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ECO SECURITIES

Determination of baselines and monitoring protocols for non-LUCF projects

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with contributions from
SGS

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IMPORTANT NOTE
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Section 1: Introduction

One of the most challenging aspects related to the quantification of emission reductions generated by greenhouse gas (GHG) mitigation projects is the determination of their baselines. A baseline is the future 'business-as-usual' scenario which would take place in case the project was not developed. Baselines are, by definition, counterfactual and thus based on a 'prediction' of future trends. Establishing the baseline scenario requires knowledge regarding conventional practices in the affected area, the local economic/sociological situation, wider (national, regional or even global) economic trends which may be affecting the conventional economic outputs of a project, and relevant policy parameters. The analysis must consider historical data, but also plausible future variables. There is a need, therefore, for the establishment of guidelines to guide project developers and validators in the process of elaborating a baseline in a coherent, consistent and transparent way.

Only after a baseline is determined can a project estimate its expected greenhouse gas emissions and emission reductions, and, consequently, what needs to be monitored to substantiate and confirm its emission reduction claims. Monitoring guidelines, however, are also highly dependent on the technical characteristics of different projects. Generalised rules formulated to regulate a wide range of non-LUCF (land use change & forestry) activities, consequently, need to be based on commonalities and if inappropriately set could lead to discrepancies and undesirable outcomes.

While the existing rules set by the official text and the Marrakech accords establish a series of requirements and constraints to the process of baseline setting and monitoring procedures, there is limited guidance available to project developers and validators. In other cases, the requirements are either ambiguous, enabling different interpretations, or inadequate with relation to the desired outcome of ensuring the environmental integrity of the Clean Development Mechanism (CDM). Refinement of existing definitions and further guidance are needed to ensure that the process of baseline setting and methodologies for monitoring is appropriate from a cost effectiveness and environmental integrity points of view.

The objective of this report is to establish a methodology to facilitate the process of determination of baselines for non-LUCF projects, removing a certain degree of uncertainty and enabling consistency of results across projects. This was based on a decision tree approach. Examples of the application of the decision tree are given, to illustrate its use. The report also addressed issues related to monitoring protocols for these projects. As a staring point, the study analysed the existing rules, regulations and guidance available in the Marrakech Accords and provided interpretations and, in cases, recommendations for further definitions and guidance to be pursued at the UNFCCC level.

Throughout the report, 'policy decision boxes' highlight the issues were further definitions and policy decisions need to be made. In these cases, alternative policy options are listed, their advantages and disadvantages are discussed, and the a policy recommendation is made.

While the study is relevant to most non-LUCF greenhouse gas mitigation activities, the report has focused on projects based on electricity generation (both grid connected and non-grid connected), transportation and fugitive gas capture.

This work was developed between February and June 2002 by EcoSecurities, with additional contributions by Societe Generale de Surveillance (SGS) (particularly in the section on Monitoring), as part of a contract with the UK Department for Environment, Food and Rural Affairs (DEFRA). All opinions, recommendations, and possible errors in the report are the responsibility of the authors only, and do not necessarily reflect the views or position of DEFRA or the UK government.

Section 2: Critical review of the official text

Paragraphs 44 to 52 in Decision 17/CP.7 of the Marrakech Accords contain the guidance provided by the CoP on selecting the baseline scenario against which to assess the net emissions reductions from a CDM project. Paragraphs 53 to 60 refer to the monitoring plan, which is used to collect data as the project is implemented, for subsequent verification of emissions reductions. Table 1 below lists the paragraphs and their main subject area.

These paragraphs were then classified with relation to the following categories:

- General guidance
- Project boundaries
- Data set: use of past vs future data, marginal vs existing techs
- Leakage
- Monitoring

These paragraphs are described and discussed in the following sections, and in some cases further guidance on their implementation is provided in Sections 3 and 5.

Table 1: Summary of main paras in Marrakech Accords dealing with baselines and monitoring issues.

Para. No.	Text	Subject/section
44	Baseline should be representative. All gases must be included Baseline must cover all sources within project boundary	General guidance Project boundary
45	Baselines must be transparent, conservative, and take into account uncertainty. Baseline takes into account future circumstances	General guidance Data set: past vs future data
46	Emissions in baseline scenario may rise	Past vs future data
47	CERs cannot be claimed for reductions in activity level	Past vs future data
48	Baseline methodologies: historical, economically attractive or superior technologies	Data set: marginal vs total
49	Crediting periods: 3x7 or 10 years	General guidance
50	CERs must be adjusted for leakage	Leakage
51	Definition of leakage	Leakage
52	Project boundary: all significant sources reasonably attributable to project	Project boundary
53	Monitoring plan requirements	Monitoring
54	Monitoring plan methodologies	Monitoring
56	Projects must implement monitoring plan	Monitoring
57	Revision of the monitoring plan	Monitoring

2.1. General guidance

The Marrakech Accords set out a few generic principles guiding the process of selecting the baseline scenario, as follows:

> ***Paragraph 44:*** *The baseline for a CDM project activity is the scenario that reasonably represents the anthropogenic emissions by sources in the absence of the project activity. A baseline should cover emissions from all gases, sectors, and source categories … within a project boundary. A baseline shall be deemed to reasonably represent the anthropogenic emissions by sources that would occur in the absence of the proposed project activity….*
>
> ***Paragraph 45:*** *A baseline shall be established:*
> *a) By project participants….*
> *b) In a transparent and conservative manner regarding the choice of approaches, assumptions, methodologies, parameters, data sources, key factors and additionality, and taking into account uncertainty;*
> *c) On a project-specific basis;*
> *e) Taking into account relevant national and/or sectoral policies and circumstances, such as sectoral reform initiatives, local fuel availability, power sector expansion plans and the economic situation in the project sector.*
>
> ***Paragraph 49:*** *Project participants shall select a crediting period for a proposed project activity from one of the following alternative approaches:*
> *a) A maximum of seven years which may be renewed at most two times, provided that, for each renewal, a designated operational entity determines and informs the executive board that the original project baseline is still valid or had been updated taking account of new data where applicable;*
> *b) A maximum of ten years with no option of renewal.*

One of the main points of this guidance is the need for transparent and consistent approaches for baseline determination, taking into account all gases and relevant policies and factors affecting future projections.

Given that the text does not provide any further guidance, a possible means to ensuring transparency and consistency would be for project proponents to utilize a standard methodology in which most of the subjective decisions required for baseline determination are taken in a consistent manner. This was addressed in this report (Section 3), in the form of a standardized methodology based on a decision tree process, in which all the more difficult decisions are highlighted, discussed, and a policy recommendation for the most desirable path is put forward. This approach should assist in providing more transparency and reducing uncertainty in the process of baseline determination.

Discussion on project boundaries, gases, and treatment of uncertainty are found elsewhere in the report.

2.2. Project boundaries

> ***Paragraph 44:*** *The baseline for a CDM project activity is the scenario that reasonably represents the anthropogenic emissions by sources in the absence of the project activity…. A baseline shall cover all gases, sectors and source categories listed in Annex A within the project boundary.*

> ***Paragraph 52:*** *The project boundary shall encompass all anthropogenic sources of greenhouse gases under the control of the project participants that are significant and reasonably attributable to the CDM project activity.*

Definition of project boundary is an important first step in the process of baseline determination. It is important, however, to make the distinction between project boundary and system boundary for baseline analysis (see Box 1 below).

Paragraph 52 mentions the words “reasonably attributable” and “significant”, but these are not defined anywhere else in the text. The box on Policy Decision 1 discusses a definition for “significant”, and Policy Decision 2 discusses the implications of different thresholds for “reasonably attributable”. Further discussion on the definitions of “reasonably attributable” is found in Box 2.

Box 1 : Project boundaries vs Baseline system boundaries

A common cause of misunderstanding relates to the use of the terms “project boundaries” and “system boundaries” interchangeably. In order to allow a better understanding of the Marrakech text, and the various methodologies used for baseline determination, it is important to make the distinction between these terms. In this regard:

- **project boundary** is its area of influence, where emissions could be “reasonably attributable to the project”. For instance, a project that uses biomass for electricity generation would be responsible for the emissions taking place in the plant as well as those associated with harvesting and transportation of the biomass to the plant. This is the implicit definition for the text in Para 52 of the Marrakech accords.
- **system boundary** for baseline analysis – in this case, the boundary may be much larger, since it is meant to include all potential sources of emissions that the project may be competing with or replacing. For the biomass project example, the system boundary could be a national grid, where this new source of electricity will be competing and displacing other more carbon intensive alternative sources. The issue of system boundaries is further discussed in Section 3.2.B of this report.

Policy Decision 1: How to define “significant” ?

According to the official text, all significant sources of greenhouse gas should be included in the determination of emission reductions generated by a project. The term “significant” relates to its importance in the overall amount of emission reductions generated by a project. Different approaches have been proposed:

- All gases and sources should be measured;
- For large projects (again, what is large ?), any gases whose emissions are equivalent to more than 1% of the total CO_2e emissions, and for small projects, larger than 5% (UNEP/OECD/IEA 2001);
- Any source of emissions that is smaller than the standard error of the measurement of a more significant source may not need to be measured (EcoSecurities, internal procedures);

Recommendation:

Given the impossibility of measuring every single possible source of emission possibly attributable to a project, it is recommended that some sort of threshold is determined. The approach of linking it to the standard error of a more significant source of emissions is a pragmatic one: essentially, it is worth more to improve the accuracy of the main source of emissions than to measure a relatively small source.

Policy decision 2: How to define "reasonably attributable"?

Different options have been proposed to definite what sources of emissions should be attributed to a project (see Box 2 for further discussion). The pros and cons of each choice are discussed in the table below, and a recommendation is provided.

	Advantages	Disadvantages
Including emissions from offsite sources	In some cases, can make the baseline study more conservative, thus benefiting the environmental integrity of the CDM	1. Potential for double-counting; 2. Costly; 3. Highly uncertain emissions estimates for oil and gas production activities; 4. Net emissions impact may be zero or close to zero for some direct off-site emissions. In general, the further away the activity is from the direct control of the developer, the more uncertain is the estimate of the emissions impact from the project being considered. Calculating direct off-site emissions can get complicated, for example, in the case where transport emissions are being displaced for an electricity generation project that displaces imported fossil fuels. The emissions displacement assessment should not be based on default assumptions because there may be policies in place in the country of origin of the fuel to control those emissions. Unless the baseline assessment takes into consideration local policies and measures impacting on GHG emission, the baseline analysis could overestimate the emissions displaced by the CDM project in question. In the case of displacement of oil or gas in the baseline, there will be fugitive emissions associated with oil and gas production and gas distribution. These fugitive emissions could be costly to estimate, and are highly uncertain. Information currently available suggests that 50 percent of global CH_4 emissions are emitted in Russia and Eastern Europe (IPCC, 1996). The impacts of miscalculating the emissions impact on the environmental integrity of the CDM could be significant because methane has a powerful global warming potential. Where there is substitution of one fuel for another, for example, biomass for a fossil fuel, or a cleaner fossil fuel for a dirtier one, transport emissions savings in the baseline scenario could cancel out the emissions from transport in the project scenario i.e. the displacement of transportation of fuel oil to the plant is largely or totally cancelled out by the transport of biomass.
Only direct on-site	Simplicity No potential for double counting Reduced transaction costs	In some cases it may ignore important sources of emissions, thereby under or overestimating claims
Case-by-case	Flexibility and inclusiveness. It allows project developers to evaluate the situations and use the approach most appropriate to the circumstances of the project.	If the direct-offsite emissions are quantified incorrectly, there could be a deliberate or inadvertent omission of some emission sources, misrepresenting the projects carbon claims

Recommendation:

Although the inclusion of all possible sources of emissions in the baseline could provide more complete analysis, it could also be significantly more costly and in some cases may lead to problems related to double counting. At the same time, in some cases there are important sources of emissions taking place offsite, that need to be included in the analysis. At this stage, a generic recommendation on what to include could lead to undesirable effects which cannot be anticipated. It is recommended that a case-by-case approach is adopted until there is more experience on this issue.

Box 2 : Various approaches to determine what is "reasonably attributable" to a project

According to the official text, all sources of greenhouse gas reasonably attributable to the project should be included in the determination of its emission reductions. The term "reasonably attributable", however, needs to be further defined and different proposals have been put forward. The Dutch ERU-pt programme, for instance, considers that activities one level up and one level down from the direct on-site activities could be attributed to the project. The OECD in a recent workshop (UNEP/OECD.IEA, 2001), on the other hand, suggested that only direct on-site emissions from electricity generation projects should be included in the baseline analysis.

In order to assess which of these approaches is most appropriate, or indeed, if there are other approaches that could be followed, it is useful to consider the possible direct emissions streams that there could be across different project types.

The main off-site direct emission impacts directly attributable from electricity generation projects would be:

- emissions from the transport of fuel in the baseline scenario;
- emissions from mining the fuel, for example, in the case of coal and oil, methane may be emitted;
- energy use in biomass production.

The main off-site direct emission impacts directly attributable from fuel switching projects would be:

- emissions from the transport of fuel in the baseline and project scenarios
- emissions from mining the fuel;
- emissions involved in the production process of the biomass.

The main off-site direct emission impacts directly attributable from supply-side energy efficiency projects could be:

- reduced transmission and distribution losses.

Further discussion on the pros and cons of a more or less inclusive approaches is found in the box on Policy Decision 2.

2.3. Data set: past, future, marginal, total

The Marrakech text makes a series of references to the type of data set to use, as follows:

> ***Paragraph 46:*** *The baseline may include a scenario where future anthropogenic emissions by sources are projected to rise above current levels due to the specific circumstances of the host Party.*
>
> ***Paragraph 48:*** *In choosing a baseline methodology for a project activity, project participants shall select from among the following approaches the one deemed most appropriate for the project activity:*
>
> *a) Existing actual or historical emissions; or*
> *b) Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment; or*
> *c) The average emissions of similar project activities undertaken in the previous five years, in similar social, economic, environmental and technological circumstances, and whose performance is among the top 20 percent of their category.*

The text in Paragraph 48 provides a series of choices, but actually mixes the concepts of time and technology. More specifically, options (a) and (c) refer to sets of historical data records, while option (b) and Paragraph 46 refer to projections to the future. At the same time, Paragraph 48 refers to the possibility of selecting subsets of data, such as best available technology used in the last five years (option c), least cost options (option b) or, supposedly, the average for the whole system (option a). Without further definitions, this paragraph leaves a wide range of options to the developers, but does not provide much guidance on which is the correct option to be chosen. This issue is discussed in Sections 3.2.C and 3.2.D in this report.

At the same time, Paragraph 46 acknowledges that in some cases the emissions of the baseline will increase in the future, implying that dynamic baselines could be used (i.e., taking into account changes in the baseline emissions that are expected to take place in the future).

> ***Paragraph 45:*** *A baseline shall be established:*
>
> *b) In a transparent and conservative manner regarding the choice of approaches, assumptions, methodologies, parameters, data sources, key factors and additionality, and taking into account uncertainty.*
>
> *e) Taking into account relevant national and/or sectoral policies and circumstances, such as sectoral reform initiatives, local fuel availability, power sector expansion plans and the economic situation in the project sector.*

While Paragraph 45 requires transparency in the selection of approaches and assumptions, it does not provide any guidance on how to select among various options. Without further guidance, this could lead to a wide range of discrepant approaches being used by project developers, and to confusion in relation to validation and verification of projects. In order to assist in the process of selection of approaches, assumptions, methodologies, parameters, data sources and key factors to be used for baseline determination, a decision tree was developed and presented in Section 3 of this study. Its widespread utilisation would also assist in standardising the process of baseline determination and the calculation of resulting CER claims.

> ***Paragraph 47:*** *The baseline shall be defined in such a way that CERs cannot be earned for decreases in activity level outside the project activity or due to force majeur.*

In essence, this paragraph limits the ability of a project to only claim credits for activities directly attributable to the project itself.

2.4. Leakage

> ***Paragraph 50:*** *Reductions in anthropogenic emissions by sources shall be adjusted for leakage in accordance with the monitoring and verification provisions in Paragraphs 59 and 62(f).*

> ***Paragraph 51:*** *Leakage is defined as the net change of anthropogenic emissions by sources of greenhouse gases which occurs outside the project boundary and which is measurable and attributable to the CDM project activity.*

While the text requests that leakage should be deducted from the project's CER claims, the text does not provide any further guidance on how to detect and estimate leakage. This issue is further discussed in Section 3.4 of this report.

2.5. Monitoring

> ***Paragraph 53:*** *Project participants shall include, as part of the project design document, a monitoring plan that provides for:*
>
> *a) The collection and archiving of all relevant data necessary for estimating or measuring anthropogenic emissions by sources of GHGs occurring within the project boundary during the crediting period.*
>
> *b) The collection and archiving of all relevant data necessary for determining the baseline of anthropogenic emissions by sources of GHGs occurring within the project boundary during the crediting period.*
>
> *c) The identification of all potential sources, and the collection and archiving of data on, increased anthropogenic emissions by sources of greenhouse gases outside the project boundary that are significant and reasonably attributable to the project activity during the crediting period.*
>
> *f) Procedures for the periodic calculation of the reductions of anthropogenic emissions by sources by the proposed CDM project activity, and for leakage effects.*

The paragraph above suffers from the same uncertainties as listed in the previous sections, in relation to project and system boundaries, "reasonably significant", "significant", etc., for which further guidance is also required. Further discussion on monitoring aspects is found in Section 5 of this report.

> ***Paragraph 54:*** *A monitoring plan for a proposed project activity shall be based on a previously approved monitoring methodology or a new methodology … that:*
>
> *a) Is determined by the designated operational entity as appropriate to the circumstances of the proposed project activity and has been successfully applied elsewhere;*
>
> *b) Reflects good monitoring practice appropriate to the type of project activity.*

Paragraph 54 provides some flexibility in the choice of monitoring methodologies, which, in any case should be acceptable to the designated operational entity involved in the project. This is a positive approach at this stage, in which there should be a period of exploration of possibilities and selection of successful approaches which in the future could be standardised.

> ***Paragraph 57:*** *Revision, if any, to the monitoring plan to improve its accuracy and/or completeness of information shall be justified by project participants and shall be submitted for validation to a designated operational entity.*

This paragraph refers to accuracy, but there is no guidance on what is an acceptable level of accuracy. In a way, defining minimum levels of accuracy may be too prescriptive, limiting the options for project developers. A system for dealing with mensuration error, however, is needed. An option is described in the box on Policy Decision 3.

Policy decision 3: Dealing with accuracy and mensuration error.

The term “accuracy” relates to the degree of uncertainty attached to a measurement, expressed as a standard error, or standard deviation of means. The issue of accuracy of measurements is often raised, and discussion revolves around whether a minimum accuracy level should be determined by the UNFCCC. Alternatively, some certification groups (e.g., SGS) have adopted the approach of accepting any level of accuracy, but deducting the mensuration error from total amount of carbon claimed (i.e., a project generating 100 tCO_2 +/- 10% would only be able to claim $90tCO_2$). The pros and cons of each choice are shown in the table below.

	Advantages	Disadvantages
Minimum accuracy level	Simplicity	The measurement of emission reductions generated by different technologies have different associated levels of accuracy, and a fixed level would favor certain technologies. The costs of ensuring more accurate measurements may not be compensated by the additional revenue from the sale of CERs. Mensuration error is a function of data availability and quality. It is related to the costs of data collection of a project's monitoring program, which may choose to gather its own data, use regional or national defaults, and the intensity of data collection.
Variable accuracy, discounting claims	Project developer can determine the level of accuracy depending on the costs of gathering better data, and on the expected benefits from CER sales. There is no loss of environmental integrity	Need to deduct the claims according to the uncertainty of measurements

Recommendation:

It is recommended that a flexible approach for determination of minimum acceptable level of accuracy is adopted, while at the same time introducing a method to deduct mensuration error from carbon claims.

3. Baseline determination and calculation of emission reductions

3.1. Introduction

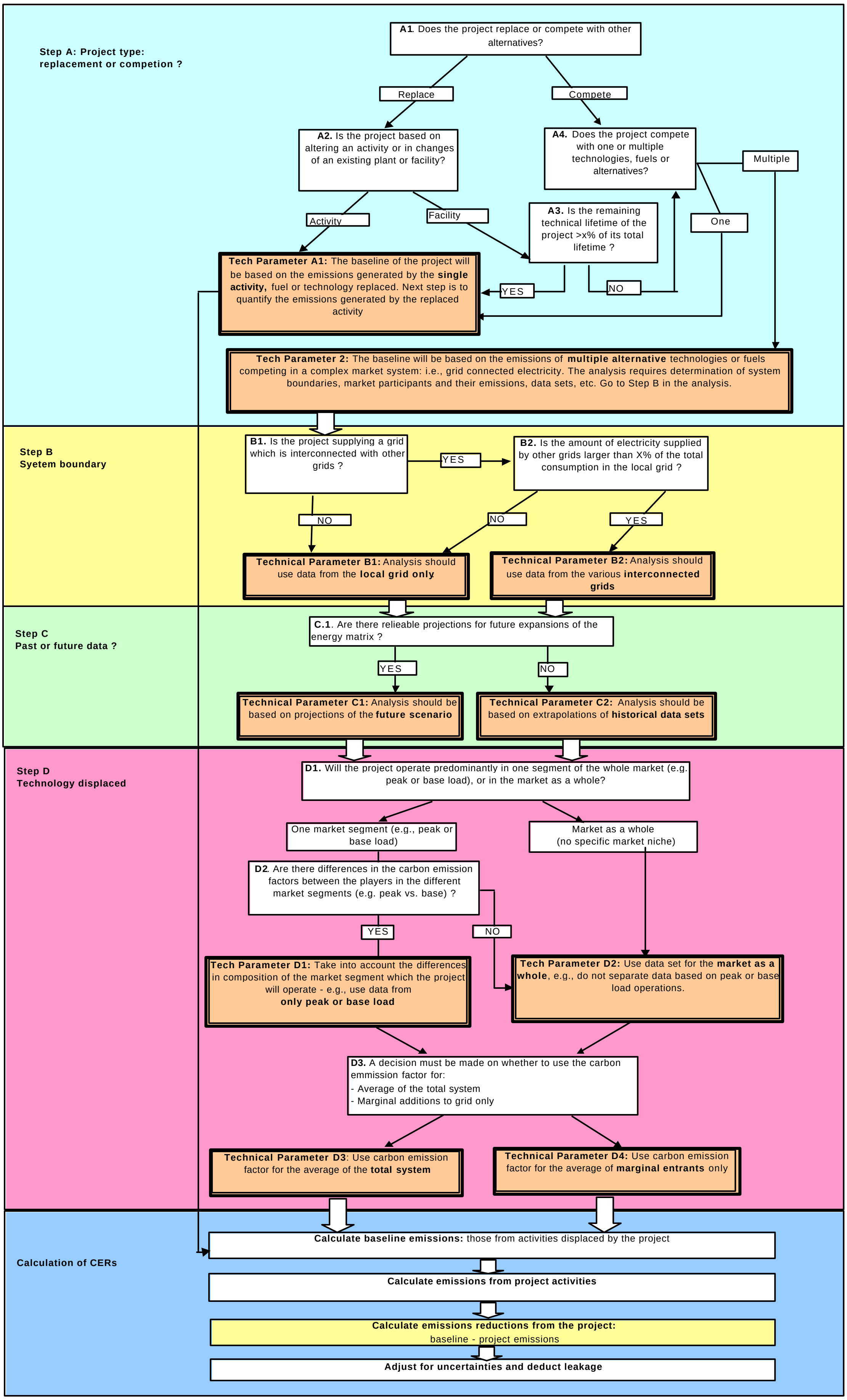
The process of baseline setting consists of 3 main steps:

- Defining a future scenario and selecting the parameters to be used for baseline determination (Section 3.2);
- Calculation of emissions in baseline and project scenarios, to estimate the emission reductions generated by the project (Section 3.3);
- Adjustment of the predicted emissions reductions to take into account uncertainty and leakage (Section 3.4).

Depending on the type of GHG mitigation project, these steps may require very distinct approaches and procedures. These steps and their application to different types of projects are described in detail in the next sections. A decision tree approach was used to facilitate the process of decision making for some of these steps, and an overall view of the whole process is shown in the diagram in the next page.

Throughout the next sections, we started from the assumption that the project being analysed has already satisfied the environmental additionality requirement of the Kyoto Protocol. A discussion on additionality tests is found in Section 3.5.

Overview of the decision tree for baseline determination. Each step is discussed separately in the next sections.



3.2. Selecting parameters for calculating emissions in the baseline scenario

The determination of technical parameters is, perhaps, the most complicated step in the process of baseline determination for non-LUCF projects. This is because it requires a series of decisions involving technical aspects which are still subject to uncertainties and lack of policy definitions.

In order to facilitate this process, a decision tree approach was utilized. The whole process was divided into 4 steps:

- Step A: Determination of project type
- Step B: Determination of system boundary
- Step C: Choice between using past data or future projections
- Step D: Determination of what technology does the project displace or compete with.

An overview of the steps is provided in the previous page, and each of the steps is discussed in further detail in the following sections.

For each of the decisions to be made, a question is asked and different paths are offered depending on the answers given. At the end of each step, the user should have chosen one single Technical Parameter, which will be used for the selection of data to calculate the emissions of the baseline scenario.

In many points in the decision process, subjective decisions may need to be made. In these cases, it is ideal that a policy decision is taken by a relevant regulatory body (either the CDM Executive Board, or national authorities) to determine what is the path to be chosen. In order to highlight these decision points, we identified the range of possible options and what are the advantages and disadvantages of each of these options as well as a policy recommendation for the most desirable path. It is the role of decision makers to select the most appropriate options.

Step A: Determination of project type

An overview of this section is shown in diagram Step A below.

The first step in the process is to determine whether the project replaces a single alternative technology, fuel or management practice or whether it competes with other alternatives.

A.1. Does the project:

- **Replace** a previous technology, fuel or management practice ? This is the case of most retrofits, fuel switch projects, and process management changes (such as utilization of landfill gases, waste management practices, industrial processes, etc.). If so, go to A.2

?? **Compete** with other alternative technologies, fuels and management practices ? This would be the case of grid connected electricity generation projects and tendering processes for the provision of a given service where there are competing alternatives. Go to A.3.

A.2. Projects that replace a previous alternative could be categorized into 2 main types:

?? Those **altering a management process for a certain activity**, but not based on an existing facility – e.g., introduction of gas collection systems in previously untapped landfills, changes in waste management systems, turning off equipment idling for periods of time, plugging steam gaps, moving materials between sites at different times of day by road to avoid congestion and running vehicles more efficiently, etc. If this is the case, go to Technical Parameter A1, and then to Section 3.3, for calculation of emissions and emission reductions.

?? Those **altering or upgrading an existing facility** – e.g., rehabilitation of existing technology through equipment replacements, or changes in equipment to enable use of different feed stocks (diesel or oil fired plant retrofits to use of natural gas or biomass), etc. In this case, go to A.3.

Where the capacity of the proposed project exceeds the current or planned capacity in the baseline, this excess capacity must be treated as a separate emissions stream, and analysed separately following the decisions A1 and A2 above.

In the case of projects that are based on the retrofitting of existing equipment, or alterations of existing plants, it is necessary to ascertain when the facility would have been retired in the absence of the project. It is important to make the distinction between retrofitting of equipment that is a result of taking advantage of better technology availability, and retrofitting as a result of planned maintenance or the equipment reaching the end of its useful or technological lifetime. Where retrofitting occurs, it must be clearly demonstrated that the alterations being made occurred as a result of an active decision to use equipment that reduced emissions over and above that that would have occurred had there been no attempt to generate CERs. In essence, claims for CERs must be seen to utilise technology that is not the currently available standard, and is in fact more likely to be the best available technology at that given moment in time. This can be done by analysing the plant's remaining technical lifetime (the timeframe during which the installation is designed to be operational, verified by reference to engineering estimates, statements from the manufacturer, independent technical experts, or comparison with other similar facilities).

A.3. Is the remaining technical lifetime of the existing facility:

?? less than or equal to **X%** of its total technical lifetime. In this case, the facility is nearly reaching the end of its lifetime and the project could be considered as equivalent to the development of a new facility, rather than the improvement of an existing one. In the latter case, it may compete with other alternatives for the provision of the same service or product. In this case, go to **A.4.**

?? larger than **X%** of its total lifetime. In this case, the facility still could operate for a substantial period without this upgrade, and the investments made by the project could be considered as a true improvement of the emissions which would be generated by the project in the absence of this investment. In this case, go to Technical Parameter A1, and then to Section 3.3, for calculation of emissions and emission reductions.

A policy decision by a regulatory body is required to determine what is the threshold X% above (see box on Policy Decision 4).

A.4. Projects that are expected to compete with other alternatives, could be competing with:

?? A single alternative – Go to Technical Parameter A1, and then to Section 3.3, for calculation of emissions and emission reductions.

?? Multiple alternatives available in a diversified market. In this case, it is necessary to determine the boundaries of this market, and what are the various alternatives available in this market. The most common example of this is grid-connected electricity generation projects, and will be the example used throughout the report to illustrate the decisions related to this type of project. Other examples include biofuel projects that displace a mix of fossil fuels in the transport sector, transport fuel efficiency, reducing transport activity, and demand side energy efficiency projects. Adopt Technical Parameter A2, and go to Step B.

So, during this step, the decision process should have led the user to choose one of the following two technical parameters:

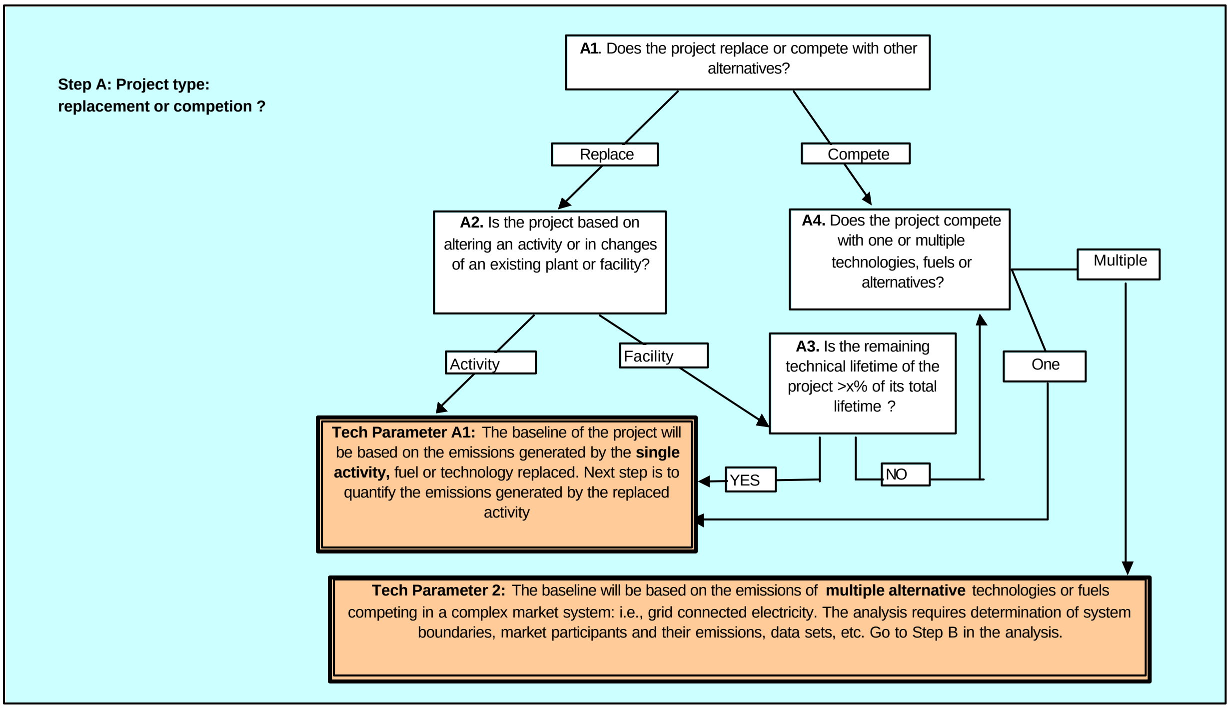
Technical Parameter A1: for projects based on replacement or substitution of a single activity, technology, fuel or management alternative. The baseline would be the emissions of the activity, technology or fuels that the project will displace. It is assumed that the project displaces emissions from other economically attractive courses of action, similar project activities initiated in the last five years, or the historical or actual emissions from an alternative course of action, in accordance with Par. 48 of the Marrakech Accords. Go to Section 3.3 for calculation of the emissions and emission reductions generated by the project.

Technical Parameter A2: for projects competing with multiple alternative technologies or fuels in a complex market system: i.e., grid connected electricity. The analysis requires determination of system boundaries, market participants and their emissions, data sets, etc., which involve a series of decisions about alternative approaches. In order to do that, go to Step B.

Table 2 below shows the most likely categorization of project types according to whether they fit into Technical Parameter A1 or A2.

Table 2. Possible GHG mitigation projects in the non-LUCF sector categorized according to whether it is likely to replace a single technology, fuels or management alternative (A1) or compete with multiple technologies (A2).

Sector	Project activities	Category in relation to Parameter A1 or A2
Electricity generation	Grid connected electricity generation	A2
	Offgrid electricity generation units	A1
	Supply side energy efficiency	A1
	Demand side energy efficiency	A2
	Fuel switching	A1
	Plant retrofits	A1 (except if it leads to an expansion of existing capacity)
Transport	Fuel switching	A1
	Fuel efficiency	A1
	Reducing transport activity	A2
	Biofuel supply to competitive systems	A2
Fugitive gas capture	Methane capture and combustion from:	
	Landfills	A1
	Anaerobic digestion systems	A1
	Waste water treatment	A1
	Natural gas production	A1
	Natural gas distribution	A1
Industry	Changes in process emissions	A1
	Fuel switching	A1



Step A: Project type: replacement or competion ?

A1. Does the project replace or compete with other alternatives?

A2. Is the project based on altering an activity or in changes of an existing plant or facility?

A4. Does the project compete with one or multiple technologies, fuels or alternatives?

A3. Is the remaining technical lifetime of the project >x% of its total lifetime ?

Tech Parameter A1: The baseline of the project will be based on the emissions generated by the **single activity,** fuel or technology replaced. Next step is to quantify the emissions generated by the replaced activity

Tech Parameter 2: The baseline will be based on the emissions of **multiple alternative** technologies or fuels competing in a complex market system: i.e., grid connected electricity. The analysis requires determination of system boundaries, market participants and their emissions, data sets, etc. Go to Step B in the analysis.

Policy decision 4: Acceptable thresholds of remaining technical lifetime for retrofitting of existing plants

In some cases, projects may claim to be replacing their existing obsolete equipment instead of characterizing them as new projects, which would need to be compared to more stringent environmental standards. A point has been raised that this should be considered as a potential form of free riding, and it is necessary to analyse the options available for dealing with this issue:

?? To set a threshold beyond which a project is not considered a retrofit, but instead a greenfield project that competes with other technologies. For example, if the remaining lifetime of the project is less than 10-20% of the equipment's expected technical lifetime, then we can assume that the technology would have to be replaced anyway. The correct baseline would be the technologies that are likely to be installed (due to, for example, cost, sector standards, government policy). If this option is chosen, it is important to determine what this % is, probably based on financial analysis related to depreciation, profitability related to maintenance costs, etc.;

?? Not to set a threshold, but instead to assume that any retrofitting of technology is a retrofit during the whole crediting period, independent of the manufacturer's estimate of the technical ability of the plant to operate.

The pros and cons of each approach are discussed in the following table:

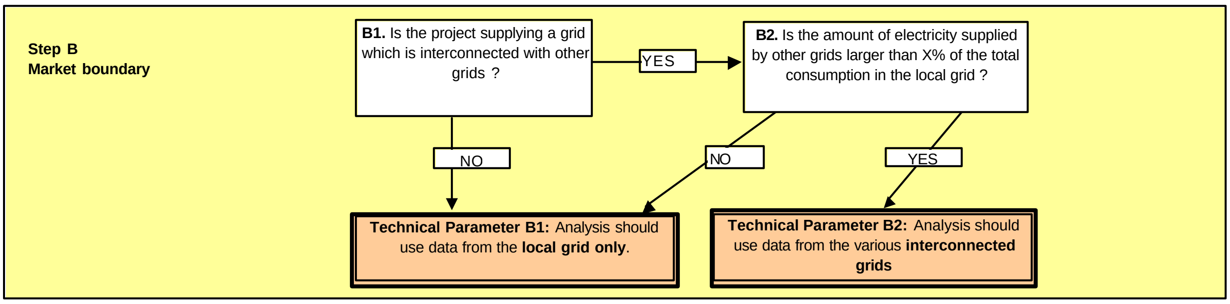
	Advantages	Disadvantages
Determining thresholds of plant remaining lifetime for accepting a project as a plant retrofit	Could prevent the inflation of credit claims which would occur if a wrong baseline was selected	This ignores the reality in many developing countries where equipment is operated far beyond the technical ability of the plant through partial rehabilitation and continued maintenance activity. Subjective judgement as to what is the expected lifetime of a plant in a given country
Accepting retrofit project claims as such for the whole of the crediting period chosen.	In many developing this is the reality. Particularly in the least developed countries, where hard currency is scarcest, equipment continues working far beyond the technical lifetime of that equipment. Maintenance and partial rehabilitation of the plant is continued, until the costs of doing so are greater than the cost of financing a new plant.	It could allow inflated claims related to the use of a more emissions-intensive baseline
Case-by-base	Flexibility and inclusiveness. It allows project developers to evaluate the situation and use the approach most appropriate to the circumstance of the project. It will give the benefit of the doubt to project developers.	In general, older technology is dirtier, so assuming that a project is a retrofit project during the whole crediting period could overestimate CERs in some cases.

Recommendation

It is preferable to enable project developers to justify which approach they use. For many developing countries, particularly the least developed countries, the reality is that the lifetime of many technologies is extended far beyond the technical capability of the technology, due to the rehabilitation and continuous maintenance of the technology.

Step B: Determination of system boundary

The Marrakech Accords require that a baseline shall cover the emissions of all gases, sectors and source categories (Para 44) under the control of the project participants that are reasonably attributable to the CDM project activity within the project boundary (Para 52). As discussed in Section 2, however, determination of a project's boundary is just a first step towards determining the system boundaries within which a baseline can be defined. This is the subject of this section.



Any project based on the introduction of a new technology, fuel type, or management alternative into a competitive situation will need to determine what are the other alternatives available in the market and what the market is. It is necessary, therefore, to determine the boundaries of the system (in effect a market) in which the project will be competing against other alternatives.

As discussed above, the most common and important type of project that requires this type of analysis is electricity generation projects supplying electricity to grids with multiple alternative sources of energy. In this case, a new project (or an expansion of a previous plant) will compete with other existing generators to supply electricity to the grid. It is necessary, therefore to determine the boundaries of this grid in order to determine which generators are or will be supplying electricity to this grid.

In some cases, however, multiple grids are interconnected and it is unclear if the analysis should be limited to the grid to which the project directly supplies electricity or whether to include all the interconnected grids. Examples of interconnected power systems in CDM countries include:

- SIEPAC (Sistema de Interconexion Electrica Para America Central) includes El Salvador, Guatemala, Honduras, Nicaragua, Costa Rica, and Panama;
- WAPP (West African Power Pool) to be installed, including Côte d'Ivoire, Benin, Ghana, Togo, Burkina Faso (under construction), Mali, and Guinea;
- SAPP (South African Power Pool) includes Namibia, Botswana, Zimbabwe, Lesotho, Swaziland, South Africa, Mozambique, and Zambia;
- ERRA (Regional Association of Energy Regulators) includes Albania, Armenia, Bulgaria, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Poland, Romania, Russia and Ukraine. The group in this region, which is important for CDM, consists of Tajikistan, Kyrgyzstan, Uzbekistan, Turkmenistan, and Kazakhstan;
- Bilateral agreements between Paraguay, a major exporter of hydropower, Brazil and Argentina;
- Bilateral agreements between Congo (Brazzaville, importer) and Congo (Kinshasa, exporter).

The extent of the trading and connection between these grids may make it more or less likely that additional generation in grid A would cause reductions in generation in grid B. This is a very complex factor to determine, however, and certainly beyond the ability of most people likely to be setting up baselines for GHG mitigation projects. It is recommended, therefore, that a policy decision be made in order to determine what is the maximum level of interconnectedness above which this additional grid should also be taken into the analysis (see box on Policy Decision 5).

So, the decisions to be made at this stage are determined in technical parameters B1 and B2 below. After selecting the appropriate Technical Parameter, go to Step C.

Technical Parameter B1: Project will compete with other players within its direct area of influence: e.g., a single electricity grid.

Technical Parameter B2: Project will compete with players in multiple interconnected markets: e.g., interconnected electricity grids.

Policy decision 5: Acceptable thresholds of grid connectivity

Electricity may be traded between two or more interconnected national grids or between two country grids (international electricity trading). The system boundary in the case of 'significant' trading becomes much wider, and the baseline study can become commensurately more costly to develop. It is important to determine what is the maximum level of interconnectedness between grids that require information on these additional grids to be included in the baseline analysis. Options include:

?? **Fixed thresholds**: Fix a maximum value of total electricity imported compared to domestically produced electricity beyond which data on the outside grid needs to be added to the baseline. If, for example, 30 percent or more of electricity is imported at any one time, consider the mix of technologies in the interconnected grids as part of the baseline;

?? **Relative thresholds**: Consider the scale of the project compared to the scale of electricity trading. Where the project's output is equal to 30% or more of the electricity traded at any one time, consider the technologies used in the interconnected grids as part of the baseline.

The pros and cons of these approaches are discussed in the following table:

	Advantages	Disadvantages
Fixed threshold	Simplicity	Inaccurate because this methodology does not consider the technologies that the project displaces or the significance of trading relative to the size of the project being considered.
Relative threshold	Takes into account the trading aspect in relation to the size of the project	Requires further analysis in relation to amounts traded, which is not always that simple. Trading volumes are also likely to vary during a project's lifetime.

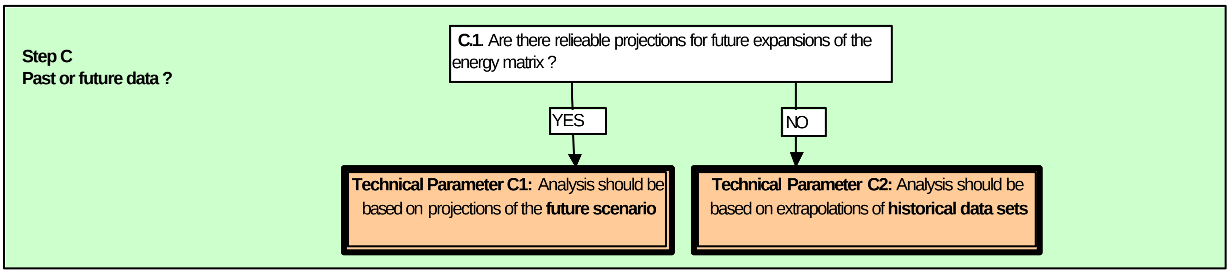
Recommendation

It is important that project developer and validators do take into account the degree of interconnectedness between grids, in order to define the full extent of the baseline. The choices shown above could assist developers and validators in this analysis, but it is too early to determine which is the most appropriate approach and what threshold to utilize. Furthermore, it needs to be ascertained how feasible it is to conduct this type of analysis in typical CDM-hosting countries.

At this stage it is inappropriate to require that this type of analysis be conducted, since it may create unreasonable difficulties in the process of project development and validation. Further research is needed in this issue.

Step C: Past data or future projections ?

After determination of the system boundary (i.e., what is the market to be analysed), it is possible to gather data on the other alternative providers of the products and services that the project will supply and what are the GHG emissions associated with the provision of these services/products. These emissions form the baseline which the project will displace by supplying the same service with lower associated emissions.



In the case of electricity projects, this process starts with the determination of the energy matrix mix for the system analysed (e.g. a given grid). Each of the sources of electricity would have a different carbon emissions factor (e.g., coal would produce around 950 kg CO2/MWh generated, hydro would produce 0 kg CO2/MWh), and so it is possible to calculate what the total emissions of the grid would be, or how much t CO2 per MWh generated.

For most countries, official records of electricity supplied in the past are available, and determination of the emissions associated with the past energy matrix can be easily calculated. But, the project will not operate in the past, and it is necessary to determine what the energy matrix will be for the future. Given that in most countries electricity supply is growing at a fast pace, the composition of the electricity matrix in the last 5 – 10 years may not correspond to the energy matrix of next 10-20 years, when the project will operate (see Box 3). In general, future projections, supported by information on policy shifts, changes in fuel prices, technologies, demand etc., will provide a better reflection of what would have happened in the absence of a project than data on past performance alone, and hence provide a more robust baseline. Therefore, if reliable projections of the electricity sector in a country are available, these may represent better what the future scenario will be, and hence may be more accurate than a simple projection of past trends. Indeed, Paragraph 46 of the Marrakech Accords predicts situations of rising emission levels in the baseline, and Para. 48 provides different options for dealing with this issue (see Section 2). At the same time, it must be recognised that estimates for the future are highly sensitive to underlying assumptions and exposed to uncertainties, errors, and even gaming. This is particularly so in more liberalized markets, in which there is a dynamic entry and exit of players. So, in order to guide the selection of choices in Para. 48, the following decisions (and those in Step D) need to be made:

C1. With relation to sources of data about the composition of the energy matrix for the grid,

?? Are there **reliable projections for future expansions** of the energy matrix? If this is the case, it is preferable that these projections are used to determine the baseline of the project (go to Technical Parameter C1).

?? When no reliable projections exist, it is necessary to **use historical data records** and extrapolate them to the future. Go to Technical Parameter C2 and see Box 4.

After selecting a Technical Parameter, go to Step D.

Technical Parameter C1: Use projections of future composition of the market - e.g., scenarios of future energy matrix.

Technical Parameter C2: Use extrapolations of historical data records. Extrapolations could be based on different approaches, but must take into account the provisions set in Paragraphs 45 and 47 of the Marrakech Accords. See Box 3 for further guidance.

Box 3: Past data or future projections

Table 1 shows the example of a simplified energy matrix for Brasil. Past data were gathered from the official records of electricity supply by the various generating sources. Future projections were extracted from the 10-Year National Expansion plan determined by the Brazilian Ministry of Energy. Which data set to use: historical data or future projections ?

As seen in the example, the Brazilian energy matrix for the last 10 years has been predominantly based on hydroelectricity, leading to very low emissions per MWh supplied to the grid (77 kg CO2/MWh). Only emissions-neutral projects (hydro, solar) could generate emission reductions in this scenario, and even then, at very low levels.

According to the Brazilian Expansion plan, however, the future outlook is very different from this past situation. Due to the problems related to large hydroelectricity plants, high transmission costs, and availability of natural gas from Bolivia, it is expected that a large number of new plants will be established in Brasil in the next 10 years, mostly using natural gas and other fossil fuels. This future scenario is, therefore, much more representative of the future outlook than a simple projection of the past energy matrix. Rising emissions in baseline scenarios is a reality recognised in Para 48 of the Marrakech Accords, and indeed the case in the majority of developing countries.

Table 1: Simplified Brazilian energy matrix for Brazil, showing past data and future projections of operating capacity (TWh) and carbon emission factors (CEFs).

		2000	2001	2002	2003	2004	2005	2006	2007
Hydro	Total cummulative installed capacity (TWh)	269.99	288.40	312.95	325.22	330.13	333.81	338.10	344.24
	Marginal additions (TWh) in that year				12.27	4.91	3.68	4.30	6.14
Gas	Total cummulative installed capacity (TWh)	36.82	42.95	55.23	98.18	122.72	122.72	122.72	122.72
	Marginal additions (TWh) in that year				42.95	24.54	0.00	0.00	0.00
Coal	Total cummulative installed capacity (TWh)	0.00	0.00	2.76	4.79	6.81	6.81	6.81	6.81
	Marginal additions (TWh) in that year				2.02	2.02	0.00	0.00	0.00
Running average CEF for total system		**77.16**	**83.35**	**102.85**	**158.12**	**185.84**	**184.36**	**182.67**	**180.30**
Running average CEF for marginal additions only					**516.24**	**532.78**	**511.55**	**488.83**	**459.66**

Source: Brazil's 10-year National Expansion Plan
CEF for coal = 956 kg CO2/MWh, for gas = 643 kg CO2/MWh, for hydro = 0 kg CO2/MWh

Box 4: Projecting data to the future

It is often the case that official or reliable projections of energy trends do not exist. In this case, one may attempt to model these trends, based on analysis of existing future plans/trends (electricity expansion, or technology shifts), simulation or modelling of future scenarios, or extrapolation of current trends into the future. Such projections must be done in a transparent and conservative manner, taking into account national and/or sectoral policies and circumstances such as sectoral reform initiatives, local fuel availability, power sector expansion plans and the economic situation in the project sector (Para 45 of Marrakech Accords).

When historic data is being used produce a baseline through extrapolation, however, a certain degree of uncertainty is invariably introduced as a result. Where the data being used to extrapolate the generating efficiency trend is comparable to the time scale being extrapolated (i.e., ten years of historic data is being used to produce a trend ten years into the future) the margin of error may be acceptable.

However, as soon as the time scale being extrapolated into is greater than the time series the extrapolation is based upon, the margin of error may become unacceptably large. This is particularly so where major changes have occurred or are likely to occur in the generating mix, e.g., through a shift from coal to gas. Where relatively little change in the mix may be expected to occur (for example, in South Africa where coal fired electricity is expected to continue to predominate), the extrapolation may be extended beyond the original time frame of the historic data available if the extrapolation is felt to be reliable.

Hence a decision must be made by the person constructing the baseline as to whether enough historic data is available to produce a reliable baseline extrapolation.

In any case, it is important to notice that the baseline shall be defined in such a way that CERs cannot be earned for decreases in activity level outside the project activity or due to force majeur, in accordance with Paragraph 47 of the Marrakech Accords..

Policy decision 6: Past or future data

Determination of baseline could be based on whether to preferably use historical data or projections of future scenarios. The Marrakech Accords authorise the use of both approaches, depending on the circumstance (Para 48). The pros and cons of each choice are shown in the table below.

	Advantages	Disadvantages
Past data	Historical data on electricity generation is readily available for most countries in the world, and is reasonably reliable.	Energy matrix of most developing countries is changing rapidly, and past data is not representative of the scenarios in which projects will operated. Furthermore, given that the penetration of fossil fuel technologies in most of these countries tend to be higher than that for cleaner technologies, the use of past data would prevent the majority of projects in the CDM from generating CERs.
Future projections	Use of good projections may be more representative of the scenario whether the country will operate. This approach also better represents the trends related to best available technologies or economic least cost options which will operate during the projects' lifetime.	There is inherent uncertainty, and there could be scope for "gaming".

Recommendation:

If credible projections of expansions of the energy sector are available, their use is preferable to the use of historical data. However, for these to be credible, they must be compiled using a wide range of data and parameters, including:

- Data on facilities for which construction has already started;
- Data on facilities planned to be operational in same year that project becomes operational;
- Planned projects and facilities of which the financing has been closed;
- Plants, facilities and systems for which construction licenses or licenses to improve facilities have been granted or received;
- National and/or sectoral policies and circumstances such as sectoral reform initiatives, local fuel availability, power sector expansion plans and the economic situation in the project sector;
- Original data used for projections are derived from credible sources, such as national governments, Ministry of Energy, Central Planning Agencies or approved independent authorities.

Step D: What technology does the project displace or compete with ?

Irrespective of whether the decision was to use past data or future projections, it is also necessary to determine what are the sectors, technologies or fuels within the total energy matrix which the project will compete with, and displace. If the emissions generated by these technology(ies) are higher than those generated by the project, then the project will generate emissions reductions (see Box 5 for an example).

Para. 48 of the Marrakech Accords authorises the use of different options for dealing with this issue (see Section 2), but no guidance on how to select between the options available. The decision process below aims at guiding the selection of an appropriate choice for the project.

As a first step in this process, it may be required to ascertain if the project expects to operate in a more restricted segment of the market, such as peak load or base load, so that the range of technologies to be included in the analysis can be limited to those operating in the same market segment. In general, base load is supplied by the cheapest generating technologies, perhaps coal, nuclear or gas fired generation, to satisfy the basic, steady state demand for electricity. In contrast, peak load suppliers satisfy the increasing demand at peak times of the day (generally early in the morning, and early to late evening). As demand progressively increases, marginal economic generating sources supply into the mix. These can often be more expensive as a result of the fuels and technologies employed, for example diesel or oil generation. Such generating sources are responsive, but often produce at a higher emissions intensity than base load supply.

D1. What market segment is the project expecting to operate on ?

?? predominantly in one specific market segment (base load or peak load) – go to D2.

?? all times ? If so, Adopt Technical Parameter D2.

D2. Are there differences in the average emission factors between peak and base load suppliers ?

?? If yes, adopt Technical Parameter D1.

?? If no, adopt Technical Parameter D2.

Technical Parameter D1: Take into account the differences in composition of the market segment which the project will operate - i.e., use data from only peak or base load, if the project will only operate in one of these periods, or, alternatively, quantify share of emissions generated by the project in both peak or baseload, if the project will operate in both periods.

Technical Parameter D2: Do not disaggregate data set, i.e., do not separate data based on peak or base load operation.

Go to D3.

D3. From the whole range of technologies operating in this market, it is necessary to determine which of them the project will most likely compete with and displace. In general, proposed approaches are that analysis could be based on either:

?? The average emissions factor for the whole grid, including both existing installed capacity and new additions coming on line during the life of the project; or,
?? Marginal additions to the grid only. This could be based on planned additions, additions in the recent past (in this case, a definition of "recent" is required), or a combination of both.

In a reasonably liberalized market scenario, it is expected that all technologies compete with each other, and it is very difficult to determine whether the project is displacing one or another of the various competing options, and therefore a comparison with a total average of the grid may be an appropriate approach to baseline setting. At the same time, a point can be made that the project is effectively competing only with the new plants that come in line. This is a more compelling argument when these various options are in the pre-investment phase, since the decision to invest in one plant may lead to a decision not to invest in another one, effectively replacing the other technology. In some cases, there may even be a justification for a comparison against a single technology. In practice, the selection of marginal versus total may yield totally different results (see Box 5) and a **policy decision** is needed (see box on Policy Decision 7).

The operating margin approach has been proposed as an alternative method. The basis of this method is similar to the total system average method, but in order to define what the project is displacing, a more detailed analysis of operating conditions of the existing operational mix is carried out.[1] The application of the operating margin method requires considerable data and analysis, and thus the exercise of data collection is time consuming and a high transaction cost. The required data (running costs, dispatch order, etc.) are often difficult to collect, and are increasingly viewed as proprietary, especially in those countries where the electricity sector is opening to competition. While the operating margin methodology seeks to determine more precisely what generation is avoided by a new project or load reduction, it is often also based on either subjective judgement or sophisticated modelling. For this reason, we discourage its widespread use in the early stages of the CDM.

Depending on the decision made, adopt one of the Technical Parameters below, and move to Section 3.3 for calculation of emissions and emission reductions.

Technical Parameter D3: Use carbon emission factor for the average of the total system - i.e., calculate emissions based on an average of all generating sources in the energy matrix (Option a of Paragraph 48 of Marrakech Accords)

Technical Parameter D4: Use carbon emission factor for the average of marginal entrants only - i.e., calculate emissions based on an average of new technologies, either coming on line in the next years, or even taking into account new entrants in the last five years (Options b and c of Paragraph 48 of Marrakech Accords)

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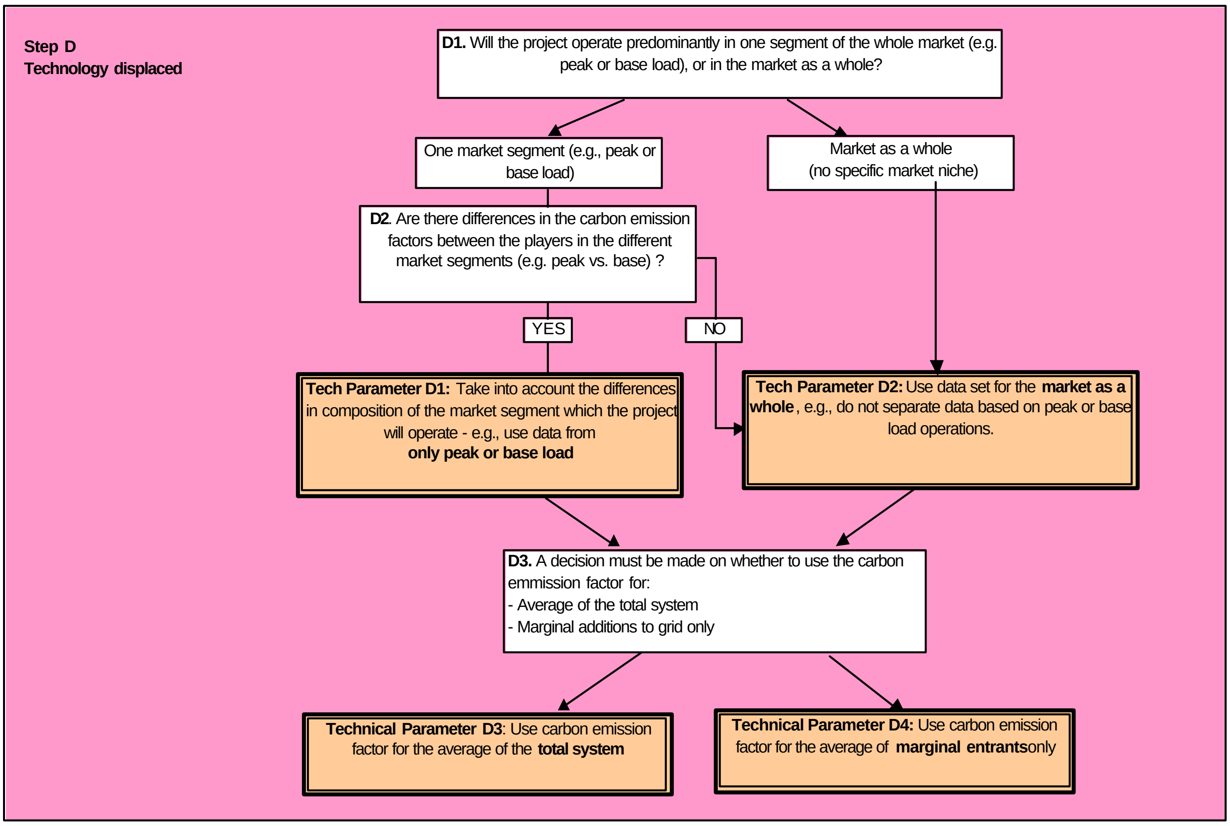
[1] An example of an operating margin method is the weighted average marginal emissions rate (WAMER) approach. The WAMER methodology involves the determination of which plant type is operating at the highest cost, or most likely to be turned down in the event that new generation is added or load is reduced, during different hours or periods of the year. It has been used for several GHG mitigation projects (Lazarus, 2001).



Step D
Technology displaced

D1. Will the project operate predominantly in one segment of the whole market (e.g. peak or base load), or in the market as a whole?

One market segment (e.g., peak or base load)

Market as a whole (no specific market niche)

D2. Are there differences in the carbon emission factors between the players in the different market segments (e.g. peak vs. base) ?

Tech Parameter D1: Take into account the differences in composition of the market segment which the project will operate - e.g., use data from **only peak or base load**

Tech Parameter D2: Use data set for the **market as a whole**, e.g., do not separate data based on peak or base load operations.

D3. A decision must be made on whether to use the carbon emmission factor for:
- Average of the total system
- Marginal additions to grid only

Technical Parameter D3: Use carbon emission factor for the average of the **total system**

Technical Parameter D4: Use carbon emission factor for the average of **marginal entrants**only

Box 5: Total system average or marginal additions only

Figures 1 and 2 below show the average carbon emissions factors (CEFs) for both the total system and the marginal additions to the electricity grids in Brazil and Country B, a more carbon intensive country introducing cleaner technologies (e.g., similar to Poland or India).

As seen below, the CEF for total system average in Brasil ranges between 158 and 180 kg CO2/MWh from 2003 to 2007, while the CEF for marginal additions (which constitutes the least cost options coming on line) ranges from 460-530 kg/MWh during the same period. If total system average is selected, very few projects could generate emission reductions, while if the baseline is based on the CEFs of the marginal additions is used, a wider range of projects could generate emission reductions. For instance, state-of-the-art natural gas technologies would have an incentive, compared to diesel generators in offgrid areas, or less efficient fossil fuel plants. In summary, using the CEF of marginal additions would allow more projects to generate emission reductions.

In the case of Country B, however, the situation is exactly the opposite. The CEF of the total system average is about 800 kg CO_2/MWh, given that the existing energy matrix is very carbon intensive, based on coal. The CEF for marginal additions, however, is lower, given that a series of new plants coming on line are either using more efficient coal technologies or less carbon intensive fuels (i.e., natural gas), i.e., best available technologies. If the baselines for these country had to be based on the CEF of marginal additions, a series of projects that could result in reductions of emissions compared to current emission levels would not be eligible to claiming carbon credits.

A policy decision is required to determine which of the approaches to accept, or even to allow either of them depending on the circumstance of the project (see Box on Policy Decision 7).

Figure 1: Projected running average of carbon emission factors (CEFs) for total system and marginal additions, compared to the CEF of a combined cycle gas plant in the Brazilian context.

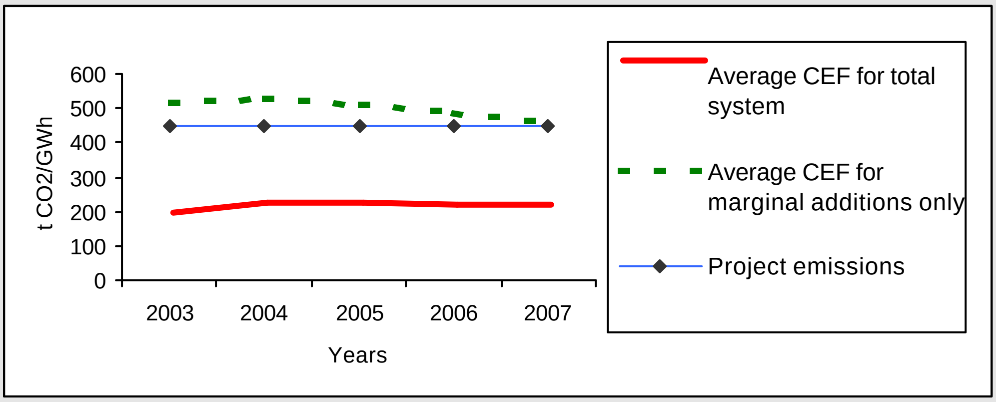
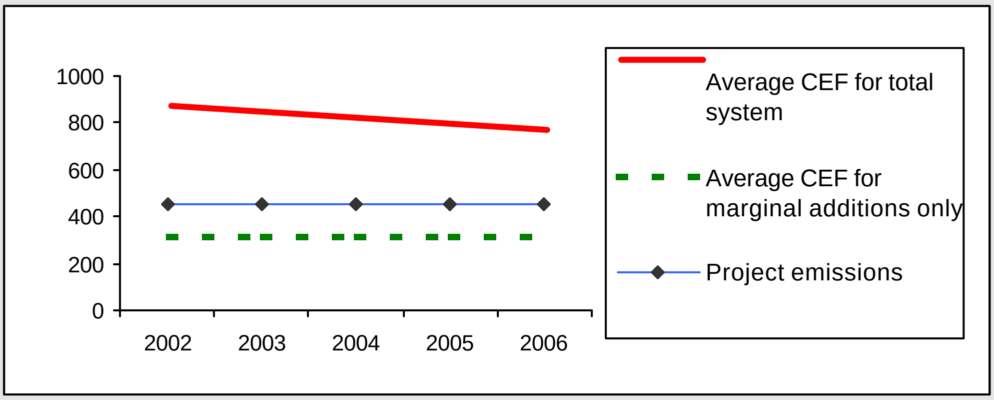


Figure 2: Projected running average of carbon emission factors (CEFs) for total system and marginal additions, compared to the CEF of a combined cycle gas plant in the Country B context.



Policy decision 7: Technology specific data

Depending on which subset of an energy matrix is used for calculating the emissions of a baseline scenario, certain projects would be seen to generate emissions or emissions reductions. Definition on what approach to use is required. The choices are:

- To insist that baselines use the carbon emissions factor (CEF) of the average of the total system;
- To insist that baselines use the CEF of marginal entrants only;
- To allow project developers to choose the option most appropriate to the project, on a case by case basis, and subject to appropriate justification by the project developer and acceptance by the Operational Entity responsible for the validation of the project design document.

The pros and cons of each choice are discussed in the table below.

	Advantages	Disadvantages
Total system average	After plants are operating, and in a situation where there is unrestricted competition between market players, it is impossible to determine which fuel/technology was not used as a consequence of an extra unit or production generated by the project. This approach, consequently, constitutes a compromise which is easy to use, since data for the grid as a whole are easily available. In some situations, this is a more conservative approach, limiting the amount of emission reductions to be generated by clean projects.	Given that most developing countries are currently in the process of expanding their energy sectors, and the penetration of fossil fuel technologies is higher than that for cleaner technologies, the use of the total system average for baseline setting would prevent the majority of projects in the CDM from generating CERs.
Marginal additions	In many cases it can be argued that the establishment of a new power plant would affect the decision to invest in another one, so any new project is directly competing with new entrants, not with those already established. This is particularly relevant in situations where investment decisions are yet to be made (for instance, in the case of tendering processes). In these cases, baselines should be made using the CEFs of the marginal entrants only. This approach also better represents the trends related to best available technologies or economic least cost options at the time that the project is operational.	In some cases it may not reflect the actual dynamics of the market, if the project technology happens to be competing with technologies already established.
Case-by-case	Flexibility and inclusiveness. It allows project developers to evaluate the situations and use the approach most appropriate to the circumstance of the project. It will give the 'benefit of the doubt' to clean projects, rather than potentially excluding a series of potentially good projects	Bias towards over-crediting, since project developers will tend to choose the approach that better suit their requirements.

Recommendation:
Given the wide range of effects that each of the approaches can generate, and the early stage we are in this process, it is recommended that the flexible case-by-case approach be adopted for the time being, until there are more indications as to what approach may be better. It is also important that the rules at this stage do not limit too much the range of activities that could participate in the CDM. It is important, however, that project developers provide full justification as to the approach chosen, and that these justifications are sufficient to convince the Operational Entities validating the project.

3.3. Calculating baseline emissions and emission reductions

3.3.1. Basic approach

Calculation of emissions of the baseline scenario is done according to the following equation:

Baseline emissions = Level of project activity (in units of input or output of the project) x CO_2 emissions factor (CEF) of the alternative to the project (baseline scenario)

The emissions of the project should also be calculated, according to the same equation, but using the CEF of the project activity:

Project emissions = Level of project activity (in units of input or output of the project) X CO_2 emissions factor (CEF) of the project's technology, fuel or gas

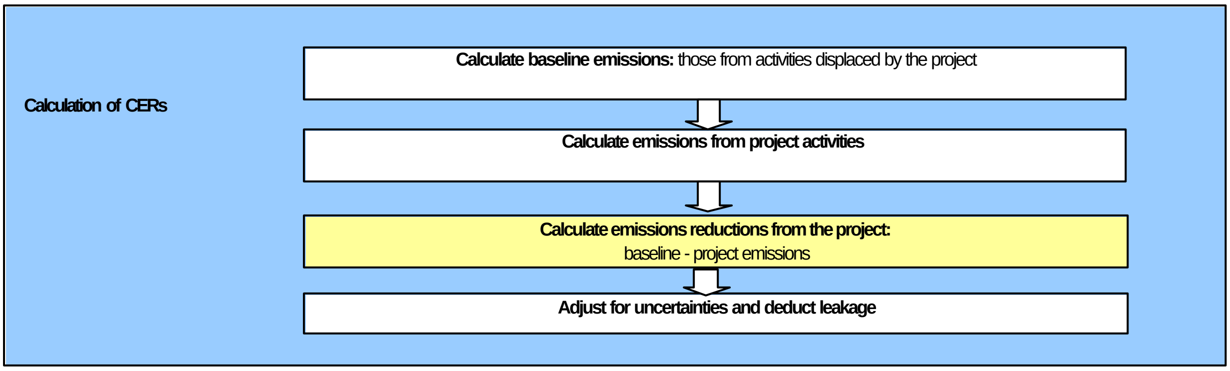
The amount of emission reductions that the project will generate are calculated as follows:

Emission reductions = Baseline emissions (t CO_2) - Project emissions (t CO_2)

If the project is expected to be reducing the emissions of multiple gases, these analysis have to be done repeated times, for each of the gases.

After calculating the emissions reductions to be generated by the project, it may be necessary to adjust the results for uncertainties, and to deduct any possible leakage that may be occurring as a consequence of the project. These issues will be discussed in Section 3.4.

A discussion about each of these parameters is given below, followed by a section providing examples of the application of these equations to different types of projects.



3.3.2. Measurement units of project activity

Different types of project will have their level of activity measured in either volumes of output or of input, as shown in Table 3 below.

Certain types of projects are more easily assessed by measuring the amount of output rather than input. This is the case of electricity generation, where it is easier to assess how much electricity is generated by a range of generating sources than to assess the amount of fuels used by each of these generating sources. Using technological parameters related to the generation efficiency of the various technologies used, it is possible to estimate the amounts of fuels used.

In some cases, however, there is no clear output, or it is difficult to quantify or estimate it, and it is necessary to work with amount of emissions generated by the activity itself. This is the case of:

- Fugitive gas collection projects – apart from the component related to the possible utilisation of gases (whose emission reductions need to be quantified in that context), the main impact of these projects relates to the effect of collecting and transforming a gas with more potent GHG effect into a gas with less potent GHG effect. In this case, there is not an easily defined unit of output, and the level of activity is measured in terms of volumes of gas collected.

- Transportation projects based on use of cleaner fuels – because of the difficulties in determination of parameters such as distance travelled, tonnages transported, occupancy and quality of the vehicle fleet, it is often very difficult to quantify the level of activity these projects in terms of their output (transportation units). Whenever possible, it is preferable to determine the amount of cleaner fuels used and assume that an equivalent amount of fuels with a higher carbon content were not used as a consequence of the project. This is further discussed in section 4 below.

In any case, the level of project input or output is a parameter easily defined, since it can be estimated by the project developer at the beginning of the project and monitored throughout the project lifetime.

Table 3: Units of project activity (in terms of units of input or output) for different project types.

Mitigation activity	Activity displaced	Units of activity level
Clean electricity generation	Fossil fuel combustion	MWh output
Reductions in electricity consumption (demand side management)	Fossil fuel combustion	KWh output
Collection of fugitive gases (e.g., landfill, coal mines, etc.)	CH_4 emissions	tonnes of CH_4 input (in gas collection systems)
Transport (fuel switch, transport efficiency, etc.)	Fossil fuel combustion	tonnes of fuel input

3.3.3. Carbon emission factors (CEFs)

Carbon emission factors are a measurement of the carbon intensity of a fuel or activity, expressed as the amount of CO2 equivalents that are emitted per unit of project activity. Depending on the type of project activity, the determination of a CEF is done in a different way (see Table 4 below).

Table 4: Units of project activity (in terms of units of input or output) for different project types.

Mitigation activity	CEF determination approach	CEF units
Clean electricity generation	Determined according to fuel and technology used	t CO_2e/MWh output
Reductions in electricity consumption (demand side management)	Determined according to fuel and technology used	t CO_2e/MWh output
Collection of fugitive gases (e.g., landfill, coal mines, etc.)	Conversion of gas collected into CO2 equivalents, using their Global Warming Potentials	t CH_4 input (in gas collection systems) converted into t CO_2e
Transport (fuel switch, transport efficiency, etc.)	Carbon content of the fuel used	t CO_2e of fuel input

For projects measured as units of output, their CEF is a function of the type of fuel used, the amount of fuel used for the production of the expected amount of output, the carbon content of the fuel, and the conversion efficiency of the technology used. This is the case of electricity projects.

CEFs for projects measured in terms of units of input could be determined in different ways:

- the carbon content of the fuel used, in terms of tC per t fuel, converted into CO2 equivalents emitted;
- the carbon content of the fuel used, in terms of tC per TJ of energy generated, and then converted into CO2 equivalents emitted;
- the Global Warming Potential of a gas, in units of CO2 equivalent (IPCC 1995). This is the case of all fugitive gas collection projects.

A brief description of sources of data on CEFs is given below.

As discussed in Section 3.2, however, the main challenge in the baseline determination process is to identify what are the alternative providers of the services or products that would operate in the absence of the project (i.e., in the baseline scenario), so that their carbon emissions factor can be used for the calculation of emissions in the baseline. The objective of the decision tree in the previous section is exactly to assist in the identification of what these alternatives are, in the form of the technologies, fuels or management practices used in the baseline. Once these are identified, it is possible to use their CEF, or to calculate an aggregated CEF for the mix of alternatives, in order to use in the equations described above.

Sources of data

Various sources of data exist for defining the CEFs of different activities. As much as possible, country-specific data should be used. This is because fuel qualities and emission factors may differ markedly between countries, sometimes as much as ten percent for nominally similarly fuels. In the absence of adequate country-specific data, however, various sources of generic default data exist, using different approaches.

The IPCC approach, for instance, is based on the net calorific value (in TJ) of different fuels (see example in Table 6), and the carbon emission factor per unit of energy generated (in tC/TJ). See IPCC Guidelines for National GHG Inventories (IPCC 1997), for a full description.

A different approach is used in the Environmental Manual for Power Development (EM model) of the Öiko institute, supported by the World Bank (Öiko, 1998). The EM model links a specific technology for burning fossil fuels to a specific CEF, expressed in CO2 equivalents per unit of electricity generated (Table 5). The CEFs provided in the EM model are similar to those made available by the US Energy Information Agency (EIA) for voluntary reporting of GHG emissions. The factors from the EM model are based on the assumption that plants are operating under good conditions and are applicable at a global level. Plants in developing countries in general operate at lower efficiency levels, and the use of CEFs from the EM model for baseline determination may lead to conservative estimates[2].

Another source of data is the International Energy Agency (IEA), which publishes historical energy balances for countries, but not always at an appropriate level of specificity.

Data on carbon content of different fuels, and the Global Warming Potential of different gases can be found in the IPCC Guidelines for National GHG Inventories (IPCC 1997), and the IPCCs' Climate Change report 1994 (IPCC 1995).

Table 5. Emission factors per technology from the EM Model for electricity production (Oko 1998).

Fuel	Technology	Carbon Intensity in t CO_2/MWh
Natural Gas	Simple Gas Turbine	0.644
	Combined Cycle	0.406
Diesel Oil	Combined Cycle	0.605
	Gas Turbine	0.895
	Steam Turbine	0.735
	Combustion Turbine	0.845
Coal	Conventional Steam	0.987

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[2] For example, from a research on carbon emission factors per plant in Venezuela carried out by Tellus Institute, it was found that natural gas combustion turbines had CEF of 0.81 tCO_2/MWh (when operating at base load) and 1.17 t CO_2/MWh for those operating at peak load. In both cases the older turbine technologies are much less efficient than the 0.644 tCO_2/MWh CEF for natural gas turbines as provided by the EM model.

Table 6. CO_2 emission factors for fuels in ktonne of CO_2/TJ. Source: IPCC 1997.

	Energy carrier	ktonne CO_2/TJ
Solid Fossil		
Primary fuels	Anthracite	0.0983
	Coking Coal	0.0946
	Other bituminous coal	0.0946
	Sub-bituminous coal	0.0961
	Lignite	0.1012
	Oil Shale	0.1067
	Peat	0.1060
Secondary fuel/products	Coke oven/Gas coke	0.1082
	Coke Oven Gas	0.0477
	Blast furnace gas	0.2420
	Patent fuel and BKB	0.0946
Liquid fossil		
Primary fuels	Crude oil	0.0733
	Orimulsion	0.0807
	Liquefied natural gas(LNG)	0.0631
Secondary fuel/products	Gasoline	0.0693
	Jet kerosene	0.0715
	Other kerosene	0.0719
	Shale oil	0.0733
	Gas/diesel oil	0.0741
	Residual fuel oil	0.0774
	LPG	0.0631
	Ethane	0.0616
	Naphtha	0.0733
	Bitumen	0.0807
	Lubricants	0.0807
	Petroleum coke	0.1008
	Refinery feedstocks	0.0807
	Refinery gas	0.0667
	Other oil	0.0733
Gaseous fossil		
	Natural gas	0.0561
	Methane	0.0551

3.4. Adjusting for uncertainties and deducting leakage

After quantification of the emission reduction potential of the project, this estimate must be adjusted to reflect uncertainty and potential leakage effects. Specification of the “without project” scenario for the project have usually been based on projections of past trends into the future. These predictions must take into consideration events that are expected to alter current behaviour (e.g., changes in legislation, changes in market preferences or prices, changes in environmental awareness, etc.). However, even a thoroughly investigated without-project baseline is prone to the risk that unexpected social or policy changes will confound predictions over the longer time frame.

Another source of uncertainty affecting a project relates to leakage, unexpected emissions taking place as a consequence of a project but outside its immediate or expected boundaries. Both these sources of uncertainty are discussed in the following sections.

3.4.1. Uncertainties

The main **uncertainties** related to a baseline are related to the parameters and assumptions used to construct it. Among the most likely to change, are:

- Market projections - including level of economic activity, price levels, penetration of technologies, etc.;

- Policy changes – the introduction of new policies related to the electricity market, for instance, could totally change the predicted future scenario, either increasing or reducing the amount of carbon credits to be generated. If policy changes are expected to come on force in the future, their impact should be included in the baseline in the first place. A related question is whether to take the policy framework of the host country as the baseline. In many countries, enforcement of standards is entirely lacking. In these cases, the business as usual scenario could be better represented by current practice, particularly if current practices are projected to continue.

- Efficiency changes - these can take place through autonomous energy efficiency improvements (this will impact by reducing emissions in the baseline) achieved through routine operation and maintenance activity; equipment performance degradation (this will impact through increasing emissions in the baseline) and transmission and distribution losses due to technical reasons. If these happen, two options can be considered: 1) ignoring the effects of efficiency changes (if there is no bias between these different types, the overall effect is likely to be zero), or 2) determining the impact of the efficiency changes and proposing standardised correction factors. The proposal for standardisation of projects for the Dutch CERUPT process makes an argument that for many developing countries, improvements in the transmission and distribution losses of an electricity grid will take many years and therefore can be assumed to be zero. A default factor of 10 percent by 2030 is also proposed (10 percent represents the upper limit of OECD transmission and distribution losses, although this assumes that electricity grids will converge to an OECD standard by 2030.

Project-related risks and mensuration errors could also affect the generation of CERs from a project. See Appendix 2 for a more thorough discussion on risks and error.

If there are strong uncertainties affecting a baseline projection, perhaps the baseline should be adjusted to a more conservative level, to minimise negative environmental effects related to ‘over crediting’ a project. Another method for dealing with possible changes in the originally predicted baseline scenarios is to have the baseline revisited. This is now a rule set out in Paragraph 49 of the Marrakech Accords, which either limits the duration of a baseline to 10 years, or allows for a longer period of 21 years, but subject to re-evaluation every 7 years. In this case, any major deviation from the predicted future scenarios can be adjusted without much risks to both project developers and the global environment.

3.4.2. Leakage

The term ‘leakage’ is commonly used to refer to an unanticipated loss of net carbon benefits of a project as a consequence of the implementation of project activities (Brown *et al.*, 1997). For this reason, leakage is also referred to as a greenhouse gas externality (Moura Costa *et al.*, 2000). Because leakage usually occurs outside of the project’s immediate boundaries, it is also referred to as an ‘offsite effect’.

While leakage often refers to the negative externalities of a project, i.e. those that result in additional greenhouse gas (GHG) emissions, it is possible that a project also produces positive GHG externalities. This has been referred to as ‘positive leakage’ or ‘spillover’. Because of its negative impact on the environment, the former requires a great deal more attention than the latter.

Existing literature also refers to a number of other terms related to sub-categories of leakage, such as slippage, activity shifting, outsourcing, market effects, life-cycle emission reductions, etc. (IPPC, 2000; Moura-Costa *et al.*, 2000; Schlamadinger and Marland, 2000; Sedjo and Sohngen, 1999; SGS 1998; Brown *et al.*, 1997; Carter 1997; Moura Costa *et al.*, 1997; USIJI, 1994).

Leakage effects can be divided into two categories, as follows.

Primary leakage, also referred to as slippage (SGS, 1998; Moura Costa *et al.*, 1997), occurs when the GHG benefits of a project are entirely or partially negated by increased GHG emissions from similar processes in another area. Primary leakage essentially results in the displacement of the negative activity tackled by the project (the ‘baseline driver’), rather than its avoidance. It is, therefore, directly related to the activities or threats that are modelled in the baseline. Primary leakage can be divided into the following sub-types:

- *Activity Shifting* – means that the activities which cause emissions are not permanently avoided, but simply displaced to another area. For example, the migration of an industrial activity to another one, giving the false impression that the activity was discontinued.
- *Outsourcing* – is the purchase or contracting out of the services or commodities that were previously produced or provided on-site. Thus, the responsibility for the activity (say, transportation) is shifted to another party, possibly not seen to be directly associated with the project.

Secondary leakage occurs when a project's outputs create incentives to increase GHG emissions elsewhere. The most common cause of this is related to *Market Effects,* which occur when emissions reductions are countered by emissions created by shifts in supply and demand of the products and services affected by the project. For example, a new power plant may lead to an increase in the supply, and hence a reduction in prices, which may lead to an increase in electricity usage in relation to the baseline projection. This type of leakage is most likely to be associated with projects that affect market-based activities in a competitive market scenario, such as grid connected electricity. It is less likely to occur in projects whose baselines are not related to competitive markets, such as, for instance, fuel switching retrofit projects..

Another source of unexpected carbon emissions occurs in the event of incomplete or inaccurate project or baseline determinations (e.g., emissions from transportation). This should be seen more as a fault of the project-baseline calculations rather than an issue of leakage.

It has been proposed that leakage needs to be incorporated into the carbon acccounting of the project, and that the leakage estimated for a project should simply be deducted from the project's claims (IPCC 2000). An alternatve approach has been proposed, whereby 'leakage coefficients' are defined based on the perceived risk of leakage of a project, and is used to reduce the project's claims accordingly (Trexler and Kosloff, 1998). While these are valid ideas, the main problem remains hoiw to identify and quantify leakage, so that it can be deducted or converted into coeficients to adjust a project's claims.

Identification and quantification of leakage remains one of the most challeging technical issues related to the development of GHG mitigation projects. This has been the subject of many studies, and it appears to be equally problematic for both land use and energy projects (Chomitz 2000, Schlamadinger and Marland, 2000). The main challenge of the analysis is to identify whether it is indeed occurring. Even if analysis of the project were extended beyond the immediate project boundaries, it is often impossible to detect whether shifts in behaviour, supply and demand of electricity, for instance, have occurred as a consequence of the project or as independent effects.

Experience to date has been limited to a few projects, and hindered by the lack of data, and short timeframes since project inception. Qualitative methods may need to be further developed, together with efforts to generate more and more accurate data at the right level of definition.

At this point in time, perhaps the most effective way of dealing with leakage should be to try to prevent it through appropriate project design (Aukland et al, in press). This could be effective in the case of sources of primary leakage, where well-structured project designs may be sufficient to prevent leakage from occurring, and avoiding the need for more complicated quantification analyses. With relation to market effects, econometric methods may prove useful, but is likely that they their application will remain limited due to the lack of data and the complexity of the analyses required. A more pragmatic approach may be to determine threshold values below which market effects can be considered negligible.

A more philosophical question relates to whether this should be the subject of concern or not. The objective of carbon finance is to provide financial incentives to promote a new paradigm, in this case related to the introduction of cleaner energy, transport or industrial system. It can be argued that the occurrence of a certain amount of leakage at this phase is a necessary step towards this desirable output. Further research is needed in order to determine effective methods for leakage identification and quantification.

3.5. Other issues

3.5.1. Additionality Tests

Even before initiating the process of determination of a project baseline, it is necessary to demonstrate that the purported GHG benefits of the project will be truly additional (environmental additionality). Several additionality tests have been devised to assess the eligibility of projects to enter the AIJ program. Tests applied by the USIJI (USIJI, 1994) included:

- Technological tests – where activities have resulted from the introduction of new technologies or through the removal of technological barriers. Evidence would include comparison of current practices and technologies with those to be adopted by the project (Carter, 1997).
- Institutional or program tests - where activities go beyond the scope of the programs of the institutions involved in the development of the project. Evidence would include the removal of institutional constraints, or the implementation of measures in excess of current activities and regulatory requirements.
- Financial tests – although in many cases negative cost projects can still be truly additional, demonstration that a project incurred higher costs (or has higher risks) compared with those of comparable baseline activities provides clear indication of its additionality.

Projects may demonstrate additionality using one or more (but not necessarily all) of the above tests. According to the USIJI experience, additionality criteria are difficult to evaluate objectively on a project-by-project basis (Carter, 1997). As with other screening programs, two types of errors exist: the approval of non-additional projects, and the exclusion of valid ones (Chomitz, 1998). The concept itself is complicated because it requires assessment of hypothetical future scenarios in the absence of the project.

Irrespective of which tool is used to demonstrate additionality, the first Conference of the Parties of the UNFCCC ruled that “the financing of AIJ shall be additional to the financial obligations of Parties included in Annex II to the Convention within the framework of the financial mechanism as well as to current international development assistance flows.”

3.5.2. Project specific versus generic baselines

Most projects developed under the AIJ Pilot Phase have used project-specific, bottom-up baselines determined by project developers (Moura-Costa et al., 2000). The attraction of this approach is that analysis is focused on the specific areas and activities relating to the project, and developers may have a better knowledge of local conditions. In many cases, it can argued that a detailed project specific study is likely to yield a more accurate prediction of emissions than a broader, regional or sectoral assessment. However, it may also be argued that giving project developers the task of developing baselines introduces the risk that they may choose scenarios that maximize their perceived benefits. Moreover, if many baselines are developed by different teams it may be difficult to ensure consistency between assessments. Allowing ad hoc project baselines may lead to inconsistent approaches among similar projects and increase the risk that project baselines would be set strategically to maximize the potential to generate credits.

Although the official text currently does not authorise the use of generic baselines, there is some merit in analysing this option for possible use in the future. Generic methods proposed to date include benchmarking models for the industrial and energy sectors (Baumert, 1998; Center for Clean Air Policy, 1998; Ellis and Bosi, 1999; Friedman, 1999; Hargrave et al., 1998; Jepma, 1999; Michaelowa, 1999). For example, certain practices could be considered “standard management practice,” and baselines might be set to reflect the level of carbon sequestration or emission avoidance that would occur if these practices were universally applied. Credit would then be available only to the extent that a project improved upon the results that would be obtained by simply applying these standard practices. Since the development of credible baseline scenarios represents a significant capital cost, there could be economies of scale by using generic baselines for sectors, technologies or regions (Baumert, 1998). If set by an organization independent from project developers, it could also provide transparency and reduce the potential for discrepancies between projects.

Particularly in the case of projects in the electricity sector, generic baselines could be set up in the national or sub-national level rather easily, and it would facilitate the process of evaluating projects in a consistent way. It would also reduce transaction costs and could be used as a tool by local governments to promote priority activities for which they would set up these baselines.

4. Examples of the application of the method

A few examples of the application of the decision tree method described in Section 3 is given for projects involving grid and off grid electricity generation, fugitive gas collection systems, and transportation. The main points that need to be monitored to enable calculation of emission reductions is also shown for each project type.

4.1. Electricity generation projects

To illustrate the use of the decision trees for electricity generation projects, the example of a biomass waste to energy plant that will both replace an existing fuel oil-fired plant which supplies electricity to an industrial plant, as well as export the exceeding electricity to the grid, thereby also displacing grid-connected electricity. The projected installed capacity of the plant is 10 MW: 1 MW is to be used for the company's production activities and 9 MW will be used to generate electricity which will be fed to the electricity grid. The additional assumptions are used:

- The utilisation rate for the biomass waste to energy boiler is 80 per cent;
- The project will use a 10 year crediting period;
- Project performance and output are assumed to be consistent over the baseline lifetime.

Given that the project has two distinct impacts, in terms of its outputs, it is necessary to establish two separate baselines, as follows:

- Replacement of the existing oil-fired plant;
- Displacement of a mix of technologies used to generate electricity in the grid.

We describe the process of baseline setting for each of these, as follows.

4.1.1. Retrofitted electricity generation plant

In the case of the component of the project that is based on the replacement of the existing oil plant, the decision tree path to be followed is as follows (see decision path highlighted in Figure 1 below):

- A.1. The project replaces an alternative (in this case, and existing oil plant)
- A.2. It is based on changing an existing facility, not an activity.
- A.3. It is assumed that the remaining technical lifetime of the project is greater than 30%, and hence it can be considered as a valid retrofit project.

Given these characteristics, the project should adopt Technical Parameter A1, and establish a baseline based on a single technology to be replaced (in this case, the existing oil plant). Using this approach, it is possible to proceed to the calculation of emission reductions expected from the project.

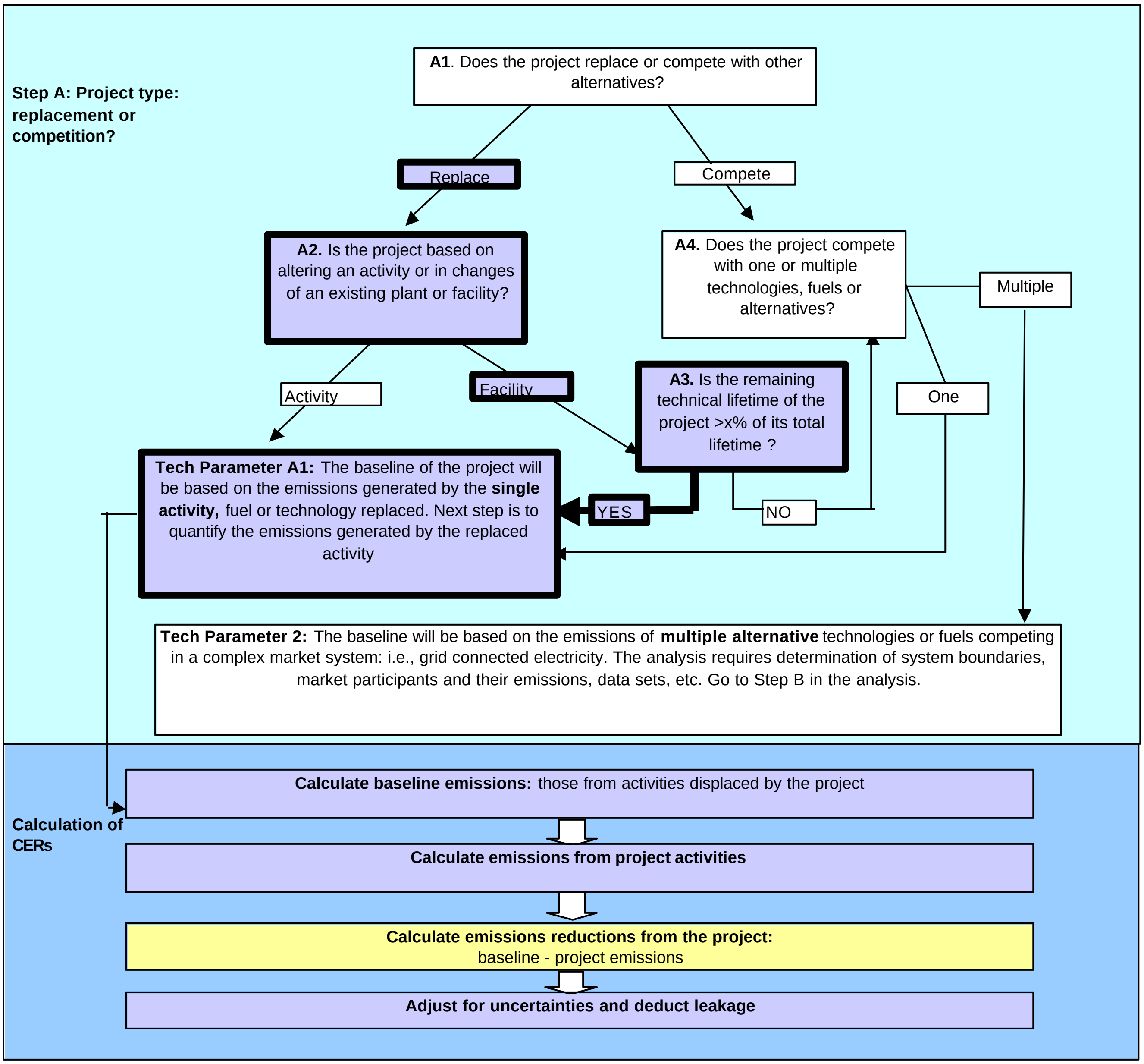

Figure 1: Decision path for baseline determination for projects that replace stand alone activities or plants. Steps highlighted in purple.

In order to calculate the emission reductions for the project, it is first necessary to determine what the CEF for the plant being replaced is, and then apply it to the baseline emissions calculation equation. Calculation of baseline emissions for a plant replacement electricity project is done by multiplying the amount of electricity to be generated by the project (in MWh) by the CEF of the fuel/technology that would be used in the absence of the project.

In the case of this biomass plant, the CEF is 0 t CO_2/MWh, given that biomass is a renewable carbon neutral fuel. The number of MWh that it will generate per year is calculated as 7000 MWh (24 h per day, 365 days/year, 80% utilization rate, 1 MW). This plant will prevent the use of an oil plant for the sae amount of hours, but generating electricity based on a CEF = 0.92 t CO_2/MWh. The calculations are as follows:

Baseline emissions per year = 7000 MWh x 0.920 t CO2/MWh = 6,440 t CO_2/year

Project emissions per year = 7000 MWh x 0 t CO2/MWh = 0 t CO_2/year

Emission reductions generated by the project = 5,100 – 2,400 = 6,440 t CO_2/year

The total amount of emission reductions to be generated by this component of the project during its 10 year lifetime is 6,440 x 10 years = 64,440 tCO_2.

The monitoring program for this project should be focused primarily on the quantity of fuel used and the electricity generated by the project, as proxys of what would have been used in the baseline scenario.

4.1.2. Grid connected plant

At the same time, this project will also generate a substantial component of electricity that will be supplied to the electricity grid. The process of determination of baseline for this component is much more complicated, because it has to try to determine what are the other sources of electricity that the project will be competing and displacing. The path followed during the baseline determination process is shown in Figure 2, below.

After determination of the CEF for the grid is, using the decision tree, it is possible to use it in the emissions quantification equation. In our example, the baseline is based on future marginal additions to the South/South-eastern/Central Brazilian energy matrix (see Box 1 in Section 3.2, for discussion), whose CEF for 2003 is 0.516 tCO2/MWH (this value varies from year to year, depending on the dynamics of the energy matrix of the grid). The number of MWh that it will generate per year is calculated as 63,000 MWh (24 h per day, 365 days/year, 80% utilization rate, 9 MW). The calculation of emissions reductions for 2003 would be as follows:

Baseline emissions in 2003 = 63,000 MWh x 0.516 t CO_2/MWh = 32,508 t CO_2

Project emissions in 2003 = 63,000 MWh x 0 t CO_2/MWh = 0 t CO_2

Emission reductions generated by the project in 2003 = 32,508 t CO_2

The monitoring program should measure the operational output of the project plant.

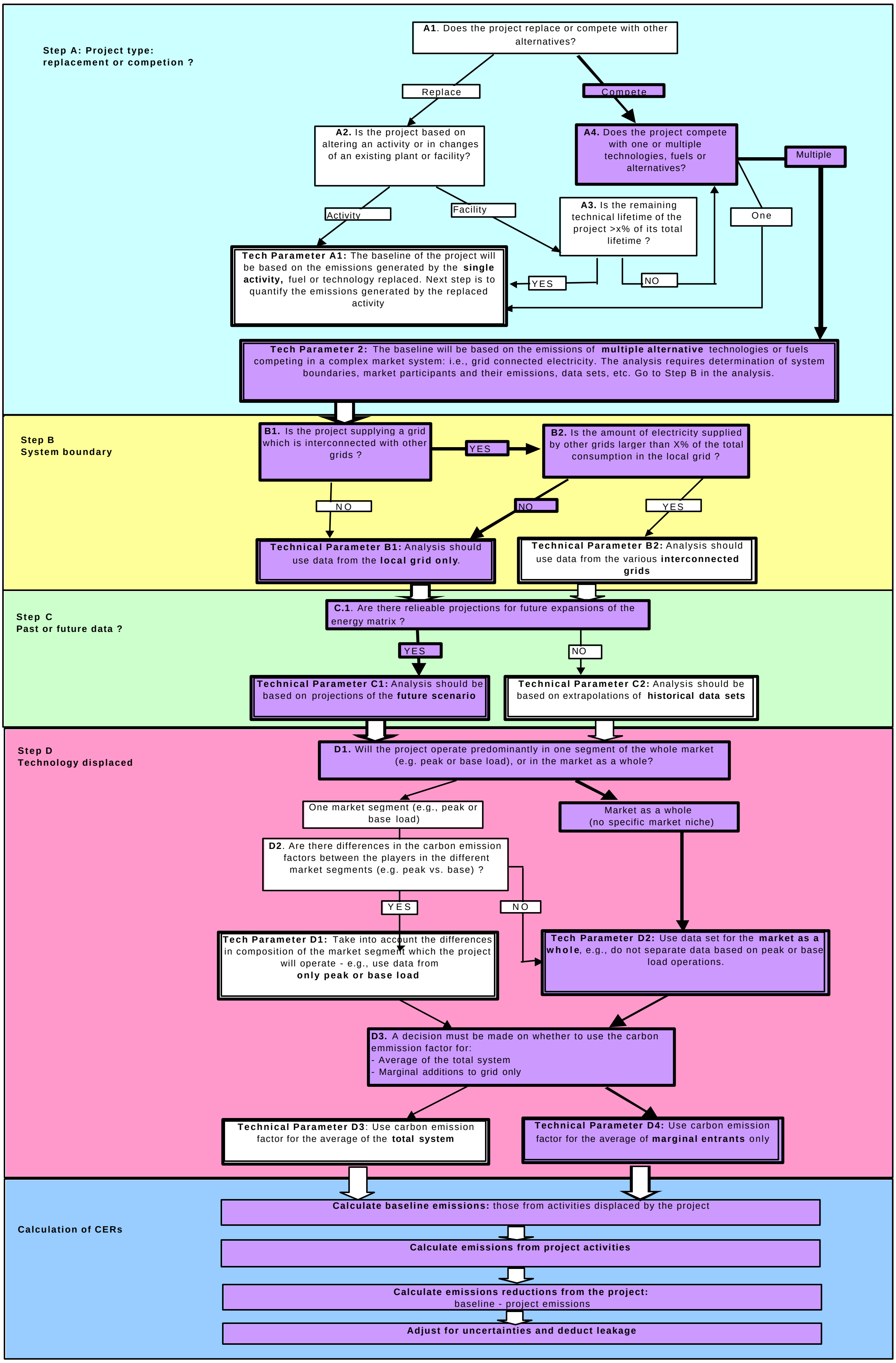

Figure 2: Decision path (highlighted in purple)for baseline determination for grid connected electricity projects.

4.2. Fugitive gas collection projects

Sources of fugitive gas emissions include landfills, coal mines, agricultural waste residues, etc. In general, the main gas emitted is methane, in varying concentrations, and the main GHG effect of these projects is related to the combustion of methane (a substance with very powerful GHG effect) transforming it into CO2, a gas with less potent GHG effect.

Calculation of baseline emissions for fugitive gas collection projects is done by multiplying the amount of gas that would have been released to the atmosphere by the CEF of that gas. It is then necessary to deduct the amount of CO2 that is emitted after flaring, to calculate the emission reductions effect of the project. The baseline determination path is the same as that for the offgrid retrofit electricity project shown in section 4.1.1 above (Figure 1).

Methane’s CEF is, in effect, its Global Warming Potential, which is 21 tCO2e per t methane (IPCC 1995). This means that the emissions of 1 tonne of methane are equivalent to the emissions of 21 tonnes of CO2. For a project collecting and flaring 1000 t methane per year, the calculations are as follows:

Baseline emissions per year = 1000 t methane x 21 t CO2 equivalents = 21,000 t CO2e/year

Project emissions per year = 2750 t CO2 generated through combustion of 1000 t methane

Emission reductions generated by the project = 21,000 – 2,750 = 18.250 t CO2/year

The calculation above assumes that the source of methane is non-organic. In the case of organic sources of methane (e.g., agricultural residues, urban waste, etc.), it has been argued that the CO2 emissions should be considered zero, given that the carbon content of the material producing the gas was fixed in vegetation in the first place. See a detailed explanation of the calculation methods and this discussion in Appendix 1.

In many cases, instead of being flared, the methane collected will be used for other purposes, such as electricity generation, transport, or bottled for domestic use (heating, cooking, etc.). In this case, there is, potentially, another source of emission reductions from the utilisation of this fuel (which is, effectively carbon neutral) displacing another fuel previously used for the generation of one of these services (heating, transport, electricity generation). A separate analysis has to be done for that component, following the decision tree in Section 3.2 above.

The monitoring program should focus on the amount of methane collected and flared by the project.

4.3. Transportation projects

Calculation of emission reductions of transportation projects based on the introduction of cleaner fuels is done by determining the amount of cleaner fuels used and assuming that an equivalent amount of more carbon intensive fuels were not used as a consequence of the project. The baseline determination path is the same as that for the offgrid retrofit electricity project shown in section 4.1.1 above (Figure 1). So, the calculation of emission reductions of a project using 1000 tonnes of natural gas replacing the previous use of gasoline is done as follows:

Baseline emissions = 1000 t gasoline x 0.85 t CO2/t gasoline = 850 t CO2

Project emissions = 1000 t natural gas x 0.74 t CO2/t natural gas = 740 t CO2

Emission reductions generated by the project = 850 – 740 = 110 t CO2

In some cases, however, the new fuel or transport alternative may have different efficiencies, and so a different amount of fuel may be needed to generate the same transportation distance. This is the case of cars run on ethanol compared to gasoline, for instance, In that case, the calculations above need to be adjusted based on the efficiencies of the different technologies compared. A thorough description of methods for calculating emissions from transportation can be found in the IPCC Guidelines for National GHG Inventories (IPCC 1997).

In the case of fuel cells, for instance, there is no replacement of a fuel by another, and the whole quantification process has to be done in terms of units of output, based on determination of parameters such as distance travelled, tonnages transported, occupancy and quality of the vehicle fleet.

The monitoring program should focus on the amount of biofuels used.

5. Monitoring

5.1. Introduction

Article 12 of the Kyoto Protocol states that CDM emission reductions must be real, long-term and measurable. Measurable relates to the demonstration that emissions have been avoided and this is proved through the development and implementation of a monitoring plan that provides objective (for example, documentary) evidence that emissions have been avoided. The monitoring plan must also demonstrate the emission reductions in a transparent, complete, consistent, comparable and accurate manner.

Monitoring may be better understood by placing it within the context of a project cycle. Once the project has been implemented, the project developers may undertake activities that can be described as Monitoring, Evaluation, Reporting and Verification or MERV (Vine *et al.*, 1999). This description also helps to separate the activities of Monitoring and Verification, which are often linked although they are discrete activities carried out by different entities.

Monitoring involves continuous or periodic measurement of specific parameters. Evaluation involves the calculation of GHG emissions using a defined protocol. Reporting is the documentation of this process, explaining how the information was collected, what quality control procedures were applied and how GHG emissions were calculated. The project participant carries out all these steps. Verification is carried out by an independent entity that checks the data collection procedures and calculations and if possible, corroborates the findings with information from an alternative source.

Depending on the type of project technology and the monitoring methodology applied, a significant proportion of the information required under the monitoring rules may be additional to monitoring data that would be gathered if the project were not part of the CDM. This may be particularly true in locations where there are fewer reporting requirements in place. The verification of the emission reductions will also place a financial burden on the project developer. Since the intensity of the verification process is determined by the risks associated with the monitoring and evaluation procedures, a good monitoring plan will result in easier and cheaper verification of emissions. A poor monitoring plan may result in higher costs, fewer emissions or, in the worst case, an inability to adequately demonstrate that emissions have been avoided.

Rules for the undertaking the monitoring of emissions are defined in Decision 17 / CP 7, Annex Paragraph 53 to 60. These rules, and particularly Paragraph 53, can be used to form a framework for monitoring project activities and emissions. In the following section, the rules are presented and analyzed. The need for guidance and policy decisions is highlighted and recommendations for each are presented. Examples are used where possible to demonstrate the issues, and the rationale behind the guidelines and the policy recommendations.

5.2. Monitoring with-project emissions

Monitoring methodologies are introduced under Paragraph 54 of Decision 17. A monitoring methodology must be approved by the CDM Executive Board, the same as for baseline methodologies, and this must be appropriate to the circumstances of the proposed project activity and reflect good monitoring practice appropriate to the type of project activity. The approval of monitoring methodologies is crucial to the monitoring plan as it determines the type and quantity of relevant data that must be collected under the plan.

There are two key elements to a monitoring methodology that impact upon the completeness, comparability, consistency, accuracy and transparency of the reported emissions. These are the techniques for estimating emissions (methodologies) and accuracy of the sampling design.

1) Technology-specific methodologies or project-specific methodologies.
2) The accuracy of estimated emissions.

5.2.1. Technology-specific methodologies or project-specific methodologies

Technology-specific methodologies would imply relatively few approved methodologies and require all projects using the same technology to utilize the same methodologies to calculate emissions. Project-specific methodologies (or perhaps regional technology-specific methodologies) would imply methodologies with greater flexibility for project developers. A combination allowing developers some flexibility would require that key principles and default values be specified.

Technology-specific methodologies promotes comparability between projects and could enhance completeness in reporting emissions (if all sources to be reported are specified in the methodology). As long as projects continue to apply the same methodology, their reported emissions will be consistent from year to year. However, specifying a single methodology may discriminate against some project developers who, for whatever reasons, would prefer to use a different methodology. For example, emissions from a project could be estimated from raw material consumption, quantity of product produced, directly measured or a combination. Specifying one methodology will disadvantage some project developers and favor others. However, allowing a choice of monitoring methodologies could enable developers to maximize estimated emissions.

Policy decision 8: Technology specific or project specific monitoring methodologies

The Marrakech Accord specifies that monitoring methodologies shall be approved in the same manner as baselines. No methodologies have been approved to date. Methodologies can be technology specific or project specific or a combination of both in which certain aspects such as key principles and default values are specified and developers have limited flexibility to alter the methodology. The advantages and disadvantages of each approach are described below, followed by a recommendation:

	Advantages	Disadvantages
Technology specific	?? Relatively few methodologies; all projects based on the same technology use the same methodology and are therefore directly comparable in terms of environmental integrity; ?? Verification is simplified; ?? Support and guidance can concentrate on fewer options.	?? Specifying methodologies may disadvantage some projects that do not have the facilities or information to apply the defined methodology; early movers that are able to influence the definition of the project may benefit.
Project specific	Projects may select from a wider range of methodologies and if no suitable methodology exists, submit their own methodology for approval. All developers have an equal right choose their most favourable monitoring methodology.	Projects of the same technology will not be directly comparable and developers may be able to manipulate the monitoring methodologies to find the one that gives them the lowest estimate of with project emissions.
Restricted choice	Lowers the number of methodologies which would be broadly comparable within similar technologies; increases flexibility whilst reducing the scope for manipulating results.	Will require more guidance to define the range of options ad a moderate amount of input from the validator and verifier to ensure that the methodology is appropriate.

Recommendation:
Offering project developers a restricted choice in monitoring methodologies allows them limited flexibility to select the most suitable and cost effective monitoring methodology without seriously compromising the environmental integrity of the CDM.

5.2.2. Accuracy of estimated emissions

The accuracy of estimated emissions is fundamental to the credibility of the trading mechanism. Rules for accuracy could be specified in methodologies and could be based around either (a) absolute levels of accuracy (for example, sampling strategies will be applied such that emissions will be estimated with a standard error of less than x% of the mean) or (b) methodologies that take account of accuracy (e.g. stating that with-project emissions will be estimated at the upper 95% confidence interval) or (c) a combination of set % standard error and use of the upper 95% confidence interval.

The advantage of the first course of action is obvious – all emissions from the same type of project will have equal accuracy. “Best Practice” levels of accuracy for different technologies would mean that, for example, renewable energy projects would be accurate to within 1 or 2 percent of the mean whilst, for example, industrial projects reducing emissions of non-CO_2 GHG might be accurate to within 10 or 20 percent of the mean (or more). It would not be practical to set the same level of accuracy for all projects because of the cost implications of sampling and data analysis and difference in the underlying variation in GHG emissions in different sectors of the economy.

The advantage of the second option is that it enables projects to set their own level of accuracy which can reflect the value of traded carbon. If traded carbon has a high value, then projects will increase sampling intensity in order to reduce the confidence limits and realize more CERs.

The third option bring both advantages of limiting the level of inaccuracy whilst rewarding improvements in accuracy above this standard.

Policy decision 9: Accuracy of with project emissions

Accuracy is fundamental to the credibility of a trading system. Due to the inherent variation in different types of technologies and different sectors of the economy, it is not practical to measure all emissions with the same level of accuracy. The options are to require all projects of given technology types to estimate with-project emissions to a defined accuracy threshold defined as a % standard error of the mean; to estimate project emissions at the upper [95%] confidence interval; or to set a minimum accuracy threshold and reward improvements above this threshold. The advantages and disadvantages of each approach are described below, followed by a recommendation.

	Advantages	Disadvantages
Defined % standard error of the mean	Would make all credits from a given technology equally accurate.	Some project developers may find it very expensive to reach the defined level due to the particular characteristics of their project design, equipment or environment.
Apply upper 95% confidence interval	Gives project developers flexibility to allocate as much resource to reducing the size of the 95% confidence interval as they wish.	Could allow very inaccurate estimates of with project emissions.
Minimum threshold with option to improve	Ensures that all projects of a given technology meet a minimum threshold that reflects best practice (not entailing excessive cost) and rewards those that can improve on accuracy.	No particular disadvantages defined.

Recommendation:
Specify a minimum accuracy threshold that all projects using a given technology must meet and use the upper 95 percent confidence interval to estimate with-project emissions. The threshold should reflect good or best practice. For example, emissions from energy projects should have estimated with a standard error of less than 2 percent of the mean. Projects that implement more intensive sampling regimes and thereby reduce the standard error will have smaller confidence intervals and hence lower with project emissions.

5.3. Monitoring baseline emissions

As discussed above, emissions may be estimated as the product of activity levels and emission factors, or emissions can be directly measured. Once the baseline methodology has been approved, it is necessary to gather data to measure the level of emissions that would have arisen in the absence of the project. The difficulty is that the project destroys the baseline. In some cases, the levels of activity or emissions in the baseline can be measured (e.g. where fossil fuel electricity is replaced with a renewable resource and the total demand does not change, then the baseline activity level and the project activity level are the same; only the emission factor changes). In other cases, the activity or emissions levels must be estimated, based on historical data, industry standards, or using a least cost approach. If the activity or the emissions have not been estimated accurately (perhaps because they were not considered to be important in the past), then future projections of emissions may not be accurate.

For example, an existing HFC facility is proposing to install a thermal combustion unit to reduce HFC emissions from the manufacturing process. Over the past five years, the facility managers have been taking quarterly point samples of the flow rate and concentration of emissions from the vents in the plant. Because of the highly variable flow rates and concentrations, this data set can only estimate the average emission factor to ± 30% at the 95 percent confidence interval. No other direct measurement data is available. The industry average inefficiency of conversion of raw material, calculated using a mass balance approach, is somewhere between 4 and 8 percent depending on the catalyst management regime. Neither the direct measurement nor the mass balance approach provides an accurate estimate of emissions per unit of production. If a new HFC facility is to be constructed on a greenfield site, the baseline could be assessed on the basis of the economically attractive course of action – which is the plant without the thermal combustion unit. Only the industry average mass balance approach is available as there are no historic emissions.

In the 'with project' scenario, because of the heightened interest in GHG emissions, the facility managers now monitor GHG emissions very closely, taking hourly reading of flow rates and concentrations from the vents to atmosphere whenever the thermal combustion unit is not in operation. As a result, with project emissions are known to within ± 3 percent at the 95 percent confidence interval.

The question is how to resolve these different levels of uncertainty. Four options are proposed:

1. Take the reported average figures for the baseline and the 'with project' scenarios, in which case the environment accepts the liability for under- or over-estimates of the mean. Under this approach, there is considerably more scope for project developers to over-estimate their baseline emissions by manipulating the availability of data (i.e. loosing data records that show lower emissions).
2. Estimate the baseline emissions at the lower 95 percent confidence limit and use the reported figures from the 'with project' emissions, provided the 'with project' emissions are estimated with a standard error around the mean is less than x%. This means that the baseline emissions must be statistically quantified and the project accepts the liability for poor quality data in the past; the environment accepts the possible under or over-estimate of with-project emissions, but this is reduced to an acceptable industry standard through the use of defined methodologies. The disadvantage of this approach is that credits may be as much determined by the baseline data as by their actual environmental benefits.
3. As above, but use the upper 95% confidence interval for the with-project emissions. The project now carries the liability for inaccuracy in both the baseline and with-project scenarios and is strongly incentivised to improve with-project emissions. The disadvantage is that the project will be squeezed from both sides and fewer credits will be awarded. The advantage is high environmental integrity.

4. Define absolute emission factors for baselines in different types of projects – this has been discussed for small-scale projects but is not considered suitable for larger projects because it could introduce significant distortions in these projects.

Policy decision 10: Addressing uncertainty in estimates of baseline emissions

Emission factors may have been estimated with low levels of accuracy. If these factors are used to predict emissions under the baseline scenario, the baseline could be inaccurate and an incorrect number of CERs awarded, undermining the environmental integrity of the CDM.

	Advantages	Disadvantages
Reported baseline and with project emissions	Simple.	Environment remains liable for over and under estimates of emissions whilst project developers may benefit.
Lower 95% confidence interval and reported with project emissions	Project developer is liable for over estimates of baseline emissions. Increases environmental integrity.	Reduces credits from project. Developers may have no means to improve baseline emission factors.
Lower 95% confidence interval on baseline and upper 95% confidence interval on with-project emissions	Project developer is liable for over estimates in baseline and under-estimates in with project emissions. The environment carries the least liability and environmental integrity is maximised.	Fewest credits are awarded. Developers can strive to reduce standard error of with project emissions (i.e. measure more accurately) but they may not be able to improve baseline estimates. Project is squeezed from both sides.
Absolute emission factors for baselines	Suitable for grid and off-grid power projects where good data is available.	Where less data is available and technologies are more project-specific, estimates of emission factors may be equally poor.

Recommendation:
The third option maximises environmental integrity and places the responsibility with the project developer to gather good baseline data before implementing the project. A maximum discount could be defined for specific technologies where baseline data are known to be of poor quality.

5.4. Monitoring within project and system boundaries

The monitoring requirements for the system and project boundaries depend very much on the individual project and what emissions have been considered as significant and reasonably attributable to the project. For some potential emissions streams, the monitoring costs could be high.

Monitoring requirements could be simplified if a selection of the following rules were applied:

?? All GHG emissions that increase as a result of the project need to be monitored and reported. The disadvantage is the costs of identifying all GHG emissions, monitoring those that increase and proving those that do not increase.

?? All GHG emissions greater than x% of the total GHG emissions under the with-project scenario must be monitored and reported. This potentially reduces the monitoring required, but developers still need to measure the size of emissions before they can determine whether or not to exclude them.

?? Some or all GHG emissions that are reduced by the project may be monitored and reported. This allows project developers to select the most cost effective sources of emission reductions.

Policy decision 11: Monitoring within project and system boundaries

System boundaries may encompass a large number of sources, some of which may increase or decrease as a result of the project and other which may be completely independent of the project. No guidance is provided as to which of these need to be monitored, but it is important to project developers because of the associated costs.

	Advantages	Disadvantages
All emissions that increase as a result of the project	Ensures environmental integrity	High costs to developers and verifiers
All emissions that increase by x% as a result of the project	Reduces costs of on-going monitoring and verification with minimum impacts on environmental integrity.	Still need to identify and measure all sources to before any can be ruled out.
Some or all emissions that are reduced by the project	Allows project developers to focus on accurately measuring the sources which contribute the biggest emission reductions	May under-estimate the true environmental benefits of the project.

Recommendation:
The second and third options combined provide the project developers flexibility to select which sources they want to monitor without significantly compromising the environmental integrity of the CDM.

5.5. Monitoring leakage

Leakage arises when the project results in increased anthropogenic emissions by sources outside the project boundary that are significant and reasonably attributable to the project activity during the crediting period. The terms "significant" and "reasonably attributable" have been discussed under Section 2 above.

Project developers have no alternative but to gain a full understanding of the relationship between their project activities and leakage and develop cost effective ways of managing the leakage and monitoring it.

5.6. Contents of the monitoring plan.

Project developers are free is develop their own monitoring methodology but guidance will help them to ensure that their monitoring plan is based on well-established techniques and a robust sampling strategy. The issues that they need to consider are shown in the table below:

Table 7: Summary of contents of monitoring plan

Description of monitoring process	This must give an overview of how the monitoring plan ensures that reported emissions are complete, consistent, comparable, accurate and transparent
Identification of sources of GHGs	This must show how sources of GHG have been identified and which have been selected for monitoring and reporting. Justification for any exclusions must be provided. A list of sources should be included.
Measurement Methodologies	Measurement methodologies based on well-established techniques for each source and type of GHG. Measurement methodologies must be approved by the CDM Executive Board. If a new measurement protocol is proposed, the developer must provide a description of the methodology, including an assessment of strengths and weaknesses and whether it has been applied successfully elsewhere.
Sampling strategy	Sampling strategies must be designed to provide the required level of accuracy.
Data retention and retrieval	Data must be stored in a secure manner and easily recovered to facilitate verification. Procedures should be defined, including when data may be destroyed.
QA/QC	Steps to ensure quality control should be defined, including a requirement for written reports on the findings of internal audits.
Procedures for calculating total emissions and emission reductions	The purpose of the monitoring plan is to estimate emission reductions due to the project. A procedure must be written explaining how the different data is to be drawn together to calculate the avoided emissions.

6 Recommendations

A series of recommendations can be derived from this study, as follows. The first set of recommendations refer to improving definitions used in the Marrakech accords text, which in many cases is ambiguous. Particularly confusing are:

- The terms “project boundaries” (Paragraph 52) and “system boundaries” need differentiation. It is proposed that the term project boundary refers to the area of influence of a project, while the term system boundary is often used to refer to the project baseline analysis

- The term “significant” in Paragraphs 52 and 53 refers to which sources of emissions to measure, based on its importance. Given the impossibility of measuring every single possible source of emission possibly attributable to a project, it is recommended that some sort of threshold is determined. The approach of linking it to the standard error of a more significant source of emissions is a pragmatic one: essentially, it is worth more to improve the accuracy of the main source of emissions than to measure a relatively small source.

- The term “reasonably attributable” in Paragraph 52 and 53 refers to project boundaries and what sources of emissions to include in the baseline analysis. Although the inclusion of all possible sources of emissions in the baseline could provide more complete analysis, it could also be significantly more costly and in some cases may lead to problems related to double counting. At the same time, in some cases there are important sources of emissions taking place offsite, that need to be included in the analysis. At this stage, a generic recommendation on what to include could lead to undesirable effects which cannot be anticipated. It is recommended that a case-by-case approach is adopted until there is more experience on this issue.

- Paragraph 54 provides some flexibility in the choice of monitoring methodologies, which, in any case should be acceptable to the designated operational entity involved in the project. This is a positive approach at this stage, in which there should be a period of exploration of possibilities and selection of successful approaches which in the future could be standardised.

- Paragraph 57 refers to accuracy of measurement, but there is no guidance on what is an acceptable level of accuracy. In a way, defining minimum levels of accuracy may be too prescriptive, limiting the options for project developers. It is recommended that a flexible approach for determination of minimum acceptable level of accuracy is adopted, while at the same time introducing a method to deduct mensuration error from carbon claims.

Additionally, a series of technical aspects are still vaguely defined in the official text, and further guidance is needed. In particular:

- Paragraph 45 of the Marrakech accords call for transparent and conservative approaches for baseline setting. Given that the text does not provide any further guidance, a possible means to ensuring transparency and consistency would be for project proponents to utilize a standard methodology in which most of the subjective decisions required for baseline determination are taken in a consistent manner. This was addressed in this report (Section 3), in the form of a standardized methodology based on a decision tree process. This approach should assist in providing more transparency and reducing uncertainty in the process of baseline determination.

?? With relation to the use of past or future data (both are allowed by the text – Paras 46 and 48), if credible projections of expansions of the energy sector are available, their use is preferable to the use of historical data. However, for these to be credible, they must be compiled using a wide range of data and parameters, including: data on facilities for which construction has already started; data on facilities planned to be operational in same year that project becomes operational; planned projects and facilities of which the financing has been closed; plants, facilities and systems for which construction licenses or licenses to improve facilities have been granted or received; national and/or sectoral policies and circumstances such as sectoral reform initiatives, local fuel availability, power sector expansion plans and the economic situation in the project sector; original data used for projections are derived from credible sources, such as national governments, Ministry of Energy, Central Planning Agencies or approved independent authorities, etc.

?? Another point in which subsets of data needs to be chosen relates to the use of Technology specific data as opposed to averages for the whole system. Given the wide range of effects that each of the approaches can generate, and the early stage we are in this process, it is recommended that the flexible case-by-case approach be adopted for the time being, until there are more indications as to what approach may be better. It is also important that the rules at this stage do not limit too much the range of activities that could participate in the CDM. It is important, however, that project developers provide full justification as to the approach chosen, and that these justifications are sufficient to convince the Operational Entities validating the project.

?? Other technical aspects related to grid connected electricity projects also need further definition, such as thresholds of remaining technical lifetime for retrofitting of existing plants, thresholds of grid connectivity, etc. At this stage it is inappropriate to define very specific requirements for this type of parameters, since it may create unreasonable difficulties in the process of project development and validation. In the future, experience may enable further definition of these parameters.

?? The issue of leakage is mentioned in Paragraphs 50 and 51, and remains a challenging one. Further research is needed in order to determine effective methods for leakage identification and quantification.

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Appendix 1: Methane quantification protocol

Reducing impact of methane emissions

The global warming effect of methane (CH4) emissions can be reduced in two ways.

1. It can be completely mitigated, and no release to atmosphere is made
2. It can be intercepted before emissions to atmosphere, combusted, and the resultant CO_2 emitted to atmosphere

This protocol discussed activities that reduce the impact of CH_4 via the second route, where methane is captured, combusted, and the resultant CO_2 emitted to atmosphere.

Quantifying the Effects of Combustion of Methane

Chemical Reaction

The chemical reaction for the combustion of methane to carbon dioxide is:

CH_4 ? CO_2

The stoichiometry of the reaction is 1:1 that is one molecule of methane will result in the production of one molecule of carbon dioxide upon combustion.

Global Warming Potential

GWP, global warming potential is measured in units of tonnes of CO_2 equivalent. The GWP of methane is 21 (i.e., it has an effect equivalent to 21 tonnes of CO_2). The GWP of carbon dioxide is 1 (1 tonne CO_2 is the base unit). Upon the combustion of methane the global warning potential of the gas is *reduced*, but not totally mitigated, therefore we must account for the effects of the residual greenhouse gases.

Quantifying Reduced GWP

?? One tonne of methane, if left to vent to atmosphere, would have the same effect as releasing 21 tonnes of CO_2 to atmosphere

?? One tonne of methane has a carbon content equal to 0.75 tonnes (the relative molecular mass of CH_4 being 16, and carbon having a molecular mass of 12. The means carbon makes up 75% of the mass of any amount of pure CH_4)

?? The combustion of 0.75 tonnes of carbon produces 2.75 tonnes of CO_2 (the relative molecular mass of carbon dioxide is 44, hence the proportion of carbon in each unit of CO_2 is 27.273%. Thus, 0.75 tonnes of carbon will produce 2.75 tonnes of CO_2)

?? Hence the effect of combustion the CH_4 is to reduce the GWP from 21 tonnes CO_2 equivalent to 2.75 tonnes CO_2 equivalent. This leads to a GWP reduction of 21 – 2.75 = 18.25

?? Net result: When combustion of methane takes place, the net emission reductions are calculated for certain activities (See below) by applying a carbon emission factor of 18.25 tonnes CO_2 equivalent.

Application of Methane CEF

The application of a CEF for methane related emission reductions activities may be affected by one of three different scenarios:

1. the methane mitigated is mineral in nature (i.e., coal mine methane of oil well vents)
2. the methane is organic in nature, i.e., biomass degradation
3. the methane comes from mixed mineral and organic sources

Mineral Methane

Where the methane is mineral in nature a CEF of 18.25 must be applied, as there is a net flow of carbon to atmosphere.

Organic Methane

Where the methane is organic in nature, as CEF of 21 may be applied. The assumption here is that the residual CO_2 emitted to atmosphere was originally fixed via biomass, and hence, there is no net flow of carbon to atmosphere.

Methane is from Mixed Sources

The is a difficult situation, and may be seen with land fill gas, where the methane emitted may be a mixture of both organically derived CH_4 and mineral CH_4 (i.e., from plastics). Three approaches may be taken:

1. Conservative: Apply CEF of 18.25, and assume all CH_4 emissions are mineral in origin;

2. Easiest: Apply CEF of 21, and assume all CH_4 emissions are organic in nature (this may not be too extreme as the UK assumes for the sake of ease that all landfill emissions are essentially organic in nature, and classifies all such gas as being from a 'renewable' source). The added complexity of the degradation profiles of the materials in the mix must also be considered, as the plastic may not degrade for many years, perhaps well after the project intervention has ceased, so an assumption may be made that all CH_4 emissions during the lifetime of a project may be organic in origin;

3. Most Complex, Balanced: Determine the proportion of mineral: organic CH_4, and apply relevant CEF to the proportions of each emissions stream.

Appendix 2: Uncertainty and risk

Quantification of emissions in GHG mitigation projects is subjected to a variety of uncertainties. Some of these are inherent to mitigation projects, while others may be generic and applicable to any project or country. Uncertainty can be classified into three main groups, i.e. mensuration error, counterfactual uncertainty and risk .

Mensuration error – relates to the degree of uncertainty attached to a measurement, expressed as a standard error, or standard deviation of means.

Counterfactual uncertainty – Unlike mensuration errors, this relates to factors that cannot be quantified, only estimated. The main source of uncertainty regards establishment of the baseline. Baseline determination is inherently based on the establishment of a series of assumptions. Consequently, quantification of GHG mitigation projects is always exposed to this uncertainty, about whether the assumptions adopted for determination of the baseline are appropriate.

***Risks* –** refer to events that negatively affect the expected GHG benefits of the project. Projects are exposed to a series of risks, such as: natural; anthropogenic; political (such as the non-enforcement of legally binding contracts between project partners, the non-compliance with guarantees, expropriation, uncertain property rights, policy changes)*;* economic (such as exchange rate and interest rate fluctuations), changes in prices of the relevant factor and product markets (Janssen, 1997); changes in opportunity costs; financial; institutional; and market risks.

Projects have dealt with uncertainty in different ways, as follows.

Mensuration error:

- *error acceptance* –acknowledging that measurement error is inevitable and listing a range of acceptable errors for different activities;
- *error minimization* – by setting acceptable errors at a low level, forcing projects to engage in more effective inventorying and monitoring exercises; more samples, larger sample size, and more frequent sampling;
- *error deduction* – this method consists of deducting the error from an emission reduction estimate. This approach has the advantage in that it allows the project to decide what is more cost effective: data gathering or CERs. This approach was used by the certification company SGS in the certification of the Costa Rican national carbon offset program (SGS 1997, Moura Costa et al. 2000).

Counterfactual uncertainty:

Methods to reduce counterfactual uncertainty include permanent monitoring of baselines re-evaluation and adjustments of baselines; estimation of effect of different uncertainty assumptions on the baseline adopted, and deduction of the claims.

Risks:

Risk mitigation can be done through a variety of internal and external mechanisms to the project. *Internal* method include:

- Introduction of good practice management systems to control occurrence of damaging events;
- Project design, aiming at diversification of activities within a project.
- Self insurance reserves or keeping a portion of the project's benefits as a reserve to ensure for any shortfalls. This reserve could be financial or in kind (GHG benefits). This approach was used by the national program of the Costa Rican Office for Joint Implementation, which placed about 40% of the credits derived from this project in a self insurance buffer reserve (SGS, 1997). In case of non-occurrence of damage, this reserve can be used at the end of the project life time;
- Diversification of sources of funding, reducing financial dependency on a single source;
- Involvement of a wide range of stakeholders, through a consultation and participatory management approach;
- Creation of positive local side effects of hosting the project, such as the transfer of needed *technologies*, the fostering of local social developments, e.g. by job creation, or the creation of positive side effects on other local or regional environmental goals in the host country (Janssen, 1997);
- Project auditing and external validation, which may serve as a way to highlight project risks early on;
- Timed allocation of GHG benefits – if GHG benefits are only credited to project partners after they are fully realized, there will be less need for long term guarantees, and a lower perception of risk.

External methods include:

- Cross-project insurance – through direct arrangements in which projects would guarantee each other;
- Regional carbon pools – a similar approach, but through the establishment of "carbon banks", with contributions from a diversified pool of projects to insure contributing projects;
- Financial insurance - some insurance companies are already offering services related to risk mitigation for carbon offset projects. It is important to note that a series of project risks are common to non-GHG specific activities, and have been traditionally been covered by standard insurance schemes.