following:

> Consider the existent process between the emission of a greenhouse gas and the consequent effects such as temperature increase. The contribution of a gas to global warming is a result of Earth's exposure to the gas, which in turn is a function of both the gas's atmospheric concentration and its residence time. This argues that responsibility of countries for the present situation is best indicated by the remaining total historical emissions, the HCD [Historical Carbon Debt]. From the standpoint of physical reality, this is a better measure of responsibility and thus for debt. (Ibid.: 157)

The practical result of applying Siegenthaler on carbon debt is, thus, that older emissions counts "less" than newer emissions since a portion of the original emission over time get absorbed by Earth's carbon sinks. While this is undoubtedly the case, it could however be argued that earlier emissions actually have contributed *more* to climate change than later emissions since it has been longer in atmosphere, and thus that newer emissions should be counted less. That is, for instance, the line of reasoning behind the famous *Brazilian proposal* (UNFCCC 1997), according to which responsibility is distributed between countries neither through cumulative emissions or carbon remaining in the atmosphere, but through *contribution to climate change.* The earlier the emission, the bigger the contribution; one way of explaining this is through a chronological "chain of causality in global warming" (Enting and Law 2002).

Societal actions–>Emissions–>Concentrations–>Radiative Forcing–>Warming–>Sea level rise & other impacts

Time does not only result in fractions of carbon being absorbed by sinks, but is also required for carbon to actually contribute to climate change. According to La Rovere et al (2002: 163), evaluating the Brazilian proposal,

> [i]t is important to realize that industrialized countries will show a larger share of responsibility using indicators late in the chain – such as temperature change and sea-level rise – mainly because of the longer average "age" of their emissions in the atmosphere.

Thus, the very opposite reasoning than behind Paredis et al's use of the Siegenthaler formula. However, also the Brazilian proposal has been criticized, because it only takes into account the climate change that has already occurred, not the effects that current emissions and current concentration have committed us to in future. To compensate for that backward-looking, it has been suggested to supplement the proposal with forward-looking indicators for responsibility (Elzen and Schaeffer 2002, Höhne and Harnich 2002). Others would, however, argue that this is a good reason for sticking to distribution of responsibility (and thus for debt) based on cumulative emissions, since in the long run it does not matter that much which link in the "chain of causality" is used for measuring climate impact. In the long run, all emissions will contribute to climate change. This approach also gains scientific rationale from research done by IPCC (2000), which states that cumulative emissions is a reasonable proxy for the relative contribution of countries to global warming (see also La Rovere et al 2002: 168). I will therefore continue using cumulative emissions.

Conclusions of Paredis et al

To conclude this part I find that the *principal difference* between Paredis et al's Model 1 and Model 2 – whether to start with GDC or HDC – is merely cosmetic and render this double approach superfluous, while the *practical difference* – the application of the Siegenthaler formula to Model 2 – is important, and speaks in favor of not using Siegenthaler. Further, it is not clearly motivated why the Siegenthaler formula is applied only to Model 2. I can not see why the emission figures in Table 1 above could not be substituted by figures of the remaining CO_2 fraction according to the Siegenthaler formula, and thereafter applied to both models. If this is the case, it makes the use of two models more obscure. As I see it, the choice between Model 1 and 2 (without Siegenthaler) is principally a matter of "bookkeeping" practices, on how to distribute the same debt on different "accounts". Thus, choosing which to use is merely a matter of taste, and since I prefer Model 1 because I think it is easier to explain and to use (which is also in consistence with the aims), I will leave Model 2 behind from now.[12]

A Modified Methodology

Still, Paredis et al's Model 1 does not fully fit the aim of this paper. I do consider it fulfilling aim a), to be in line with the definition of emissions debt as part of total climate debt that has emerged from the climate justice movement, including the sustainability criteria expressed as a debt to "mother Earth" (although substituted by "future generations"). But regarding aim b), on scientific accuracy, the sustainable level is, I would argue, constructed in a dubious way and based on outdated scientific data. Regarding c) the method is not quite applicable to existing data, and regarding d), I hope to be able to simplify the concept at least some to make it more user friendly. Finally, it is a method of calculating *carbon* debt while my aim concerns *emissions debt as part of total climate* debt. I will therefore propose three deviations from Paredis et al's Model 1.

Climate debt instead of carbon debt

Whether to call the sum of these formulas carbon debt or emissions debt as part of climate debt is partly a question of connecting to a certain current of thought. Since climate debt is the principal term used within the environmental and climate justice movements, it is logical to use it in a paper that explicitly sets out to be part of that strain of thought. But it is also a question of what is ultimately measured: emissions of carbon or contribution to climate change. If the latter is the case, emissions of all greenhouse gases (GHGs) – such as methane, nitrous oxide and hydrocarbons besides carbon dioxide – should ideally be included. Doing so gives a scientifically more accurate picture of the causes

[12] Hypothetically, other practical uses not considered here could make the difference between the models relevant again.

of climate change. Principally, the notion of climate debt is therefore preferable. But practically, it is another story. Data on emissions of all greenhouse gases are very scarce up until recent years[13], and if one wants to have a long-term historical perspective, only data on CO_2-emissions from fossil fuels and cement are available. As so often in historical research, there is a sinister trade-off between data accuracy and age, but staying true to the definition of carbon/climate debt means including this historical perspective if possible. When defining a sustainable limit I will also apply a method for indirectly including other GHGs than CO_2 (see below). Thus, using the notion of climate debt in this context is not only an expression of principal ambition and connecting to a certain current, but is also rooted in the applied method.

Another sustainable level of emissions

As mentioned, Paredis et al do not consider the settling of a sustainable level of annual, global emissions as a straightforward business; "there is no such thing as an absolute level of sustainability, no absolute criterion for equity /.../ these will always have to be 'social constructs'" (Paredis et al 2008: 154). I subscribe to this approach, which of course does not exclude an aspiration of making as accurate an assessment as possible. In Goeminne and Paredis (2010: 706) it says:

> Based on the latest IPCC assessment reports, a 60% reduction with regard to 1990 could be regarded as a first rough estimate for such a "sustainable level" of worldwide greenhouse gas emissions.

There is no closer reference to the then latest IPCC assessment report, AR4 from 2007, but this 60% reduction was suggested also in Paredis et al 2004 – published years before AR4 – with a reference to IPCC's Second assessment report (AR2) from 1995. After browsing through the IPCC assessment reports I strongly suspect, however, that the reference to a 60% reduction goes back to the first report from 1990. There, WP1 writes that "the long-lived gases [carbon dioxide, nitrious oxide and CFC's] would require immediate reductions in emissions from human activities of over 60% to stabilise their concentrations at today's levels" (IPCC 1990: XI). If I am correct, the figure is based on research that is quite old by now.

But a more important question than in which IPCC report the figure referred to is printed is whether the method results in a valid estimate of a "sustainable level", defined as an amount of emissions that do not "overshoot the absorption capacity of the atmosphere and are thus causing ecological impact"

[13] CAIT, the database used in this paper, only reports data on GHG emissions for 1990, 1995, 2000 and 2005.

(Paredis et al 2008: 150)? I would argue that it is not, although Paredis et al are not alone in using a similar methodology (cf. Simms et al 1999, UNDP 2007). The reduction scenarios are estimations of what is needed in order to keep global mean temperature rise at a certain level with a certain amount of risk taking, but it does not say that the proposed reduction results in a long-term sustainable level that equals Earth's absorption capacity, nor is it necessarily an estimate for such a level. Thus, IPCC 1990 does not state that the stabilization of the 1990 level of emission is sustainable – on the opposite, it states that a temperature rise of 0.3-0.6 C had already occurred in 1990 – and with more in the pipeline (IPCC 1990: XI).

Rather than starting from reduction scenarios, finding an estimate for the sustainable level would have to start with an assessment of the absorption capacities of the global carbon sinks. The most reliable sinks are the oceans, which are believed to have absorbed about 8 $GtCO_2$ per year the last decades (Khativala et al 2009). That the sink capacity of oceans hitherto has increased with higher emissions has eased global warming but with a clear downside: stronger acidification of the oceans which might lead to very severe consequences for sea life (Honish et al 2012). It is thus a clear example of an "ecological impact" according to the definition above.

Also biomass, mainly forests, have acted as a sink of about the same size as the oceans the latest decades. But biomass is an unreliable sink, whose net contribution to the carbon cycle varies greatly from year to year. The rising sink capacity of forests is largely due to the expansion of commercial forestry which have increased the amount of standing trees, but this is a development that logically can not continue forever. According to one estimate by IPCC (referred by Khativala et al 2009), ocean and land sinks used to absorb about 7.7 $GtCO_2$ per year, which rose to 11.7 during the 1990s and 12.8 after the millennium shift. But as shown above, the higher carbon uptake can not be regarded as long-term sustainable. UNDP (2007: 34) is much closer to a definition of a *sustainable* level of emissions: "Over the long term, the Earth's natural capacity to remove greenhouse gases without sustaining damage to the ecological systems of carbon sinks is probably between 1 and 5 $GtCO_2e$". Although more research is wanted in this matter, I will for the time being use this assessment of UNDP. To be conservative, I will use the highest figure in the range, but since we will only account for emissions of CO_2, not other GHGs, and since emissions of CO_2 historically have contributed to about 60 percent of the human made global warming (IPCC 1995: 8), I will put the sustainable level for emissions of CO_2 at 3 $GtCO_2$.

A modified formula

A remaining challenge is that the method developed by Paredis et al requires a lot of data and a lot of calculations in order to be applied, which in effect harms the longer historical perspective. In order to apply their models, one needs data on emissions and population for every country and every year within the period of research, and one needs to make one calculation for every country and every year, before adding the results to the country's climate debt. According to Goeminne & Paredis (2010: 707) it is "impossible" to calculate HDC and GDC according to Model 1 due to "[u]navailability of emission data". The fact that they have presented calculations of the CD, HCD, GCD (Model 2 style) for only 10 countries and for the relatively short period of 1950–2000 (Paredis et al 2008: 166, Goeminne & Paredis 2010: 707) is perhaps a sign of the difficulties in applying the method on existing data.

Unavailability of data is of course a serious obstacle, but does it mean that a longer historical perspective on climate debt is impossible? I would argue that it is not; partly because the data coverage is not as bad as it first seems, and partly because I think a simplification of the model that largely overcomes the lack of data still can give valid results.

Starting with emissions data, there actually seems to be a very close correlation between historical emissions and access to emissions data. Thus, for most industrialized countries – with great historical emissions – there is data going back to 1850 or longer, while for developing countries – with small, even negligible emissions before 1950 – the emissions data regularly starts in the 20^{th} century (see table 3 for an overview). Even though the emissions data for, say, 1850 only cover 30 countries in the database used (Climate Analysis Indicator Tools, CAIT), one can assume that it covers a very large part of actual emissions that year. Even among the 30 countries, 94.25% of emissions were concentrated to only five countries (UK, USA, France, Germany and Belgium). The part of a large but still agricultural country such as Russia was 0.04% 1850, while it can be noted that when the world's most populous country China enters the statistics in 1902, its emission was 0.1 Mton CO2 – 0.005 % of the recorded global emissions that year. Even though the evidence presented here is anecdotal, it appears reasonable to assume that the statistical coverage of historical emissions is not as bad as it first seems.

Table 3. Countries covered by CAIT:s emission statistics, major Annex 1 countries missing. Selected years.

Year	*Nr of included countries*	*Excluded Annex 1-countries*
1850	30	Australia, Bulgaria, Croatia, Czech Republic, Finland, Greece, Iceland, Italy, Japan, Luxembourg, Malta, New Zealand, Portugal, Romania, Slovakia, Slovenia, Switzerland, Turkey
1860	37	Bulgaria, Croatia, Greece, Iceland, Ireland, Japan, Luxembourg, Malta, New Zealand, Portugal, Slovenia, Turkey
1870	39	Bulgaria, Croatia, Iceland, Ireland, Japan, Luxembourg, Malta, New Zealand, Slovenia
1880	42	Croatia, Greece, Iceland, Japan, Luxembourg, Malta, Slovenia
1890	51	Greece, Iceland, Ireland, Japan, Luxembourg, Malta
1900	57	Iceland, Ireland, Japan, Luxembourg, Malta
1910	65	Iceland, Japan, Luxembourg, Malta
1920	72	Iceland, Japan, Luxembourg, Malta
1930	80	Iceland, Japan, Luxembourg, Malta
1940	80	Japan, Luxembourg, Malta
1950	164	
1960	164	
1970	177	
1980	182	
1990	183	
2000	185	

The other kind of data needed for calculating climate debt is population figures. Data on population before 1950 is very patchy for many countries, and in order to fill in all the empty fields in the data base used – Maddisson 2010 – many uncertain assumptions has to be made. In an attempt to obviate this obstacle, I will propose a modification of Paredis et al's Model 1. As their models, the modified model aims at pinpointing the difference between a country's actual historical emissions and its fair and sustainable share, naming this difference its debt. It also uses the same principles for determining what is fair and sustainable, namely per capita-justice and a sustainable level of global emissions. The main difference is that instead of calculating the debts for every single year and summing the results, I propose to make the calculation only once per country, using the existing statistics of cumulative emissions. As already discussed, this is a bias favoring countries which lack a long historical data series of emissions – i.e. mainly developing countries – but it is assumed that the distortion is very limited and I hope to be able to find a method for adjusting this bias in another context.

Formally, the modified model can be put this way

$$CD_C = E_{CT} - \left[S_{WT} \frac{Pop_C}{Pop_W} \right] \qquad (5)$$

where CD_C is understood as climate debt of country C, E_{CT} as C's cumulative emissions during the time period T, S_{WT} is the sustainable level of global, annual CO_2-emissions that are absorbed by the ecosystems without damaging their functions times the number of years of the time period of choice T, Pop_C is the population of C and Pop_W the world population.

This method does not only save a lot of computing power, but also a great deal of the problem of missing figures in the population statistics. One problem remains unresolved, though: when during T to measure the population. If population is measured at the end of the period a bias occurs, since it would result in comparatively greater climate debt for countries whose population as a rate of world population is decreasing; i.e. generally developed countries. If population is measured at the very start of T, we have the opposite problem. This bias can, however, largely be obviated by using the mean value of the population rates of the country at a few points spread out during the time period. It means a little more work and requires a little more data, but still far less than in Paredis et al's method.

One problem that can not be fully overcome when applying a long historical perspective is the fact that many states did not exist as sovereign entities until much later than 1850. In some instances, territories later constituted as states were colonies and arguably not responsible for their historical emissions. For the time being, however, it is assumed that also this obstacle is more theoretical than practical. The emissions from developing countries before decolonization are seldom in the statistics anyway, and in the cases where they are, the emissions were so small that they hardly effect the results.

Comparing the results of different models, see Table 4, it is obvious that the different assumptions regarding a sustainable level matter more than the construction of the models. In Table 4, the climate debt for "North" and "South" 1980-1989 resulting from the models EP9 (Erik Paredis et al's Model 1 with a sustainable level of 9 $GtCO_2$), RWa9 (The modified model in formula 5 with a sustainable level of 9 $GtCO_2$, population measured at the end of T), RWb9 (Formula 5 with a sustainable level of 9 $GtCO_2$, population measured as the mean value of the first and the last year within T) and RWb3 (as RWb9 but with a sustainable level of 3 $GtCO_2$) is reported. Note that the model bias of RWa9 is largely obviated in RWb9, with a result very close to EP9.

Table 4. "North's" and "South's" carbon debt 1980–1989 according to four models ($GtCO_2$)

	EP9	*RWa9*	*RWb9*	*RWb3*
North	118.9	120	119	133.3
South	-12.9	-14	-13	32.7

The stronger ecological concern of RWb3 increases the climate debt of both North and South; actually turning the latter's climate claim into a debt if only counting for the period 1980-1989. An advantage of the modified model, however, is that the debt over longer periods of time can be calculated relatively easy. With a longer perspective, South still has a climate claim.

A Calculation of Emissions Debt of 154 Countries

In the Appendix, the results from a calculation of the climate debt of 154 countries according to the modified model (RWb3) are presented. Besides the guidelines outlined above, the following methodological considerations were made. The emissions counted, for every country and for the world, are the cumulative emissions of CO_2 from fossil fuels and cement 1850-2008 according to CAIT. A sustainable level of 3 $GtCO_2$ is used. The population figures are from Maddison 2010. The population of every country is divided with world population for three years spread out during the period – 1870, 1950 and 2000 – using the average percentage as the country's population rate. Thereby, most population trends during 200 years of industrialization should be taken into account[14].

For parts of Eastern Europe, Asia and Africa, no country statistics even for 1870 exists. But there is data on total population of subregions or continents, so in those cases, the 1950 distribution between countries within a region or continent have been projected on the 1870 totals (assuming that the population growth of every individual country has been the same as for the sub-region/continent as a whole).

As mentioned, the full result for 154 countries is reported in the Appendix. In Table 5, the result is divided into two blocks, North (included Annex 1 states) and South (the rest of the included countries).

[14] The years chosen and the weighting of them is a matter of further consideration. For instance, 1850, 1900, 1950 and 2000 would have been more evenly spread out during the period, but unfortunately there is substantially less data for 1850 and 1900 than for 1870, which was therefore selected. That a relatively larger weight is put on the later part of the period also corresponds to the fact that total emissions have increased dramatically during the period.

Of total emissions 1850-2008, 60 percent have been unsustainable and thus form the generational debt, which on this level of abstraction is the absolutely largest part of the emissions debt. South – which includes many semi-industrialized countries – only has a quite small historical emissions claim, while the North – in which most of the so-called emerging economies in Eastern Europe are included – has an enormously large emissions debt; a historical debt of 14.5 $GtCO_2$, and a generational debt of 732 Gt.

In 2008, the inhabitants of North only made up 18.8 percent of world population, but had historically emitted 72.7 percent of the global CO_2. The per capita debt was 594 tons of CO_2, which is roughly the same as 46 years of per capita emissions on current, 2008, levels. With a historical population ratio (27.7 % as in Table 5), a fair distribution and no unsustainable emissions over time, the North could only have emitted 15 percent of what it has actually done. The South could have emitted more carbon without being unfair or unsustainable, but not very much; only about 4.4% more.

Table 5. A calculation of the climate debts of "North" and "South"

	World	*North*[i]	*South*[ii]
a. Emissions 1850-2008 ($GtCO_2$)	1209.0	878.6	330.4
b. Share of emissions (%)	100	72.7	27.3
c. Population ratios[iii] (%)	100	27.7	72.3
d. "Sustainable" emissions[iv] ($GtCO_2$)	477	132.1	344.9
e. Total climate debt (a-d) ($GtCO_2$)	732	746.5	-14.5
f. Historical climate debt ($GtCO_2$)	0	14.5	-14.5
g. Generational climate debt ($GtCO_2$)	-732	732	0
h. Total climate debt per capita[v] (tCO_2)	128	594	-3.7

i Annex 1 excluding Iceland, Lichtenstein, Luxemburg, Malta, Monaco, Slovenia.
ii The remaining countries in the study after subtraction of included Annex 1 states.
iii Average of 1870, 1950 and 2000 rates of world population
iv 3 Gt*159 years/share of pop.
v Based on population 2008

Conclusions

The aim of this paper is to propose a method for calculating climate debt that is a) in line with the definition of climate debt that has emerged from the climate justice movement, b) scientifically accurate, c) applicable on existing data, and d) user friendly, i.e. relatively easy to grasp and use by activists and citizens. The modified version of Paredis et al's method, called RWb3 above, is my best attempt at meeting the aims. I have also applied the modified method on the data of 154 states and the result is presented above and in the Appendix. It clearly shows that the developed countries have an immense emissions debt, but also that the emissions claim of the developing countries, taken as a group, is quite small and decreasing.

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Appendix: Emissions Debt of 154 Countries

Columns B-D show population for the years 1870, 1950 and 2000. Figures for 1870 written in green indicate that there is no data in Maddison 2010, instead the 1950 distribution between countries within a sub-region or continent has been projected on the 1870 totals, assuming that the population growth 1870-1950 of every individual country was the same as for the sub-region/continent as a whole. In column E average share of world population is calculated. Column F sums total emission of CO_2 from energy sector 1850-2008 according to CAIT. Column G presents total climate debt (CD) in million tons of CO_2 up until 2008. An annual, global emission level of 3 $GtCO_2$ is considered sustainable. In column H, total CD is divided with 2008 population (in column J) for an estimate of Climate Debt per capita in tons of CO_2.