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Project-based greenhouse-gas accounting: guiding principles with a focus on baselines and additionality☆

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Abstract

Implementation of some of the articles of the Kyoto Protocol will require rules for accounting and for defining baselines against which reduction of greenhouse-gas emissions, or enhancement of greenhouse-gas removals, are to be measured. Project accounting needs to provide incentives to ensure that the objective of the United Nations Framework Convention on Climate Change (UNFCCC) is served and that the interests of all participating parties are respected. To establish the emission reduction achievements of activities is complex as it is inherently very difficult to define the counterfatctuel baseline. Here, we articulate four basic principles — accuracy, comprehensiveness, conservativeness and practicability — that can be used to guide the construction of baselines for greenhouse-gas mitigation projects. The overall aim is to have accurate, comprehensive, and conservative baselines; but this aim needs to be balanced to yield baselines that are as simple as possible, can be practically implemented, and provide incentives to fulfill the ultimate objective of the UNFCCC.

Keywords: Baselines; Greenhouse-gas mitigation; Guiding principles

1. Introduction

The ultimate objective of Article 2 in the United Nations' Framework Convention on Climate Change (UNFCCC, 1992) is to achieve "stabilization of greenhouse-gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner".

The UNFCCC obliges the Parties to the Convention to inventory and report their anthropogenic emissions by sources and removals by sinks of greenhouse gases (hereafter simply referred to as net emission of greenhouse gases). At the Third Conference of the Parties to the UNFCCC (1997 in Kyoto, Japan) the parties agreed to "quantified emission limitation or reduction commitments" for those 38 developed countries, or countries with an economy in transition, listed in Annex B to the Kyoto Protocol (UNFCCC, 1997). The protocol does not suggest emission reduction targets for non-Annex B countries.

Ratification of the Kyoto Protocol would put in place a set of mechanisms assumed to facilitate the reduction in net greenhouse-gas emissions through a credit/debit system for activities in a potentially wide range of economic sectors and for cross-border transactions. Examples of

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these mechanisms are joint implementation activities between Annex B countries (Article 6); joint activities[1] between Annex B and non-Annex B countries (Article 12); and emission trading between Annex B countries (Article 17).

Although the Kyoto Protocol prescribes targets for reduction of greenhouse-gas emissions in terms of the 1990 levels of emissions, some articles of the Protocol call for baselines against which the achievements of specific activities can be compared.

Implementation of Articles 6 and 12 clearly requires baselines, while implementation of Article 3.4 ("… additional human-induced activities related to changes in greenhouse-gas emissions and removals in the agricultural soil and land-use change and forestry categories") may require baselines. Baselines may also be required for within-country guidance to motivate or allocate compliance with national-level commitments. The concept of 'additionality' is explicitly stated in Articles 6 and 12 where credit is limited to reductions of emissions that are additional to any that would occur in the absence of project activities. Determining additionality is inextricably linked to baselines, as the baseline is the reference to judge if an activity is additional.[2]

The role of baselines differs between the various articles. Projects under Article 6 are generally a 'zero-sum game', reducing the assigned amount of one country while increasing the assigned amount of another to the same extent. In contrast, projects undertaken under Article 12 have an impact on the total obligation of Annex B countries, because the obligation of these countries is reduced as a result of emission reductions in non-Annex B countries. Thus, the baselines play a more important role in Article 12 projects.

To accommodate the accounting needs of different activities, we adopt a general definition of 'baseline' as "*a path through time that an accounting variable would have followed in the absence of a specific greenhouse-gas mitigation activity*". It is, of course, impossible to know the exact route of the path not followed so the challenge is, for each project, to provide a credible description of its most probable path.

Different types of baselines have been discussed. Ellis and Bosi (1999) have discussed project-specific, multi-project and hybrid baselines. According to them, a project-specific baseline is "determined case-by-case basis with project-specific measurements or assumptions for all key parameters"; a multi-project baseline is "equivalent to an 'activity standard' or policy target that is aggregated at a certain level"; hybrid baselines are "determined in hybrid fashion, with some key parameters project-specific and others standardized". Multi-project baselines include benchmarking, default, sectoral, and technology-matrix baseline approaches. A benchmarking baseline is developed from benchmarking rules that could be based on historic emission intensity of a sector or projected intensities. A default baseline is defined from a narrow category of projects while a sectoral baseline is based on historic or predicted sector intensity emissions. A technology-matrix baseline is based on pre-defined technologies present in the region (Puhl, 1998). Another type is top-down baselines that could be based on aggregated country-specific data. A baseline could also be static or dynamic. A static baseline is, in contrast to a dynamic baseline, at a constant level throughout the credit time of the project. Even if a different type of baseline could be used, with a varied standardization and aggregation, a baseline must to some degree be project specific — at least the magnitude of the project must be given (area of afforestation, capacity of biomass-fired plant, etc).

Here, we articulate four basic principles — accuracy, comprehensiveness, conservativeness and practicability — that can be used to guide the construction of baselines for greenhouse-gas mitigation projects. We point out that there are many challenges in constructing useful baselines but that a conscientious application of these principles will help to assure appropriate credits to projects that serve the objectives of the UNFCCC.

2. Basic principles for baselines

Apps et al. (1997) have suggested carbon accounting principles for Land-Use Change and Forestry (LUCF) projects and the Terrestrial Carbon Working Group of IGBP (IGBP, 1998) has discussed carbon accounting methodologies for LUCF. There remains, however, the difficult task of establishing activity-specific reference levels (baselines) against which credits and debits can be allocated. As a number of authors have pointed out (e.g. Chomitz, 1998; Ellis, 1999a; Tipper, 1998), selection of the baseline can significantly affect the credit allocation resulting from a project. Recognizing that it will be exceedingly difficult to establish suitable baselines for many emission reduction projects and acknowledging the rather comprehensive literature on, or linked to, the topic (see e.g. Andrasko, 1997; Baumert, 1999; Begg *et al.*, 1998; CCAP, 1998a, b; Chomitz, 1998; Ellis, 1999a, b; Ellis and Bosi, 1999; Friedman, 1999; Hamvey, 1998;

[1] Defined as a clean development mechanism in the Kyoto Protocol.

[2] The US Initiative on Joint Implementation (USIJI) has divided the concept in three components: emission, financial and program additionality. Emission additionality means that a project must clearly demonstrate greenhouse-gas emission reduction above the reference (baseline). Financial additionality means that project developers must demonstrate that the project is independent of (in addition to) federal and multilateral funds and programs. Program additionality means that the project was initiated as a result of the USIJI program (e. g. the economic benefits of the project hindered an implementation without the USIJI program). (Dixon, 1999). We focus on emission additionality.

Hargrave *et al.*, 1999; Jepma, 1999; Matsuo, 1999; Mendis, 1999; Meyers, 1999; Michaelowa, 1998; Michaelowa and Dutschke, 1999; Michaelowa and Schmidt, 1997; OECD, 1998; Puhl, 1998; Rentz, 1998; Swisher, 1998; Takedahara, 1999; Tipper, 1998; Trexler and Gibbons, 1999; UNFCCC, 1998; Vine and Sathaye, 1999; Vine *et al.*, 1999), we suggest that there are a few basic principles that could be used to guide the selection of appropriate baselines.

Our goal here is to articulate a set of basic principles that can guide the development of scientifically sound and technically useful baselines for greenhouse-gas emissions mitigation. We suggest that baselines only have meaning within the broad context of the greenhouse-gas accounting system employed. Although our main interest is on biomass-related activities, and in particular bioenergy,[3] where both changes in technical and biotic systems have to be considered, the principles suggested here should be broadly applicable across all types of mitigation projects and activities. Although Article 12 of the Kyoto Protocol does not explicitly state whether or not activities that sequester carbon in the biosphere will qualify under the clean development mechanism, our discussion includes the principles that would need to govern the development of baselines if such projects are ultimately accepted.

We recognize that there may be basic principles, such as equity, that transcend the scientific and technical ones, but these are beyond the scope of this technical paper. A primary consideration in the selection of baselines must be their efficacy in helping to achieve the ultimate objective of the UNFCCC, i.e. stabilization of greenhouse-gas concentrations in the atmosphere.

The first three principles discussed below suggest that baselines should be accurate, comprehensive, and conservative. These principles must be balanced against the fourth principle, practicability, by acknowledging that excessively stringent application of the first principles can discourage implementation of projects and activities that may serve the objective of mitigating the increasing atmospheric concentration of greenhouse gases.

The net greenhouse-gas emission reduction of a mitigation project is the difference between the baseline and the project net emissions. Thus, to enable an evaluation of mitigation projects, the project net greenhouse-gas emissions must also be estimated. Such estimation is less complex than the baseline estimation, as the project path of emission is determined by the mitigation activities, and is not explicitly dealt with here. The principles elaborated here for baselines, however, could at least partly be used to guide such an estimation.

[3] The link between technical and biotic systems is unique for bioenergy mitigation activities.

3. Accuracy

A baseline should provide an accurate description of the path of net emissions in the absence of a purposeful intervention. Had not a project been implemented, what would have been the net emissions of greenhouse gases?

We suggest that an accurate enumeration of the full set of net emissions in the baseline is more critical than a precise statement of any portion of the emissions. Precision can be refined and improved once an accurate description is provided. We recognize that data and expertise may constrain the desired accounting — and that we might be obliged to accept this, at least in an initial phase of implementation of the different mechanisms. This stresses that the system description should be as simple as possible while still accommodating the principles.

It is often perceived that a baseline is a static scenario (determined before the start of a project) against which the performance of a mitigation project is to be measured. However, to avoid unexpected outcomes that run counter to the UNFCCC objectives, the baseline could be amenable to updating on some regular basis or if it is discovered that there is some error or misconception in the input to the baseline estimates. This is especially important for projects with a long duration as it is difficult to provide an accurate description of the path-not-followed over longer periods. One might even envision cases where large investments in a mitigation project are stranded by improvements that result in better alternatives. In such instances a credible baseline may eventually have lower net emissions than the ongoing mitigation project and the assumed reduction of emissions could not be verified. The lifetime of investments should be balanced against technology improvements. A technology with a short lifetime could be a better choice than a technology with a long lifetime, at least if large technology improvements are expected. From a practical point of view, however, the baseline cannot be subject to continual revision; it must have sufficient definition that the project is not continually measured against a weakly defined moving target.

Technology improves in incremental ways even in the absence of a mitigation project. Hence, a realistic baseline might converge toward the project technology over time. New technologies will replace old ones, though perhaps at a slower rate than might be achieved through the implementation of mitigating activities. The technologies available and their progress may also vary between countries as the availability and progress may depend on the socioeconomic conditions of the countries considered. Some baselines may not depend on existing investments and new investments may be required at a specific time-point, e.g. investments in a new power plant due to an expanding load. Here, the baseline depends on the technologies available at that time-point.

It may be possible to define (in advance) a baseline in the way that a scientific experiment would define a control (reference) group. In this way, measurement and verification would evaluate both the treatment and the control and would credit emission reductions according to the difference between the two. This latter approach might be especially appropriate for energy-efficiency programs and the approach has already been used broadly for demand-side management projects (Chomitz, 1998). The project scale, however, may limit the application of a control group because large-scale projects may have an influence on the whole sector studied, e.g. retrofits to a large power plant may influence the total national power supply, creating new baseline circumstances.

A baseline for a biotic project may have to consider stochastic changes in variables that have low probability and are beyond the control of the participants, such as damage by weather or insect outbreaks. Control treatments may be less useful here, as stochastic variables with low probability require a large number of independent control and treatment areas. More generalized values based on established and accepted research results may have to be used instead. The stochastic changes in variables will also vary between different biotic projects. Projects located in humid areas and in areas largely surrounded by non-forest areas might be less affected, e.g. by fire, than those located in large un-managed forest areas in boreal regions.

4. Comprehensiveness

An ideal baseline should be comprehensive in the sense that it captures all important consequences of alternative, "without project" activities. Thus, the baseline should also consider secondary effects outside of the immediate project. For example, in a forest protection project we should consider if wood fuel was produced from that forest earlier and if the wood fuel was used to displace fossil fuels. The project case should provide at least the same goods and services as the baseline case. This means that we have to carefully define the system boundaries (both in space and in time) for the system that will be affected by a mitigation project or activity. Some important questions hence arise about leakage across the system boundaries and the extent to which specific project activities have impacts in the larger socio-economic system.

4.1. Spatial boundaries

Accounting for a mitigation project should ideally demonstrate that all significant impacts on net greenhouse-gas balances are included within the defined system boundaries. Leakage across system boundaries of projects carried out in non-Annex B countries but credited in Annex B countries is especially important to consider because such leakage is not captured by the emission limitations of Annex B countries. If protection of one area of forest results in accelerated clearing of forests elsewhere, in a non-Annex B country, this effect needs to be captured in the evaluation of the project against its baseline. In practice, however, it may be very difficult or even impossible to cover this on a project level. Thus, such leakage may have to be considered on a national level. Still, leakage between non-Annex B countries is not easily included.

Accounting systems should be equally appropriate across a range of spatial scales in order to avoid unintended artifacts. With international commitments being made at the national level, accounting at the project level should be such that it is compatible with national level reporting. The selection of a baseline may influence the perceived benefits at these various scales differently. Thus, what is good for a specific project operator may not satisfy the national objective, which in turn may not be the optimum solution from the global perspective. Recognition and reconciliation of these scale-dependent issues need to be a part of the creation and selection of baselines.

Some of the difficulty of project baselines can be avoided with the use of national or regional (top-down) baselines. Baselines at this scale require, however, some forecast of national or regional greenhouse-gas emission levels and hence of the development of the energy (or other) system. Thus, such baselines of greenhouse-gas emissions will depend on the availability and cost of resources and technologies and on policy measures used to shape energy systems, economic growth, and the structure of the economy — all of which change with time. While these are admittedly obstacles to establishing top-down baselines, some observers suggest that national (regional) baselines are needed because they may capture leakage between sectors or between project and non-project activities.

4.2. Temporal boundaries

Mitigation measures can affect greenhouse-gas emissions beyond the temporal boundaries of a project as well as beyond its spatial boundaries. Reductions of net carbon emissions (for which credits are received) can potentially be reversed at later times, with an associated increase in net emissions. In setting baselines we need to recognize the temporal characteristics of mitigation measures. At least two basic circumstances can be envisioned in which temporal boundaries play an important role: (i) the baseline converges on the project path or (ii) the project path converges on the baseline.

(i) The carbon mitigation achievements of a project can get smaller over time as the baseline of net emissions moves closer to or even below the emissions of the project path. In an energy-efficiency project, e.g. some years after the project initiation even greater improvements in energy efficiency might become a general requirement, e.g. due to new standards. In this case, project operators could be tempted to choose a project duration that credits the project even if technology progress has outplayed the additionality of the project. Such a development has to be considered in the design of a baseline or the baseline has to be revised. Another alternative is to choose a short duration for the project credit.

(ii) The project path of net emissions may converge on, or even surpass, that of the baseline and thus the project may lose its additionality. The carbon mitigation achievements of a project may, e.g. be subsequently lost to fire, deforestation or harvest after the carbon credits were received. This is not going to happen for avoided fossil-fuel emissions because of the very long residence time of the fossil-fuel pools and the permanence of avoided fossil-fuel emissions. For biotic mitigation projects, however, this does present potential problems, as the carbon turnover times are much shorter and emissions offset by sequestration in such reservoirs can have a temporary character (IGBP, 1998). This suggests that we need to recognize that the reductions in net emissions depend in part on the residence time of the reservoir in which carbon is sequestered. For afforestation or reforestation projects, as well as for projects aiming to decrease deforestation, the accounting system must be able to assess the post-project fate of any carbon stock. To do otherwise at the project scale could potentially undo the global-scale benefits to the atmosphere. Here, project operators could be tempted to choose the project duration such that benefits occur within the project duration, but net losses are beyond the temporal boundary. Temporal boundaries should be extended far enough into the future to avoid such effects. Safeguards might also be designed in parts of the accounting system not directly linked to baselines to secure the objective of the UNFCCC. The risks of temporal leakage of sequestered carbon could, e.g. be reduced if the accounting system ensured that at least one of the involved parties (with commitments under the Kyoto Protocol) is responsible for continued stewardship of sequestered carbon. Concepts for minimizing impacts in the absence of continued stewardship include insurance coverage for credited carbon stocks, reduced credit for more vulnerable carbon stocks, or diversification of the project portfolio.

4.3. Rebound effects

Another aspect of comprehensiveness is that mitigation projects might result in reduced commitment to measures, both in the host and investor country, that would have been carried out otherwise to reduce net greenhouse-gas emissions. Examples of such measures include reduced fossil-fuel subsidies, carbon taxes, and fostered innovation in renewable energy technologies and energy efficiency. In setting baseline such effects should be considered. Also, the supply–demand relationship can be impacted through mitigation projects. A project to improve energy efficiency may lead to lower-energy demand and lower-energy costs, and result in an increase of energy services, e.g. lower-fuel consumption per km can lead to longer distances traveled. Assume a project scenario that involves a fleet of cars travelling 10 000 km a year and with a fuel consumption reduced 50% compared with the baseline. The specific fuel consumption in the counter-factual baseline could be determined through comparison of the fleet affected by the project with the rest of the fleet. Similarly, a change in driving behavior due to lower operating cost per km could be considered by means of such a comparison.

Another issue is the flow of capital, through mitigation projects, from entities with excess emissions to entities that reduce their emissions. The availability of new capital can have effects on the local economy and thereby increase energy use and greenhouse-gas emissions. The effects of capital infusion on the net greenhouse-gas emissions will probably vary between different projects and could be less important in some project types, e.g. solar electricity in rural areas, than in others, e.g. payments to land owners for changes in land-management practices.

4.4. Other objectives

Greenhouse-gas mitigation projects that run counter to other goals — like prevention of acidification, prevention of soil erosion, protection of biodiversity, and sustainable development of local economies — are less likely to be implemented. In contrast, projects that contribute to local welfare — including, e.g. job creation, transfer of technology and know-how, and capacity building — and are seen to provide multiple benefits will be more likely to succeed. Ideally, projects should be designed to achieve multiple benefits where the climate benefit is but one of several positive outcomes. The local benefits of a project may be so high that no greenhouse-gas reduction credits should be awarded because the baseline should have dictated that the project be undertaken even in the absence of emission reduction credits. Thus, baselines and additionality analysis will need to acknowledge objectives other than greenhouse-gas reduction.

5. Conservativeness

Activities that involve selling and buying of net emission reductions will be evaluated in financial terms, and a large reduction of net emissions will improve the financial terms of projects. Larger reductions will benefit the seller (as her/his project will be more profitable) and the buyer (as her/his commitment will be more easily and cheaply fulfilled). Thus, there are strong incentives for both sellers and buyers to overestimate the net emission reduction by establishing artificially high baselines and baselines that are easy to manipulate (Begg *et al.*, 1998; Chomitz, 1998; Jepma, 1999; Michaelowa, 1998). The opportunity to trade reductions may even affect projects that would have been carried out in the ordinary course of business. Here, baselines may be selected that would give such projects an appearance of additionality. Similarly, the large uncertainty of several parameters influencing the financial terms (e.g. discount rate, lifetime of activity and value of local environmental impact) may lead to manipulation of project evaluation (Chomitz, 1998). Finally, the overall evaluation of a project will depend on national policies, which could change during the duration of a project. These factors all add to the difficulty of selecting appropriate baselines and call for conservativeness, i.e. that greenhouse-gas credits should not be overestimated due to uncertainties.

It should be shown with sufficient confidence that the credits for emission reduction do not exceed the improvements for the global system. Thus, the choice of baseline should tend to result in conservative greenhouse-gas credits. A conservative accounting should make involved parties responsible for demonstrating that the chosen baseline results in claimed credits that are less than or equal to the mitigation benefits that actually occur. Fig. 1 shows how an artificially high baseline — a baseline that results in an overestimation of greenhouse-gas credits — could be used to inflate the estimation of a project's impact on the net emissions of greenhouse gases and, hence, on the credit for the activity. The mitigation project in Fig. 1 could be a fuel-switching project, e.g. switching from a coal-fired to a natural gas-fired power plant. If the fuel-switching project had not been implemented, the coal-fired plant might have been retrofitted later, resulting in significantly lower net greenhouse-gas emission compared with the net emissions at the time the fuel-switching project was started. A conservative baseline should be chosen. The area between the "true" and the conservative baselines (buffer project credit) may be credited if it is shown during the project that the greenhouse-gas reduction includes the reduction reflected in this area, see also section "Partial accounting". Similarly, measurements during the project may allow the calculated path of project net emissions to converge on the true path of project net emissions.

5.1. Partial accounting

For reasons of convenience, simplicity, cost, or small numbers, some components of the total system are likely to be omitted in any practical system. If the conservative principle is adopted and it is demonstrated that the omitted components are not a net source of greenhouse-gas emissions, use of a partial accounting system would not be in conflict with the objective of the UNFCCC. Similarly, in cases where the baseline is highly uncertain or where the sequestered carbon is believed to be vulnerable to loss, it might be appropriate to claim only a predefined share of the estimated credits.[4] The predefined share could be the area between the conservative baseline and the "calculated" path of project net emission while the area between the conservative and the "true" baseline could be the buffer project credit (Fig. 1). This buffer credit (or parts of it) might be added to the project if it is shown that the greenhouse-gas reduction includes the reduction reflected in the buffer area (e.g. due to reduced uncertainties during the project). The high costs to reduce uncertainties in the estimated project emissions is reflected in the difference between true and calculated project net emissions in Fig. 1. In practice, the "true" baseline would also be replaced with a calculated baseline where the cost to reduce the uncertainties in baseline settings could be balanced against the benefits of a more precisely defined baseline. Finally, for ease of implementation, a default, but clearly conservative baseline could probably be used temporarily, without contravening the objectives of the UNFCCC, until a more justifiable, project-specific baseline is developed.

5.2. Project portfolios and multiple baselines

A portfolio of different types of mitigation projects with different types and levels of uncertainties can decrease the overall risk compared with a single project. Multiple baselines might be used to indicate the level of uncertainties and to assess the risk for a single project. These multiple baselines might include a range from optimistic to pessimistic scenarios. To be conservative, the initial greenhouse-gas accounting could be based on the pessimistic scenario. If it is possible to show, during the project, that the greenhouse-gas reduction is actually greater, then this enhanced level of reduction may be credited.

5.3. Windfall reductions

An issue that arises is whether baselines should be set to avoid awarding credits for fortuitous or windfall reductions that have not been a direct result of project activities (e.g. beneficial effects of CO_2 fertilization, climate-enhanced growth of forests, economic downturn

[4] Meyers (1999) has suggested to judge additionality in terms of probability where carbon credits are scaled as a function of estimated probability of additionality.

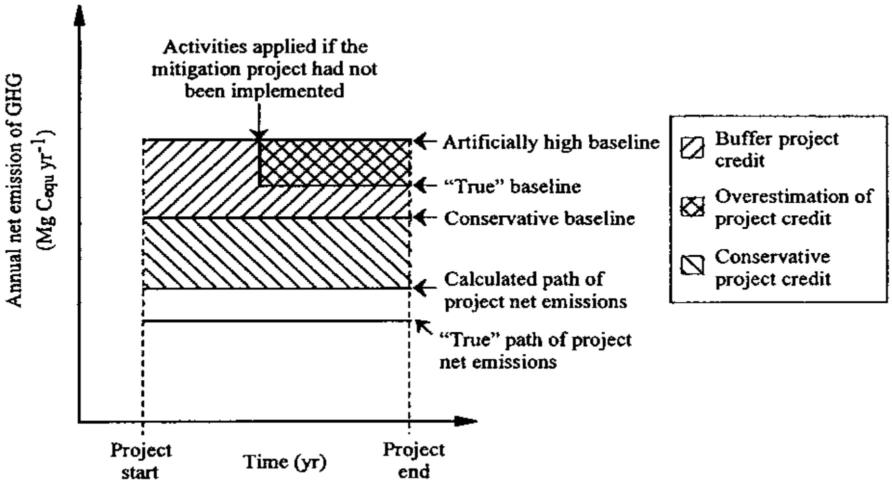

Fig. 1. Activity scale accounting showing the notional relationship between artificially high, "true" and conservative baselines as well as calculated and "true" project net emission paths. An artificially high baseline results in an overestimated greenhouse-gas credit.

leading to lower emissions). Similarly, should debits be allocated for unavoidable shortfalls that are beyond project level control (e.g. disturbances exacerbated by climate change)? The concept of additionality suggests there should be neither credits nor debits for such events. Thus, to ensure that only the improvements due to "direct, human-induced activities" are counted and credited, the baseline should include such windfall effects to the extent possible. For example, carbon dioxide fertilization could be included in the baseline by means of a control plot and thus the fertilization effects would cancel out in the comparison of project and baseline emissions. A change in energy output from an energy conversion plant, e.g. due to reduced demand, would have to be factored into the baseline as well.

6. Practicability

From the UNFCCC perspective, the rules for definition of baselines should favor projects that yield real, measurable, and verifiable long-term reduction in net emissions but discourage projects that do not. Project baselines should be verifiable so that they can be accepted not only by the project host and project investor, but also by an impartial third party or a body that oversees the project in the interest of the UNFCCC. And yet, the rules for setting baselines need to be broadly practical and simple enough to be applicable in a variety of places and circumstances and by a large enough group of people, while not being so simple that the principles of accuracy, comprehensiveness, and conservativeness are violated.

It should be acknowledged that there is effectively a trade-off between practicability and the other principles. By being conservative one avoids emission credits for projects that do not provide emission reductions that are additional to what have occurred at the absence of a project, type II error.[5] On the other hand, the principle of conservativeness, if applied too strictly, can prevent worthwhile projects from being carried out, type I error[6] (Chomitz, 1998). Similarly, excessive demands for accuracy or comprehensiveness could discourage worthwhile projects or raise the cost of project management to the point that discourages implementation. Since the "true path" of net emissions without the project will never be exactly known, one can only define a likely path. It is not always practicable to define a project baseline that is below the true "without-project-path" with 100% certainty, because then the type I error would be high and projects that would have provided net greenhouse-gas reductions would not be implemented. Therefore, when determining and trying to minimize the uncertainty in estimating the "true baseline path" of emissions, it is important to concentrate on those parameters that have great uncertainty and to which the estimated baseline is most sensitive.

A standardization of project baseline settings based on clarity, transparency and comparability between similar types of mitigation projects may increase the practicability as the transaction costs and the possibilities to inflate greenhouse-gas credits are reduced (Ellis, 1999a). The design of standardization, however, should not reduce the project baseline accuracy.

Alternatives to a project-specific baseline have been discussed, e.g. sector-averaged, benchmarking, and technology-matrix baselines (CCAP, 1998b; Friedman, 1999; Hargrave *et al.*, 1999; Jepma, 1999; Puhl, 1998). One

[5] Certifying non-additional projects.

[6] Denying certification to genuinely additional projects.

important drawback of these approaches is that site-specific circumstances of the projects are not considered in the baseline settings. The Activities Implemented Jointly projects have shown that baseline emissions are highly project- and site-specific (Ellis, 1999a, b). Still, one argument for not using project baselines is high transaction costs. The project transaction costs will be reduced if sector-averaged baselines, benchmarking, and technology matrix or similar approaches are used. Upstream transaction costs for these approaches: i.e. establishing, administering and revising costs; might outweigh the reduced project transaction costs (Hargrave *et al.*, 1999; Meyers, 1999). The transaction costs for different approaches appear to depend on the type and scale of project.

There will be projects where it is not possible to verify greenhouse-gas benefits in a cost-effective manner; practicability will not always be achievable. The challenge is to minimize credits to projects that do not provide additionality (type II error), while at the same time keeping a reasonable level of practicability and thus avoiding extreme impacts on the magnitude and frequency of worthwhile projects (type I error).

7. Application of principles to some example cases

The four principles outlined above are discussed in relation to five different types of mitigation projects: improved end-use energy efficiency, fuel switching, use of bioenergy, afforestation, and avoiding deforestation.

7.1. Improved end-use energy efficiency

An energy system consists of a chain of subsystems where a primary energy carrier is transformed and transported to deliver required energy services. Typical subsystems are recovery of the primary energy source, fuel refining, transportation of refined fuel, conversion of refined fuel to secondary energy carriers, and distribution of these energy carriers to end-users. End-use energy-efficiency measures could have an impact on all of these steps and, ideally, all upstream net greenhouse-gas emissions, accounted from the end-user, should be considered. However, it might not be practical to consider all minor upstream emissions. This is in accordance with the conservative principle. But, the magnitude of conservativeness should not discourage implementation of worthwhile projects (practicability). Sufficient net emission reductions should be considered to secure implementation of worthwhile projects.

The impact of energy-efficiency activities on the net greenhouse-gas emissions can have very different temporal and spatial scales. The lifetime of an energy-efficient light bulb may be a couple of years, affecting the light in one room, while the lifetime of an energy-efficient infrastructure are decades, affecting the energy use in a whole region. Some activities will also have an impact on greenhouse-gas emissions outside the energy sector. The complexity of constructing the baseline for an energy-efficiency activity will strongly depend on the type of activity considered.

As an example, an accurate estimate of electricity savings when changing to energy-efficient light bulbs appears not to a problem, if the utilization time is known. The savings in lighting, however, could have an impact on cooling and heating demands in buildings. That should be considered in a comprehensive evaluation, as well as differences during production of the different types of light bulbs. In many cases such changes will have a small impact on the overall result and conservative default values may be practical.

An energy-efficiency program might initiate the change to energy-efficient light bulbs. In such programs free riders and positive project spillover can influence the net energy savings. Free riders are participants in a program that would have changed to energy-efficient light bulbs independent of the program. Their savings are not additional and free riders should be considered in a comprehensive baseline. This can be done by interviews and by using a control group to secure an accurate estimate. Positive project spillover is the impact of the project outside of the target of the project. A project participant might implement efficiency measures beyond the target or a non-participant might implement energy-efficiency measures as a result of the program. Neglecting spillover will not violate the conservative principle.

The greenhouse-gas reductions from electricity savings will depend on how the electricity is produced. The average electricity production might differ significantly from the marginal production: daily, weekly and seasonally. Ideally, the electricity savings should be matched against the marginal changes they initiate in the electricity production system. Such estimates are complicated and conservative default values might be used instead. In a deregulated market the issue will be more complicated. Here electricity could be bought on a short-term basis from utilities that might have very different production systems, e.g. hydroelectric or coal-fired plants. Some power plants might even be located abroad. Thus, the greenhouse-gas reduction from electricity savings could vary significantly with the choice of utility and several different utilities might be employed during the lifetime of a mitigation project. The use of default values based on the electricity supplier with the lowest greenhouse-gas emissions, however, will probably not violate the conservative or practicability principles. The default values should be revised as the emissions change, i.e. if the regional production capacity is renewed, performance of the new power plants should be considered.

Energy savings from material switching, e.g. in building construction, are more difficult to estimate than energy savings from single energy-efficiency measures. An accurate estimate of the difference in energy use between different construction materials may be difficult due to lack of data or uncertain data (Börjesson and Gustavsson, 2000). In a comprehensive analysis, all products and process steps that differ in greenhouse-gas implications should be considered. The choice of materials could also have a significant impact on greenhouse gases outside of the energy sector. Examples are greenhouse-gas implications of the chemical process of cement production and of disposal of wood waste after demolition. Export and import of products could also complicate the estimate. If materials are imported the change in emissions will occur in another country. Thus, uncertain data and the complex issues call for a comprehensive analysis and a conservative approach. The magnitude of conservativeness should, however, be weighed against possible losses in net emission reductions if worthwhile projects are not implemented (practicability).

7.2. *Fuel switching*

In the circumstance of projects involving fuel switching, e.g. from coal to natural gas, two main cases have to be distinguished: (i) Retrofit or upgrade of an existing plant to use a different fuel, and (ii) investment for a new plant with a decision to be made between different types of fuel. In either case the baseline and the project have to provide the same level of energy services. In the second case the power plant is likely to make use of the best available technology, even though based on different fuels (Schlamadinger *et al.*, 1997).

In the case of a new power plant, it will be difficult to determine what kind of plant would have been chosen in absence of the project, although the date of initiation of the baseline investment is clearly determined. In the case of a retrofit plant, one will exactly know the energy system that would have continued to operate without the project, but it might be difficult to know how long that plant would have continued to operate, what kind of energy system would have replaced it, and whether and how much that replacement is delayed due to the retrofit.

Comprehensiveness will require that the system boundary of the baseline includes not only the direct emissions of the reference energy system, but also its upstream emissions (such as from mining and refining the fuel). These upstream emissions can occur abroad, especially when fossil fuels are traded between countries. Omitting such upstream emissions in the baseline can be acceptable if the upstream emissions of the project case are below those of the baseline.

Some of the data needed for the establishing a baseline such as the economics, technical data and lifetimes of energy investments, are quite well known in most fuel-switching cases (but may not be available for commercial reasons). In order to set up a conservative baseline, however, one will have to consider technological development, i.e. that the replaced energy system might have been changed anyway over the course of time. One way of implementing conservativeness would be to use a dynamic baseline.

7.3. *Bioenergy*

Bioenergy projects can be seen as a special case of fuel switching, i.e. from fossil fuels to biofuels. Establishing baselines will be the same as for other for fuel-switching projects, with one important exception. Net greenhouse-gas emissions from the fuel supply could be more complicated and more difficult to estimate for biomass than for fossil fuels, and will depend on the type and management of the biomass resource. Recovering biomass fuel from biological systems could change carbon stocks in plants, plant debris, and soils; and the dynamic nature of biological systems complicates the estimation of such changes.

Here, we discuss the baseline setting for two different types of biomass resources: (i) processing and consumer-end-use waste and (ii) primary biomass from energy crops and forest plantations. A basic differences between these biomass resources is that the alternative utilization of waste, and the resulting greenhouse-gas implications, must be considered in the first category. In the second category, the alternative land use, and the greenhouse-gas implications of this land use, must be considered.

(i) *Waste for fuel*: The combustible fraction of waste from wood industries and from the end-use consumption of wood products is a suitable biofuel. When some fraction of waste, that otherwise would have been deposited in landfills, is used as fuel the amount of carbon in landfills will be lower. This limits the carbon-sink impact of the landfills but also the methane (CH_4) generation of the landfills. Methane is a greenhouse-gas about 21 times more powerful than carbon dioxide on a mass basis, if considered on a 100-year time horizon (Albritton *et al.*, 1996). A reduction of methane emissions can strongly contribute to the overall net greenhouse-gas benefit from this type of project. Methane emissions from the landfills, however, can also be controlled directly by collecting and using it as an energy source or by just burning it in torches. For comprehensiveness, the baseline should include the greenhouse-gas implication of landfill methane emissions and any effect on the carbon sink. To be on the conservative side, the methane emissions should not be overestimated and the carbon sink not underestimated. Alternatively, the wood waste could be used to produce new material, such as particle-board, or re-used in construction. Thus, there are tradeoffs with recycling projects and other waste-management projects. The tradeoffs between different ways to use wood waste have to be considered in the baseline so that the conservative principle is not violated.

(ii) *Energy crops and forest plantations*: The use of primary biomass resources, e.g. energy crops, will lead to a utilization of primary land resources. In such a case it is necessary to evaluate what would have been the use of the land without the bioenergy project — the reference land use — and what are the greenhouse-gas implications of the change in land use. It is also necessary to look at the total carbon balance of the land, not only in the biomass above ground. For example, does a change in land use change the soil carbon? The accuracy of estimating carbon pools can depend on the rotation period of the crop. The longer the rotation period, the more difficult it is to predict carbon-balance implications for a given piece of land. In some cases there may also be different risks between the project and the reference land use. The probability of fire, insects and other pests, wind, and other damage could affect the carbon pools. This change in risk may be difficult to quantify, but biomass production with similar production conditions might be used as a reference. The land use after the end of a project may also have to be considered. Has the flexibility of land use changed and will a change in flexibility have greenhouse-gas implications? Here there is a clear difference between herbaceous energy crops and forest plantations. Cultivation of herbaceous energy crops will typically not reduce the flexibility of the land use. For forest plantations, the length of the rotation period could have an impact on the flexibility. It may be easier to change the land use back to the previous use, or to a new use, if the rotation period is shorter.

In a comprehensive analysis of project emissions, greenhouse-gas emissions of the full biomass fuel cycle should be considered. This would include the emissions from fossil fuels used for planting, fertilizers, irrigation, harvesting, etc; in addition to changes in the biological carbon stocks. Intensive biomass production would provide more biomass than less-intensive production, but could require more energy inputs. It is also possible that energy inputs may be higher than calculated during project planning if, e.g. it turns out that more fertilizer or irrigation are needed than originally planned. Typically the energy inputs are a small fraction of the biomass yield, and a high yield is more important than low-energy inputs (Börjesson, 1996).

There is also a possibility for trade-off among multiple products, instead of producing only raw material for energy. Part of the stemwood might be used for bioenergy while other parts could be used for wood products. This could conserve natural or indigenous forests by reducing the overall logging demand. Biomass for energy purposes may also be part of agroforestry or silvipastural projects. These types of land use may be more advantageous, from a greenhouse-gas perspective, than using the land only for biomass production for energy.

Forest residues from felling and agricultural residues from harvesting are a large biomass resource that could play an increasingly important role in future energy systems. Here, the baseline setting is quite clear and involves leaving the residues in the field or forest. To calculate the project greenhouse-gas emissions the change in biotic carbon stocks as a result of the removal of agricultural and forest residues has to be considered. Collecting and removing of the forest residues from felling and agricultural residues from harvesting transfer carbon and nutrients (like nitrogen and base cations) from the ecosystem. Removal of these essential nutrients may have an impact on several carbon pools in addition to affecting the long-term productivity of the site. Recovering agricultural residues affects other nutrients but mainly changes the soil carbon pools. The magnitude of such a change will depend on the amount of residue produced, the fraction of residues recovered, and the turnover time of soil organic carbon fractions (Christensen and Johnston, 1997). The impact on soil carbon from harvesting forest residues appears to be small (Johnson, 1992). Generally, carbon changes in the soil pools are relatively difficult to measure due to large spatial and temporal variability. The harvesting of forest residues will change the amount of forest litter and coarse woody debris and lead to a lower carbon stock, at least over the short term. For conservatism, the development of some carbon pools might have to be considered by using default values. This conservatism, however, should not prevent worthwhile projects, and result in a continuing use of fossil fuels.

7.4. *Afforestation*

In afforestation projects, the alternative land use sets an important frame for the baseline. It may be difficult to assess carbon gains the project would provide compared to the situation without the project. Earlier projects with similar conditions could provide data to estimate potential carbon gains, but growth-and-yield tables and model studies might also be used. Forest inventories have a long tradition and could provide information, at least about stem volume and changes in stem volume (increment). This kind of information is cost effective and practical to use. From the comprehensiveness point of view, all biomass pools should be considered, but in practice it is difficult to accurately estimate and verify all pools. In a conservative approach the change in soil carbon might not be measured if it is clear that it is not decreasing. It is also crucial to consider how the afforestation will be managed after the project has ended, and who has the responsibility for the carbon sequestered.

7.5. *Avoiding deforestation*

Avoided deforestation can have a more immediate impact on the atmospheric carbon concentration than does afforestation because of the potentially large release of carbon over a short time. There are, however, some crucial issues for the setting of baselines. Can we be sure that the deforestation would have taken place without the mitigation project? Can we know that the deforestation will not be displaced to somewhere else or at a later time? There is a large potential for both spatial and temporal leakage. If the deforestation is displaced to another country not even national baselines can solve the problem. In practice, it would be difficult to know if deforestation in one area is a consequence of avoided deforestation elsewhere. Mitigation projects that identify and address the primary causes[7] (driving forces) of deforestation will reduce the risks of leakage compared with projects that serve to protect specific areas of forest.

If it is possible to verify that deforestation has been avoided, the carbon stock of the potential deforestation should be estimated as part of the baseline. It may be practical to consider only the above ground biomass, and that would be a conservative approach if the soil carbon is not increasing as a result of deforestation. Also part of the biomass from deforestation might be stored in wood products or wood might be use to displace fossil fuels. Such storage of carbon and fossil-fuel substitution should be considered in the baseline, in keeping with the principles of comprehensiveness and conservativeness.

8. Conclusion and discussion

Implementation of some of the articles of the Kyoto Protocol will require rules for accounting and for defining baselines against which reduction of net greenhouse-gas are to be measured. Baselines are clearly required for implementation of Articles 6 and 12 in the Kyoto Protocol, and may be needed for Article 3.4. Project accounting needs to provide incentives to assure that the objective of the UNFCCC is served and that the interests of all participating parties are respected.

It is inherently very difficult to define the path-not-traveled baseline and hence to establish the emission–reduction achievements of many activities. The overall aim is to have accurate, comprehensive, and conservative baselines but this aim needs to be balanced to yield baselines that are as simple as possible, can be practically implemented, and provide incentives to fulfill the ultimate objective of the UNFCCC.

Application of the principles articulated here to different types of emission–reduction projects will lead to a variety of challenges, and yet these principles provide guidance on how baselines could be constructed for projects in such a way as to be ultimately consistent with the intent of the Kyoto Protocol and the objectives of the UNFCCC. Looking at a variety of project types with these principles in mind warns where difficulties in defining baselines are likely to be encountered. Accuracy will be less of a problem for small projects, such as several energy-efficiency projects, where it is possible to define a control group. Accuracy will be a greater challenge for all projects where the march of technological progress and socioeconomic development is likely to determine the length of time for which a project provides savings with respect to the without-project baseline. Similarly, accuracy can be an issue for those projects in the biosphere with greater inherent variability and less precise measurements, where verification may be more problematic and permanence of greenhouse-gas benefits less certain. Comprehensiveness will challenge baseline definition in projects aimed at changing infrastructure, or in projects involving product substitution.

In the wake of the Kyoto Protocol, what we need is an accounting system with which to measure our achievements. A system accurate enough to define verifiable greenhouse-gas mitigation, sufficiently comprehensive to assure that gains are not eroded outside of accounting boundaries, and sufficiently conservative to assure that rewards are earned. A system that does not place obstacles so onerous that it stifles worthwhile projects and activities. A system that rewards projects and activities that are consistent with global change, and with other human goals.

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[7] Primary causes of deforestation can be an increased demand for agriculture land, timber or fuelwood. Increased agricultural yields, enhanced yields in managed forests and plantations, and improved energy efficiency of cook stoves may reduce these primary causes and thereby the potential deforestation.

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