DISCUSSION PAPER

Avoiding perverse effects of baseline and investment additionality determination in the case of renewable energy projects

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CONTENTS

Abstract

As part of the international climate negotiations there is a lot of discussion about methodologies for quantifying emission reductions of greenhouse gas reduction projects (baseline discussion) and about granting emission reduction credits only to projects that are additional (Investment Additionality discussion). So far this discussion has been fairly general and has not systematically analysed the impacts on investor decisions. We analyse these impacts for the case of renewable energies and show that the approaches under discussion can all give perverse incentives to invest at unfavourable sites. Thus, higher CO_2 abatement costs than without any crediting system might be realised resulting in inefficiencies in climate policy. To overcome this problem we introduce a new Investment Additionality concept and propose to have only one emission reduction factor for each electricity grid.

Zusammenfassung

Im Rahmen der internationalen Klimaverhandlungen wird z. Z. intensiv über Methodologien zur Quantifizierung von CO_2 Reduktionen durch Projekte zur Treibhausgasminderung (sog. Baseline-Diskussion) sowie über die ausschließliche Vergabe von Emissionsreduktionszertifikaten für Projekte, die zu zusätzlichen Reduktionen führen (Investment Additionality Diskussion), diskutiert. Bisher war diese Diskussion sehr allgemein gehalten und die Auswirkungen der betreffenden Regelungen auf das Entscheidungsverhalten von Investoren wurden nicht systematisch untersucht. Wir analysieren diese Wirkungen für erneuerbare Energien und zeigen, dass die diskutierten Verfahren den Anreiz geben können, an ungünstigen Standorten zu investieren. Auf diese Weise können höhere CO_2 Vermeidungskosten realisiert werden, als dies ohne jegliches Anreizsystem der Fall wäre, woraus wiederum eine ineffiziente Klimapolitik resultieren würde. Um die Probleme zu lösen, führen wir ein neues Konzept der Investment Additionality ein und fordern für jedes elektrische Netz jeweils einheitliche Baselines (Emissionsreduktionsfaktoren) zu verwenden.

1 Introduction

Among the variety of possibilities to reduce greenhouse gas (GHG) emissions into the atmosphere, the use of renewable energies (RE)[1] is generally considered as a promising option and lots of studies have been undertaken to assess abatement costs and reduction potential of CO_2 (FME 2000, IEA Greenhouse Gas R&D Programme 2000). These studies only focus on the macro economic level. However, the quantification of emission reductions achieved by a single project becomes more and more important as additional revenues by sale of emission reduction credits may become more and more relevant for individual investor's decisions making. This is why micro-economic aspects have also to be analysed. The project based calculation, that is strongly dependent on the criteria used, is necessary for different reasons:

- According to Art. 6 and 12 of the Kyoto-Protocol, it is possible for Annex B countries to invest in JI and CDM-projects in order to create emission reductions that may help to reduce costs for achieving compliance with the emission targets (UNFCCC 1997).

- Interest in acquisition of emission reductions for other reasons as for example voluntary emission targets (e.g. companies organised in the partnership for climate action) or in order to meet legal national requirements (Climate Trust 2001).

For quantifying project based emission reductions it is necessary to determine a business as usual scenario to be able to answer the question "What would have happened in the absence of the project?". This issue is also referred to as baseline setting. Apart from the question "How much emissions are reduced by a project?" one can ask if these reductions are additional to anything that would have happened anyway. This issue is referred to as Investment Additionality and aims at assuring environmental integrity when using flexible mechanisms as part of an efficient climate policy.

In the following sections we describe these two aspects more detailed before discussing the relationship between individual investor's decision making and macro-economic CO_2 abatement costs. We then show theoretically how the different approaches for baseline setting and investment additionality influence the aforementioned relationship between micro- and macro-economic aspects. We continue by examining the theoretic

1 In the following the term renewable energies refers to zero GHG emission technologies as for example wind, solar or wave power, i.e. technologies where the yield is dependent on the site of installation. Consequently, biomass is not considered in this context.

findings in a simulation with actual data before discussing our findings. Finally, we come up with new proposals for setting baselines for RE and investment additionality.

2 CO_2 Emission reductions

When talking about quantification of CO_2 emission reductions one has to distinguish between the reduced quantity calculated by applying whatever baseline methodology and the factual reductions. These two figures do not need to be inevitably equal. They may even be likely to be unequal since exact quantification seems to be desirable on the one hand but one the other hand transaction costs might be by far too high to justify exact determination.

2.1 Baseline determination

To answer the question "What quantity of GHGs was abated by the project?" requires (Baumert 1999):

- A project baseline (reference scenario) that estimates what would have happened in the absence of the project
- Methods for quantifying a project's GHG emissions (that are zero in the case of the RE investigated in this paper)
- A quantitative comparison of actual emissions to baseline projections.

The steps are visualised in Fig. 1.

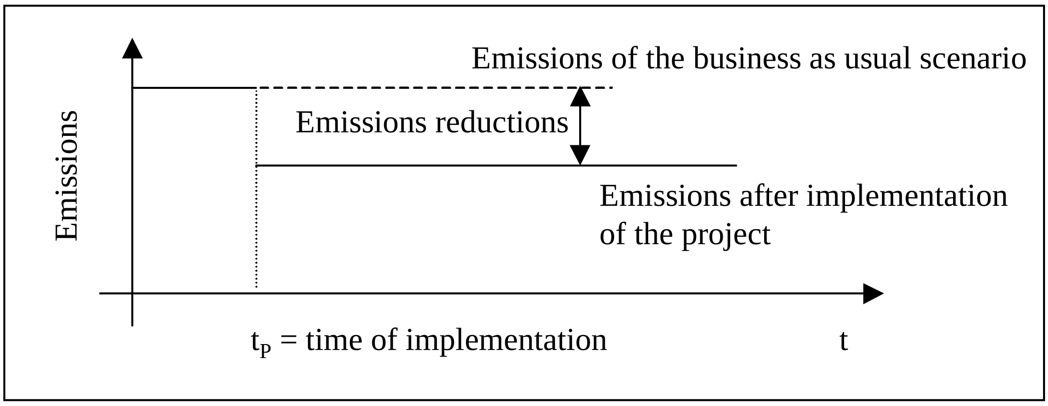

Fig. 1: Schematic graph of quantification of emission reductions

The schematic graph in Fig. 1 may be deceptive since the determination of the reference scenario is everything but trivial. First of all there are several possible approaches as shown in Fig. 2. Furthermore, even for the standardised approaches there are several parameters that have to be (arbitrarily ?) set before emissions reductions can be quantified, as for example:

- Geographical range of baseline (regional, national, supra-national)
- Sectoral range of benchmark (encompassing single fuel vs. all fuels)
- If a technology standard is chosen: Should it be based on industrialised or developing countries standards of technology?

The aforementioned problems are discussed in detail in several papers (OECD 1999, WB 1998, Michaelowa et. al. 1999).

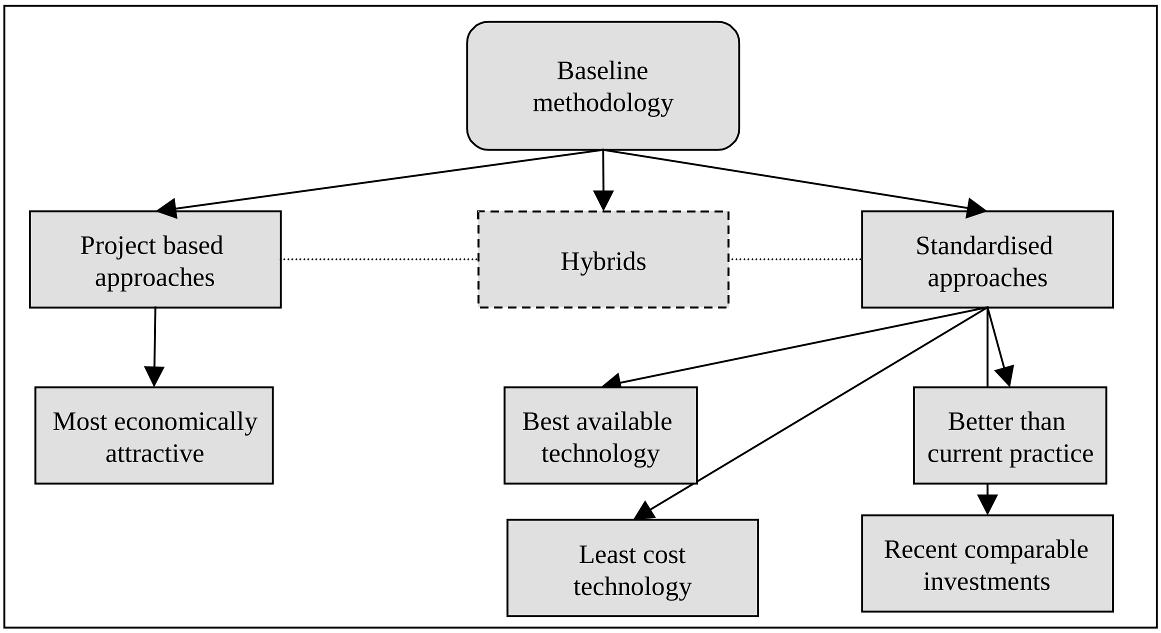

Fig. 2: Important baseline methodologies

However, we do not want comment on the different methodologies nor discuss the pros and cons at this point. We rather acknowledge the fact that there are different approaches and that consequently even “standardised” baselines may lead to granting of different quantities of emission reductions to the same kind of projects undertaken at different sites[2]. This will be the case when the decision on methodologies to apply is

2 Referring to figure 1, this means two different horizontal dashed lines.

taken only against the background of national aspects. We will focus on the analysis of the impacts of the different granting strategies.

2.2 Factual Reductions

As already mentioned there might be a difference between emission reductions quantified according to a certain baseline methodology on the one hand and factual reductions on the other hand. In this context it is of crucial importance to note that the factual reductions occurring have to be considered as one uniform figure for each electricity grid and load period regardless of the quantity of credits granted following whatever baseline methodology. In this context it is irrelevant the whether it is a grid in a single country or a grid extended over several countries.

Fig. 3 shows a situation that can be found throughout the world: Two countries have their electricity grids that are connected and each of them has a national portfolio of power plants. Energy may flow in both directions during a certain period, for example due to the specific demand curves.

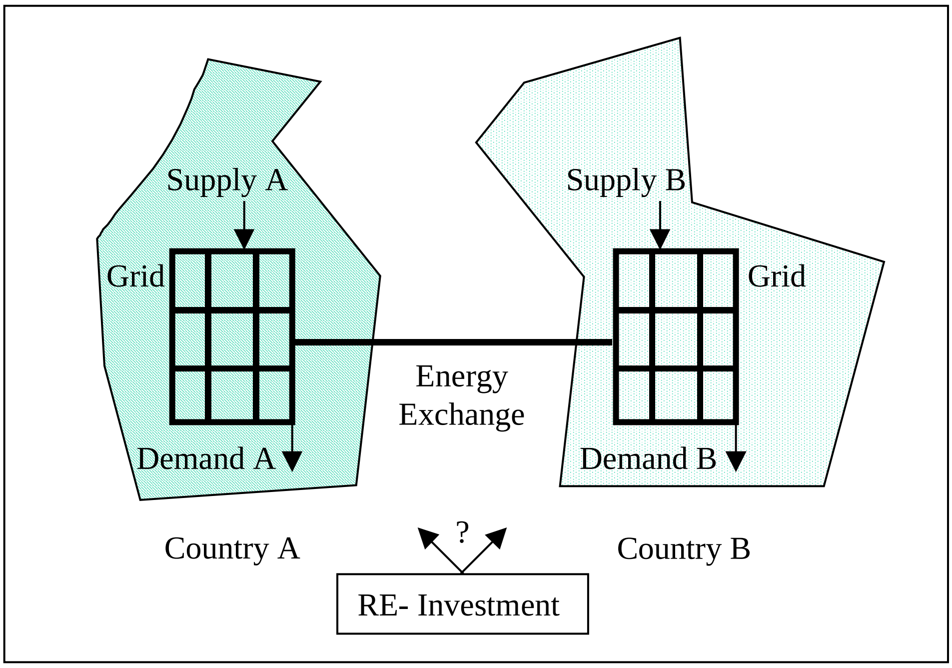

Fig. 3: Common structure of electricity grids in and between two countries

Provided that any demand for electricity is met sooner or later, two cases have to be considered when investing in RE:

(a) Constant demand and thus early replacement of a fossil fuelled power plant in operation

(b) Increasing demand and thus enlargement of total capacity

Keeping in mind that energy is exchanged, one can see that for both cases that it is not important for the factual reductions where a RE-project is undertaken. For case (a) one would argue that energy from the fossil fuelled power plant with the highest variable production costs would be driven out of the market. The quantity of CO_2 reduced would be that, that was not released by burning of fossil fuels. It is irrelevant, whether it is located in the same country where the RE-project is undertaken or not[3]. For case (b) the argumentation is slightly different: When energy demand is increasing, total emissions cannot decrease. In the best case they remain constant[4]. In this case it is necessary to construct a business as usual scenario in to be able to quantify emission reductions. However, if the additional demand was to be met by construction of a conventional plant and if we assume that there was an optimal location for its constructions, it would be irrelevant (compared to the BAU-scenario) if the RE-project was located in the same country or not.

Fig. 4 gives an example about the potential regional extension of existing electricity grids. Fig. 5 provides some data on energy exchange for some parts of the grid depicted in Fig. 4.

3 The investor‘s decision whether to invest in country A of B is discussed later.

4 For example, if additional demand is met by increase of efficiency.

Fig. 4: Mediterranean electric networks (Medelec no year)

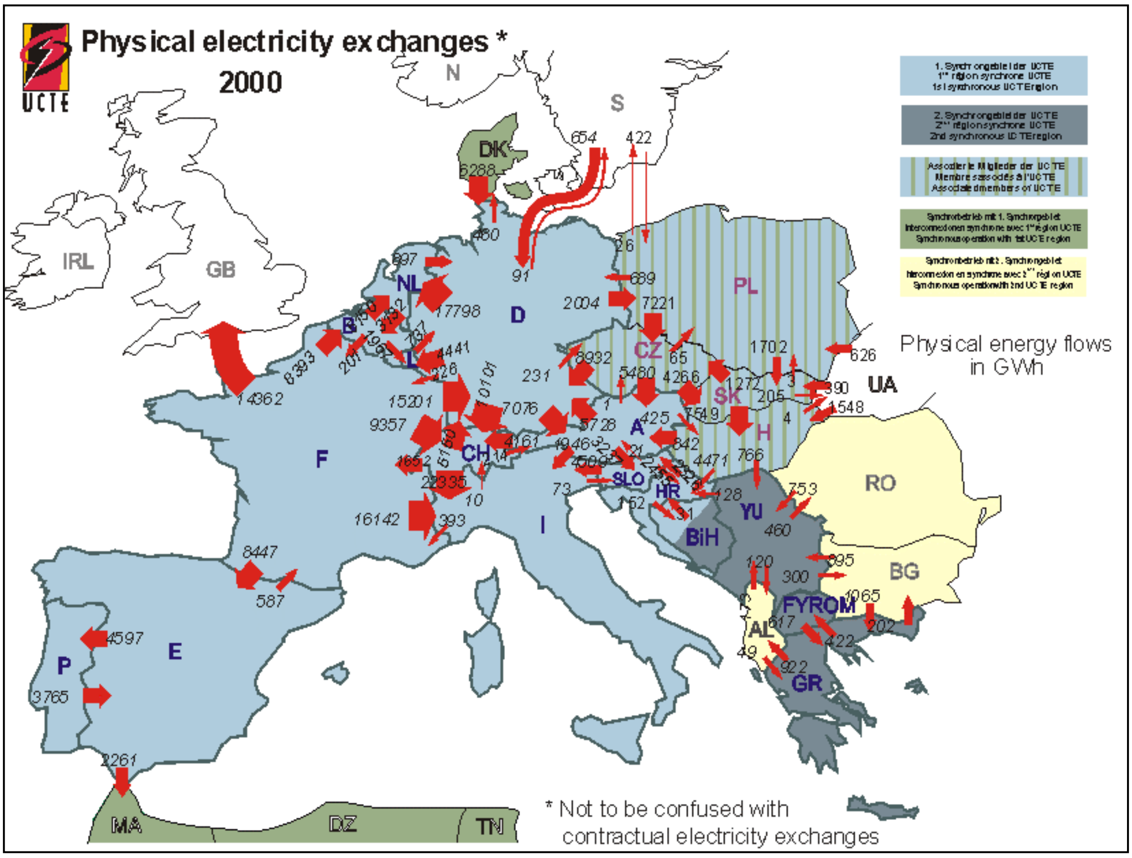

Fig. 5: Physical electricity exchanges within UTCE (UTCE 2000)

One should note that there is a connection between grids in Annex I and Non-Annex I countries.

3 Investment Additionality – Assuring Environmental Integrity

Apart from the question "How much emissions are reduced?" one has to ask if and how much reduction credits should be granted to the project in question. An important issue in this context is the so-called Investment Additionality (in short: IA)[5]. Derived from the wording in the Kyoto Protocol that a JI-project must provide "a reduction in emissions by sources, or an enhancement of removals by sinks, that is additional to any that would otherwise occur" (Art. 6.1) and that a CDM-project must provide "reductions in emissions that are additional to any that would occur in the absence of the certified project activity" (Art. 12.5) the IA-criterion says that any project that is already sufficiently attractive in terms of both, financial and non-financial aspects, cannot be granted any emission reduction credits. Thus, it is of crucial importance to distinguish between *real and measurable* emission reductions (that might have happened anyway) and *crediting* of these (additional) reductions resulting in Emission Reduction Units (ERU) or Certified Emission Reductions (CER) for JI and CDM-projects respectively. The rationale behind the IA-argumentation is the integrity of environmental targets. However, this is not relevant in case of JI since emission reductions from JI projects are deducted from the host's emission budget. On the other hand the risk of non-compliance may increase. For CDM-projects the call for IA seems quite reasonable since CERs enhance the industrialised countries' emissions budgets and any crediting of "fake" emission reductions would inflate the industrialised countries' emission target. This is why in the following sections only CERs are considered. Emission reductions not motivated by the Kyoto-mechanisms as mentioned above are also summarised under CERs for simplicity reasons. Furthermore, we concentrate on financial aspects[6] only as they are likely to play an important role when defining IA as they are less vulnerable to manipulation than qualitative criteria. For a detailed discussion see Langrock et al. (2000).

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5 Note that Investment Additionality as it is understood in this paper, is called Financial Additionality by other authors (see for example Baumert 1999). However, we understand Financial Additionality in the sense "additional to Official Development Assistance (ODA)" which is now an accepted term in the international climate negotiations.

6 There is a large variety of parameters to judge on attractiveness as for example the internal rate of return, the net present value, the payback period etc. We go into detail later.

The credited emission reductions are commodities that can be sold and thus provide additional revenues and increase the economic attractiveness of a project. Fig. 6 illustrates this effect. By receiving reduction credits a project may either beat the IA threshold (P_1) or simply become more attractive without beating it (P_2).

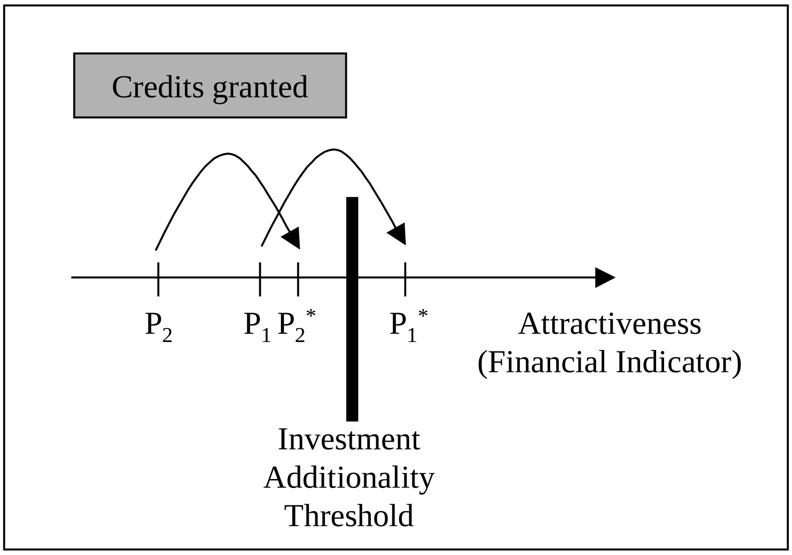

Fig. 6: Granting of CERs and change of attractiveness of a project

For other projects not expressively labelled CDM the IA requirement can also be found: “The Requesters will only fund projects where mitigation measures would not occur in absence of offset project funding.” (Climate Trust 2001)

4 Individual Investor’s Optimisation Behaviour and Macro-Economic CO_2 Abatement Costs

We look at a single investor who is trying to maximise his profit. When talking about RE it is of crucial importance to note, that – in contrast to conventional power plants - the yield (and thus cost) of renewable energy devices is heavily dependent on the site where the plant is constructed (for example: different average wind speed in coastal areas and inland or more or less increasing irradiation from the poles to the equator). On the other hand electricity is a very homogenous good the price of which is set on the market and can only be influenced to small degree by the investor. Assuming that the investor wants to carry out a RE-project he will maximise the profit P over the project life-time

$$P = (p^{el} - c_v) * x_i - c_f \qquad (1)$$

where p^{el} = Price for electricity

x_i = Quantity of electricity produced at site i

c_f = fixed costs [7]

c_v = variable costs [8]

by choosing the site with the maximum expected yield of energy[9].

By carrying out a RE project the investor may also reduce CO_2 emissions depending on the circumstances. We describe these factual emission reductions e_F. One can now determine the macro-economic CO_2 abatement costs C^{CO_2} as

$$C^{CO_2} = \frac{c_f - x_i * c^*}{x_i * e_F} \qquad (2)$$

where c^* = Average specific costs of electricity from alternative investment

By introducing the factor $x_i * c^*$ we take into consideration that the electricity produced by the RE-device would have had to be generated by a conventional power plant in the absence of the RE project.

If we now take into account that the investor may also get additional revenues from the sale of emission reductions, we have to change equation (1):

$$P = p^{el} * x_i - c_f + x_i * e_i * p^{co_2} \qquad (3)$$

where p^{co_2} = Price of emission reductions (that is assumed to be determined exogenously since a single RE-project is unlikely to generate an amount of certificates big enough to influence the price.)

e_i = emission reduction factor at site i

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7 Set up costs may also vary from site to site. However, there is no correlation between average expected yield and set up costs so that we regard fixed costs as independent of the site of installation.

8 During the following investigation we neglect variable costs. Most costs considered to be variable are rather dependent on the size of the installation (as for example insurance, rent for the ground) but not the exact number of kWh produced. There are of course some costs for wear and tear. However, we do not consider them, since RE-devices are normally designed for high utilisation (e.g. high wind speed). Reduced utilisation does consequently not result in considerable savings. Interestingly, none the major wind turbine manufacturers contacted by the authors was able to provide any detailed data on “real“ variable costs.

9 We neglect discounting of future costs and revenues at this point. It is important to note that the investor will decide in favour of the site with the highest expected yield of energy.

5 The Impact of Differences in Reduction Factors

As already mentioned the costs for renewable energies vary from site to site. In case that two different emission reduction factors are calculated within the range of only one single electricity grid a new situation is faced. This could either be the case if a national range is set for standardised baselines in the electricity sector or if project based baselines are to be used. It should be noted, that it is still unclear which one to apply (UNFCCC 2001 p. 26). Table 1 provides a view over emission intensity for heat and power generation in different Annex I countries.

Table 1: Emissions from Electricity and Heat Generation in Annex I Countries in 1998 (OECD 2000 pp. 84-87)[10]

(all in g CO_2/kWh)	Low	Country	High	Country	Difference
Emissions from Electricity and Heat Generation (incl. RE)	3	Iceland	865	Greece	862
Emissions from Electricity and Heat Generation using Coal	407	Lithuania	1435	Slovak Republic	1028
Emissions from Electricity and Heat Generation using Oil	322	Germany	1258	Ukraine	936
Emissions from Electricity and Heat Generation using Gas	204	Czech Republic	1327	Ukraine	1123
Emissions from Electricity and Heat Generation Fossil Average	**311**	n.a.	**1340**	n.a.	**1029**

The investor – still maximising his profit – has to decide whether to invest at site A or B by comparing the following options:

$$p^{el} * x_A - c_f + x_A * e_A * p^{co_2} > ? < p^{el} * x_B - c_f + x_B * e_B * p^{co_2} \qquad (4)$$

10 Since emissions per kWh varied significantly from one year to the next it is not reasonable to consider maximum und minimum figures even though it would be desirable.

Let A be a site with less favourable conditions (e.g. lower average wind speed) than at site B. At the same time e_A be greater e_B, i. e. the baseline emission reduction factor at A is higher even though the same unit of energy in the same grid is replaced.

A rational investor has the incentive to invest in (the worse) region A in case his additional revenues from sale of emission reductions at B offset the lower yield of energy at A. Transforming equation (4) we get for a decision in favour of unfavourable site A:

$$\frac{x_B}{x_A} < \frac{1 + e_A * \frac{p^{CO_2}}{p^{el}}}{1 + e_B * \frac{p^{CO_2}}{p^{el}}} \qquad (5)$$

One can see in unequation 5 that the decision is of course dependent on the emission reduction factor e_i and also from the ratio of p^{CO_2} and p^{el}.

Since the energy yield curve is theoretically continuous, there will always be a marginal site for which the inequation can be satisfied by the investor's choice as long as all variables are greater than zero. However, for practical decision making there is no use to distinguish between sites that differ from each other in the 10^{th} decimal place since for example wind speed or data for irradiation vary from year to year and mean values for investment appraisal provide anyway only an expected value.

We still assume that A is the site with the less favourable conditions, i.e. $x_A < x_B$. If now unequation 5 is satisfied, the investor decides in favour of A and considering (2) macro-economic abatement costs amounting to

$$C^{CO_2}{}_A = \frac{c_f - x_A * c^*}{x_A * e_F} \qquad (6)$$

are realised. However, with x_A being smaller than x_B, $C^{CO_2}{}_A$ becomes greater than $C^{CO_2}{}_B$. This is to say, that by maximising his profit, the investor realises higher abatement costs than without any crediting system. By granting CERs, doubtful incentives for investor can be given. To overcome this problem, there must be only one single emission reduction factor e_i^* for each discrete electric grid. Furthermore, it would be desirable that e_i^* equals e_F. However, the later issue is explicitly not discussed in this investigation since it would blow up the paper.

6 Renewable Energies and Investment Additionality

As already mentioned the yield (and thus costs) of renewable energy devices is heavily dependent on the site where the plant is constructed. Consequently, an investor has a bearing on the fact, whether his RE-project is classified additional or not and whether he will thus be granted CERs by simply choosing an appropriate site. If we prescribe that site A is more unfavourable than site B, that is to say that projects at A would be additional and thus be granted credits in case of an investment compared to site B where no CERs are granted, he faces the following problem:

$$p^{el} * x_A - c_f + x_A * e_y * p^{co_2} > ? < p^{el} * x_B - c_f \qquad (7)$$

This degree of freedom leads to the following phenomenon:

As mentioned in the section *Investment Additionality* a financial indicator has to be calculated when judging on additionality. This parameter can be derived from equation 7. However, we continue using the general expression *FI* for further reflections. We will use a concrete parameter when conducting the simulation.

Let FI_U and FI_F be the financial indicator for an RE project at a favourable and an unfavourable site respectively.

When

$$FI_U > \text{IA-threshold} > FI_F \qquad (8)$$

(that is to say only the investment at the unfavourable site is additional and is thus granted CERs that can be sold) the investor has an incentive to invest at an unfavourable site as long as the additional revenues from CER sale offset the reduced income from energy sale at the unfavourable site.

However, assumed the price of the CERs and the reduction factor cannot become infinite, the unfavourable site cannot not become arbitrarily bad: Installing wind turbines in a forest will definitely result in production costs that meet any IA-threshold but they will not generate enough CERs to offset these costs. This fact is illustrated generally in Fig 6.

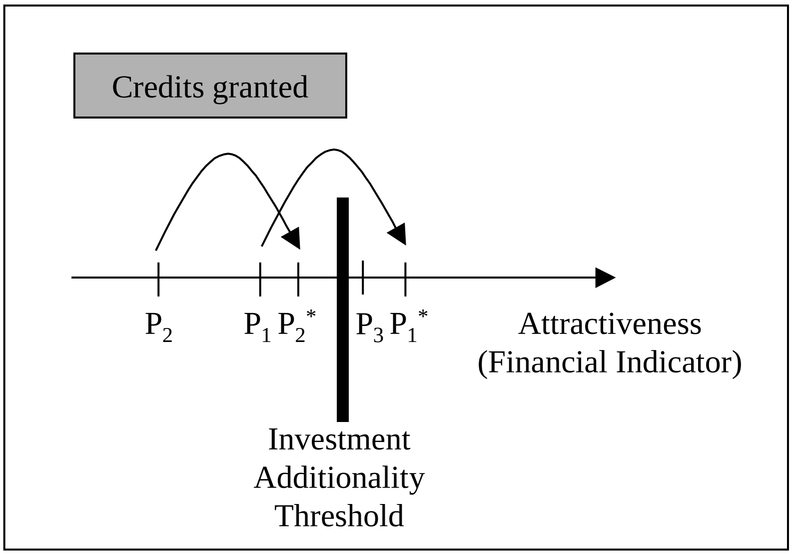

Fig. 7: Over-crediting of unattractive RE-projects

Both, P_1 and P_2, are granted credits and thus become more attractive. Taking into account these credits, P_1* may become even more attractive than a project that was not classified additional (P_3).

7 Simulation of RE-projects

If we change unequation (4) in the way that we do not focus on absolute emission reduction factors but rather on the difference we get

$$p^{el} * x_A - c_{fA} + x_A * e_\Delta * p^{co_2} > ? < p^{el} * x_B - c_{fB} \qquad (9)$$

where e_Δ denotes the difference in the reduction factors $e_\Delta = e_A - e_B$. If we prescribe that region A has always the greater emission reduction factor, e_Δ must always be greater zero.

If we compare unequation 7 and 9, we can than see that the structure of the problem is the same for both, differences in reduction factors and the IA issue. However, the outcome has to be interpreted differently.

In the following simulation the internal rate of return (IRR) was chosen as parameter to compare different projects. An investor will decide in favour of the project with the highest IRR. Other parameters as for example the net present value or the pay back period also could have been applied, however, we restrained from so doing for capacity reasons. Furthermore, the simulation is restricted to wind turbines and solar modules. This selection was judged to be representative for other RE- technologies.

For all cycles of the simulation we set p^{elec} = 0,05 €/kWh. c^*, i.e. the average specific costs of electricity form alternative investment, is set to 0,03 €/kWh. This is to represent average production costs of fossil fuelled power plants. This selection is necessary since it can be assumed, that wind energy replaces power in the middle load range, where fossil fuelled power plants are set in (Mayer 2000 p.56). Consequently, nuclear power plants must not be considered.

7.1 Investments in Wind Turbines

From the variety of available wind turbines a *NEG-Micon NM 750/48* (750 kW rated power) was selected. Measured power curve and costs were taken from literature (BVW 1999). Other parameters (see Tab. 2) were set by the authors.

Table 2: Costs for Wind power

Investment Costs ('000€):	600
Set up Costs: 30% of Investment Costs ('000 €):	180
Subtotal ('000 €):	780
Operation Time (y):	18
Interest Rate:	12%
Capital Costs ('000 €/y):	108
Maintenance: 1,5% of subtotal ('000 €/y):	12
Total Costs ('000 €/y):	**119**

The yield the sites with different wind speeds was always calculated by using the Raleigh-distribution.

7.1.1 Simulation 1: Low CER price, small difference in emission reduction factors and investment in wind turbines at current costs

For the first simulation we assumed a benchmark of 0,5 t_{CO2} per MWh. This represents either the differences in emission reduction factors in different countries (see Tab. 1) or the reductions assigned to a project that was judged to be additional[11]. The price for CER is 5 € / t_{CO2}. Results for different sites are depicted in Tab. 3.

Table 3: IRR with low CER price, small difference in emission reduction factors and investment in wind turbines at current costs

Nr.	Average Wind Speed (m/s):	Yield (MWh/y)	IRR (without CER-Revenues)	CO2 Reduction (t/y)	Revenues from sales of CERs (€/y)	IRR (incl. CER Revenues)	Macro- CO2 Abatement Costs (€/t)
1	4.00	428	-14%	214	1071	-13%	497
2	4.50	632	-8%	316	1580	-7%	317
3	5.00	865	-4%	432	2162	-3%	216
4	5.50	1126	0%	563	2816	0%	152
5	6.00	1399	3%	699	3497	4%	111
6	6.50	1682	6%	841	4205	6%	82
7	7.00	1971	8%	986	4928	9%	61
8	7.50	2257	11%	1128	5641	12%	46

To see whether one of the aforementioned effects appears one has to compare the IRR including CER revenues in line i with the IRR without CER revenues in line i + x.

With the boundary conditions set in simulation 1 none of the aforementioned effects appears.

11 For example if emissions from a natural gas fired power plant with an efficiency of about 40% are avoided.

7.1.2 Simulation 2: High CER price, small difference in emission reduction factors and investment in wind turbines at current costs

As already mentioned the price of the CERs is of crucial importance. Tab. 4 shows the simulation results for a CER price of 25 €.

Table 4 IRR with high CER Price, small difference in emission reduction factors and investment in wind turbines at current costs

Nr.	Average Wind Speed (m/s):	Yield (MWh/y)	IRR (without CER-Revenues)	CO2 Reduction (t/y)	Revenues from sales of CERs (€/y)	IRR (incl. CER Revenues)	Macro- CO2 Abatement Costs (€/t)
1	4.00	428	-14%	214	5355	-10%	497
2	4.50	632	-8%	316	7901	-5%	317
3	5.00	865	-4%	432	10808	-1%	216
4	5.50	1126	0%	563	14079	3%	152
5	6.00	1399	3%	699	17483	6%	111
6	6.50	1682	6%	841	21023	9%	82
7	7.00	1971	8%	986	24641	12%	61
8	7.50	2257	11%	1128	28207	15%	46

As one might have expected with a higher CER price the distorting effect appears. Depending on the site available, an investor can have the incentive to invest at unfavourable sites.

Case a): differences in emission reduction factors

Assuming that he can for example decide between site no. 6 where the emission reduction factor is higher and site 7, he is likely to invest at no. 6 instead of site no.7 since the IRR is higher at the former.

While there is nothing to argue against this decision on micro-economic level it turns out that from a macro-economic point of view this decision does not lead to an efficient abatement policy: By optimising his personal investment strategy the investor realises higher CO_2 abatement costs as can be seen in the last row.

Case b): Investment Additionality

We assume that the IA-threshold was set to an IRR of 7%. In this case the project at site 6 would be additional whereas the one at site 7 would not (compare IRR of site 6 and 7 in the 4th row from the left). This would imply the same result as in case a) even in the same region with only one emission reduction factor.

7.1.3 Simulation 3: High CER price, big difference in emission reduction factors and investment in wind turbines at current costs

Furthermore, the influence of difference in emission reduction factors has to be investigated[12]. We suggest a difference in reduction factors of 1 t_{CO2} per MWh. This corresponds also to emissions from a hard coal fired power plant with an efficiency of about 33% that may be avoided and credited for a project found to be additional. The price is still 25 € per t_{CO2}. The results are given in Tab. 5.

Table 5 IRR with high CER Price, big difference in emission reduction factors and investment in wind turbines at current costs

Nr.	Average Wind Speed (m/s):	Yield (MWh/y)	IRR (without CER-Revenues)	CO2 Reduction (t/y)	Revenues from sales of CERs (€/y)	IRR (incl. CER Revenues)	Macro- CO2 Abatement Costs (€/t)
1	4.00	428	-14%	428	10711	-8%	248
2	4.50	632	-8%	632	15802	-3%	159
3	5.00	865	-4%	865	21617	2%	108
4	5.50	1126	0%	1126	28157	6%	76
5	6.00	1399	3%	1399	34967	9%	55
6	6.50	1682	6%	1682	42047	13%	41
7	7.00	1971	8%	1971	49282	16%	31
8	7.50	2257	11%	2257	56414	19%	23

As can be seen, the distorting effect is now occurring for a wider range of sites. It first appears for decisions between site no. 3 and 4. If site no. 6 was the best available one in

12 For conceivable differences in emission reduction factors see also Tab. 1.

region A, even more favourable sites like no. 8 in region B could not compete. Again, higher CO_2 abatement costs are realised.

7.1.4 Simulation 4: Low CER price, small difference in emission reduction factors and investment in wind turbines at future costs

As stated earlier an enormous cost cutting potential can be expected for wind power. To analyse this effect, we cut costs by 75% (as predicted in FME 2000 p. 14) from 600.000 € to 150.000.

The results are shown is Tab. 6.

Table 6: IRR with low CER price, small difference in emission reduction factors and investment in wind turbines at future costs

Nr.	Average Wind Speed (m/s):	Yield (MWh/y)	IRR (without CER-Revenues)	CO2 Reduction (t/y)	Revenues from sales of CERs (€/y)	IRR (incl. CER Revenues)	Macro- CO2 Abatement Costs (€/t)
1	4.00	428	6%	214	1071	7%	79
2	4.50	632	13%	316	1580	14%	34
3	5.00	865	20%	432	2162	21%	9
4	5.50	1126	27%	563	2816	28%	-7
5	6.00	1399	34%	699	3497	36%	-17
6	6.50	1682	42%	841	4205	44%	-25
7	7.00	1971	49%	986	4928	52%	-30
8	7.50	2257	56%	1128	5641	59%	-34

As in the first cycle, the distorting effect does not occur since with decreasing investment costs both IRR with and without revenues form sale of CERs are reduced.

7.2 Investments in Solar Modules

In contrast to the approach for wind turbines no specific type of solar module is selected. The key parameters are rather modelled in a way that they represent the physics of existing modules. Details are given in Tab. 7.

Table 7: Costs for photovoltaics

Installed Surface A (m2):	1000
Efficiency Factor η (System):	0.13
Power (kWp):	130
Specific. Costs ('000€)/kWp):	2[13]
Investment Costs ('000€):	260
Lifetime (y):	20
Interest rate:	12%
Capital Costs ('000€/y):	35
Maintenance (1.5% of Inv. Costs) ('000€/y):	4
Total Costs ('000€/y):	**39**

7.2.1 Simulation 5: High CER price, big difference in emission reduction factors and investment in photovoltaics at future costs

We assume again a difference in emission reduction factors of 1 t_{CO2} per MWh. The price for CER is 25 € / t_{CO2}. Results for different sites are depicted in Tab. 8.

It was necessary to restrict the simulation of photovoltaics to these boundary conditions since otherwise it was not possible to calculate any IRR using standard software.

13 Current costs amount to about 6000 € / kWh_p.

Table 8: IRR with high CER Price, big difference in emission reduction factors and investment in photovoltaics at future costs

Nr	H (kWh/ (m^2*d)) *)	Yield (MWh/y) **)	IRR (without CER-Revenues)	CO2 Reduction (t/y)	Revenues from sales of CERs (€/y)	IRR (incl. CER Revenues)	Macro- CO2 Abatement Costs (€/t)
1	2.5	118.63	/	118.63	2966	-9%	296
2	3	142.35	-12%	142.35	3559	-6%	242
3	3.5	166.08	-9%	166.08	4152	-4%	203
4	4	189.80	-8%	189.80	4745	-3%	174
5	4.5	213.53	-6%	213.53	5338	-1%	151
6	5	237.25	-5%	237.25	5931	0%	133
7	5.5	260.98	-4%	260.98	6524	1%	118
8	6	284.70	-3%	284.70	7118	3%	106
9	6.5	308.43	-2%	308.43	7711	4%	96

*) Annual Average of Global irradiation on vertical surfaces; **) Simplified Formula: Yield = H * A * η

As for wind power, the questionable effect occurs for photovoltaic projects when certain boundary conditions are assumed.

7.3 Results of the Simulation and Conclusion

The simulation revealed that the distorting incentive to invest at unfavourable sites as theoretically described in the sections "*The Impact of Differences in Reduction Factors*" and "*Investment Additionality – Assuring Environmental Integrity*" may also occur in project implementation, when using realistic data. It turned out that the micro-economic decision making aiming in maximising profit can result in macro economic inefficiencies.

However, it seems to be impossible to say whether or not the effect will occur. Current grey-market prices range from 0.6-3 € (Natsource 2001 p. 3) and thus are lower than the price assumed in the simulation. On the other hand other studies suggest even higher prices than assumed of up to 59 € per t CO_2 for an Annex I emission trading scenario (EcoSecurities 2001). Furthermore, future prices will strongly depend on emission targets in subsequent commitment periods and on the emitters' abatement strategies.

The importance of the latter aspect can currently be seen from the NOx price development in the US-Reclaim programme.

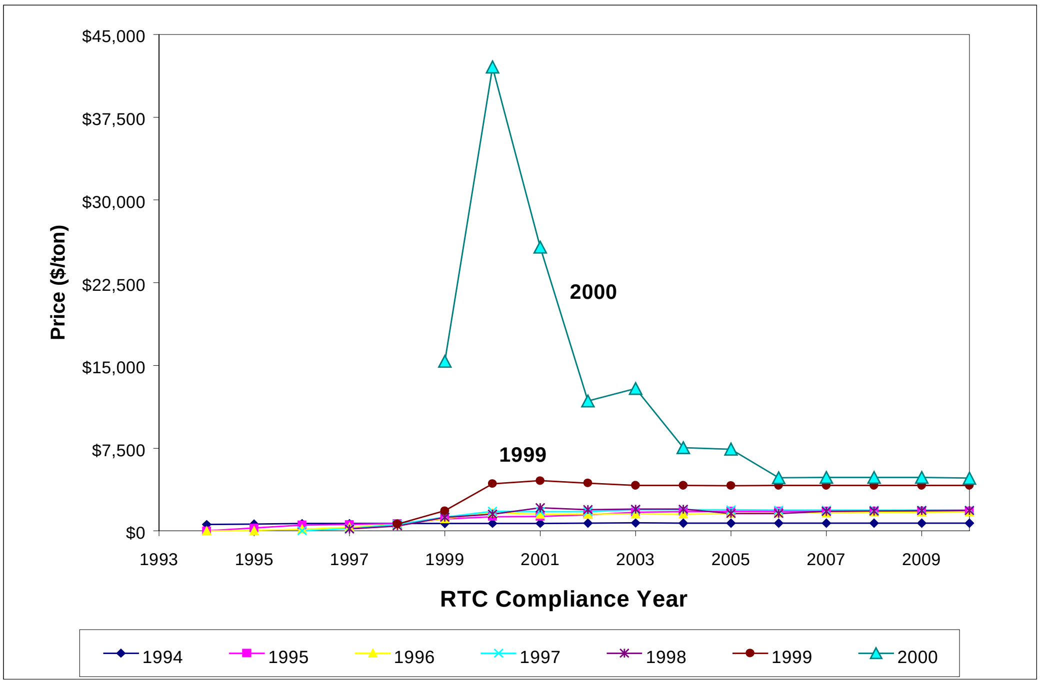

Figure 8: Development of NOx prices in the US-Reclaim programme (SCAQMD 2001)

Consequently, this issue should be already addressed today in order to avoid problems and confusion in the future. One might be tented to argue that there will only be a short term struggle for the relevant sites that will run out sooner or later. But with increasing prices for carbon credits in the future the number of site affected will also continuously increase so that action is required.

Apart from the influence of the price the crucial role of emission reduction factors – i.e. the baseline – becomes obvious. In contrast to other CO_2 abatement options as for example fuel switch or energy efficiency improvements, a unified baseline methodology for each electricity grid seems to be necessary for renewable energies in order to prevent unreasonable investments from the macro-economic point of view. Detached from this prerequisite one has to find a way to determine the emission reduction factor for a grid that is close to factual reductions.

Finally, we suggest a more fuzzy Investment Additionality threshold (for renewable energies) as depicted in Fig. 9. In so doing, the perverse incentive to invest at unfavourable sites is alleviated[14]. Furthermore, the determination of the threshold - that is anything else but trivial (see Langrock 2000 et al.) - is simplified in that sense that no choice of an exact threshold is necessary and that consequently the risk of a wrong choice is reduced.

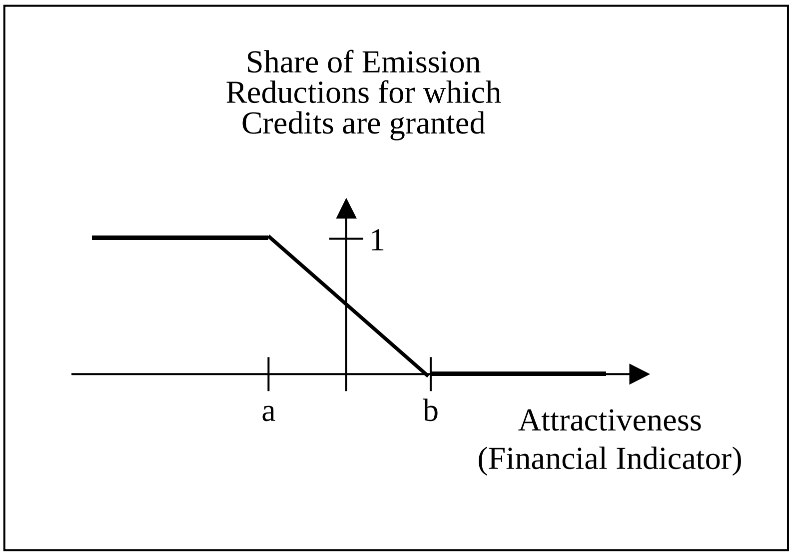

Fig. 9: Fuzzy Investment Additionality Threshold

14 The effect might still occur at marginal sites in theoretical analysis, however, this is not of relevance for practical decision making.

8 Summary

Among the variety of open questions within the international climate negotiations the issue of detailed rules for quantifying emission reductions by single projects and the question of how to define projects that deliver additional emission reduction to any that would have happened anyway are quite important. Unfortunately, there has been no systematic analysis of the impact of the different rules under discussion on investors' decision-making.

In this paper we show that the concrete design of the climate regime is, however, of crucial importance: Firstly, a uniform emission reduction factor for each electricity grid and load period is necessary. Otherwise, investors can have the incentive to invest at unfavourable sites, since the disadvantages from the reduced yield of energy can be more than offset by the revenues from the sale of the additional reduction credits. Consequently, an investor can realise higher macro-economic abatement costs by maximising his personnel profit.

The concept of Investment Additionality as discussed so far has to be reconsidered. Though aiming at assuring environmental integrity when applying the Clean Development Mechanism under the Kyoto-Protocol, it can give undesirable incentives to invest at unfavourable sites and thus result in higher CO_2 abatement costs, too. This is quite unsatisfactory since the flexible mechanism were introduced to reduce overall compliance costs. The use of a fuzzy Investment Additionality threshold can help overcome this problem from the authors' point of view.

The findings have not only been derived from theoretical conclusions but also been analysed with realistic data. As a result, it seems quite possible that the effects occur in reality. The price of emission reduction certificates and the emission reduction factor applied are the most important parameters.

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