GÖTEBORGS UNIVERSITET
HANDELSHÖGSKOLAN

WORKING PAPERS IN ECONOMICS

No 342

A Case-Study on Project-Level CO2 Mitigation Costs in Industrialised Countries - The Climate Cent Foundation in Switzerland

Laura Kunz and Adrian Muller

Version 2, February 2009

ISSN 1403-2473 (print)
ISSN 1403-2465 (online)

Institutionen för nationalekonomi med statistik
Handelshögskolan vid Göteborgs universitet
Vasagatan 1, Box 640, SE 405 30 Göteborg
031 786 0000, 031 786 1326 (fax)
www.handels.gu.se   info@handels.gu.se

TITLE:

A Case-Study on Project-Level CO_2 Mitigation Costs in Industrialised Countries - The Climate Cent Foundation in Switzerland

AUTHORS:

Laura Kunz
Socioeconomic Institute, University of Zurich, Blümlisalpstrasse 10, 8006 Zürich, Switzerland
e-mail: lauraKunz@gmx.ch; phone: 0041-44-634 37 35; fax: 0041 44 634 49 07

Corresponding author: Adrian Muller
Socioeconomic Institute, University of Zurich, Blümlisalpstrasse 10, 8006 Zürich, Switzerland
e-mail: adrian.mueller@soi.uzh.ch; phone: 0041-44-634 06 05; fax: 0041 44 634 49 07

A Case-Study on Project-Level CO_2 Mitigation Costs in Industrialised Countries - The Climate Cent Foundation in Switzerland

Abstract: We analyse CO_2 emissions reduction costs based on project data from the Climate Cent Foundation (CCF), a climate policy instrument in Switzerland. We draw four conclusions. First, for the projects investigated, the CCF on average pays € 63/t. Due to the Kyoto Protocol, the CCF buys reductions until 2012 only. This cutoff increases reported per ton reduction costs, as the additional lifetime project costs are set in relation to reductions until 2012 only, rather than to reductions realised over the whole lifetime. Lifetime reduction costs are € 45/t. Second, correlation between CCF's payments and lifetime reduction costs per ton is low. Projects with low per ton reduction costs should thus be identified based on lifetime per ton reduction costs. Third, the wide range of project costs per ton observed casts doubts on the widely used identification of the merit order of reduction measures based on average per ton costs for technology types. Finally, the CCF covers only a fraction of additional reduction costs. Decisions to take reduction efforts thus depend on additional, non-observable and/or non-economic motives. Any generalisation of results has to consider that this analysis is based on prospective costs of a sub-sample of projects in Switzerland.

Keywords: abatement cost curve; Climate Cent Foundation; climate policy; emissions reduction; mitigation costs;

Abbreviations: CCF: Climate Cent Foundation; GHG: Greenhouse gas; m: million;

1 Introduction

Like most industrialised countries, Switzerland has ambitious greenhouse gas (GHG) reduction goals (-8% from 1990 levels by 2012). Which policy instruments are best suited to reach those and how much this will cost are key questions of climate policy. Information on reduction costs per ton CO_2 and other GHGs is thus an important input to ongoing discussions on concrete design of mitigation policies in any industrialised country. In this paper, we add a piece of information on how expensive domestic reductions are. In addition, we shed some light on the functioning of one specific climate policy instrument, namely the "Climate Cent Foundation" (CCF; "Stiftung Klimarappen"), a project subsidy scheme in Switzerland. In contrast to many other studies on mitigation costs, our assessment is based on data of 96 single projects and not on aggregate or hypothetical assessment based on a low number of case studies or expert opinions only. It is, however, prospective data as provided by the project design documents of the projects supported by the CCF. Realized mitigation costs thus may be adapted retrospectively after running those projects for some years.

Although of high importance for policy making, there is limited information on costs of mitigation measures in industrialised countries. Most assessments are based on average costs of technology types or on test projects rather than on a significant number of real-world projects. Examples of such analysis for CO_2 are Koschel et al. 2006, BMU 2007, ISI 2007, Ürge-Vorsatz and Novikova 2008. Very detailed and encompassing is the recent report by McKinsey on mitigation costs and potential in Germany (McKinsey 2007). It analyses mitigation costs and potentials in several sectors, assessing around 300 single measures. The analysis is based on estimated and forecasted costs per technology type. In combination with estimated potential per technology type, an abatement cost curve is then built. Cost information for technology types seems to stem from the relevant industries and experts, but it is not clearly stated (neither in the appendices nor in the references on the method). It is also unclear, whether costs per technology type are marginal or average costs, we thus assume that it rather refers to average costs. A similar analysis was undertaken for Switzerland (less detailed), the US, Australia, Sweden, the Czech Republic and globally. Analysis for further countries will be added (McKinsey 2008, Enkvist et al. 2007). A very comprehensive report on non-CO_2 greenhouse gases containing mitigation cost curves is EPA (2006). As many binding mitigation policies are only in place since a few years, encompassing analysis of costs based on implemented measures may be available in some years only. Some project level studies exist, though, e.g. for the building sector (e.g. Jakob 2006).

Due to the flexibility mechanisms in the Kyoto Protocol, GHG reductions need, however, not necessarily to be realized domestically, but can be bought abroad, either in other countries with reduction goals (Emissions Trade ET and Joint Implementation JI) or in countries without such, i.e. mainly developing countries (Clean Development Mechanism CDM). This possibility to realise reductions abroad is important when assessing mitigation costs in industrialised countries, as these flexibility mechanisms have the potential to considerably lower compliance costs to reach the reduction goals. Currently (as of October 2008), the prices for permits in the EU Emissions market are around 18-25 €.[1] Estimates for abatement measures abroad are largely below these values (Wetzelaer et a. 2007, UBA 2007; in 2007, 1$ $\approx$ 0.7€). Estimates for costs of most domestic measures in Germany with positive costs lie above these values (McKinsey 2007). Such data lie behind the commonly held view that reductions abroad are less expensive than domestic reductions.

On the other hand, it is sometimes claimed that reductions in developing countries may be more insecure than domestic reductions. In addition, parts of society hold strong moral attitudes that reductions should not be incurred abroad, as a society should clean up its own pollution without buying its way out of responsibility. Finally, there is the often neglected fact that

[1]Depending on the type of permit, e.g. differentiated by the delivery period; for data, see e.g. the links on CO2-Handel.de 2008.

many reduction measures come at negative costs if calculated correctly (see e.g. McKinsey 2007, 2008). This is the case for measures in the building sector, for example, which have a high initial investment but a long lifetime of several decades without variable costs (e.g. insulation measures reducing oil consumption for heating). Depending on the oil price, the net present value of the additional costs of these reduction measures becomes negative sooner or later and they thus become profitable.

In our analysis, we get average reduction costs per ton CO_2 of around € 45[2], while the official expectation of costs for the CCF is 62.5 € per ton (CHF 100.-, CCF 2007a), which parallels the actual costs the CCF on average pays per ton CO_2 in our sample, namely € 63.1. This difference arises because, due to the Kyoto Protocol, the CCF sets lifetime additional costs in relation to emissions reductions until 2012 only, while a consistent per ton cost assessment should relate lifetime additional costs to lifetime reductions. In addition to gaining information on mitigation costs, this investigation of the CCF thus sheds light on some important features of instrument design for mitigation policies, such as the problem of differing time-horizons of policy measures for project support and the lifetimes of these projects.

In the following section, the CCF is presented. The data we investigate is described in section 3. Section 4 presents descriptive analysis of forecast data on costs and emissions of 96 projects procured under the CCF. Section 5 concludes.

We emphasise that all cost data for the CCF in this paper are based on project-wise net present values of current and future costs. We also emphasise, that these costs are very sensitive to the presence of outliers (see section 4; for the values reported above, outliers are excluded). A further caveat is that the representativeness of the costs of the projects investigated hinges on the absence of any selection bias. The data clearly shows some bias regarding type of projects, but we do not have enough information to

[2] All monetary values originally given in Swiss Francs CHF were converted to Euro, using an exchange rate of 1€ $\approx$ 1.6 CHF.

assess presence or absence of further selection bias within a given type. The "winner's curse", for example, a known pattern in such mechanisms for procurement as the CCF partly uses (basically a common value auction), may lead to selection of projects with unrealistically low cost expectations. On the other hand, this pattern seems unlikely in the case of the CCF, given the cost levels observed.

2 Swiss CO_2 Policy and the Climate Cent Foundation

Ratifying the Kyoto Protocol in 2003, Switzerland agreed on GHG emissions reductions of 8% with respect to base level emissions in 1990 by 2008-2012, which were 52.80 million (m) t CO_2 equivalents (the newest emissions data available is for 2006, reporting 53.21 m t CO_2 equivalents, BAFU 2008a). To meet this goal, reductions of 4.22 m t CO_2 equivalents each year from 2008 to 2012 need to be realised. Nationally, this goal is in line with the so-called "CO_2-law" from 2000, which is also the most important measure to implement the Kyoto goals in Switzerland. The CO_2-law requests the reduction of CO_2-emissions from energetic use of fossil combustibles and fuels by 10% with respect to the level of 1990 in 2010.[3] Relevant are the annual average emissions over 2008-2012 (CO_2-law, Art. 2 Abs. 1-2). It was planned that voluntary measures would reach these goals (CO_2-law, Art. 3, Abs.1). Examples of such measures are voluntary agreements on reductions between companies and the state and the program "EnergieSchweiz" to increase energy efficiency and support renewable energy (BUWAL 2005, North et al. 2007, UVEK 2007a). In case the goals will not be reached, a tax on CO_2-emissions from fossil energy sources can be levied (CO_2-law, Art 3. Abs.2). Due to slower reductions in aggregate national emissions than planned, such a tax was introduced on fossil heating fuels (not on fossil transportation fuels) at a level of 7.5 €/t CO_2 (12 CHF/t) from January 1, 2008 onwards to

[3] By 15% (3.81 m t CO_2) for cumbustibles and 8% (1.24 m t CO_2) for fuels

reach the targets of the CO_2-law (UVEK 2007c).

2.1 The Climate Cent Foundation

The Climate Cent Foundation CCF has to be seen in the light of these voluntary measures of the CO_2-law. It was initiated as such in 2002 by the interest group of oil importers (Erdölvereinigung) with the support of other industry groups such as EconomieSuisse (the largest umbrella organization representing the Swiss economy), Strasse Schweiz (Swiss road traffic association) and Schweizerischer Gewerbeverband (a Swiss trade and crafts association), and was accepted by the government as an alternative to a direct fee on CO_2 emissions from fossil transportation fuels after several assessments of realisability and scope (Factor 2002, Prognos 2002, Infras 2003, UVEK 2005, Arquit Niederberger 2005, Thalmann and Baranzini 2006). The final implementation occurs via a fee of 1.5 Swiss pence (1 Euro cent) per litre of gasoline and Diesel imported into Switzerland. This amount is one point of criticism against the CCF, as it does not harvest the price effect on consumption, which a higher tax on CO_2 would effectuate.[4] The revenues from the CCF are then used to finance CO_2-emissions reduction measures in Switzerland and abroad. With these revenues, the CCF should reduce a total of 9 m tCO_2 until 2012, whereof at most 8 m t can be reduced abroad and at least 1 m t have to be realised through domestic measures (CCF 2007a). The CCF has to report periodically on its performance. A first assessment of the CCF in September 2007 was positive (UVEK 2007b).

According to the business plan from June 2007, the CCF expects revenues of 464 m € in the period 2005 to 2013, during which the CCF is active. Costs for projects and administration in this same period are estimated to 393 m €. 94% thereof (369 m €) are used for financing reduction measures, while 6% (24 m €) are used for the administrative, acquisition, monitoring etc.

[4]The current (as of October 2008) tax on gasoline in Switzerland is around 0.47 €/l (CH 2008); the price including the tax is currently around 1.20 €/l, which is lower than in most other European countries; Erdölvereinigung 2008, EC 2008.

work of the CCF (CCF 2007b). It is expected that from 2008 to 2012, 12.7 m t CO_2-emissions reductions will be financed. The CCF would thus have overcompliance of its reduction goal of 9 m t CO_2, which hedges against the risk of undersupply from contracted projects (CCF 2007a). Adding emission reductions realised before 2008, the total emissions reductions realized until the end of 2012 will be 12.98 m t CO_2 (CCF 2007b).

About 79% of all planned reductions, that is 10.25 m t CO_2, are planned to be acquired abroad, via the CDM. For this, 137 m € will be used (thereof 2.5 m € for acquisition, monitoring and implementation). The expected average price for reductions abroad is thus about 13 € per ton CO_2 (CCF 2007b).

The remaining 21% in reductions will be realised by domestic measures in Switzerland. For this, the CCF has three programs, one aimed at increased energy efficiency in the building sector, one based on voluntary targets of individual companies and the third on various projects in the area of spatial heating, process heat, waste heat use and fuel efficiency that can apply for funding. The building sector program will reduce 0.39 m t CO_2 by 2012 at average costs of 280.- €/t CO_2. Voluntary targets will contribute 1.14 m t CO_2 from 2008 to 2012 at an average cost of 58 €/t CO_2, and the single projects program will reduce 0.95 m t CO_2 by 2012. Average costs are expected to be around 62.5 €/t CO_2 (CCF 2007a). In total, the CCF reduces 2.48 m t CO_2 from 2008-2012 in Switzerland, at total costs of about 235 m €. Adding emissions reductions already realised in the years 2006 and 2007 (CCF started operation in 2005), the total domestic reduction planned is 2.73 m t CO_2 (CCF 2007b).

2.2 The Single Projects Program of the Climate Cent Foundation

Due to data availability and comparability, we restrict the analysis on the single project program. More details on this program are provided here. Acquisition of projects is done through three channels, via auctions, brokers (intermediaries) and direct identification of promising single large scale projects. Support is available for projects in the areas of heating, process heat, waste heat utilization and transportation efficiency. These types of projects are further differentiated according to table 1. No support is available for research and development, projects that switch between different types of fossil fuels or projects related to power generation (CCF 2007b).

Insert table 1 here.

The CCF works via compensation paid to the projects for each ton CO_2 reduced. Payment is effected after verification of the emissions reductions. In the application for support by the CCF, the project partner fixes the amount of support per ton CO_2 reduced requested[5]. The level of this support per ton is the key decisive variable for acceptance or decline of a proposal.

Requirements for funding by the CCF are the same as for mitigation projects in the context of the Kyoto Protocol, such as the CDM. Central criteria are additionality and monitoring with verification of emissions reductions (CCF 2007b). Additionality is given in case the project leads to reductions otherwise not realised (physical additionality) and in case the project would not have been realized without the support of the CCF (financial additionality). For the monitoring and verification, reductions must be measurable and verifiably causally related to the project activity. This verification has to be undertaken by independent experts on annual basis following previously accepted methods. Besides these key criteria, there are further additional criteria that have to be fulfilled (see table 2). In practice, it is also required that the compensation from the CCF covers at least 10% of the additional costs of the project. This is based on the assumption that

[5]Project owners calculate additional costs for the whole project lifetime (net present value). They apply for all or a part of this to be funded by the CCF. This is then divided by expected reductions until 2012. This gives the expected per ton price of reductions, which is the basis for the decision of the CCF that decides then to pay the full or only a part of the amount required. For some more information on the reference scenario, which is needed to calculate reductions and additional costs, see footnote 6.

projects with lower coverage are not additional as such a small contribution is not expected to be decisive for the implementation decision.

Insert table 2 here.

The process of identification of promising projects is different for the three channels. In the auctions channel, projects of at least 1'000 t reduction between 2008 and 2012 can apply. Applications are possible at several dates, according to the different auctions planned. Some assessment of the proposals in form and content is undertaken by the CCF, which then decides on admission to the auction. For each auction, a total of financial means available is fixed by the CCF. Project proposals admitted to the auction are then ordered according to increasing specific costs as claimed by the project owners (CCF 2007b). Until the end of 2008, eight auctions are planned for a total of 19 m €. Expected indirect costs of the auctions (experts for the screening; implementation of the auction, which is outsourced) amount to 0.9 m € (4.8% of the total financial means for the auctions) (CCF 2007b).

In the intermediaries channel (open until June 2007), seven organizations were contracted for providing adequate projects, that reduce at least 500 t in the period of 2008-2012. A preliminary screening as in the auctions program takes place and then support is decided based on the specific funds per ton CO_2 reduced requested (CCF 2007b). Intermediaries get a provision for each project finally accepted. This provision depends on the costs per ton reduced (determined as shortly described in footnote 5) and is higher for cheaper projects (CCF 2007b, Appendix 3.23). This sets incentives for intermediaries to provide cheaper projects. A total of 16.4 m € is allocated to the intermediaries program, whereof 15.6 m € (95.4%) are reserved for project support and 0.8 m € (4.6%) for provisions and for costs of external experts (CCF 2007b).

The third channel consists of large scale projects that reduce more than 10'000 t CO_2 between 2008-2012. Acquisition is done by the CCF itself and the quality assessment is the same as for the other types of projects (CCF

2007b). 25 m € in total are planned for such large scale projects, wherefrom 0.06 m € (0.2%) are used for project acquisition and administration (CCF 2007b). This channel has thus lowest indirect costs, while it can be expected that costs incurred by the CCF itself are higher than for the other channels. These are, however, not included in the indirect costs and neither listed separately anywhere else.

3 The Data

The data is drawn from several sources from the CCF. A central source are the project development documents (PDD) filed in by the project developer. A second central document are the calculations for additionality. The third central document is the internal CO_2 account of the CCF for each project. These sources partly contain the same variables, which led to some inconsistencies between values from different sources. This could partly be explained by internal processes that updated information only in parts of these sources because the other were not relevant anymore. After consulting the CCF, we thus decided to take general information on the projects from the PDD, data on costs from the additionality calculations and data on reductions from the internal CO_2-assessment. Further inconsistences in the data that emerged during processing could mostly be resolved by discussion with the CCF. Where this has not been possible, the project was deleted from the analysis.

The data available for analysis thus contains several characteristics of the projects and forecasts on costs and emissions reductions, both with respect to some fictional reference scenario, which is calculated according to some predefined methods provided by CCF.[6] Due to the legal security of the Ky-

[6]CCF (2006) describes in detail how the emissions and costs for the reference scenario have to be calculated and how the monitoring has to be organised. Standard methods for the project categories (cf. table 1) and values for key parameters (product life times, emission factors of different fuels, energy prices, etc.) are provided. Based on CCF (2006), new guidelines were developed that apply from 2008 onwards (BAFU 2008b); therein,

oto Protocol ending in 2012, the CCF only buys reductions until 2012, and emissions and emissions reductions were projected until 2012 only. For the calculations over the whole project lifetime, we decided to insert the values for the year 2012 for all subsequent years until the end of the project lifetime. This is a conservative assumption regarding emissions reductions incurred, as some project may reach full reduction capacity only after 2012. The calculated specific reduction costs per ton are thus rather an upper bound. This is further accentuated as the project lifetime reported in the PDD is a imputed value for the depreciation of the installation. Usually, the physical capital stays in operation and correspondingly produces emissions reductions for some additional years. Due to the data being forecasts, real emissions and costs necessarily will somewhat deviate and true assessment of reduction costs will only be possible after completion of the projects.

We restrict the analysis to projects contracted for reductions, as information for the projects in the application process is often subject to changes and thus less reliable and complete. In addition, we are only interested in projects that are implemented, which is only given for projects under contract. The basic data set consisted in 102 projects contracted under the single project programme (as of mid-October 2007). 5 thereof were deleted due to missing data. An additional project was deleted because the project owner withdrew the project. In total, we thus have data from 96 projects for the analysis, which reduce 0.5 m t CO_2 by 2012 (1.3 m t over the whole lifetimes of the projects). The projects are mainly from the intermediaries channel (78). 14 are from the auctions and 4 are large-scale projects. More projects from the

---

energy prices were updated, for example. Procedures are also geared to procedures from the Clean Development Mechanism. Clearly, the choice of the reference scenario is of paramount importance for the calculation of additional costs, the reductions achieved in a project and its additionality (if the assessment of this is not based on other barriers). The choice of the reference scenario is a complex task and not free of controversies. All values reported in this paper crucially depend on the reference scenarios chosen for the projects under consideration. In this paper, we do not address questions related to the additionality of the projects we investigate.

latter two channels are expected, as there are additional 5 auctions until the end of 2008 and also acquisition of large-scale projects will continue until then, while acquisition through the intermediaries channel was finished by the end of June 2007.

Project types and their frequency in the data are listed in table 3. Most projects are from the category renewable heat production, which is at least partly due to the most active intermediaire procuring almost only such projects - the Swiss umbrella organization for wood energy (Verein Holzenergie Schweiz: Dachorganisation der Schweizer Holzenergiebranche). Project ownership is disperse, but a third is owned by municipalities (29 district heating projects). 30 additional projects are private or company owned from the energy sector and the remaining 37 are private and company owned from various other sectors.

Insert table 3 here.

The size of the projects varies considerably, 94 projects realize lifetime reductions between 330 and 62'000 t with a median of 7'004 t (mean 24'350 t, s.d. 79'400 t). Two outliers realize much higher total reductions, by almost a factor 10 (both over 500'000 t). Definitions of and some descriptive statistics for the variables we base our analysis on are provided in table 4.

Insert table 4 here.

4 Results

Due to data availability, no econometric analysis of the cost structure of the projects in the single project programme was possible. However, even some simple descriptive analysis reveals interesting information on the reduction costs per ton CO_2 for these projects. For this, we first illustrate what the CCF pays per ton CO_2 reduced (p_{CCF}, see figure 1). We emphasise again that all cost information on the CCF provided is based on net present value assessments for the projects analysed.

Insert figure 1 here.

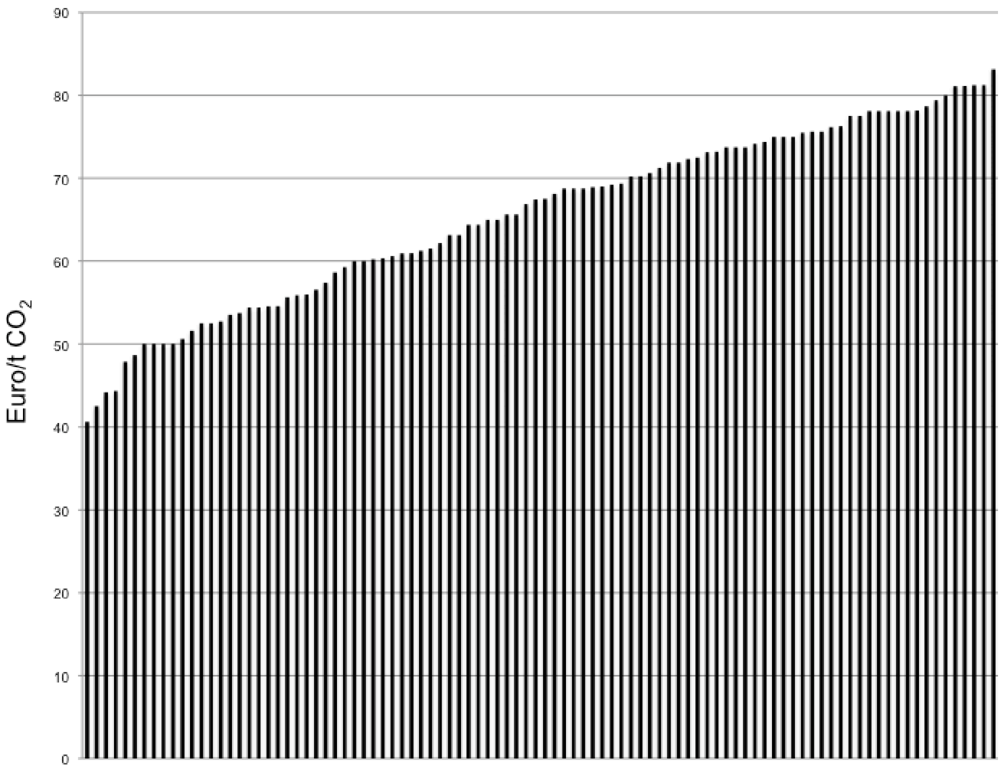

Figure 1: Payments of the CCF per ton CO_2 reduced (p_{CCF}). x-axis: projects in increasing order.

Weighted with the reductions produced until 2012, the mean value is € 63.1 (standard deviation (s.d.) 10.94; median 67.5; this excludes the two outliers in total lifetime reduction (see table 4); including those, the weighted mean is 59.3). The payments per ton of reduction by the CCF thus largely coincide with the ex-ante expectation of the CCF on these mean values and the range of these payments (€ 62.5 (CCF 2007a), €30 to 95 (section 8.2.1 in CCF 2006)). A possible explanation is that project owners apply for funds largely in this range, as the price expectations of the CCF were known.[7] The

[7]The values communicated by the CCF were expert guesses to send some price signal or information on willingness to pay in a situation where no market for permits existed in

costs paid by the CCF compares to the costs per ton reduced over the whole project lifetime (c_{LT}, see figure 2).

Insert figure 2 here.

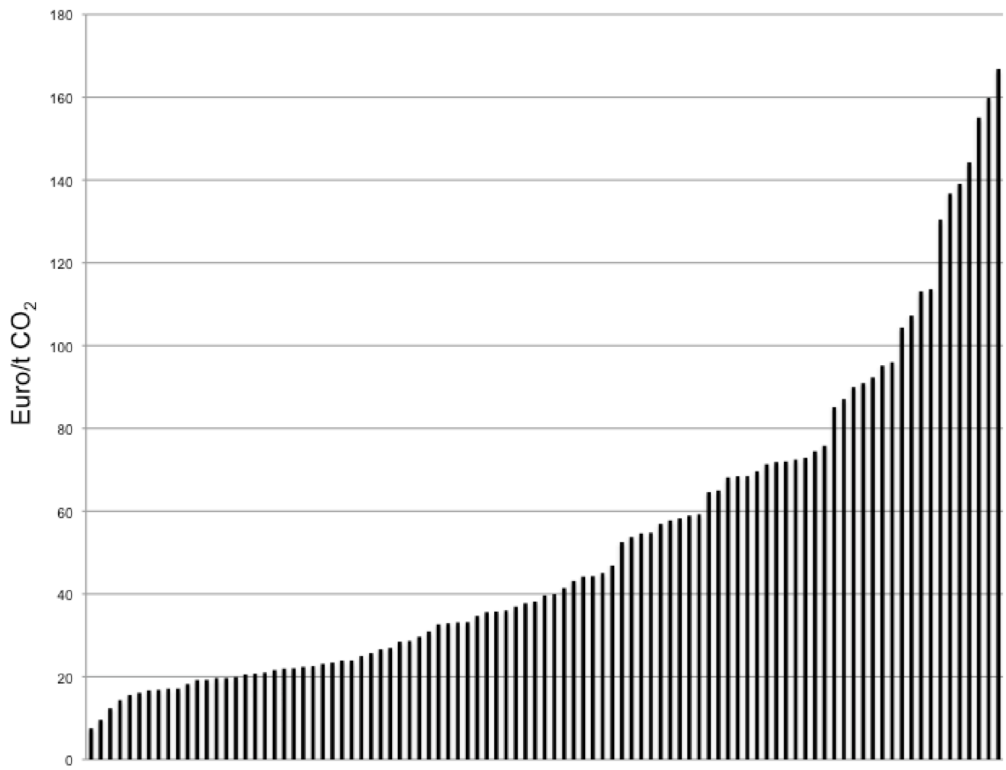

Figure 2: Costs per ton CO_2 reduced, c_{LT} (over the whole lifetime; an outlier at € 280 is excluded). x-axis: projects in increasing order.

c_{LT} is calculated by division of the discounted additional costs incurred by the project with respect to the reference scenario over the whole lifetime divided by the emissions reduced over the lifetime. Weighted with the reductions produced over the whole lifetime, the mean value for this is € 45.44 (s.d. 30.13; median 40). Here, the three outliers are excluded. Including

Switzerland and where the CCF would be the only buyer of permits (personal communication CCF).

those, the mean value lies at 32.94). It is important to note the great influence of the outliers (especially of the two large-scale outliers regarding total lifetime reductions, see table 4).

The correlation between these two costs is low (0.35) and the mean values differ significantly at 1% (t-test, N= 94 for each group; including the three outliers, the difference is significant only at the 5% level; with weighted data, the difference in means is insignificant with the three outliers and nearly significant at the 5% level without). Superficially, one might conclude that the CCF pays too much for reductions. But this is not true, as the higher payments can be motivated by the fact that the CCF only pays emissions reduced up to 2012, while the project usually runs and produces reductions for additional 10 to 15 years[8]. Accounting for this by dividing total lifetime reduction costs by emissions reduced up to 2012 only, gives much higher values (c_{2012}, mean: € 160.6, s.d. 140.25; median 131.63; including the three outliers, the mean is € 141), see figure 3.

Insert figure 3 here.

These numbers from total cost-recovery by 2012 and the actual payments made by the CCF are linked via the coverage rate, which is the quotient of total payments by the CCF over total additional costs incurred. The CCF covers part of the additional costs only (excluding the three outliers: mean 0.52, s.d. 0.3; median 0.49; weighted mean with total lifetime reductions as weights: 0.50), see figure 4.

Insert figure 4 here.

There is a large negative correlation between coverage rates and lifetime reduction costs per ton c_{LT} (-0.73) and even more between coverage rates and c_{2012}, i.e. lifetime reduction costs divided by emissions until 2012 (-0.80; logarithmic -0.98), see figure 5. There are thus high coverage rates for low

[8] The imputed project lifetime reported in the PDD. In reality, projects may operate even longer (cf. note "*" for Table 4)

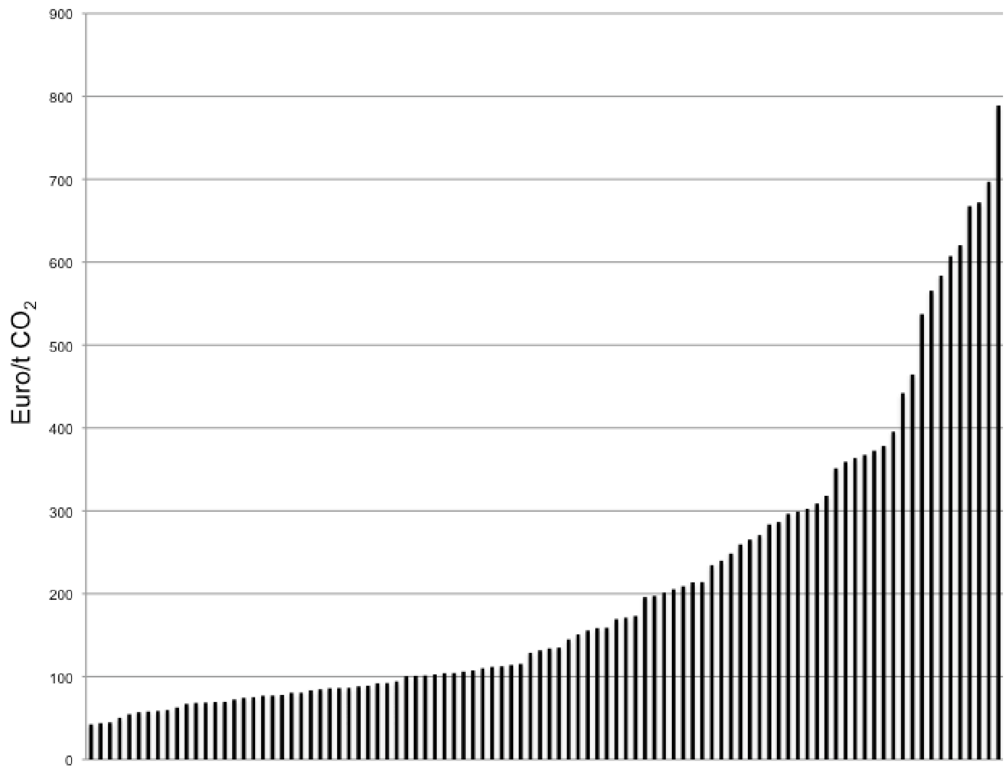

Figure 3: Costs per ton CO_2 in case total lifetime-costs are divided by reductions until 2012 only, c_{2012}. x-axis: projects in increasing order.

cost projects and low coverage for high cost projects, thus effectuating more similar payments to all projects. This can be due to the fact that there are expectations from the CCF regarding costs of reductions. The CCF does not look at life time reduction costs or other own cost analysis to decide on the funding. There is thus expectedly no large correlation between life time costs per ton c_{LT} or coverage and payments by the CCF p_{CCF} (0.35 and -0.3, respectively; all numbers without the three outliers).

Insert figure 5 here.

The analysis above refers to direct project costs only. As already mentioned, indirect costs for the CCF, incurred through the management of the

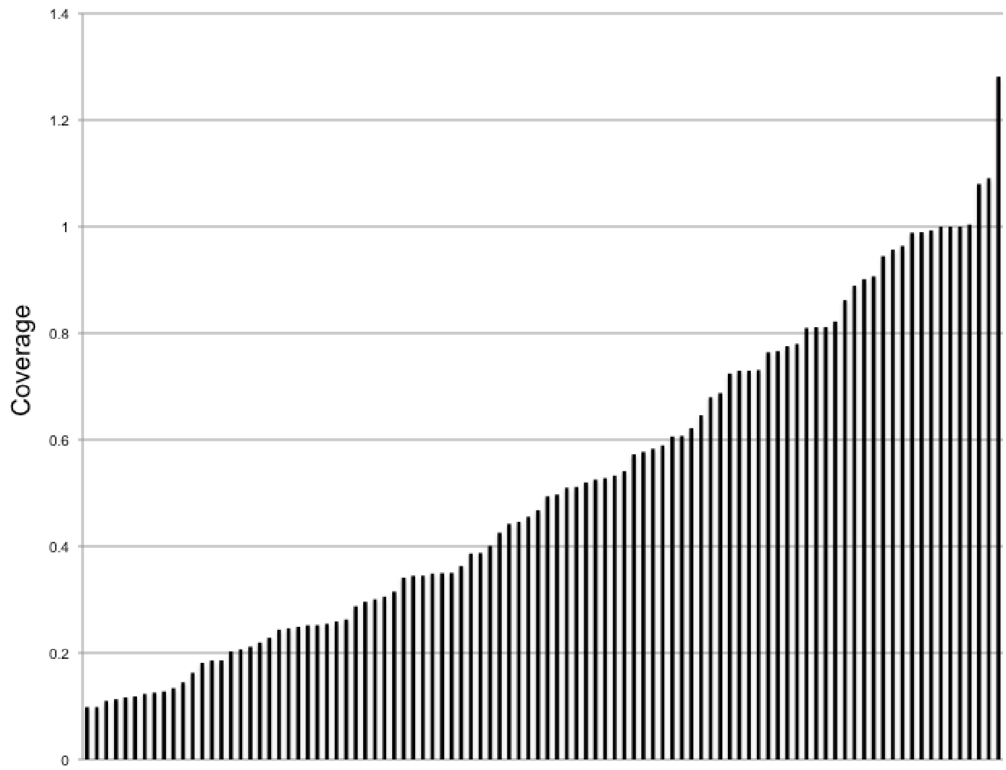

Figure 4: Coverage of the payments of the CCF in relation to total lifetime costs of the project (percentage). x-axis: projects in increasing order.

programs, etc. are at 4.8% and 4.6% of the total financial means of the auctions and intermediaries program, respectively, and 0.2% for the large scale projects program. The mean value for reduction costs per ton thus may by enlarged by the corresponding amount.

Some further analysis (excluding the three outliers) reveals that there is only weak correlation between size of the project (measured in lifetime emissions reductions) and lifetime costs per ton c_{LK} (-0.2) or payments by the CCF per ton p_{CCF} (-0.16). The costs of the 2 large-size projects with more than 500'000 t lifetime reduction are however among the lowest. This information on correlations is a purely descriptive analysis; we emphasize again, that due to lack in data, we could not estimate the size and significance

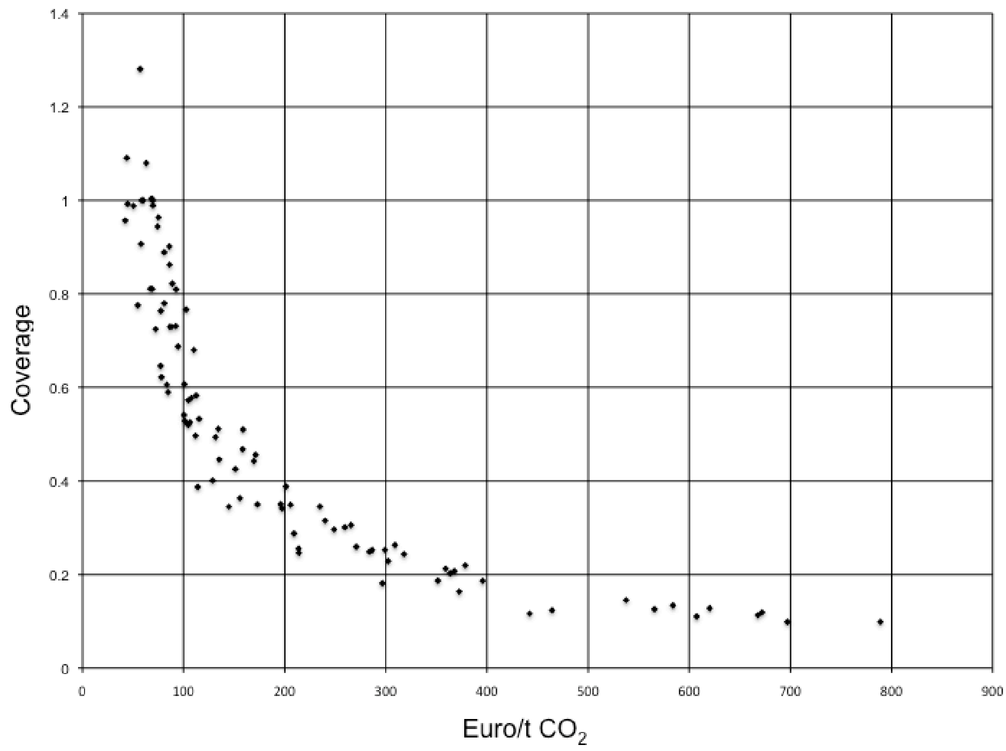

Figure 5: Lifetime reduction costs divided by emissions until 2012 (c_{2012}) vs. coverage of the payments of the CCF.

of the connections between the variables in a full regression model.

Furthermore, no significant differences in the mean lifetime reduction costs per ton c_{LT} of the different project categories as listed in table 3 can be found (with and without the outliers).[9] Similarly, there are no significant differences in average costs paid by the CCF between the three channels for project acquisition. There, however, the means are very similar also at first sight (including outliers), less so but still insignificantly different after exclusion of the outliers with lifetime reduction of over 500'000 t. This contrasts

[9] t-test with the original and weighted data; this result emerges although the means seem quite different at first sight; the results of these t-tests have to be taken with caution as the number of observations are actually too low to reliably apply it: 79, 9 and less observations per group, no knowledge on the distribution and variances.

the expectation that intermediaries may provide projects with lower costs because the payment structure to the intermediaries sets incentives to provide low cost projects. Also here, the impossibility of more sophisticated analysis hinders controlling for other influences that may shadow this expected effect.[10]

As a last analysis, we shortly compare the payments per ton by the CCF (€ 63.-) to the costs McKinsey (2007) reports. Much lower reduction costs are reported for most measures in the energy and industry sector, not so in the buildings[11] and transport sector, though. This pattern changes for the energy and industry sector when comparing with the lifetime reduction costs we find (€ 45.-), which lie in the mid-range of the McKinsey energy sector abatement cost curve and in the lower part for the industry sector. We emphasise that McKinsey (2007) addresses measures in Germany and that any analysis based on comparison with those should take this into account. To better account for this than only by exchange rates, purchase power parity (PPP) comparisons can be employed (using data from World Bank 2008). We provide this comparison to Germany, as the similar analysis of abatement costs in Switzerland (see McKinsey 2008) is less detailed. It draws a similar picture, though, as most costs are lower than € 63.- and more in line with the lifetime reduction costs € 45.-.

For the payments per ton by the CCF, this leads to € 51.- per ton when using GDP PPP, € 47.- for construction PPP and € 64.- for machinery and equipment PPP. The first two of these numbers are then in the mid-range for the energy and industry sector. Clearly, this is even more pronounced for already lower lifetime reduction costs, which, accounting for PPP, lie in the lower part of the McKinsey cost curve for energy and industry. We

[10] It could for example happen that certain intermediaries systematically provide projects from a more expensive type - e.g. by being linked to a certain industry. Those could then still be cheaper than without intermediaries but would still be more expensive than other types.

[11] Where costs are positive; the mitigation cost curve for the buildings sector has a large part with negative costs.

emphasise that this PPP corrected comparison is also only very gross and should be used with due caution. Comparability hinges also on whether costs reported in McKinsey (2007) are marginal or average costs. We assume they report average costs per technology type. This is not clearly stated, but we assume that estimating marginal costs is hindered due to data restrictions. In this case, this comparison with our results is in principle legitimate, as both refer to average costs.

5 Conclusions

The CCF helps to establish a price for CO_2 reductions in Switzerland. It fulfils its requirements and is successful measured against its goals.[12] Nevertheless, there is potential for improvement, be it for a continuation of the CCF after 2012 or for similar instruments in other countries. Potential improvements are related to the four main conclusions that can be based on the observations made in the previous section. First, measured in lifetime costs per ton reduced (c_{LT}), domestic projects are cheaper than expected when referring to the values per ton reduction the CCF reports, i.e. the payments by the CCF, p_{CCF} (€ 45.- in contrast to € 63.-). These lower reduction costs we find are linked to the time-frame the projects are evaluated over. The CCF can only buy reductions up to 2012, when the Kyoto Protocol and the corresponding legal security ends. The projects contracted, however, largely run for additional 10 to 15 years. The higher costs the CCF reports arise because additional lifetime project costs are put in relation to the reductions incurred until 2012 only and not to the total lifetime reductions of the project. The lower per ton costs we report stem from relating additional lifetime project costs to the total lifetime reductions.

[12] We did not investigate the additionality of the CCF projects, though. There is also the fundamental critique of the CCF that it does not harvest the consumption effect of a policy measure, as it does not lead to reductions from emissions in the transport sector, which could realise with higher markups than 1 Eurocent per litre gasoline (e.g. OcCC 2004).

This deadline 2012 for accountable credits is given by the structure of the Kyoto Protocol. It would be profitable if the CCF could also buy credits for reductions realised after 2012. Those could then be used for reduction goals potentially agreed on under a future agreement succeeding the Kyoto Protocol. This could be done without further costs as the same coverage level per project could be agreed on and the total lifetime cost per ton reduction would be the basis for the amount of reductions thus purchased. This would result in the same amount of reductions until 2012, and in additional reductions afterwards. Calculating this by identifying how many reductions at lifetime costs per ton could be purchased from each project with the same financial investment as incurred now, this generates additional 813'000 tons of reductions after 2012 (while 507'000 t reductions are realised until 2012). This hypothetical assessment is based on the assumption that the projects may not be undertaken with lower coverage and that the same amount of reductions should be delivered by 2012. This calculation is hypothetical, and it is likely not possible to belatedly change the rules of the CCF to somehow use these additional reductions after 2012 which are not counted in any GHG-account. On the other hand, this property has unplanned positive effects for the environment, as it results in increased reductions. Currently, it is not clear what will happen with the reductions realised after 2012.

This critique of the CCF is not new. In particular, measures in the building sector with a lifetime of several decades and no variable costs (e.g. wall insulation or efficient windows) are sensitive to such calculatory cutoffs. We expect that the difference in lifetime reduction costs and payments by the CCF are much more pronounced for the programs in the building sector (in particular as some of those are expected to be profitable over the whole lifetime). In this paper, this critique is supported with concrete numbers and the effect of this is quantified. It is understandable that national GHG mitigation policies are designed in parallel to the Kyoto Protocol and its time horizon 2012. On the other hand, the analysis in this paper shows how providing legal security beyond 2012 would lead to a more efficient policy. In the case of the CCF, providing this legal security could have been possible without additional costs or commitments.

Second, the missing correlation between lifetime costs and payments by the CCF suggests that - if assessed on a lifetime basis - not necessarily the projects with lowest per ton reduction costs are funded. The project choice of the CCF is based on a merit order according to per ton payments requested by the project owner. Based on life time per ton costs, the merit order looks different (see figure 6). Thus, a cut-off for funding based on life-time per ton costs may include projects that were otherwise dropped and vice versa. With the possibility to also buy and use credits after 2012, an assessment based on lifetime per ton costs would avoid a distortion towards projects with higher per ton costs. In addition, it should be investigated whether and if so, how much, some cost expectations of the CCF that became public in the course of its development and implementation influenced the costs claimed by the project owners.

Insert figure 6 here.

Third, in comparison with the type-wise merit order for Germany, as provided by McKinsey (2007) for example, the importance of project-wise cost differences becomes clearly visible. Most of the projects in our data are from biomass-based district heating, and average lifetime reduction costs per ton lie at € 45, i.e. somewhat above the level of "offshore wind" and way above "solid biomass", higher than "biogas" and "biomass co-firing" and "onshore wind" in the cost curve for the energy sector in McKinsey (2007).[13] The distribution of lifetime reduction costs for this type, however, spans a range from € 7.5 to 167, i.e. all of the total positive range assessed in the McKinsey report (this is still valid for PPP corrected values). A true project-wise merit order thus probably needs to be much more detailed

[13]PPP corrected values lie somewhat lower at € 37.- for GDP PPP; Interestingly, biomass-based district heating is not considered in this study and neither in the less detailed study on Switzerland, McKinsey 2008.

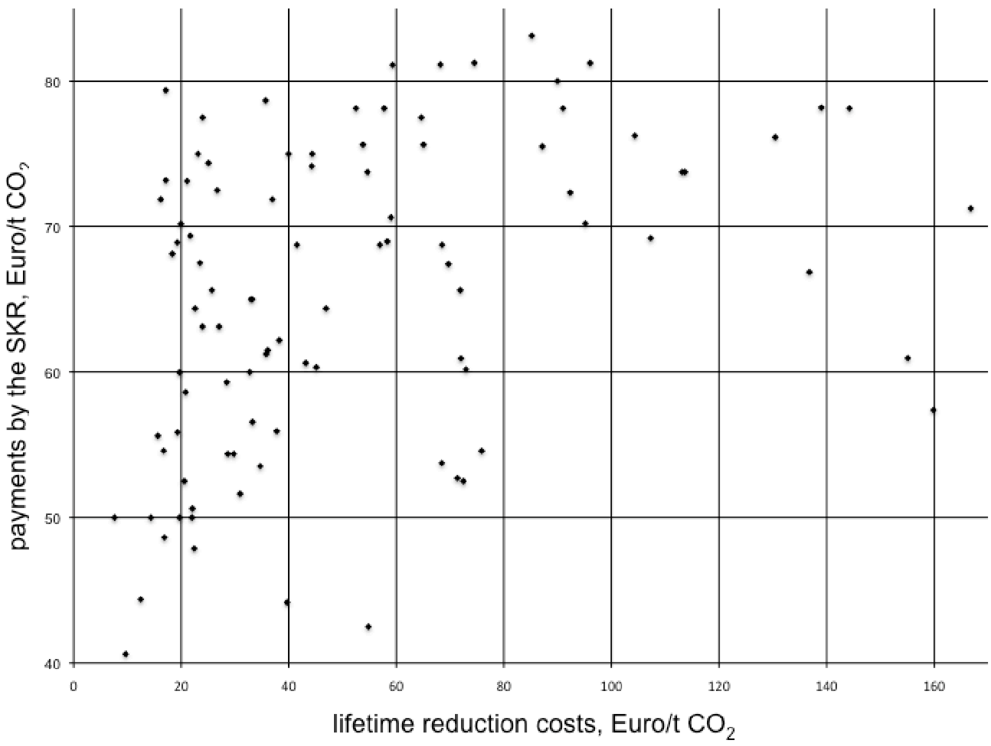

Figure 6: Lifetime costs per ton c_{LT} vs. payments of the CCF p_{CCF}.

(project level). Furthermore, policies based on type-wise average costs may not be efficient. This observation is further illustrated with the sensitivity of the mean values to large-scale outliers. Interesting in this context are also the results from the comparison of Non-Annex I region abatement cost estimates with costs of concrete CDM projects in Wetzelaer et al. (2007), where coincidence in per ton cost levels is given in half of the cases only (it has to be emphasized, though, that a comparison (same country and same project type) was possible for 14 cases only). On the other hand, type-wise assessment may be the only viable solution for choosing policies of support or priority programs, for example, as ex-ante project-wise assessment allowing for any type of projects would be too expensive.

A fourth important result is the observation that project owners seem to decide on realisation of a project not only based on financial considerations. Given that the coverage rate is considerably below 100% for most projects, project owners actually incur additional costs with respect to the base-line. Assuming that the baseline is roughly correct, other criteria than maximising profits seem to play an important role. We could think of several intuitively appealing story-lines that could be the motivation for this. On the other hand, we could also think of some reasoning that also with less than 100% coverage, most projects may turn out to be profit maximising (e.g. in case project owners expect that the credits after 2012 can be sold to other parties[14]). As the data at hand does not allow for clarity on the question of project developer motivation, we refrain from further interpretation. We only emphasise, that non-economic factors potentially play an important role here.

Acknowledgements

Many thanks to the Climate Cent Foundation for opening its archives for this study and for the continuous willingness to discuss and answer questions, in particular to Thomas Schmid and Marco Berg. Many thanks to Silvia Banfi, Marco Berg, Åsa Löfgren, Armin Schmutzler and Simon Mason for helpful comments. We are also grateful to the Climate-L and ResEcon list members who provided some of the literature on CO_2 abatement costs. The usual disclaimer applies.

References

Arquit Niederberger, A., 2005. The Swiss Climate Penny: An innovative approach to transport sector emissions. *Transport Policy*, 12(4), 303-13.

[14]This is unlikely to be possible, but the legal status of these post 2012 reductions is not yet settled. In case these credits can be sold, double-selling may occur, as the CCF already covers a part of the additional costs that is larger than the share of reductions realised until 2012.

BAFU 2008a. *Emissionen nach CO_2-Gesetz und Kyotoprotokoll*, actualised on June 25, 2008, http://www.bafu.admin.ch/ klima/ 00509/ 00513/ index. html? lang=de

BAFU 2008b. *Klimaschutzprojekte in der Schweiz. Vollzugsweisung zur Durchführung von Kompensationsmassnahmen.* Gemeinsame Mitteilung des BAFU und des BFE als Vollzugsbehörden. Umwelt-Vollzug Nr. 0826. www.umwelt-schweiz.ch/uv-0826-d (3.11.2008)

BMU 2007. *Kosten und Nutzen des Energie- und Klimaprogramms der Bundesregierung*, Bundesumweltministerium BMU. http:// www.bmu.de/ files/ pdfs/ allgemein/ application/ pdf/ bmu_hintergrund_iekp.pdf, 9.6.2008.

BUWAL 2005. *Vierter Bericht der Schweiz zuhanden der UNO-Klimakonvention. Erster Bericht der Schweiz zuhanden des Protokolls von Kyoto.* Kurzversion. http://www.bafu.admin.ch/php/modules/shop/files/pdf/php GisWBm.pdf

CCF 2006. *Ausschreibung Emissionsreduktionsprojekte* - *Wegleitung zum Antragsformular.* http://www.stiftungklimarappen.ch/klimarappen/ _data/ pages/ images/ wegleitung_ skr_ deutsch_ 061117.pdf (3.11.2008)

CCF 2007a. *Jahresbericht 2006 + Businessplan.* http://www.stiftung klimarappen.ch/ klimarappen/ _data/pages/images/klimarappen _businessplan _de.pdf

CCF 2007b. *Definitiver Businessplan der Stiftung Klimarappen.* Definitiver Businessplan vom 29. Juni 2007 zuhanden des Eidgenössischen Departements für Umwelt, Verkehr, Energie und Kommunikation, unveröffentlicht, Zürich.

CH 2008. *Ordonnance sur l'adaptation des taux d'impôt sur les huiles minérales applicables à lessence*, http://www.admin.ch/ch/f/rs/6/641.613.fr.pdf; this is the document on the tax rate adjustment, the basic tax law for gasoline can be found here: http://www.admin.ch/ch/f/rs/c641_61.html (14.10.2008)

CO2-Handel.de 2008. *Info-Portal zum Emissionshandel und Klimaschutz*, http://www.co2-handel.de/article58_0.html (4.11.2008).

CO2-Law. *Bundesgesetz ber die Reduktion der CO2-Emissionen* vom 8. Oktober 1999, Stand am 1. Mai 2007, (SR 641.71).

EC 2008. *Oil Bulletin 2008*, European Commission, http://ec.europa.eu/ energy/ oil/ bulletin/ 2008_en.htm (14.10.2008)

Enkvist, P.-A., Naucler, T. and Rosander, J., 2007. A cost curve for greenhouse gas reduction. *The McKinsey Quarterly*, 2007(1).

EPA 2006. *Global Mitigation of Non-CO_2 Greenhouse Gases*, United States Environmental Protection Agency, Report EPA 430-R-06-005 June 2006, http:/www.epa.gov/nonco2/econ- inv/international.html

Erdölvereinigung 2008. *Preise - Monats- und Jahresstatistiken* (price data), Erdölvereinigung Schweiz, http://www.erdoel-vereinigung.ch/ de/ erdoelvereinigung/ Preise.aspx (14.102008)

Factor 2002. *Klimarappen. Freiwillige Treibstoffabgabe zur Finanzierung von Treibhausgasreduktionen.* Gutachten im Auftrag der Erdöl-Vereinigung, Executive Summary, Factor Consulting + Management AG, Zürich.

Infras 2003. *CO2-Abgabe / Klimarappen bei Treibstoffen.* Schlussbericht der Arbeitsgruppe unter der Leitung des Bundesamts fr Umwelt, Wald und Landschaft vom 16. Juni 2003, Bern.

Interface/Infras 2006. *Evaluation Car-Sharing.* Projekt im Auftrag des Bundesamtes fr Energie BFE.

ISI 2007. *Wirtschaftliche Bewertung von Massnahmen des Integrierten Energie und Klimaprogramms (IEKP)*, Fraunhofer Institut für System- und Innovationsforschung (ISI), in coop. with Öko-Institut, Berlin, Forschungszentrum Jülich, Programmgruppe STE, Dr. Hans-Joachim Ziesing, Berlin. http:// www.bmu.de/ files/ pdfs/ allgemein/ application/ pdf/ fraunhofer _bewertung _iekp.pdf (9.6.2008).

Jakob, M., 2006. Marginal costs and co-benefits of energy efficiency investments - The case of the Swiss residential sector. *Energy Policy*, 34, 172-187.

Koschel, H., Moshammer, U., Sturm, B., Falh, U., Rühle, B. and Wolf, H. 2006. *Integriertes Klimaschutzprogramm Hessen - InKlim 2012 - Endbericht*, http:// www.hmulv.hessen.de/ irj/HMULV _Internet ?cid=5ec6add 988184f55 cc1af07c8e8b96bd (9.6.2008).

McKinsey 2007. *Costs and Potentials of Greenhouse Gas Abatement in Germany*, McKinsey & Company, http://www.mckinsey.com/clientservice/ccsi/pdf/costs_and_potentials_of_geenhouse_gas_full_report.pdf (9.6.2008).

McKinsey 2008. *Greenhouse Gas Abatement Cost Curves*, McKinsey Climate Change Special Initiative, http://www.mckinsey.com/clientservice/ccsi/Costcurves.asp (3.12.2008).

North, N., Kljun, N., Kasser, F., Heldstab, J., Maibach, M., Reutimann, J. and Guyer, M. 2007. *Klimaänderung in der Schweiz. Indikatoren zu Ursachen, Auswirkungen und Massnahmen.* Umwelt-Zustand Nr. 0728, eine Schriftenreihe des Bundesamts fr Umwelt, Bern.

OcCC 2004. *Stellungnahme des OcCC zum Klimarappen*, Organe consultatif sur les changements climatiques OcCC, http://www.occc.ch/ Products/Stellungnahmen/Klimarappen04/KlimaRp04.pdf (5.1.2009)

Prognos 2002. *Standortbestimmung CO2-Gesetz.* CO2-Perspektiven und Sensitivitäten. Stand Oktober 2002. Bericht im Auftrag des Bundesamts für Umwelt, Wald und Landschaft, Prognos AG, Basel.

Thalmann, P. and Baranzini, A., 2006. *Gradual Introduction of Coercive Instruments in Climate Policy*, Cahier de Recherche, Haute école de gestion de Genève HEG

UBA 2007. *Long-term prospects of CDM and JI*, Research Report 204 41 192, UBA-FB 00 1029, Federal Environmental Agency UBA (Umweltbundesamt).

Ürge-Vorsatz, D and Novikova, A., 2008. Potentials and costs of carbondioxide mitigation in the worlds buildings. *Energy Policy*, 36(2), 642-661.

UVEK. 2005. *CO2-Abgabe auf Brennstoffen - bei Treibstoffen Klimarappen auf Probe.* Medienmitteilung des Eidgenssischen Departements für Umwelt, Verkehr, Energie und Kommunikation vom 23.03.2005, http:// www. uvek.admin.ch/ dokumentation/ 00474/00492/ index.html? lang=de& msg-id=733

UVEK. 2007a. *Klimabericht* Bericht des UVEK über die zukünftige Klimapolitik der Schweiz, Bern.

UVEK 2007b. *Klimarappen läuft weiter.* Medienmitteilung des Eidgenössischen Departements für Umwelt, Verkehr, Energie und Kommunikation vom 28.09.2007, http://www.bfe.admin.ch/energie/00588/00589/00644/index.html?lang=de&msg-id=14906.

UVEK 2007c. *CO2-Abgabe auf Brennstoffe wird auf Januar 2008 eingeführt*, Medienmitteilung des Eidgenössischen Departements für Umwelt, Verkehr, Energie und Kommunikation vom 28.06.2007, http://www.bafu.admin.ch/dokumentation/ medieninformation/ 00962/ index. html? lang=de& msg-id=13369

Wetzelaer, B., van der Linden, N., Groenenberg, H. and de Coninck, H., 2007. *GHG Marginal Abatement Cost Curves for the Non-Annex I region*, Report ECN-E–06-060, Energy Research Centre of the Netherlands ECN.

List of Tables and Table Captions

	Category	Examples
-	Renewable heat	Wood energy based district heating system
-	Waste heat utilization	Using waste heat from waste incineration plants for district heating or industrial processes
-	Efficiency increase in industrial processes	Energy efficient production of heat for industrial processes
-	Renewable automotive fuels	Production of biogas for cars
-	Efficiency increase in fuel use	Measures to support fuel-efficient driving practices

Table 1: Project categories in the single projects program of the CCF

-	the project belongs to one of the categories listed in table 1
-	implementation of the project reduces domestic CO_2-emissions that would not be reduced in absence of the project activity (i.e. emissions reductions are physically additional)
-	the project is financially additional
-	reductions realised by the end of 2012 can be calculated and measured
-	the minimal reduction requirements per channel will be achieved
-	project partners are involved on contractual basis only
-	financial requirements can be calculated
-	the project starts realising emissions reductions by January 1 2010 latest
-	financing the project is assured (accounting for the support by the CCF)
-	implementation of the project is possible (licenses, etc. required are available or will be so with highest probability)
-	emissions reductions are not subject to voluntary reduction targets under the CO_2-law

Table 2: Requirements in the single projects program of the CCF

Category	Projects
Renewable heat	71 projects with a central heating station for district heating of several buildings. Reductions via replacement of fossil fuels with wood. Backup (for emergencies or extraordinary peak loads) is often fossil fuel (for 65% of these projects). 30 projects set up a new district heating distribution system, while 41 consist in replacement or enlargement of existing systems. 3 projects for heating or cooling in cheese production based on wood energy. 2 projects with heat pumps and one with solar collectors for heat production. 2 projects consist in building and operation of a production plant for biomass energy carriers.
Waste heat utilization	3 projects using waste heat from industrial production and one from waste water treatment for district heating. 1 project using waste heat from a ice-scating arena for an indoor swimming pool. 2 projects use waste heat from waste incineration for district heating and 2 projects use waste heat from industrial processes for other industrial processes within the same production unit.
Efficiency (Industry)	2 projects of increased efficiency due to improved heat energy management in a school and a hospital.
Renewable fuels	4 projects generating biogas from biomass, which then is used to subsitute fossil gas.
Efficiency (Fuel)	2 projects increasing aggregate car use fuel efficiency via mobility reorganisation and reduction (car-sharing platforms). Reductions are achieved by the claimed generally more environmental mobility pattern of car-sharing users (Interface/Infras 2006).

Table 3: Projects in the single projects program of the CCF

Variable	Definition	Unit	Mean value*	Std. Dev.*	Outliers
total lifetime reduction⋆	CO_2 reductions over the total lifetime of the project	t	12'941	14'556	at 513'160, 597'363
reductions until 2012	reductions realized by the project until 2012	t	3'662	4'895	at 76'974, 81'250 (the same as above)
total lifetime costs	net present value of additional costs of the project over the whole lifetime, with respect to the reference scenario	€	0.56 m	0.81 m	-
lifetime reduction costs per ton# (c_{LT})	total lifetime costs divided by total lifetime reductions	€/t	45.44†	30.13	at 280 (a different observation)
reduction costs per ton until 2012# (c_{2012})	total lifetime costs divided by reductions until 2012	€/t	160.56†	140.25	-
payment by the CCF	payments by the CCF for the reductions realized until 2012	€	0.25 m	0.31 m	-
payment by the CCF per ton# (p_{CCF})	payments by the CCF per t reduction realized	€/t	63.1‡	10.94	-
Coverage	payment by the CCF divided by totale lifetime costs	%	0.52	0.30	-

Table 4: Description of variables; the first two outliers are 8 and almost 10 times larger than the next lower value, the third is far less extreme at 1.7 times the next lower value (* without outliers; ⋆ the project lifetime reported

in the PDD is a calculatory quantity referring to the time period over which the physical capital is depreciated. Usually, installations remain in operation after this for some additional years and correspondingly produce additional reductions. This will reduce lifetime costs, but due to lack of data, we use the lifetime values reported in the PDD; # mean values and standard deviations are weighted with the relevant amount of reductions (lifetime or until 2012)) - outliers in these weights are also dropped (i.e. the first two); † including the outliers in total lifetime reduction, these mean values reduce to € 30.38 and 141.0, respectively. This is due to the strong influence of these observations via the weights; ‡ € 59.31 when including all three outliers)

List of Figure Captions

Figure 1: Payments of the CCF per ton CO_2 reduced (p_{CCF}). x-axis: projects in increasing order.

Figure 2: Costs per ton CO_2 reduced, c_{LT} (over the whole lifetime; an outlier at € 280 is excluded). x-axis: projects in increasing order.

Figure 3: Costs per ton CO_2 in case total lifetime-costs are divided by reductions until 2012 only, c_{2012}. x-axis: projects in increasing order.

Figure 4: Coverage of the payments of the CCF in relation to total lifetime costs of the project (percentage). x-axis: projects in increasing order.

Figure 5: Lifetime reduction costs divided by emissions until 2012 (c_{2012}) vs. coverage of the payments of the CCF.

Figure 6: Lifetime costs per ton c_{LT} vs. payments of the CCF p_{CCF}.