WHY A 100-YEAR TIME HORIZON SHOULD BE USED FOR GLOBAL WARMING MITIGATION CALCULATIONS

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(Received 16 February 2000; accepted in final form 12 October 2001)

Abstract. Global warming mitigation calculations require consistent procedures for handling time in order to compare 'permanent' gains from energy-sector mitigation options with 'impermanent' gains from many forest-sector options. A critical part of carbon accounting methodologies such as those based on 'ton-years' (the product of the number of tons of carbon times the number of years that each ton is held out of the atmosphere) is definition of a time horizon, or the time period over which carbon impacts and benefits are considered. Here a case is made for using a time horizon of 100 years. This choice avoids distortions created by much longer time horizons that would lead to decisions inconsistent with societal behavior in other spheres; it also avoids a rapid increase in the implied value of time if horizons shorter than 100 years are used. Selection of a time horizon affects decisions on financial mechanisms and carbon credit. Simple adaptations can allow a time horizon to be specified and used to calculate mitigation benefits and at the same time reserve a given percentage of weight in decision making for generations beyond the end of the time horizon. The choice of a time horizon will heavily influence whether mitigation options such as avoided deforestation are considered viable.

Keywords: carbon accounting, deforestation avoidance, global warming, Kyoto Protocol, land-use change, ton-year accounting

1. Introduction

Allocating effort among different means of mitigating global warming requires comparisons of the benefits of each option using a consistent carbon (C) accounting methodology. When fossil fuel combustion is avoided, the benefits are considered to be permanent and, in most situations, the certainty of these benefits is virtually complete. For forest-sector options, other than those that displace fossil fuels, both permanence (the time that carbon remains out of the atmosphere) and certainty (the probability that the carbon benefits are achieved) can be substantially lower. The point in time when C benefits occur may also be delayed, for example for C being sequestered by growing trees. The climate benefit per ton (Mg) of C is therefore less for many forestry options than for fossil fuel emissions reductions. Credit given for options that result in temporary C storage should not be equal to that from permanent displacement per physical ton of carbon, but neither should it be zero (Fearnside, nd-a). Various proposals exist for crediting the C benefits. Credit could either be assigned based directly on a carbon accounting calculation, or could

Mitigation and Adaptation Strategies for Global Change **7:** 19–30, 2002.

be based on a market-based mechanism such as the ‘Colombian proposal,’ under which the Kyoto Protocol’s Certified Emissions Reductions (CERs) for forest-sector projects would have finite periods of validity rather than offering permanent credit (Blanco and Forner 2000; see also similar proposals by Dutschke 2001 and Marland et al. nd). In either case, a carbon accounting methodology is needed to compare options. Definition of a time horizon is one of the most critical decisions in accounting for carbon.

2. Ton-Year Accounting

‘Ton-year’ accounting has been proposed as a way to make units comparable for such options as avoided fossil fuel emissions, avoided deforestation, and silvicultural plantations with different durations. Under a ton-year system, credit would be given for the number of tons of C held out of the atmosphere each year, that is, credit is proportional to the number of tons of carbon multiplied by the number of years it is held. Ton-year accounting can be combined with discounting or other time-preference weighting mechanisms to reflect societal choices on the value of time. Ton-year accounting includes the gradual removal of carbon from the atmosphere by oceans or terrestrial ecosystems in the baseline (no-project) scenario and, depending on the method, also in the project scenario. To make the comparison, it is necessary to establish a time horizon within which the areas of the integrals of two curves are compared, one curve being for the baseline scenario and the other for the project scenario. The difference between the areas of the integrals in the two scenarios will represent the carbon benefit. The areas of the integrals will depend on the time horizon that defines their upper boundaries.

Two approaches to ton-year accounting have been proposed. In the first method, known as the ‘Moura-Costa method’, the carbon in the project scenario is followed in the biosphere (Moura-Costa and Collins 2000), while in the second method, known as the ‘Lashof method’ it is followed in the atmosphere (see explanation of different methods in Fearnside et al. 2000). Both methods depend critically on definition of a time horizon. The discussion that follows uses the Lashof method.

Curves representing atmospheric carbon in the baseline (no-project) and mitigation (project) scenarios are drawn with tons of carbon on the Y-axis and years on the X-axis; the areas under the curves (discounted or not) represent ton-years (Figure 1). In the example in Figure 1, a 50-year delay in emitting a ton of C reduces the atmospheric impact of a one-ton emission from 46 ton-years to 28 ton-years; the corresponding credit for such a delay would therefore be 46–28 = 18 ton-years, or 18/46 = 40% of the total (i.e., one ton of C held in a forest-sector mitigation project like this hypothetical scenario would have a climate benefit equal to 0.4 tons of C from fossil-fuel emission reduction). Ton-year accounting can be used for both CO_2 and non-CO_2 greenhouse gases, as well as with discounting over the course of the time horizon (see Fearnside 1997 for examples of both).

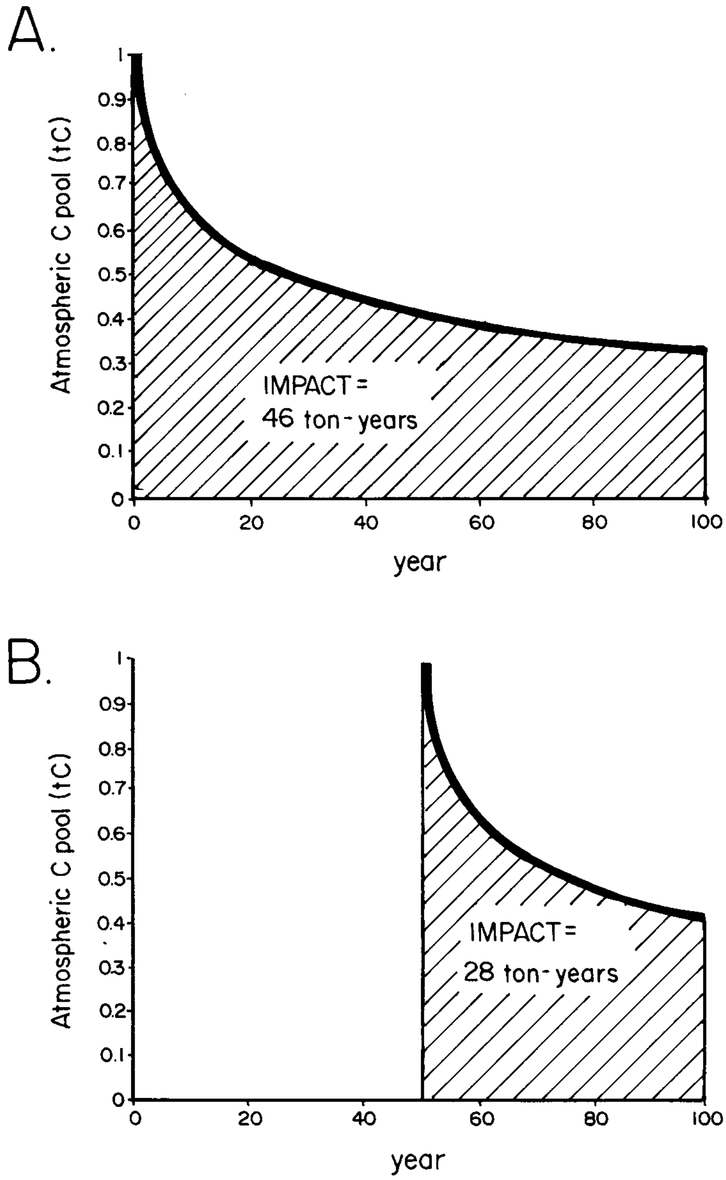

Figure 1. An example of ton-year accounting using the 'Lashof method,' a 100-year time horizon and no discounting over the time horizon (see Fearnside et al. 2000 for detailed explanation of methodology). In this example a baseline (no-project) scenario (Panel A) represents carbon in the atmosphere if one ton of carbon is emitted in year 0, while in the project scenario (Panel B), one ton of carbon is sequestered, for example in trees, and is emitted in year 50. The ton-year benefit will be the sum over the 100-year time horizon of the differences between the atmospheric loads of carbon at each year, weighted by the time preference at each respective year (always equal to one in this example without discounting, making the difference between the areas under the curves a direct measure of the carbon benefit). The amount credited would be 46 – 28 = 18 ton-years.

Ton-year accounting has been resisted by different interest groups for very different reasons. Some of those interested in promoting silvicultural plantations believe that the system gives insufficient financial incentives to project developers because carbon credit accrues too slowly. Others promoting forest preservation through creation of forest reserves think that it gives inadequate weight to the permanent nature of these reserves. On the other hand, Brazilian diplomats resist the system because it provides the intellectual underpinnings for giving credit to avoiding deforestation by reducing clearing rates, which is perceived as a potential incentive to foreign interference with Brazil's sovereignty in Amazonia. These 'ulterior' concerns, justified or not, can be reflected in a perhaps unconscious desire to find a theoretical argument on the basis of which ton-year accounting can be rejected. This author's perception is that this search for moral high ground has settled on attacking the choice of a time horizon as immoral because it supposedly writes off the interests of all future generations beyond the end of the horizon.

For example, Luis Gylvan Meira Filho, an influential voice in defining Brazilian diplomatic positions related to global warming, has argued that consideration should be given to events 30,000 years in the future because some greenhouse gases emitted now will still be in the atmosphere (L.G. Meira Filho, statement to Intergovernmental Panel on Climate Change [IPCC] Special Report on Land Use, Land-Use Change and Forestry chapter 5 authors, Geneva, January 2000). The following sections present arguments for not giving weight in carbon accounting to such far-future events, instead setting a time horizon at 100 years.

3. Relationship between Time Horizon and Discount Rate

The choice of a time horizon is a policy decision, not a scientific result. For policy makers to arrive at decisions on the time horizon that reflect the interests of society they must think through both the factors on which time horizons are based and the consequences of different choices.

The importance of time will be expressed in two decisions: time preference weighting (for example by discounting) and choice of a time horizon. 'Time preference weighting' refers to the weight in decision-making that is given to future events at each point in time. This may be derived by combining considerations such as 'growth discounting' (adjustment for the marginal utility of wealth, more wealthy people attaching lower importance to the loss or gain of a unit of wealth) and the 'pure rate of time preference' (weighting based solely on the event's position in time, irrespective of how wealthy one expects to be at that time) (Azar and Sterner 1996). The most commonly used means of achieving a time preference weighting is application of a discount rate, which adjusts the present value of future events by a factor based on a simple negative exponential relationship to time. Several alternative means of deriving time preference weightings have been proposed for global warming calculations (Heal 1997; Fearnside nd-b).

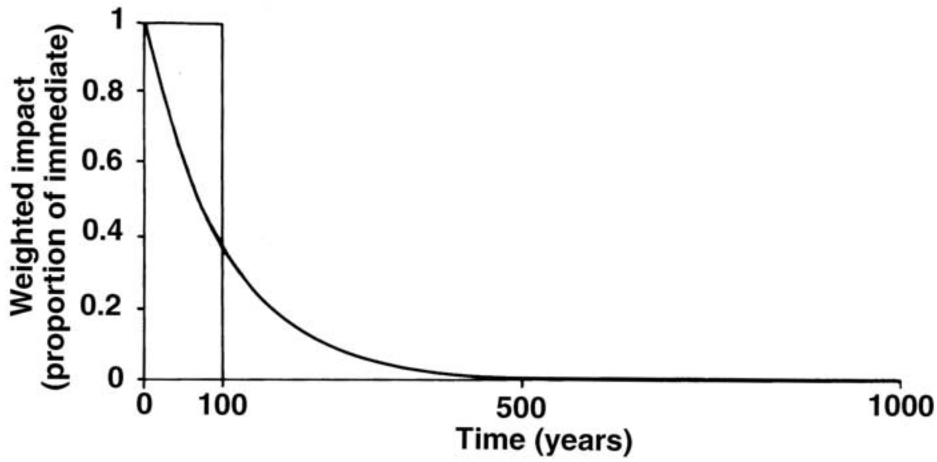

Figure 2. Discount rate equivalent of a time horizon. The area under a negative exponential curve at 0.9% annual discount (assuming truncation at year 1000) is equal to that under the 100-year time horizon zero-discount system adopted for global warming potentials (source: Fearnside et al. 2000).

Setting a time horizon has an effect similar to the choice of a discount rate. The equivalence is illustrated in Figure 2 (Fearnside et al. 2000). The curves represent the weight given to impacts or benefits occurring at each point in time, relative to an immediate impact or benefit. The rectangle represents a 100-year time horizon with no discounting, which is equivalent to the 100-year zero-discount formulation used for the global warming potentials (GWPs) that have been adopted under the Kyoto Protocol for its first commitment period (2008–2012). The area under the rectangle is the same as that under the negative exponential curve shown, truncated at year 1000. The negative exponential curve shown represents an annual discount rate of 0.9%. An equivalence between the time horizon (with no discounting) and the discount rate (with an infinite or very long time horizon) can be derived in this way for any proposed time horizon.

The equivalence between time horizon and discount rate for carbon accounting in mitigation is the same as that between these factors in proposals for calculating GWPs to express the equivalence of the different greenhouse gases in terms of CO_2 equivalents. A 5% annual discount rate over a long (1000-year) time horizon (Lashof and Ahuja 1990) produces a GWP for methane approximately equal to that derived using similar parameters over a 30-year time horizon with no discounting (Arrhenius and Waltz 1990), or slightly lower than with a 20-year horizon (Shine et al. 1990).

The inter-relationship between the length of the time horizon and the discount rate applied over that time period is shown in Figure 3 in terms of their effect on the discount rate equivalent for an infinite or very long time horizon. As the time horizon shortens below 100 years, the discount-rate equivalent increases rapidly and would approach infinity as the time horizon approaches zero. The family of

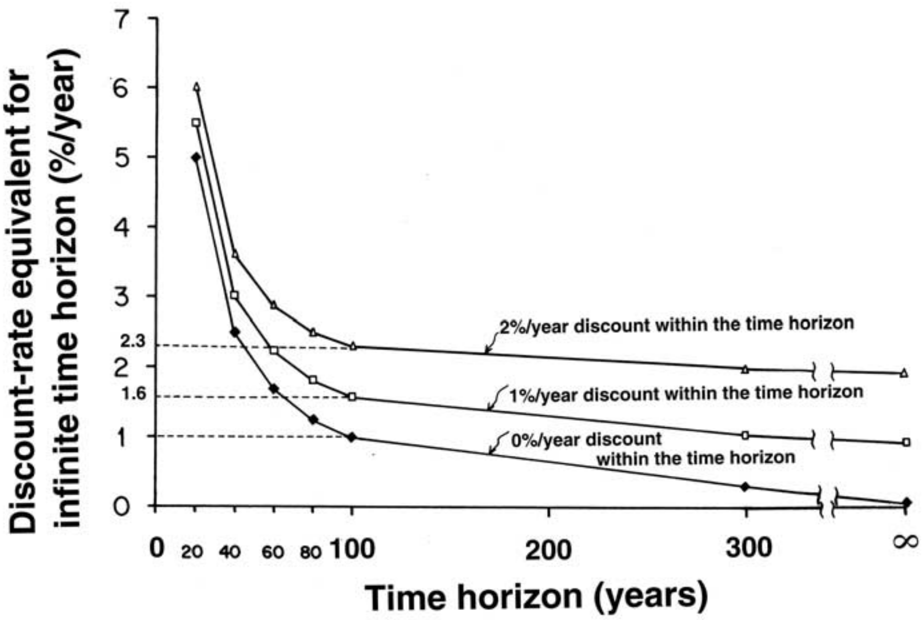

Figure 3. Relationship between time horizon, the discount rate applied over the time horizon and the discount-rate equivalent (as defined in Figure 2) of the combined result of the time horizon and the discount rate applied over that horizon, with all calculations carried over a 1000-year period. The effect of a 100-year time horizon with no discounting is approximately equal to a 1% annual discount rate over a 1000-year time horizon (i.e., the integrals of the two will be equal if compared as in Figure 2). If annual discount rates of 1% or 2% are applied to time horizons of different lengths, the discount-rate equivalent of the combined result of the time horizon and the discount rate over that horizon will be a higher annual percentage than if no discounting (i.e., 0% annual discount) is applied. In the case of a 100-year time horizon, the discount-rate equivalent of 1% with no discounting rises to 1.6% per year and 2.3% per year, respectively, if annual discount rates of 1% and 2% are applied over the course of the time horizon.

curves representing different rates of annual discount applied over the course of the time horizon shows a rise in the discount-rate equivalent for any given length of time horizon as the discount rate within the time horizon increases.

4. Choice of a Time Horizon

The joint effect of time horizon and discount rate means that decisions on these two parameters should be made simultaneously. In the case of time preference, using a time-preference weighting of zero (i.e., a zero discount rate) is just as much a decision as picking any other number. While an infinite time horizon is unrealistic, an approximation could be achieved by picking a finite but far-distant horizon, say

2000 years. However, policy makers must ask if such a choice would reflect the values they want to have governing economic behavior.

If one sets a short time horizon, say 20 years, even with a discount rate of zero the effect is to attribute a high value to time. The 20-year integration GWPs offered by the IPCC as one of the options in each of its assessment reports provide an example (e.g., Schimel et al. 1996, p. 121).

If one sets a long time horizon, say thousands of years, one has the effect of giving almost no value to time if a zero discount rate is applied, and behavior will be encouraged that does not distinguish between events now and, for example, several decades in the future. This is inconsistent with speedy action on climate change. In other words, we currently behave as though time had great value. Moreover, the United Nations Framework Convention on Climate Change (UN-FCCC) states clearly the urgency of identifying and altering any potentially dangerous atmospheric concentrations of greenhouse gases (UN-FCCC 1992).

If we really thought that events thousands or millions of years in the future should have the same weight as events today, we would be paralyzed in terms of action from day to day in our own time. Instead, we all use a variety of means to give value to time, one of which is focusing on a finite period of time during which we hope to be able to influence events. People set time horizons as a means of focusing their efforts on a period that results in productive action. This should be taken as a virtue, not as a selfish and immoral excuse to write off the rest of history.

Why pick 100 years as the time horizon for C accounting? Several lines of reasoning indicate a figure of around 100 years as a wise choice, aside from the fact that the Kyoto Protocol has already specified 100 years as the time horizon applying to global warming potentials for comparing different greenhouse gases (UN-FCCC 1997).

One hundred years approximately corresponds to the time that decision-makers today have direct contact with the living population. Consider as a hypothetical example that the decision-maker is 50 years old, that the children of each generation are born when the parents are 25 years old, and that all people die at age 75. The decision-maker's great-grandchildren (the last people known directly to the decision maker) will die in year 100. A discontinuity in our contact with the future therefore falls at about 100 years.

The 100-year mark also corresponds to a discontinuity in the relationship between time horizon and its discount-rate equivalent (Figure 3). In this example, assuming no discounting over the course of the time horizon (i.e., the 0% curve in Figure 3), the infinite time horizon discount-rate equivalent of the chosen time horizon falls from infinity to 1%/year as the time horizon increases from zero to 100 years; after year 100 the decline is much slower, gradually falling from 1% to 0% over the length of the calculation (1000 years in this case). Choices of time horizons shorter than 100 years therefore imply values for time that may be greater than decision makers would like (although, in theory, one could compensate for the time horizon effect by applying a negative discount rate).

One hundred years also represents approximately the maximum time horizon at which one can get away with using a zero discount rate without provoking glaring distortions in current decision-making. The well-known difficulty in arriving at consensus on values for discount rate often results in zero values being selected based on the mistaken assumption that using a zero value avoids having to make a decision. Should this not-improbable scenario unfold in the coming rounds of climate negotiations, a 100-year time horizon would at least maintain values within a reasonable ballpark.

The choice of a time horizon will greatly affect the behavior of those who invest in mitigation options. If the horizon is too long, then the return to investors in mitigation projects will be insufficient to motivate them to enter this field at all. On the other hand, if the time horizon were made very short to give developers a quicker financial return and boost the profitability of mitigation relative to other kinds of possible investments, the horizon might be so short that the decision-maker's immediate interests in other spheres were sacrificed. A risk exists that developers might lobby successfully for adoption of a very short time horizon, say 25 years.

It is advisable to examine the practical implications of different choices of time horizon before making a decision, independent of whether one wants to engage in 'gaming' of the result, that is, picking a time horizon that, when decisions are made about mitigation, will lead to an outcome that is desired for other reasons. If one chooses a very long time horizon, say 2000 years, and combines it with no discounting of carbon, only 'permanent' changes, such as avoided fossil fuel emissions, would be chosen as mitigation options. If one chooses a very short time horizon, say 25 years, the effect is to favor options that give quick returns, such as avoided deforestation and, to a lesser extent, plantations of fast-growing species.

An important policy decision that would affect the consequences of choosing a short time horizon is whether provisions are established in climate negotiations creating a liability for what happens after the end of the time horizon. Part of the attractiveness of ton-year accounting for mitigation project proponents is that it can provide a rationale for freeing them of such liabilities. This, however, touches on a legitimate concern for global climate: whether the accounting system should include either an adjustment or a liability for emissions occurring after the end of a time horizon. This applies both to standardized time horizons for comparing different options on the basis of ton years (such as the 100-year horizon proposed here) or to the period of a given project.

Ton-year accounting has advantages over methods that use creation of a perpetual liability as a means of justifying credit that is given immediately (i.e., in advance of actually achieving the carbon results). One advantage is that it allows the project proponent to obtain actual carbon credit as the project goes along, rather than waiting until the end of the project to obtain financial returns beyond what may be negotiated in a futures market. Another advantage over perpetual liabilities is that the ton-year system provides a means of avoiding sovereignty concerns in countries hosting the projects. Such countries are likely not to want to promise to keep specific tracts of land in forest, perpetual-rotation plantations or any other specific land use in perpetuity, but ton-year accounting offers a means of allowing projects to be credited as they go along and to be terminated at any time that the host country may wish, while minimizing both damage to the climate system and the need for liabilities that may be difficult to collect in practice.

5. Financial Mechanisms and Carbon Credit

As pointed out above, some of the concern about establishing a time horizon may reflect a concern with short-term economic incentives. However, it should be emphasized that financial mechanisms are, or can be, separate from carbon accounting. If it is decided that funds must be provided to project developers in advance of their producing the carbon benefits, this can be done by loans and contracts through financial institutions, without giving credit for carbon benefits that are only promised. Caution should be used in subsidizing such systems, however, as they can potentially distort the reasons for which the carbon-accounting system was established.

One cannot logically expect to receive the financial benefits immediately from mitigation measures if the benefits for climate only accrue over many years. If one invests money by putting it in a savings account for ten years, one only receives interest at the end of each interest period; the bank does not offer to pay all of the interest for the ten-year period on day one, in exchange for a promise that you will leave the principal in the account for ten years. Yet, this is the way C accounting is normally done for fossil fuel emission reductions. The damage that emitting one ton of C to the atmosphere causes occurs over the course of many years, depending on the quantity of carbon remaining in the atmosphere at each point in time, the amount of radiation flux this impedes, and the resulting climatic impacts. Conversely, the benefit of not emitting a given ton of C accrues in the same way.

If avoided fossil fuel emissions are to be compared fairly with carbon sequestration from forestry projects, the timing of the carbon crediting should reflect the time that each option produces benefits for the atmosphere. It would be unfair to give full immediate credit for the avoided fossil fuel emission because of the certainty that its atmospheric benefit will not be reversed, while making the sequestration project wait to receive its credit in parcels after the terrestrial carbon stocks have been created, held and verified. The differences between fossil fuel emissions reduction and forest-sector mitigation measures in terms of the timing of benefits should not be confounded with the differences between these measures in terms of certainty. Adjustment for uncertainty can be incorporated into C accounting if desired (Noble et al. 2000), although caution is indicated in the level of certainty demanded (Fearnside 2000). The potential inequality in the treatment of timing

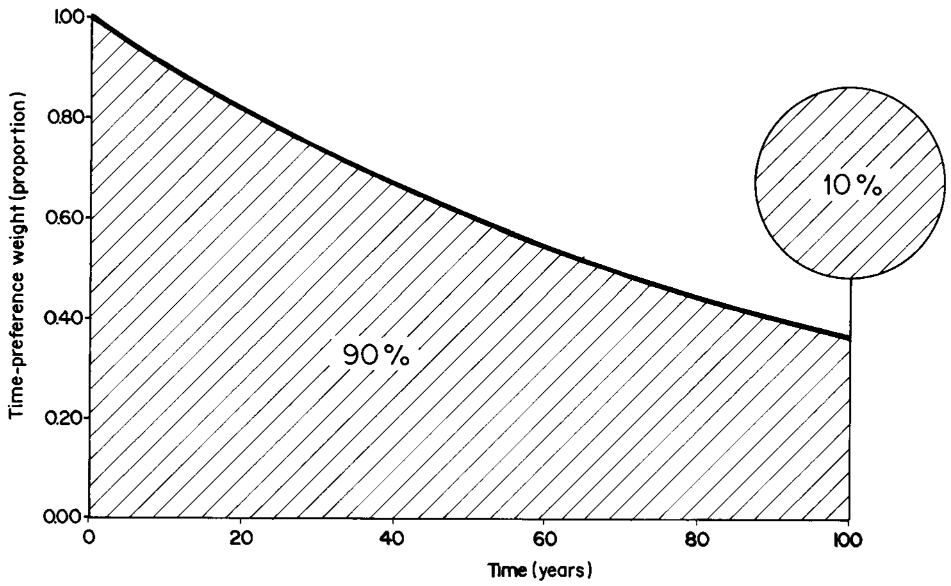

Figure 4. A possible mechanism to transfer a given proportion of decision-making weight to the period beyond the end of the time horizon. In this example, 10% of the total weight, represented by the area in the 'bubble' at the right-hand end of the curve, is passed to the subsequent century.

could be addressed by crediting the avoided fossil fuel emission on the same basis: as small parcels extended over a 100-year time frame.

While the mechanism of granting carbon credit in small parcels over many years would solve the problem of unequal treatment for the two classes of mitigation measures (energy sector vs. biotic 'sinks'), it would also have the undesirable effect of making all mitigation less financially attractive. One option for dealing with this is to simply grant the carbon credit for all options at the outset. This would negate some of the advantages of ton-year accounting for biotic sinks (the effect of ton-year accounting in reducing the need for long-term liabilities and avoiding potential objections to mitigation projects on the grounds that they infringe sovereignty by requiring countries to promise to maintain specific land uses for long periods or even permanently). Another option would be to grant carbon credit over time, but to create a futures market that would pay financial rewards at the outset. Avoided fossil fuel emissions would receive a (deserved) advantage in such a market because of the certainty that the promised carbon credit will, in fact, accrue.

6. Beyond the 100-Year Time Horizon

One can devise ways to deal with the interests of generations ‘after 100 years’ by assigning them a fixed amount of weight in decision-making. This weight can be represented as a discrete block, as if it were at a single point in time – not as the long tail of a negative exponential distribution. In the example in Figure 4, 10% of the total weight is given to the period beyond the 100-year time horizon. This 10% is represented by the bubble at the right-hand side of the graph. At the end of the 100-years, the 10% weight that remains could then be allocated over the following century following the same system, including the 10% transfer to the following century. However, from the point of view of accounting being done now, only the first century plus the ‘bubble’ would be considered (i.e., Figure 4).

7. Conclusion

Some decision on time horizon is inevitable. It is an illusion to imagine that one can avoid choosing a time horizon and give consideration to an infinite period, even if discounting decreases the weight applied to the long-term future. Applying either very short or very long time horizons can create perversities for decision-making. A variety of arguments converge on a value of around 100 years as a wise choice, in addition to the perhaps coincidental choice of a 100-year time horizon that has already been made by the Kyoto Protocol for global warming potentials of the different gases.

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