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Absolute or relative baselines for JI/CDM projects in the energy sector?

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Abstract

The two project-based Kyoto mechanisms, joint implementation (JI) and the clean development mechanism (CDM), require a determination of the "baseline", the development of greenhouse gas (GHG) emissions in the absence of the project. This paper examines, whether absolute (given in tCO_2 equivalent) or relative baselines ("benchmarks", given, e.g. in tCO_2 equivalent/MWh) should be applied for JI/CDM projects in the energy sector. Accuracy of the GHG emission reduction and manageability of GHG emission balances are used as evaluation criteria. The results show that relative baselines are a more accurate instrument for the estimation of emission reductions in JI/CDM projects in the energy sector without posing significant additional risks to the management of GHG emission balances for large entities. In comparison to absolute baselines, relative baselines indicate in a more realistic and conservative manner the amount of emission reductions obtained in the energy system and give more appropriate incentives to project sponsors. The additional risks of relative baselines are likely to be small compared to the normal deviation of the domestic/internal GHG emissions. The findings are in line with the Marrakesh Accords, which set restrictions to application of absolute baselines. © 2002 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Essential climate policy instruments in the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) are the so-called "Kyoto mechanisms": emissions trading (ET), joint implementation (JI), and the clean development mechanism (CDM). The two project-based mechanisms, JI and the CDM, require an analysis on the development of greenhouse gas (GHG) emissions in the absence of the project. The amount of GHG emissions emitted in the hypothetical non-project scenario is referred to as a project's *baseline*. CDM projects will qualify for certified emission reduction (CERs)

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units and JI projects for emission reduction units (ERUs) if they reduce the GHG emissions relative to the baseline (Ellis et al., 2001).

The baseline is thus a quantification of the additionality[1] concept presented in Articles 6 and 12 of the Kyoto Protocol, although it has been suggested that the procedures to check additionality and determine the baseline should be kept separate (Ellis et al., 2001).

Different kinds of baseline methodologies have been intensively discussed during the last few years (lately, e.g. Ellis et al., 2001; Lazarus et al., 2001; OECD and IEA, 2000; Parkinson et al., 2000). Broadly, approaches to establish baselines can be divided into project-specific, multi-project and hybrid approaches (OECD and IEA, 2000). *Project-specific* baselines are determined on a case-by-case basis, with project-specific measurements or assumptions for all key parameters. *Multi-project* baselines can be used for more than one project. The combination of the two is called a *hybrid* baseline (Willems, 2000; Ellis and Bosi, 1999).

General approaches are only one of the topics that have been discussed. Other issues include, e.g. baseline dynamics and data aggregation (e.g. Lazarus et al., 2001; Willems, 2000; Worthington et al., 2000; Gustavsson et al., 2000; Baumert, 1999).

One such issue has been the application of absolute baselines (given in tCO_2 equivalent, also: emission levels) versus relative or rate-based baselines, often called "benchmarks" (given, e.g. in tCO_2 equivalent/MWh). The topic has been brought up as one of the main questions in baseline standardisation, as it may have large implications regarding the simplicity of baseline determination and the environmental performance of the Kyoto mechanisms (Ellis et al., 2001). In addition, the potential co-existence of both absolute and relative baselines has been identified to have important implications for risk management of investments (Janssen, 2001).

It has been argued that both absolute and relative baselines create problems. Baselines expressed in terms of absolute tonnes of CO_2 equivalent need assumptions about the activity level in the absence of the project and thus make the development of baselines and the process of project crediting more difficult (Willems, 2000). They would also allow credits to be generated if the production lagged with a slowed economy or the plant was simply closed down (Ellis et al., 2001).

On the other hand, Baumert (1999) notes that an absolute baseline might prevent crediting from taking place while GHG emissions rapidly increase, because the focus is on "verified actual emission reduction". Relative baselines, on the contrary, would allow projects where absolute emissions might increase due to a higher output to generate emission credits from "avoided future emissions".

According to Ellis et al. (2001), relative baselines might also present challenges to countries' and companies' compliance with an absolute emission target. Rates would thus be desirable for greenfield projects in growing economies in order to take into account the development objectives and needs of developing countries.

At the seventh conference of the parties to the UNFCCC (COP-7) in Marrakesh, Marocco, some important decisions regarding the use of absolute versus relative baselines were reached. For JI, the Marrakesh Accords (UNFCCC, 2001) state "a baseline shall be established ... in such a way that ERUs cannot be earned for decreases in activity levels outside the project activity or due to *force majeure*". For the

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[1] Regarding JI, the Article 6 of the Protocol defines that ERUs can be acquired and transferred from projects that 'provide a reduction in emissions by sources, or an enhancement of removals by sinks, that is additional to any that would otherwise occur'. In the context of CDM (Article 12), the formulation is similar: emission reductions can be generated by projects providing 'a reduction in emissions by sources, or an enhancement of removals by sinks, that is additional to any that would otherwise occur'.

CDM, the formulation is basically identical. These sentences significantly reduce the scope for applying absolute baselines, because unforeseen activity level drops both within and outside the project activity can prevent crediting of the emission reductions. However, the Marrakesh Accords *do not explicitly prohibit* absolute baselines.

This paper contributes to the discussion whether absolute or relative baselines should be applied for JI/CDM projects in two cases: in an energy supply project (Section 4) and in an energy efficiency project (Section 5). Accuracy of the GHG emission reduction estimation is used as the first evaluation criterion (see discussion on the criteria in Section 3). The second criterion, manageability of a GHG emission balance, is discussed separately in Section 6.

According to IPCC (2001), energy supply and energy efficiency improvement[2] offer a major potential for GHG emissions mitigation. They are forecast to represent 60–70% of the global emission reduction potential[3] until 2020. Around 40–60% of the potential in energy supply and energy efficiency should be available at net negative direct costs.

2. Absolute and relative baselines

Emission reductions from a project for each period j during the baseline lifetime can be obtained from:[4]

$$\Delta E_{\mathrm{net}} = \Delta E_{\mathrm{gross}} - E_{\mathrm{leakage}} = (E_{\mathrm{b}} - E_{\mathrm{p}}) - E_{\mathrm{leakage}} = (e_{\mathrm{b}}x_{\mathrm{b}} - e_{\mathrm{p}}x_{\mathrm{p}}) - E_{\mathrm{leakage}} \tag{1}$$

where ΔE_{net} is the net reduction of GHG emissions (in tCO_2 equivalent) taking into account the gross emission reduction within the project boundary ($\Delta E_{\mathrm{gross}}$) and the leakage of emissions outside of the project boundary as a result of the project activities (E_{leakage}).[5] E_{b} is the baseline emission level (in tCO_2 equivalent) within the project boundary, E_{p} the project emissions within the project boundary, e_{b} the emission intensity (e.g. in tCO_2 equivalent/GWh) and x_{b} is the activity level (e.g. in GWh) in the baseline case. Correspondingly, e_{p} is the project emission intensity and x_{p} is the project activity level after the project implementation.

The estimation of E_{leakage} has been found to require greater concern in cases, where supply of GHG emitting or sequestering products is reduced, than in cases, where demand of such products is cut (Lazarus et al., 2001). Protection of agricultural land, timber or other forest resources are, for example, supply-reducing projects as they shrink the carbon flow to the economic system by managing the source. Most energy-related climate change mitigation projects are, on the contrary, demand-reducing projects as they usually cut consumption of fossil fuels.

In Eq. (1), the unit of the baseline (E_{b}) is tonnes of GHG emissions, and the baseline is therefore called *absolute*. If it is assumed that the baseline activity level is always equal to the project activity level

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[2] Including energy supply and conversion, building appliances, buildings, buildings shell, and energy and material efficiency measures in industry.

[3] Forestry emissions and carbon sinks are not included here.

[4] All the parameters of Eq. (1) can be time-dependent, i.e. vary with j. The indices are not shown here for simplicity.

[5] Gross emission reductions do not take into account the price-mediated leakage impacts. For example, any project decreasing the consumption of a fuel will have a marginal negative impact on the price of that fuel that according to the economic theory will again increase its consumption. The magnitude of this impact can be estimated with price elasticities of demand and supply for the given commodity. E_{leakage} can be a fraction of the $\Delta E_{\mathrm{gross}}$ or a more complex function. For further details, see Section 5 of this paper, Lazarus et al. (2001) and Chomitz (1998).

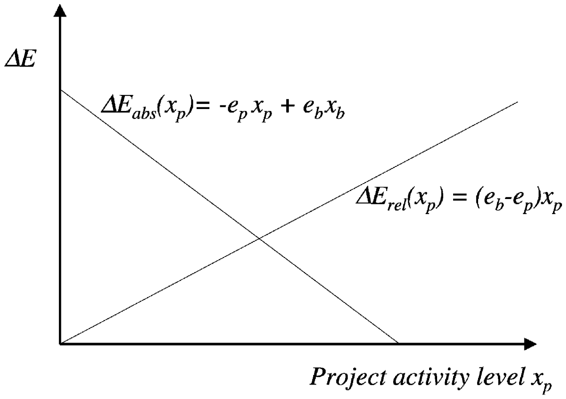

Fig. 1. Emission reduction to be credited (ΔE) as a function of the project activity level (x_p) in an absolute and a relative baseline.

(i.e. $x_b = x_p$), then ΔE_{gross} reduces to:

$$\Delta E_{gross} = E_b - E_p = (e_b - e_p)x_p \tag{2}$$

In Eq. (2), the baseline-case is only reflected by the baseline emission intensity, and the baseline is therefore called *relative* or *rate*.

Eqs. (1) and (2) can be illustrated as functions of the project activity level x_p (Fig. 1).[6] Janssen (2001) has examined the different characteristics of the emission reduction functions in absolute and relative baseline cases relative to the project activity level. In the case of an absolute baseline, the amount of emission reductions obtained (ΔE) declines with an increasing project activity level x_p. A relative baseline, on the contrary, produces more emission reductions with a higher output.

Which approach should be applied for JI/CDM projects in the energy sector?

I will now discuss the explicit evaluation criteria for the decision between absolute and relative baselines and analyse the implications in two cases: in an energy supply project and in an energy efficiency project.

3. Evaluation criteria

Criteria for evaluating baseline methods and alternatives have been analysed in many guidelines and papers (see, e.g. Lazarus et al., 2001; Ellis et al., 2001; Ellis and Bosi, 1999; PCF, 2000). Table 1 draws from these contributions.

The criteria accuracy and manageability of GHG emission balances are considered to be of high relevance in the context of this paper. Practicality and cost-effectiveness are considered of less relevance here due to the small differences between absolute and relative approaches. An absolute baseline is somewhat trickier to estimate than a relative baseline due to the additional estimation of baseline activity level (Ellis et al., 2001; Willems, 2000). In many cases, the ex ante projection of x_p might be a reasonable proxy for x_b. Since x_p must be estimated by any project developer in all cases, there would be virtually no extra effort or costs for the estimation of x_b.

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[6] Assuming that e_p, $(e_b - e_p)$ and $e_b x_b$ are all ≥ 0.

Table 1
Criteria to evaluate baselines and their relevance in the context of this paper

Criterion	Explanation	Relevance in the decision: absolute vs. relative baseline
Accuracy of the GHG emission reduction	Baseline should contribute to an accurate and realistic estimation of emission reductions	High
Manageability of a GHG emission balance	A baseline method should support easy manageability of GHG emission balances of the parties to GHG emission reduction agreements	High
Practicality and cost-effectiveness	Baseline should be rather straightforward and access to reliable data should be secured in order to maintain the costs at a competitive level	Low
Verifiability and transparency	Baselines should be easy to verify and evaluate for project stakeholders	Low
Consistency across projects	Baseline method should support a consistent treatment of different projects	Low

There are no major differences in the verifiability and transparency of absolute and relative baselines. Also both methods could be implemented in a way that follows the principle of consistency across projects. In the following discussion, the focus of the evaluation will thus be on accuracy and manageability of GHG emission balances.

4. Energy supply projects

Energy supply projects are defined here as changes in energy supply capacity in its different variants, such as electricity, heat, steam and cooling. Any energy supply project can be either a new "greenfield" plant, a plant closure or a retrofit (which is virtually a combination of the two former types). In this section, I examine the implications of absolute and relative baselines in two distinct cases: in an energy system with no immediate capacity constraints and in an energy system, where the capacity is low compared to demand. I illustrate the case using data from a wind power project awarded with a contract in the Dutch ERU-procurement tender (ERU-PT).

In the baseline of a new energy project, the activity levels x_b and x_p should refer to the energy output of the plant, which is the product of the capacity (P in MW) and the full-load hours (t in h), i.e. $x = P \times t$. It is reasonable to assume that $P_b = P_p$. If the plant did not exist and if there were no immediate capacity constraints, the electricity would be produced by the other power plants in the energy system.

Nuon International Projects BV together with EPA Ltd., a Polish project developer, have been initiating a wind farm project in Skrobotowo, Karnice Municipality, in Poland. The project developers have made a contract in 2001 with the Dutch government concerning the transfer of ERUs between 2008 and 2012. The wind farm will consist of 30 turbines of 2000 kW, totalling an electric capacity (P) of 60 MW, and the estimated annual production will be 125 GWh (Nuon International Projects BV, 2001). The project emission intensity (e_p) is 0 tCO_2/GWh of electricity.

Energy supply from a new efficient plant is likely to replace production from older plants with the highest marginal costs. In the Skrobotowo case, the alternative electricity supply is mainly based on coal-

Table 2
Case Skrobotowo, emission reductions with an absolute baseline

Variable	Abbreviation	Unit	Year(s)				Total
			2003	2004	2005–2007	2008–2012	
Baseline activity level	x_b	GWh	125	125	125	125	1250
Project activity level	x_p	GWh	120	100	105	110	1085
Baseline emission intensity	e_b	tCO_2/GWh	980	972	958	934	–
Project emission intensity	e_p	tCO_2/GWh	0	0	0	0	–
Baseline emissions	E_b	$ktCO_2$	122.5	121.5	119.8	116.7	1187
Project emissions	E_p	$ktCO_2$	0	0	0	0	0
Emission reduction	ΔE	$ktCO_2$	122.5	121.5	119.8	116.7	1187

Variables x_b and e_b are adopted from Nuon International Projects BV (2001).

and lignite-fired power plants, for which the baseline emission intensity (e_b)[7] was estimated between 2003 and 2012.

Table 2 describes the emission reductions between 2003 and 2012 for the Skrobotowo wind farm using an absolute baseline and fictional actual production (x_p) that would be slightly smaller than expected.

An absolute baseline omits the new information obtained about the actual production of the plant. However, any new plant in the system can replace other plants only as far as it provides the equivalent energy service to the system (for a detailed discussion of this argument, see Appendix A). Therefore, an absolute baseline would overestimate the emission reductions generated by the project in this fictional case.

A relative baseline, where $x_b = x_p$, would reflect the new information obtained from monitoring and thus give a more realistic picture about the emission reductions. In this case, the actual reductions generated would be around 1030 $ktCO_2$, some 13% less than shown by the absolute baseline.

The resulting difference (i.e. $1187 - 1030\,ktCO_2 = 157\,ktCO_2$) would create “virtual” emission reductions into the market. “Virtual” refers to the fact that certificates would be claimed for less emission-intensive power production that never takes place. These emission reductions would appear in the national GHG emissions accounting of the host country, but would not be visible in the actual fuel use statistics, thus increasing the non-compliance risk and compliance costs of the host country in the case of JI. In the case of the CDM, the virtual emission reductions undermine the environmental integrity of the mechanism.

The notion above is particularly important if we return to Fig. 1. It shows that an absolute baseline would create (i) an incentive for the project sponsor to show x_b as high as possible in a baseline study and (ii) no incentives for the project sponsor to manage the project efficiently, i.e. to maximise x_p. An absolute baseline means basically that the host government of the JI project or the UNFCCC in a CDM project makes a deal with the project sponsor with the motto: “the less you work, the more money you get”.

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[7] It is important to note that the first ex ante baseline study is based on an estimation of e_b for period j from the available information when time $T \leq 0$. Further, e_b is a counter-factual, non-measurable parameter, but after the implementation, new information is obtained, e.g. from the development of the national or regional grid and the power production. It is therefore justified to say that e_b can be more accurately estimated, when time T grows and finally becomes $>j$, i.e. ex post. The baseline emission intensity, e_b, cannot often be derived from the data on-site, but can be monitored as well, e.g. by the authority or an accredited organisation.

However, it could be argued that $x_p > x_b$, e.g. in a situation, where the energy system has a low capacity compared to demand. For example:

- Electricity grid with a severe shortage of capacity and power cuts. When new capacity is added to the supply side, the power consumption in the total system increases.
- Heat and steam production to a greenfield industrial plant. The energy system is virtually established through the project.
- Off-grid power projects often create additional services (e.g. electricity for lighting). The baseline is mostly not another power source, but an alternative way of providing the service (e.g. electric lighting in comparison to oil lamps), or the service is not even possible without the project (e.g. electricity for household appliances) and the JI/CDM project provides an additional service.

It is important to note that these projects can potentially increase the actual *observed* emissions, if $e_p > 0$.

- What would be the right baseline in these cases?

In developing countries, the UNFCCC and the Kyoto Protocol emphasise the sustainability dimension of climate change mitigation.[8] Sustainability concept includes environmental, social and economic objectives. From this perspective and the general equality considerations between the annex I and the non-annex I countries, it might in general prove to be politically difficult to suggest a baseline where $x_b < x_p$. This implies that no constraints in the baseline methodology could be set to the demand of energy in non-annex I countries.[9] In other words, CDM projects in the energy sector would solely target improvements in the quality and efficiency of the energy supply. Baseline activity level x_b must thus be equal to x_p, and the baseline method relative.

In JI projects, the final decision about acceptance of these kinds of projects is by the host country. If the projects are approved as JI projects, it is essential for GHG emission balance management of the host country that the increase in energy consumption, i.e. $x_p - x_b$ is consistent with the assumptions about "business-as-usual (BAU)" development of energy consumption and the respective emission scenario. If this is not the case, the projects could be rejected if $\Delta E \leq 0$, or, alternatively, BAU should be revised upward and respective measures to compensate the increase taken. In the latter case, we are back in the situation without a capacity shortage (the energy consumption would rise anyway) and a relative baseline could be applied with the projected emission intensity from BAU.

5. Energy efficiency projects

Energy efficiency improvement aims at reducing the demand of energy supply. It can take various forms. Ellis et al. (2001) distinguish between the following types of measures to improve energy efficiency.

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[8] Article 4.7 of the convention: "The extent to which developing country parties will effectively implement their commitments under the convention ... will take fully into account that economic and social development and poverty eradication are the first and overriding priorities of the developing country parties." (UNFCCC, 1992). As per Article 12.2: "The purpose of the clean development mechanism shall be to assist parties not included in annex 1 in achieving sustainable development and in contributing to the ultimate objective of the convention, and to assist parties included in annex 1 in achieving compliance with their quantified emission limitation and reduction commitments under Article 3." (UNFCCC, 1997).

[9] The baseline emission intensity e_b could however be adjusted.

- Projects involving a technical retrofit to upgrade energy (e.g. improving energy efficiency of a water boiler in a factory).
- Demand side management (DSM) projects to deal with change in demand for energy at the consumer's end (e.g. replacement of incandescent lamps by compact fluorescent lamps). DSM projects may have behavioural, technical and policy components.
- Regulations and standards (e.g. a minimum energy efficiency standard for refrigerators).

But what should be the activity level x in the baseline for an energy efficiency project? The development of a GHG emission baseline for an energy efficiency project typically includes two steps: (i) the development of the energy use baseline and (ii) the translation of this baseline into GHG emissions (Violette et al., 2000). The reduction in GHG emissions is thus caused by the resulting difference in energy use. Activity level, x, could thus simply be the energy use on the project site in both baseline (x_b) and project cases (x_p). The problem is however that x is not necessarily solely dependent on the efficiency project. Vine and Sathaye (2000) note several additional factors affecting energy use: growth, technological changes, input and product prices, policy or regulatory shifts, social and population pressure, and market barriers.

While an analysis of a project to reduce, e.g. the electricity consumption of site lighting may in many cases be based on the assumption of a relatively stable baseline consumption, the activity level of a production-process-related energy efficiency project may vary strongly. Thus, we could rewrite Eq. (1) as follows:

$$\Delta E_{\mathrm{gross}} = e_b x_b - e_p x_p = Y_b i_b e_b - Y_p i_p e_p \tag{3}$$

where Y refers to the output of the *energy user* (e.g. in tonnes of paper), i the energy intensity (e.g. in MWh electricity per tonne of paper) and e is the emission intensity of the energy as in Eq. (1). Eq. (3) takes into account the effects of energy user's activity level on the monitored energy savings in a simplified way thus emphasising environmental additionality.

The baseline in Eq. (3) (Y_b i_b e_b) is again absolute, if the baseline-case does not reflect the activity level, i.e. $Y_b \neq Y_p$.

If $Y_b \neq Y_p$ it would be possible for the company consuming energy to obtain extra emission credits by not only reducing its energy consumption per unit of output, but also by reducing the output itself. This two-way option has both benefits and problems.

On the one hand, it gives a monetary incentive for companies to reconsider their production strategy. Say, a company would obtain emissions reductions worth US$ 1 million annually, if it reduced its production (Y_p) by 50 000 t. The company would have an incentive to reduce production, if the income from emission credits was larger than the marginal income from production, i.e. 50 000 t × (revenue from the last 50 000 units − cost from the last 50 000 units in US$/t).

On the other hand, the reduction of 50 000 t would achieve real *net* emission reductions (ΔE_{net}, see Eq. (1)) only if the production in the total system factually decreased and was not replaced either by other production sites of the company or its competitors that are not subject to an emissions cap, i.e. E_{leakage} would not simultaneously grow. In the case of supply-reducing projects, the fraction leaked is given by $s/(s - d)$, where s is the price elasticity of supply and d is the price elasticity of demand (Lazarus et al., 2001). It may thus be significant for any commodity for which supply elasticity is large compared to the demand elasticity.

Table 3
Determinants of price elasticities (Mankiw, 2001)

High price elasticity of demand	High price elasticity of supply
Long time-horizon	Long time-horizon
Luxuries (vs. necessities)	The flexibility of sellers to change the amount of production (e.g. manufactured goods vs. beachfront land)
Availability of close substitutes	
Broad definition of the market (e.g. food vs. ice-cream)	

What does the situation look like in industrial energy efficiency projects?

These are typically made in heavy industries having a high energy consumption and producing necessity products (e.g. chemical/petrochemical products, non-ferrous metals such as aluminium, non-metallic minerals such as cement and glass, pulp and paper, and iron and steel). The lifetime of the projects is typically at least 2–4 years. If we look at the determinants of s and d (Table 3), we notice that the price elasticity of supply in the conventional industries, which have in many cases a global, well-developed market for their products, tends to be high on a longer time-scale. The long time-scale increases the price elasticity of demand as well, but the manufactured goods in heavy industry are often necessities having a limited amount of substitutes (e.g. steel) that tend to be rather inelastic.

Therefore, if $Y_\mathrm{b} \neq Y_\mathrm{p}$ it would be crucial to extend Eq. (3) to consider the net reductions in order to capture the external effects in the system. This would further require the determination of the energy intensity (i_rest) and emission intensity (e_rest) of an alternative site, say, those of a competitor in a developing country. In some cases, if the fraction leaked (i.e. $s/(s-d)$) is high and $i_\mathrm{b} < i_\mathrm{rest}$ and $e_\mathrm{b} < e_\mathrm{rest}$, the reduction of output Y on the site might actually lead to an *increase* in global GHG emissions.

The output Y should also include all activities of the company, that are not covered by emission caps. Otherwise, the company would be allowed to transfer a part or all of its production to other sites outside the project boundary and the emission accounting system, and nevertheless obtain the emission credits.

All in all, the generation of emission reductions through reductions in the output Y seems in most cases rather difficult. If it was possible, the problem of the estimation and monitoring of s, d, i_rest and e_rest remains. This is tricky and leaves a lot of opportunities for gaming hence reducing the environmental credibility of the credits.

If we consider the opportunities to generate emission reductions through supply restrictions negligible, it implies $Y_\mathrm{b} = Y_\mathrm{p}$ in all circumstances. The unit of the baseline ($i_\mathrm{b}\, e_\mathrm{b}$) becomes $\mathrm{tCO_2}$ per unit of output, and it is clearly relative.

If it is further assumed that the capacity of the energy source is very large in comparison to the reduction in capacity need in the plant, where the energy efficiency project takes place, then the project does not significantly affect the quality of the supply. Hence, we are able to set $e_\mathrm{b} = e_\mathrm{p}$ and the energy intensity of the production unit (i_b) remains as the only baseline variable. This is normally the case, for example, when the project reduces electricity consumption in the grid.

6. Manageability of a GHG emission balance

The previous sections suggest that relative baselines provide with less effort a more realistic picture of the GHG emission reductions in comparison to absolute baselines in the energy sector. In this section, I will discuss in more detail the foreseen problem that relative baselines allow projects where absolute emissions increase due to an increased output, thus presenting challenges to compliance with absolute emission targets.

Parties to the Kyoto Protocol and economic actors with absolute emission targets need to manage the compliance risk related to their GHG emissions balance. The decision-making setting can be characterised by the following formula:

$$\text{TARGET} = \text{BAU} - \text{P\&M} - \Delta\text{MECHANISMS} \tag{4}$$

where TARGET is the absolute target (in MtCO_2 equivalent), BAU the so-called ‘business-as-usual’ scenario (e.g. in MtCO_2 equivalent), where no measures are taken to reduce the emissions, P&M the domestic/internal policies and measures taken to reduce the emissions (in MtCO_2 equivalent), and ΔMECHANISMS (in MtCO_2 equivalent) refers to the combined balance of the emission credits purchased and sold (such as CERs from the CDM and the ERUs from JI) and allowances (such as assigned amount units from ET).

Compliance risk management in this setting (i.e. to reach the TARGET) requires a careful monitoring and management of all the three variables on the right side of the Eq. (4). The important question in the context of relative baselines versus absolute baselines is, if the relative baselines make this management process to a significant extent more complex?

I will address first the question of additional risk from using a relative baseline versus an absolute baseline. Absolute baselines also include a certain activity level risk (see Fig. 1), when $e_{\mathrm{p}} > 0$. This uncertainty reduces the additional risk from a relative baseline. Take an energy supply project with capacity P, where we estimate ex ante that the plant is likely to run for t_{estimate} hours per year, and in no case more than $t_{\max}$ hours per year. Let ΔE_{abs} be the emission reduction in the case of an absolute baseline, and ΔE_{rel} the reduction in the case of a relative baseline, respectively.

From Fig. 2 we get the following uncertainty ranges (i.e. maximum–minimum) for both baseline types:

$$\Delta E_{\mathrm{abs,max}} - \Delta E_{\mathrm{abs,min}} = P(e_{\mathrm{b}}t_{\mathrm{estimate}} - (-e_{\mathrm{p}}t_{\max} + e_{\mathrm{b}}t_{\mathrm{estimate}})) = Pe_{\mathrm{p}}t_{\max} \tag{5}$$

$$\Delta E_{\mathrm{rel,max}} - \Delta E_{\mathrm{rel,min}} = P((e_{\mathrm{b}} - e_{\mathrm{p}})t_{\max} - 0) = P(e_{\mathrm{b}} - e_{\mathrm{p}})t_{\max} \tag{6}$$

From Eqs. (5) and (6) we easily see that the relation of the uncertainty ranges of the two baseline types is given by:

$$\frac{\text{Uncertainty range}_{\mathrm{rel}}}{\text{Uncertainty range}_{\mathrm{abs}}} = \frac{\Delta E_{\mathrm{rel,max}} - \Delta E_{\mathrm{rel,min}}}{\Delta E_{\mathrm{abs,max}} - \Delta E_{\mathrm{abs,min}}} = \frac{P(e_{\mathrm{b}} - e_{\mathrm{p}})t_{\max}}{Pe_{\mathrm{p}}t_{\max}} = \frac{e_{\mathrm{b}} - e_{\mathrm{p}}}{e_{\mathrm{p}}} \tag{7}$$

The uncertainty range related to a relative baseline is thus only greater than that of an absolute baseline, when $e_{\mathrm{p}} < 0.5\, e_{\mathrm{b}}$. For modest improvements in the efficiency, the uncertainty range is, indeed, smaller. If $e_{\mathrm{p}} < 0.5\, e_{\mathrm{b}}$, we can ask, if this difference is significant given the uncertainties of BAU and P&M.

The following reasons suggest it is not. First, the estimation of emission reductions always requires an estimate of the output level for management purposes, even though this is not visible in the baseline itself (i.e. in the case of a relative baseline). If this estimate has been set well and the compliance period is more than 1 year, the project may compensate bad years on coming ones.

If the ex ante performance estimate is conservative enough, it is also likely that the activity deviation is much smaller than the activity level. The problem of the deviation are actually the activity movements downward: a project that creates more emission credits than expected is at least as good as a project providing the expected amount of credits.

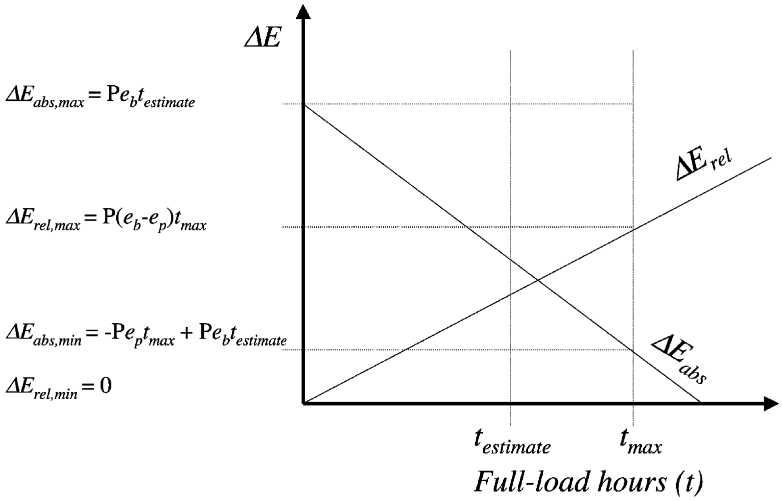

Fig. 2. Uncertainty ranges for emissions reductions (ΔE) in absolute and relative baseline cases in an energy supply project.

Springer (2002) has compared planned and annual emission reductions from 11 projects (energy efficiency and renewable energy) in the Swedish AIJ program in 1995–2000. The planned annual emission reductions in the projects were on average overestimated by 23%. Some other examples: for the 17 Finnish wind power turbines operating in 1994–2000, the average activity deviation in projects has been 15% (VTT, 2001).[10] In the UK, the activity (i.e. the full-load hours) standard deviation of the *total*[11] power production capacity has been 10% for combined cycle gas turbines and 26% for hydropower plants in 1995–1999 (DTI, 2000). During the project lifetime, experience and real monitoring data will improve the estimation of t_p for coming years.

The second point reducing the relative importance of uncertainty related to baselines is the risk diversification effect. A portfolio of JI/CDM projects is likely to reduce the deviations from realistic activity estimates compared to single projects, when the project activity levels are not perfectly correlated (Springer, 2002; Janssen, 2001).

Third, the absolute deviation of BAU is in many cases likely to be large in comparison to the deviation of ΔMECHANISMS in the total GHG emission balance (Eq. (4)). For example, in Finland the emission reduction requirement until 2010 (i.e. BAU–TARGET) is estimated at 14 $MtCO_2$ equivalent (Ministry of Trade and Industry Finland, 2001). Due to the uncertain future of the Kyoto mechanisms, 100% of the reduction requirement was prepared to be carried out exclusively with P&M. Finland's BAU-emissions are considered to be chiefly dependent on a couple of key factors (Table 4). The range of the potential impacts (from -13 to $+10$ $MtCO_2$ equivalent) is almost of the size of the emission reduction requirement itself.

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[10] The presented deviation is based on average *real* production. The deviation would likely be somewhat larger for *planned* production.

[11] The average standard deviation in full-load hours of the individual projects would be larger than the standard deviation in the activity of the total capacity.

Table 4
The impact of key variables on Finland's BAU-emissions (Ministry of Trade and Industry Finland, 2001)

Projections affecting the BAU-emissions	BAU-assumption	Sensitivity analysis	Impact on CO_2 emissions (Mt)
Net electricity imports, 2010	6 TWh	0–15 TWh	From −9 to +5.5
Annual economic growth, 1998–2020			
Pulp and paper industry	1.8%	±1%	
Metal industry	2.0%	±1%	
Chemical industry (including oil refineries)	1.4%	±1%	From −3.7 to +4.0 (all industries total)
Total			From −12.7 to +9.5

Fourth, for many countries, where BAU $>$ TARGET, it is likely that P&M has a significant size compared to ΔMECHANISMS due to the supplementarity[12] considerations. The real impacts of several individual actions in P&M, such as economic incentives, information campaigns, and training, are similarly uncertain as ΔMECHANISMS.

Finally, part of the activity in Kyoto mechanisms on a national level may run through international ET, which further reduces the volume of JI- and CDM-based transactions in comparison to deviations in BAU and P&M.

Based on these considerations, it can be concluded that the downside activity risk of relative baselines is the greater:

- the lower the emission intensity of the projects compared to the baseline;
- the shorter the compliance period;
- the lower the amount of projects with non-correlating activity levels in the portfolio; and
- the higher the volume of projected emission reductions from projects compared to the internal/domestic BAU-emissions.

Large entities, such as states or multinational companies, tend to have high BAU emissions and are likely to invest rather in a portfolio of JI/CDM projects than a single project. Many of them perform P&M to abate their GHG emissions, the effect of which is also dependent on many factors and often uncertain. It can be therefore expected that the use of relative baselines for JI and CDM projects does not pose significant additional risks to management of GHG emission balances. For smaller private entities with absolute emission caps and a significant amount of ΔMECHANISMS, the situation might be different, when $e_p < 0.5\, e_b$.

7. Conclusions

The above analysis has shown that relative baselines are a more accurate instrument for the estimation of emission reductions in JI/CDM projects in the energy sector without posing significant additional risks to the management of GHG emission balances for large entities such as states or multinational companies.

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[12] "Supplementarity" refers to the Articles 6.1(d) and 17 of the Kyoto Protocol that say the purchase of ERUs or assigned amount units should be supplemental to the domestic actions of meeting the commitments (UNFCCC, 1997). Domestic action must be a "significant element" of the efforts made by the parties (UNFCCC, 2001).

In comparison to absolute baselines, relative baselines indicate in a more realistic and conservative manner the amount of emission reductions obtained in the energy system and give more appropriate incentives to project sponsors.

The additional risks of relative baselines for the manageability of GHG emission balances are likely to be small compared to the normal deviation of the domestic/internal GHG emissions. Companies with a critical mass and ability to absorb the risk of activity deviation have the potential to sell constant reductions to risk-averse organisations with a corresponding risk premium.

The findings are in line with the Marrakesh Accords, the decisions made in COP-7 (UNFCCC, 2001), which set limits to the application of absolute baselines thus favouring relative baselines. The text in the Marrakesh Accords is, however, not explicit and enables different interpretations of “decreases of activity levels outside the project activity”.

Further research could test the hypotheses presented here about the relevance of relative versus absolute baselines to the GHG emission balance management and address the country-specific differences.

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Appendix A. Calculation of the emission reduction in an energy system, when capacity changes through a JI/CDM project

In a rationally operating energy system, the dispatch order of capacity is determined by the variable production costs. Let us define that before the JI/CDM project, there are two parts in the energy system: the capacity P_{cons} (in MW) definitely not going to be affected by the planned project (e.g. nuclear plants or old hydro power plants having very low variable costs), and the capacity being in a potential competitive situation with the project (P_{comp}). P_{comp} is defined as capacity that has—with a certain probability significantly higher than zero—variable costs higher than those of the JI/CDM project. Before the investment, the energy balance in the system is given by

$$C = P_{\mathrm{comp}} t_{\mathrm{comp},0} \eta_{\mathrm{comp},0} + P_{\mathrm{cons}} t_{\mathrm{cons}} \eta_{\mathrm{cons}} \tag{A.1}$$

where C is the energy consumption in the system, $t_{\mathrm{comp},0}$ the full-load hours (hour per year) of the capacity in the competitive situation with the project, and $\eta_{\mathrm{comp},0}$ the energy efficiency of the distribution chain, and t_{cons} and η_{cons} are the same indices for the constant system. After the project investment, the equation can be rewritten as follows:

$$C + \Delta c = (P_{\mathrm{p}} t_{\mathrm{p}} + P_{\mathrm{comp}} t_{\mathrm{comp},1}) \eta_{\mathrm{comp},1} + P_{\mathrm{cons}} t_{\mathrm{cons}} \eta_{\mathrm{cons}} \tag{A.2}$$

where P_{p} is the capacity of the project, t_{p} its full-load hours, $\eta_{\mathrm{comp},1}$ the new energy efficiency of the distribution chain taking into account the impact of the investment, and Δc is the supply-mediated increase in energy consumption.

Eqs. (A.1) and (A.2) can be combined, and we get:

$$P_{\text{comp}}t_{\text{comp},0} = (P_{\text{p}}t_{\text{p},1} + P_{\text{comp}}t_{\text{comp},1})\frac{\eta_{\text{comp},1}}{\eta_{\text{comp},0}} - \frac{\Delta c}{\eta_{\text{comp},0}} \tag{A.3}$$

If we look at the GHG emissions before the investment for P_{comp} we obtain:

$$E_0 = P_{\text{comp}}t_{\text{comp},0}e_{\text{comp},0} = \left[(P_{\text{p}}t_{\text{p}} + P_{\text{comp}}t_{\text{comp},1})\frac{\eta_{\text{comp},1}}{\eta_{\text{comp},0}} - \frac{\Delta c}{\eta_{\text{comp},0}}\right]e_{\text{comp},0} \tag{A.4}$$

where $e_{\text{comp},0}$ is the emission intensity of the P_{comp} before the investment (given in kg CO_2/MWh). The GHG emissions after the investment are given by

$$E_1 = P_{\text{comp}}t_{\text{comp},1}e_{\text{comp},1} + P_{\text{p}}t_{\text{p}}e_{\text{p}} \tag{A.5}$$

where $e_{\text{comp},1}$ is the emission intensity of the P_{comp} after the investment and e_{p} that of the project, respectively (both in kg CO_2/MWh).

The emission reduction (ΔE) becomes:

$$\begin{aligned}\Delta E = E_0 - E_1 &= \left[(P_{\text{p}}t_{\text{p}} + P_{\text{comp}}t_{\text{comp},1})\frac{\eta_{\text{comp},1}}{\eta_{\text{comp},0}} - \frac{\Delta c}{\eta_{\text{comp},0}}\right]e_{\text{comp},0} - P_{\text{comp}}t_{\text{comp},1}e_{\text{comp},1} - P_{\text{p}}t_{\text{p}}e_{\text{p}} \\ &= P_{\text{comp}}t_{\text{comp},1}\left(\frac{\eta_{\text{comp},1}}{\eta_{\text{comp},0}}e_{\text{comp},0} - e_{\text{comp},1}\right) + P_{\text{p}}t_{\text{p}}\left(\frac{\eta_{\text{comp},1}}{\eta_{\text{comp},0}}e_{\text{comp},0} - e_{\text{p}}\right) - \frac{\Delta c}{\eta_{\text{comp},0}}e_{\text{comp},0}\end{aligned} \tag{A.6}$$

We note here that if:

$$\frac{\eta_{\text{comp},1}}{\eta_{\text{comp},0}}e_{\text{comp},0} \approx e_{\text{comp},1} \tag{A.7}$$

then we obtain:

$$\Delta E \approx P_{\text{p}}t_{\text{p}}\left(\frac{\eta_{\text{comp},1}}{\eta_{\text{comp},0}}e_{\text{comp},0} - e_{\text{p}}\right) - \frac{\Delta c}{\eta_{\text{comp},0}}e_{\text{comp},0} \tag{A.8}$$

This is the case in particular when $P_{\text{comp}} \gg P_{\text{p}}$, which is mostly the case, e.g. in electricity grids.

In Eq. (A.8), the baseline case is solely reflected by the emission intensity $e_{\text{comp},0}$ and the baseline becomes relative. Determination of the terms P_{comp} and $e_{\text{comp},0}$ has been called the data aggregation problem (Ellis and Bosi, 1999). For example, *system average* and *operating margin* approaches have been discussed extensively within the electricity context (e.g. Lazarus et al., 2001; OECD and IEA, 2000; Bosi, 2000).

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